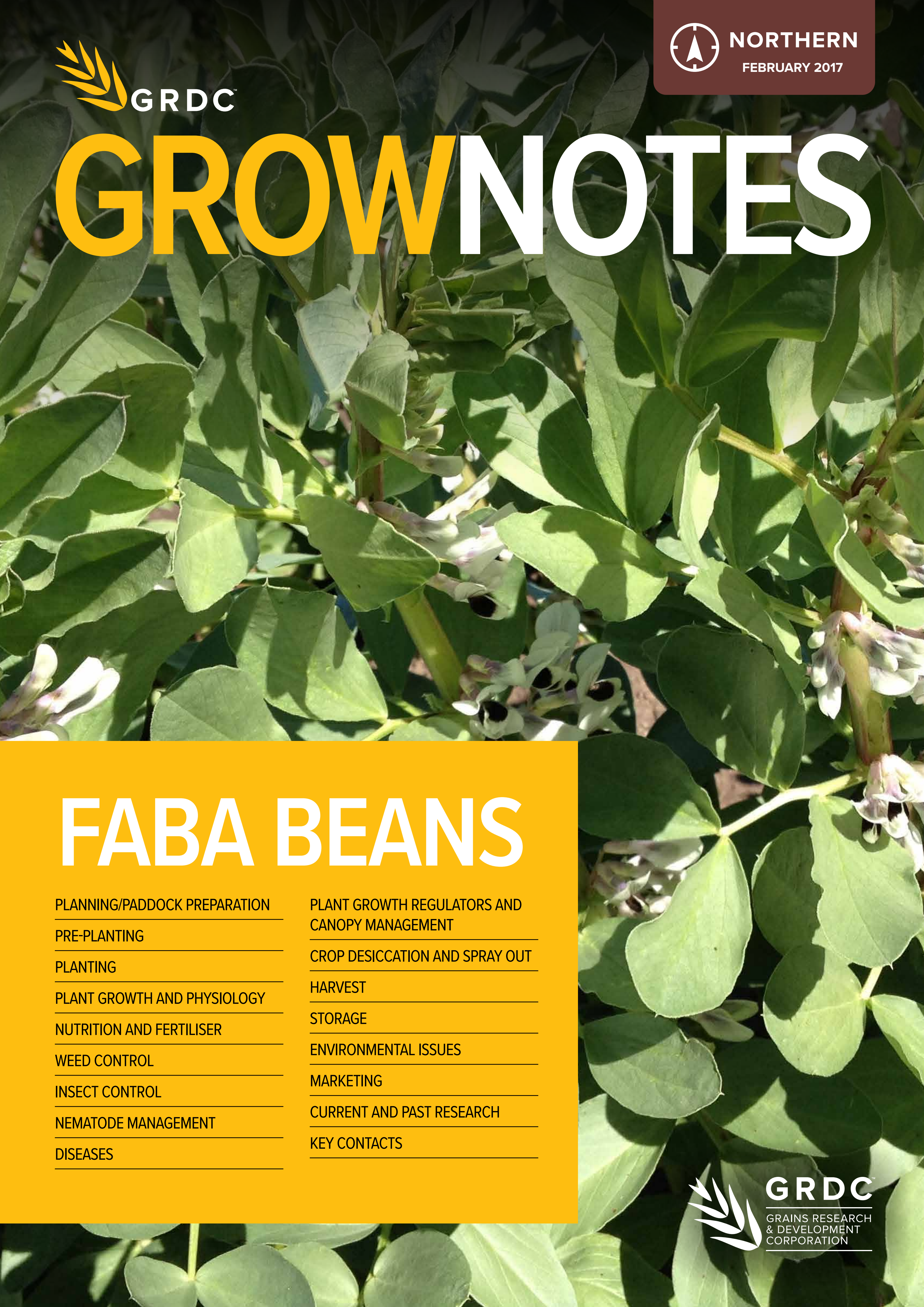

NORTHERN
FEBRUARY 2017

GRDC

GROWNOTES

FABA BEANS

GRDC
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What's new

The GRDC GrowNotes are dynamic documents that are updated according to user feedback and newly available information.

This version of the GRDC Faba Beans GrowNotes (updated November 2016) contains the following updates on original content published in July 2014:

Section A – Introduction

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- New link: Sowing time and variety selection for faba bean in southern NSW: https://grdc.com.au/Research-and-Development/GRDC-Update-Papers/2016/02/Sowing-time-and-variety-selection-for-faba-bean-in-southern-NSW

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- New link: Faba bean and lentils expand pulse options: https://grdc.com.au/Media-Centre/Ground-Cover/Ground-Cover-Issue-114-JanFeb-2015/Faba-bean-and-lentils-expand-pulse-options

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- New link: SARDI sowing guide: http://www.pulseaus.com.au/growing-pulses/bmp/faba-and-broad-bean/northern-guide
- New link: Faba bean production: Northern region: http://www.pulseaus.com.au/growing-pulses/bmp/faba-and-broad-bean/northern-guide

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- New link: Weigh up the risks, benefits of pulse harvest: https://grdc.com.au/Media-Centre/Ground-Cover-Supplements/Ground-Cover-Issue-115-Profitable-pulses-and-pastures/Weigh-up-the-risks-benefits-of-pulse-harvest

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- New link: Impact of soil acidity on crop yield and management in Central Western NSW: https://grdc.com.au/Research-and-Development/GRDC-Update-Papers/2016/07/Soil-acidity-Crop-yield-impacts-and-management-in-Central-Western-NSW

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- New link: Soil acidity holds back pulse potential: https://grdc.com.au/Media-Centre/Ground-Cover/Ground-Cover-Issue-120-Jan-Feb-2016/Soil-acidity-holds-back-pulse-potential

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- New link: Faba bean potential as southern rotation option: https://grdc.com.au/Media-Centre/Ground-Cover/Ground-Cover-Issue-114-JanFeb-2015/Faba-bean-potential-as-southern-rotation-option

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- New link: Fusarium head blight in the north: https://grdc.com.au/Media-Centre/Ground-Cover/GC112/Fusarium-head-blight-in-the-north

- New text: Trials in the northern region have indicated that faba beans and canola are better break crops for crown rot than chickpeas. https://grdc.com.au/Research-and-Development/GRDC-Update-Papers/2015/07/Crown-rot-an-update-on-latest-research
- New text: Managing crown rot through crop sequencing and row placement: https://grdc.com.au/Research-and-Development/GRDC-Update-Papers/2014/07/Managing-crown-rot-through-crop-sequencing-and-row-placement

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- New link: Key outcomes arising from the crop sequence project: https://grdc.com.au/Research-and-Development/GRDC-Update-Papers/2015/02/Key-outcomes-arising-from-the-crop-sequence-project
- New link: New varieties and rotations rescue lost potential: https://grdc.com.au/Media-Centre/Ground-Cover/GC111/New-varieties-and-rotations-rescue-lost-potential

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- New link: Legume effects on soil N dynamics - comparisons of crop response to legume and fertiliser N (Corowa): https://grdc.com.au/Research-and-Development/GRDC-Update-Papers/2015/02/Legume-effects-on-soil-N-dynamics-Corowa

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- New link: Fixing more nitrogen in pulse crops: https://grdc.com.au/Research-and-Development/GRDC-Update-Papers/2015/07/Fixing-more-nitrogen-in-pulse-crops

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- New link: Residual herbicides and weed control: http://www.pulseaus.com.au/growing-pulses/publications/residual-herbicides
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- New link: Predicta B an identity kit for soil borne pathogens: https://grdc.com.au/Media-Centre/Ground-Cover-Supplements/Ground-Cover-Issue-115-Profitable-pulses-and-pastures/Predicta-B-an-identity-kit-for-soil-borne-pathogens
- New link: Single test improves stubble-borne disease management: https://grdc.com.au/Media-Centre/Ground-Cover/GC111/Single-test-improves-stubble-borne-disease-management

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- New link: Impact of crop varieties on RLN multiplication: https://grdc.com.au/Research-and-Development/GRDC-Update-Papers/2015/03/Impact-of-crop-varieties-on-RLN-multiplication

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- New link: Profitable integration of pulses in farming systems: https://grdc.com.au/Research-and-Development/GRDC-Update-Papers/2016/02/Profitable-integration-of-pulses-in-farming-systems

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- New table: Winter crop variety sowing guide 2016: http://www.dpi.nsw.gov.au/__data/assets/pdf_file/0011/272945/winter-crop-variety-sowing-guide-2016.pdf

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- New variety: http://www.seednet.com.au/documents/PBA_Nasma_Web.pdf

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- New link: Northern expansion stretches to Egypt: https://grdc.com.au/Media-Centre/Ground-Cover/Ground-Cover-Issue-114-JanFeb-2015/Northern-expansion-stretches-to-Egypt

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- New information: http://www.pulseaus.com.au/growing-pulses/bmp/faba-and-broad-bean/northern-guide
- Variety Central: http://www.varietycentral.com.au
- New information: http://varietycentral.com.au/varieties-and-rates/201617-harvest/pulse/

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- New link: Pulse inoculation techniques: http://www.pulseaus.com.au/growing-pulses/publications/pulse-inoculation

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- New link: Soil acidity holds back pulse potential: https://grdc.com.au/Media-Centre/Ground-Cover/Ground-Cover-Issue-120-Jan-Feb-2016/Soil-acidity-holds-back-pulse-potential

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- New link: Aphids – to spray or not to spray: https://grdc.com.au/Media-Centre/Ground-Cover/Ground-Cover-Issue-117-July-August-2015/Aphids-to-spray-or-not-to-spray
- New link: Avoiding stubble trouble: https://grdc.com.au/Media-Centre/Ground-Cover/GC112/Avoiding-stubble-trouble

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- New link: Faba beans for acidic soils in southern NSW - yields and time of sowing effects: https://grdc.com.au/Research-and-Development/GRDC-Update-Papers/2015/07/Faba-beans-for-acidic-soils-in-southern-NSW
- New link: Faba bean foray into the north takes hold: https://grdc.com.au/Media-Centre/Ground-Cover/Ground-Cover-Issue-114-JanFeb-2015/Faba-bean-foray-into-the-north-takes-hold
- New link: Chickpea and faba bean agronomy ideal row spacing and populations: https://grdc.com.au/Research-and-Development/GRDC-Update-Papers/2015/07/Chickpea-and-faba-bean-agronomy-ideal-row-spacing-and-populations
- New link: Minimising frost damage in pulses: http://www.pulseaus.com.au/growing-pulses/publications/minimise-frost-damage

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- New text: https://grdc.com.au/Research-and-Development/GRDC-Update-Papers/2015/07/Faba-beans-for-acidic-soils-in-southern-NSW

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- New link: Faba bean foray into the north takes hold: https://grdc.com.au/Media-Centre/Ground-Cover/Ground-Cover-Issue-114-JanFeb-2015/Faba-bean-foray-into-the-north-takes-hold

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- New text and link: Faba bean density experiments 2015 (Northern Winter Pulse Agronomy): https://grdc.com.au/Research-and-Development/GRDC-Update-Papers/2016/02/Faba-bean-density-experiments-2015
- New link: Effect of seed size at sowing on grain yield of PBA Nasma faba bean: https://grdc.com.au/Research-and-Development/GRDC-Update-Papers/2016/02/Effect-of-seed-size-at-sowing-on-grain-yield-of-PBA-Nasma-faba-bean

- New link: Northern Winter Pulse Agronomy (Walgett 2015): https://grdc.com.au/Research-and-Development/GRDC-Update-Papers/2016/02/Northern-Winter-Pulse-Agronomy-Walgett-2015
- New text and figure: https://grdc.com.au/Research-and-Development/GRDC-Update-Papers/2016/02/Northern-Winter-Pulse-Agronomy-Walgett-2015

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- New table: https://grdc.com.au/Research-and-Development/GRDC-Update-Papers/2016/02/Effect-of-seed-size-at-sowing-on-grain-yield-of-PBA-Nasma-faba-bean
- New link: Impact of row spacing on chickpea fababean and mungbean: https://grdc.com.au/Research-and-Development/GRDC-Update-Papers/2015/07/Impact-of-row-spacing-on-chickpea-fababean-and-mungbean
- New link: Wider row pulses and stubble retention: http://www.pulseaus.com.au/growing-pulses/publications/wide-rows-and-stubble-retention - faba/broad-bean-

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- New link: Impact of row spacing on chickpea and faba bean: https://grdc.com.au/Research-and-Development/GRDC-Update-Papers/2015/03/Impact-of-row-spacing-on-chickpea-and-faba-bean
- Chickpea and faba bean agronomy ideal row spacing and populations: https://grdc.com.au/Research-and-Development/GRDC-Update-Papers/2015/07/Chickpea-and-faba-bean-agronomy-ideal-row-spacing-and-populations
- New text: Northern region data are currently being generated however trials on the Darling Downs showed narrow row spacing (25–50 cm) consistently yielded higher than wider row spacings (75 cm and above) for faba beans. This effect was seen across 2 years and differing seasons and environments. Row spacing has a larger effect on yield than plant population. https://grdc.com.au/Research-and-Development/GRDC-Update-Papers/2016/03/Faba-bean-agronomy-Ideal-row-spacing-and-time-of-sowing

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- New link: Crop sequencing for irrigated double cropping within the Murrumbidgee Valley region: https://grdc.com.au/Research-and-Development/GRDC-Update-Papers/2016/07/Crop-sequencing-for-irrigated-double-cropping-Murrumbidgee-Valley-site

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- New text: Soil organic matter

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- New link: Managing resistant ryegrass in break crops and new herbicides for resistant ryegrass: https://grdc.com.au/Research-and-Development/GRDC-Update-Papers/2015/07/Managing-resistant-ryegrass-in-break-crops-and-new-herbicides-for-resistant-ryegrass

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- New link: SA trial assesses different weed strategies: https://grdc.com.au/Media-Centre/Ground-Cover/Ground-Cover-Issue-114-JanFeb-2015/SA-trial-assesses-different-weed-strategies
- New link: Herbicides for control of clethodim-resistant annual ryegrass: https://grdc.com.au/Research-and-Development/GRDC-Update-Papers/2015/02/Herbicides-for-control-of-clethodim

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- GRDC podcast: https://grdc.com.au/Media-Centre/GRDC-Podcasts/Driving-Agronomy-Podcasts/2014/05/Faba-Bean-Revolution

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- New link: Herbicide resistance management, a local, in-field perspective: https://grdc.com.au/Research-and-Development/GRDC-Update-Papers/2015/07/Herbicide-resistance-management-a-local-infield-perspective

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- New text: Pre-harvest Herbicide Use: http://www.grdc.com.au/GRDC-FS-PreHarvestHerbicide

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- New text: https://grdc.com.au/Media-Centre/Ground-Cover/Ground-Cover-Issue-124-SeptemberOctober-2016/Paraquat-preferred-for-croptopping-pulses

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- Desiccation and croptopping in pulses: http://www.pulseaus.com.au/growing-pulses/publications/desiccation-and-croptopping

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- New link: Spotting green mirid damage on faba beans: https://grdc.com.au/Media-Centre/Ground-Cover/Ground-Cover-Issue-121-Mar-Apr-2016/Spotting-green-mirid-damage-on-faba-beans

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- New link: Insect pest management in faba beans: https://grdc.com.au/Media-Centre/Ground-Cover/Ground-Cover-Issue-117-July-August-2015/Insect-pest-management-in-faba-beans

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- New link: Insect management in fababeans and canola recent research: https://grdc.com.au/Research-and-Development/GRDC-Update-Papers/2015/02/Insect-management-in-fababeans-and-canola-recent-research
- New link: Recent insect pest management research findings: https://grdc.com.au/Research-and-Development/GRDC-Update-Papers/2016/02/Recent-insect-pest-management-research-findings-and-the-application-of-results-in-the-field

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- New link: Aphids – to spray or not to spray: https://grdc.com.au/Media-Centre/Ground-Cover/Ground-Cover-Issue-117-July-August-2015/Aphids-to-spray-or-not-to-spray

Section 8 – Nematode control

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- New text: https://grdc.com.au/Resources/Factsheets/2015/03/Root-Lesion-Nematodes

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- New link: Northern researchers dig deep to understand root lesion nematode life span: https://grdc.com.au/Media-Centre/Ground-Cover-Supplements/Ground-Cover-Issue-115-Profitable-pulses-and-pastures/Northern-researchers-dig-deep-to-understand-root-lesion-nematode-life-span
- New text: https://grdc.com.au/Resources/Factsheets/2015/03/Root-Lesion-Nematodes

- New figures: https://grdc.com.au/Resources/Factsheets/2015/03/Root-Lesion-Nematodes

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- New link: Impact from Pratylenchus thornei, Macalister 2015: https://grdc.com.au/Research-and-Development/GRDC-Update-Papers/2016/03/Impact-from-Pratylenchus-thornei-Macalister-2015
- New figure: https://grdc.com.au/Resources/Factsheets/2015/03/Root-Lesion-Nematodes

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- New case study: https://grdc.com.au/Resources/Factsheets/2015/03/Root-Lesion-Nematodes
- New link: Root lesion nematodes importance impact and management: https://grdc.com.au/Research-and-Development/GRDC-Update-Papers/2015/08/Root-lesion-nematodes-importance-impact-and-management
- New link: Single test improves stubble-borne disease management: https://grdc.com.au/Media-Centre/Ground-Cover/GC111/Single-test-improves-stubble-borne-disease-management
- New link: Predicta B an identity kit for soil borne pathogens: https://grdc.com.au/Media-Centre/Ground-Cover-Supplements/Ground-Cover-Issue-115-Profitable-pulses-and-pastures/Predicta-B-an-identity-kit-for-soil-borne-pathogens

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- New link: Impact from Pratylenchus thornei, Macalister 2015: https://grdc.com.au/Research-and-Development/GRDC-Update-Papers/2016/03/Impact-from-Pratylenchus-thornei-Macalister-2015

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- New table: https://grdc.com.au/Research-and-Development/GRDC-Update-Papers/2015/08/Root-lesion-nematodes-importance-impact-and-management and https://grdc.com.au/Research-and-Development/GRDC-Update-Papers/2015/03/Impact-of-crop-varieties-on-RLN-multiplication

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- New link: Single test improves stubble-borne disease management: https://grdc.com.au/Media-Centre/Ground-Cover/GC111/Single-test-improves-stubble-borne-disease-management

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- New link: Predicta B an identity kit for soil borne pathogens: https://grdc.com.au/Media-Centre/Ground-Cover-Supplements/Ground-Cover-Issue-115-Profitable-pulses-and-pastures/Predicta-B-an-identity-kit-for-soil-borne-pathogens

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- New link: Nationally coordinated effort to tackle ascochyta blight of pulses: https://grdc.com.au/Media-Centre/Ground-Cover-Supplements/Ground-Cover-Issue-116-Foliar-fungal-diseases-of-pulses-and-oilseeds/Nationally-coordinated-effort-to-tackle-ascochyta-blight-of-pulses

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- New link: Pulse diseases the watch outs for 2016: https://grdc.com.au/Research-and-Development/GRDC-Update-Papers/2016/02/Pulse-diseases-the-watch-outs-for-2016

- New text: The disease can develop very quickly, requiring only six hours of leaf wetness for infection. Rust is not usually a problem every year in southern regions, and often occurs in years with good spring rainfall and mild temperatures. https://grdc.com.au/Research-and-Development/GRDC-Update-Papers/2016/02/Pulse-diseases-the-watch-outs-for-2016

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- New link: Faba bean fungicide guide 2016 season: http://pulseaus.com.au/growing-pulses/bmp/faba-and-broad-bean/2016-season-fungicide-guide

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- New link: Pulse diseases the watch outs for 2016: https://grdc.com.au/Research-and-Development/GRDC-Update-Papers/2016/02/Pulse-diseases-the-watch-outs-for-2016

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- New link: Close monitoring shows changing pathogen strains: https://grdc.com.au/Media-Centre/Ground-Cover-Supplements/Ground-Cover-Issue-116-Foliar-fungal-diseases-of-pulses-and-oilseeds/Close-monitoring-shows-changing-pathogen-strains

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- New reference: http://www.pulseaus.com.au/growing-pulses/bmp/faba-and-broad-bean/idm-strategies
- New reference: http://www.pulseaus.com.au/growing-pulses/publications/manage-viruses

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- New link: Faba bean foray into the north takes hold: https://grdc.com.au/Media-Centre/Ground-Cover/Ground-Cover-Issue-114-JanFeb-2015/Faba-bean-foray-into-the-north-takes-hold

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- New link: Minimising frost damage in pulses: http://www.pulseaus.com.au/growing-pulses/publications/minimise-frost-damage

Section 15 – Marketing

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- New text, figures and tables: Profarmer

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Introduction

2 Pre-planting

Introduction

A.1 Crop overview

A.1.1 The role of pulses in farming systems

Pulses have a role in the modern farming system, far greater than the traditional 'nitrogen fixation' and 'disease break'. They are a cash crop in their own right, but also a valuable part of the whole farming system, especially for weed control within crop rotations.

Stubble retention is common for erosion protection and moisture retention, and pulses fit into such systems. Seeding machinery used in no-till or minimum tillage systems can now handle stubble retention, to allow pulse crops to be sown after a cereal.

Diversity of crops in a rotation is important for continuous cropping systems:

- to handle herbicide-resistant weeds or delay the onset of herbicide resistance by varying herbicide options and timings for weed control
- to control disease of all crops in the rotation
- to spread the timing of farm operations
- to spread risks across commodities
- to minimise the impact of increased costs of fertiliser nitrogen (N) and fuel

Crop-topping or 'wick'-wiping of weeds with herbicide in the pulse crop prevents the seed-set of escape weeds in the crop. Desiccation or windrowing may also help. [1]

It is usual practice to deep-sow legumes, because they have great ability to emerge from depth (Figure 1). Faba bean seed inoculated with rhizobium (Group F) should be planted into moist soil, and can be planted to 15–20 cm depth. [2]

1 GRDC (2008) Grain Legume Handbook. Update 7 February 2008. Grains Research & Development Corporation, hhttps://grdc.com.au/uploads/documents/Index.pdf

2 G Onus. Fababean Growing Program. Landmark Moree.

Figure 1: *Faba beans have the ability to emerge from deep sowing of up to 20 cm.*

Drew Penberthy, Penagcon

Pulses can be sown in wide rows if required, enabling non-selective weed control between the rows using hooded shields. Sowing the pulse crop between the standing rows of cereal stubble is beneficial and can be done with GPS guidance and auto-steer sowing systems. [3] This enables the cereal crop in the following season to be planted down the legume row to separate it from the previous cereal stubble and reduce the crop's exposure to the crown rot fungus.

Planting faba beans with the cereal stubble standing also helps to protect the seedling faba beans from aphid infestations, which in turn can reduce the incidence of virus in the crop. [4]

A.1.2 About faba bean

Faba bean, *Vicia faba*, is a winter-growing pulse, or food legume crop. It originated in the Middle East in the prehistoric period, and has since been cultivated throughout Europe, North Africa, and Central Asia. It was introduced to China over 2,000 years ago via traders along the Silk Road, to South America in the Columbian period, and more recently to Canada and Australia.

Faba bean was first grown commercially for grain in northern New South Wales in the early 1980s, and is now cultivated in Victoria, New South Wales and Western Australia. Small areas are grown in Tasmania and southern Queensland. It is a cool-season crop in Australia, planted in autumn and harvested in late spring–early summer. Because of its value in livestock nutrition and crop rotation, faba bean will receive greater attention and there will be an increasing export potential for Australian grain. [5]

A.1.3 Growing faba bean

The faba bean plant is tall (it may grow a height of 2 m at maturity under optimum conditions), erect and multi-stemmed from basal branches. Faba bean plants in Australian crops are usually <1.5 m tall. Leaves are compound, having 2–7 leaflets.

MORE INFORMATION

GRDC Update Paper: Sowing time and variety selection for faba bean in southern NSW

3 GRDC (2008) Grain Legume Handbook. Update 7 February 2008. Grains Research & Development Corporation, https://www.grdc.com.au/uploads/documents/Index.pdf

4 G Onus. Fababean Growing Program. Landmark Moree.

5 P Matthews, H Marcellos (2003) Faba bean. Agfact P4.2.7. 2nd edn. NSW Department of Primary Industries, http://www.dpi.nsw.gov.au/__data/assets/pdf_file/0004/157729/faba-bean-pt1.pdf

MORE INFORMATION

Ground Cover: Faba bean and lentils expand pulse options

First leaves have only two leaflets, but there are seven in the last formed leaves. It has a well-developed taproot, which bears a profusion of fibrous roots in the top 30 cm of soil. Plants will flower profusely and under cool, moist conditions may flower over a 5–10-week period.

Flowering in early varieties begins from about the 5th to 7th leaf-bearing stem node (joint), and up to the 15th or higher node in late varieties. Flowers are borne in clusters (inflorescences) comprising 3–8 flowers (depending on variety) in the angle between leaf and stem (axil) at each node (Figure 2). Inflorescences form in succession up the stem as each new node is produced, over a period of 6–10 weeks, or at ~15 flowering nodes.

Figure 2: *Faba bean flowering.*

Gordon Cumming, Pulse Australia

Like many legumes, excess flowers are produced and <15% will develop to produce pods.

Honeybees seek nectar from the flowers and in the process pick up pollen, transferring it between plants and causing cross-pollination to occur at rates commonly in the range 25–30%.

Flowering finishes once the maximum average weekly temperatures reach >25°C and/or moisture becomes limited, after which an extra few leaf-bearing nodes are produced.

Pods in a well-grown crop are borne from ~20 cm aboveground to ~30 cm below crop height (Figure 3). Each pod contains 2–6 seeds. As pods mature, they turn black, as do the stems and leaves of the plant eventually.

Figure 3: *Podded faba bean plant.*

NSW DPI Agfact P4.2.7

Seeds vary in size depending on variety, from large flattened beans (also known as broad beans) through medium sizes to smaller, rounded seeds that are like field peas (Figures 4–7). Varieties with medium-sized seed are the main types grown in Australia, whereas the smaller seeded types are common in Europe.

Figure 4: *Faba bean seeds come in different colours and sizes.*

Pulse Australia

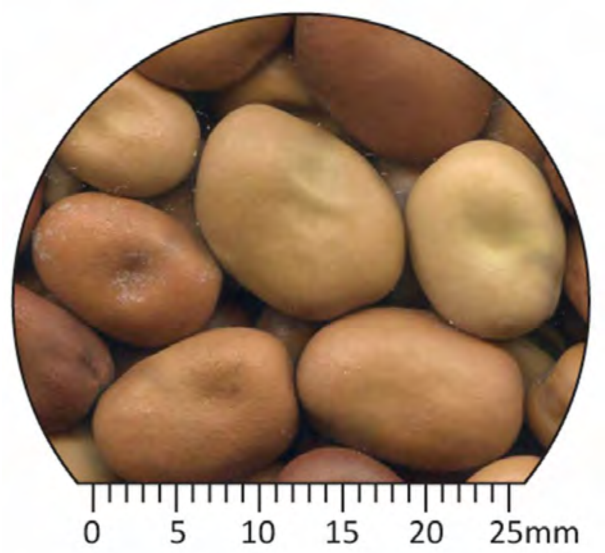

Figure 5: *Faba bean variety Cairo⦶ (released 2004); seed size 55–75 g/100.*

Pulse Australia

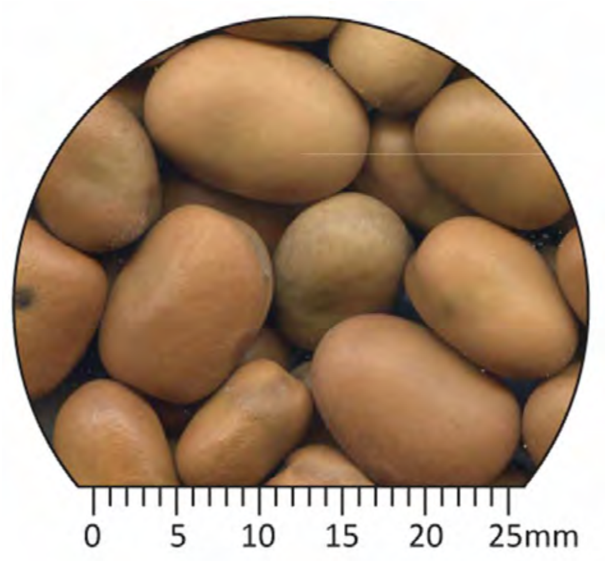

Figure 6: *Faba bean variety Doza⦶ (released 2008); seed size 35–55 g/100.*

Pulse Australia

MORE INFORMATION

Grain Legume Handbook 2008

SARDI sowing guide: Faba bean variety sowing guide 2015

MORE INFORMATION

Pulse Australia: Faba bean production: Northern region

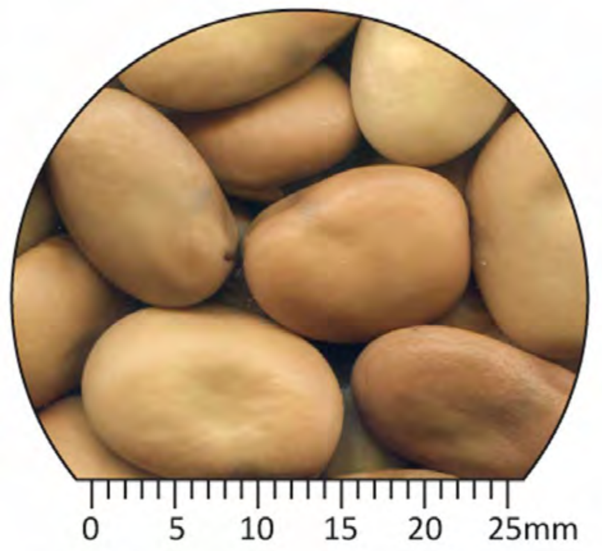

Figure 7: *Faba bean variety PBA Warda⊕ (released 2012); seed size 55–75 g/100.*

Pulse Australia

A.1.4 Suitable environments

Faba beans may be grown over much of the northern grains region, being well suited to the eastern districts where rainfall is higher and spring temperatures are milder than in western areas (Figure 8). Faba beans respond well to irrigation on heavy clay soils.

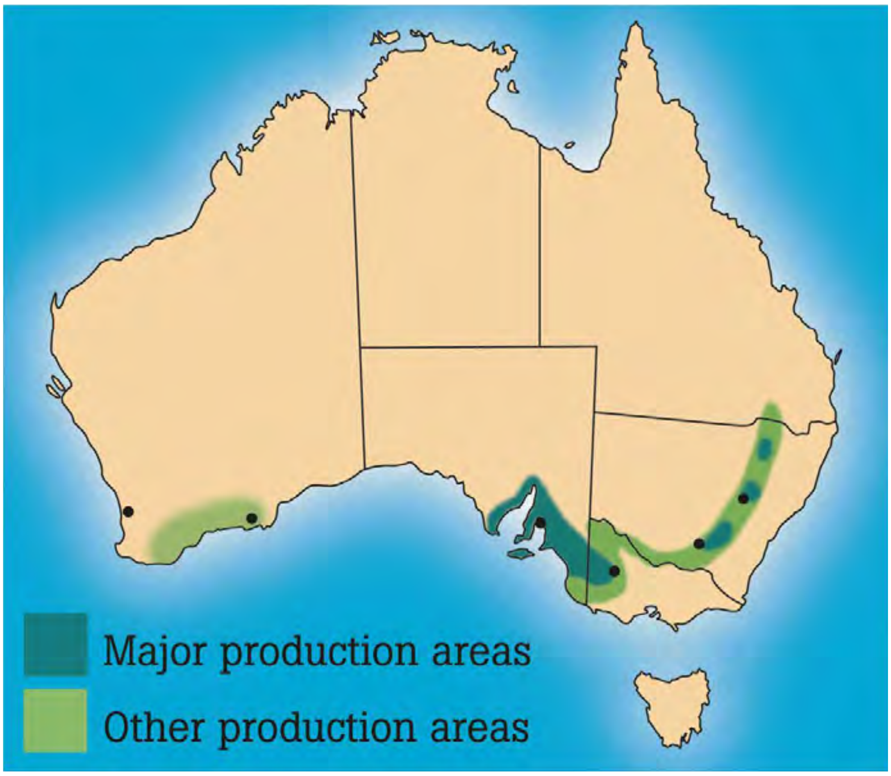

Figure 8: *Faba bean production areas in Australia, showing breeding centres.*

http://pulseaus.com.au/growing-pulses/bmp/faba-and-broad-bean. Image: Pulse Australia

Faba bean plants can tolerate frost during vegetative stages, but severe frosts can deform and lodge stems. Frosts can also cause death of flowers and immature pods after flowering. The exact temperatures at which damage occurs to flowers and pods are not known. Experience indicates that beans may tolerate temperatures that would normally damage wheat heads in their flowering stage, i.e. below about –4°C. The loss of flowers from frost may be compensated for by pod development at later flowering nodes. Pod development will be adversely affected by hot, dry periods in August and September in northern regions, and during October in the south.

A.2 Products and uses

All seed types are used as dry beans for human consumption or livestock feed. Large-seeded varieties are often used for human consumption as a green vegetable. Value-adding in the form of canning, splitting, and preparation as snack foods services niche markets. In China, faba beans are used to make extruded starch products (vermicelli) and sauces.

Pulses taste good, and are nutritious, versatile and inexpensive. They are in the 'eat most' category of the Healthy Living Pyramid produced by Nutrition Australia. Pulses are cholesterol-free and most are low in fat (except soybeans and peanuts). The majority of fatty acids in pulses are unsaturated and they comprise both monounsaturated and essential polyunsaturated fatty acids. These unsaturated fatty acids lower the total cholesterol and the harmful LDL (low-density lipoprotein) cholesterol levels in the blood when substituted for saturated fatty acids in the diet.

MORE INFORMATION

Ground Cover Supplement: Weigh up the risks, benefits of pulse harvest

Pulses are an excellent source of vegetable protein. They are high in minerals such as iron, calcium, magnesium and potassium, and essential trace minerals copper, manganese, molybdenum, selenium and zinc. They also contain essential vitamins such as the B vitamins thiamine, niacin and folate. [6]

Faba bean is sometimes used as a green manure crop, as it is capable of producing a large amount of N-rich biomass.

A.3 Market

World production of faba beans now exceeds 4.0 million tonnes annually, but only about 2% of this production is traded internationally. The major exporting countries are Australia, France, and the United Kingdom. China was a major exporter of faba beans but has recently become an importer. Figure 9 depicts Australian production of faba bean over the past 30 years.

All faba bean grown in Australia is targeted at the human consumption markets. Countries in the Middle East, specifically Egypt, Saudi Arabia, United Arab Emirates are our major buyers of faba bean. Faba bean is generally consumed whole, canned, split and/or milled into flour.

Producing a high-quality product with continuity of supply is important to current and increased access to world faba bean markets.

International trade in food-quality faba beans is dominated by Egypt as the major importer, with several other countries importing smaller but still significant amounts. In addition, several countries are significant importers of faba beans for livestock feed.

The relatively small volume of faba beans traded is insufficient to interest a transparent marketing system such as futures, which is available with other major grain commodities such as corn, wheat and canola.

The price of faba bean as a commodity is quite stable, rising and falling in line with supply and demand. Traditionally, there were stronger markets prior to the Ramadan festive season but this is less relevant today.

The relatively small tonnage traded means that any delay in harvest or shipping in an exporting country can threaten a contract being met, resulting in a 'short' or 'spike' in

6 Southern/Western Faba & Broad Bean—Best Management Practices Training Course. Pulse Australia 2014.

MORE INFORMATION

Pulse Australia. 'Australian Pulse Crop Forecast & Market News': http://www.pulseaus.com.au/marketing/crop-forecast

the market. These are normally short term and reflect a contractual supply problem rather than a fluctuation in the market.

Recently, the price of faba beans has shown a rising trend as production in the traditional countries has fluctuated for a number of reasons, with insufficient expansion in the exporting countries to fill the demand.

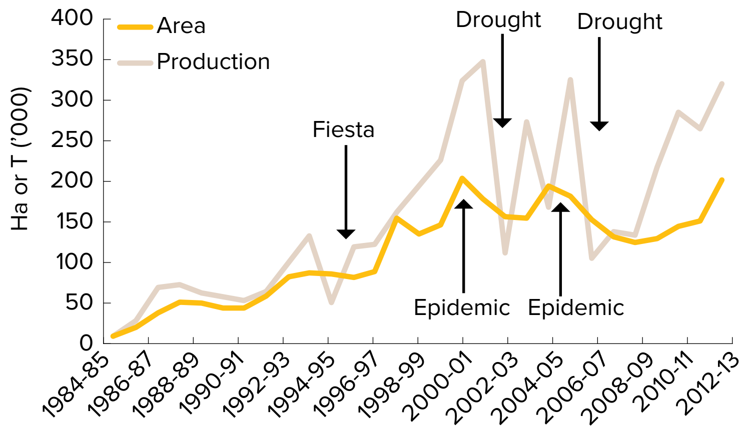

Figure 9: *Australian faba bean production by area and tonnage.*

J Paull. PBA Faba bean breeding: aims and progress.

Nutritional Information

Faba beans are a good source of carbohydrate and protein and contain a low amount of fats. Starch is the principal carbohydrate component. The crude protein content of faba bean ranges from 24 to 31%.

Faba beans meet adult human requirements for all essential amino acids except methionine and tryptophan. They also provide the recommended daily allowance of all essential minerals, except calcium.

Faba beans are highly digestible and have metabolisable energy value for pigs, poultry and ruminants similar to those of lupin, field pea and soybean meal. [7]

A.4 Faba bean research

The development of new varieties of faba bean for different regions is a high priority, supported across Australia by the Grains Research and Development Corporation (GRDC) in partnership with New South Wales Department of Primary Industries (NSW DPI), the University of Adelaide and the Australian Centre for International Agricultural Research (ACIAR). Faba bean varieties show a high degree of specific adaptation, which means that different varieties are required for different regions. Generally, improvements in yield and quality arising through improved specific adaptation and increased disease resistance are needed in new varieties.

All varieties released have been developed from genetic material introduced to Australia, mostly from an international genetic resources centre in Syria (the International Center for Agricultural Research in the Dry Areas, or ICARDA), with the best germplasm so far originating from the Mediterranean, southern China and South America.

In northern NSW/Queensland, faba bean improvement is coordinated by NSW DPI, with breeding activities at Narrabri and Tamworth. The aim is to develop faba bean

7 Northern Faba Bean—Best Management Practices Training Course. Pulse Australia 2014.

varieties suited to subtropical climates with narrower daylength range and earlier springs than southern Australia, and summer-dominant rainfall.

Pulse Breeding Australia (PBA) is a world-class, Australian breeding program for chickpeas, field peas, faba beans, lentils and lupins. PBA has operated since 2006 and its vision is to see pulses expand to >15% of the cropping area, to underpin the productivity, profitability and sustainability of Australian grain-farming systems.

PBA is developing a pipeline of improved varieties for Australian growers that achieve higher yields, have resistance to major diseases and stresses, and have grain qualities that enhance market competitiveness.

PBA is an unincorporated joint venture between:

Department of Primary Industries, Victoria (DPI Vic)

South Australian Research and Development Institute (SARDI)

Department of Agriculture, Fisheries and Forestry, Queensland (QDAF Qld)

New South Wales Department of Primary Industries (NSW DPI)

Department of Agriculture and Food Western Australia (DAFWA)

University of Adelaide

University of Sydney

Pulse Australia

A.5 Keywords

Faba beans, pulse, nitrogen-fixing, crop rotation, northern region.

MORE INFORMATION

Australian Faba Bean Breeding Program: http://finalreports.grdc.com.au/final_reports.php

Pulse Australia: http://www.pulseaus.com.au/growing-pulses/bmp/faba-and-broad-bean

http://grdc.com.au/Research-and-Development/Major-Initiatives/PBA

Planning/Paddock preparation

1.1 Paddock selection and ground preparation

Uniformity of soil type, paddock topography, and surface condition of the paddock are important criteria in assessing whether country is suitable for faba bean production.

Harvest losses are much higher in rough or uneven paddocks, particularly in dry seasons when crop height is reduced. Sticks or rocks, eroded gullies or gilgais ('melon' or 'crab' holes) will prevent headers from operating at low cutting height. The smoother the paddocks the better is the harvesting result, particularly when using headers with wide fronts. Small variations in paddock topography can lead to large variations in cutting height across a wide front and subsequent harvest losses.

Faba beans are easier to harvest than chickpeas or field peas in these conditions, but can sometimes be prone to lodging when planted too early. Frost can cause 'hockey stick', which can also lead to some harvesting difficulties, but newer varieties have better tolerances to this phenomenon.

If growing irrigated faba beans, select fields with good irrigation layout and tail-water drainage. Beds or hills are preferred if flood-irrigating; however, border-check layout has been successful with grades steeper than 1 : 800 or with short runs that can be watered quickly (<8 h). There is a greater risk of irrigating after flowering with border-check, whereas beds and hills are satisfactory and sprinkler irrigation is the safest method overall.

Paddocks that have even soil types are easier to manage, and are preferred for faba beans. [1]

1.1.1 Avoid major variations in soil types

Crop maturity can be significantly affected by moisture supply during the growing season. Any major changes in soil type and moisture-storage capacity across a paddock can lead to uneven crop maturity, delayed harvest, and increased risk of weather damage and/or high harvest losses due to cracking and splits. Uneven crop development also complicates the timing of insecticide sprays, timing of desiccation, and disease management. Disease concerns in the northern region include chocolate spot and rust.

Selecting a paddock with minimal variation in soil type will help to provide even maturity and ripening of the crop. This will enable harvesting at the earliest possible time, increase quality, and minimise harvest losses. The overall result is usually a more profitable crop.

The best soils for faba beans are deep, neutral to alkaline, well-structured soils with high clay content (Figure 1). In northern New South Wales (NSW)/southern Queensland, grey clays, black earths and brigalow clay loams are ideal. The crop will also grow well on red earth clay soils.

MORE INFORMATION

GRDC Update Paper: Impact of soil acidity on crop yield and management in Central Western NSW

1 Northern Faba Bean—Best Management Practices Training Course. Pulse Australia 2014.

Figure 1: *The best soils for faba bean are deep, neutral to alkaline, well-structured soils with high clay content. In northern New South Wales/southern Queensland, grey clays, black earths and brigalow clay loams are ideal.*

Photo: NSW DPI

Avoid soils that are shallow, acidic (pH in $CaCl_2$ <5.2), or very light and sandy in texture. Growers considering planting faba beans on lower pH soils need to check for aluminium (Al) and manganese (Mn) levels, because these will adversely affect plant growth. If soil pH is <5.2, an application of lime should be considered. Avoid soils that are acid at depth, i.e. pH($CaCl_2$) <5.2 at 20–30 cm depth.

Good yields have been achieved in Victoria in paddocks with pH as low as 4.6 where Al and Mn levels are low (Al <20 µg/g and/or Mn <50 µg/g). [2]

Soil sodicity should also be checked, and soils with high exchangeable sodium percentages (ESP) avoided (Figure 2). This is particularly relevant for some of the grey clay soils in the northern region.

MORE INFORMATION

Ground Cover: Soil acidity holds back pulse potential

2 DEPI (2013) Growing faba bean. AG0083. Update May 2013. Department of Environment and Primary Industries, http://www.depi.vic.gov.au/agriculture-and-food/grains-and-other-crops/crop-production/growing-faba-bean

Figure 2: *Soils with high exchangeable sodium percentages (ESP) should be avoided.*

Photo: Drew Penberthy, Penagcon

The crop can handle wet soil conditions better than other pulses and grows very well under furrow irrigation. It is common for dry seedbeds to be pre-watered before sowing, or for dry-sown crops to be watered up. Strategic irrigation during flowering and pod-filling is desirable to maintain high crop growth rates and to maximise pod development.

Paddocks for faba beans can be prepared using conventional or minimum cultivation, as for other winter crops, but the use of no-till or direct-drill methods is preferred and recommended in NSW. However, some soils in central NSW may require cultivation prior to sowing to remove the hardpans that reduce healthy root development.

Management of the fallow after wheat or barley should start when the cereal is harvested, ensuring that straw is left at ~30 cm height and kept as intact as possible by restricting access to support traffic such as chaser bins. Repeated in-fallow herbicide applications should be done on tramlines to minimise damage to stubble. [3]

Weed management for all pulses should involve particular attention to controlling broadleaf weeds in the preceding crop to minimise broadleaf weed pressure in the pulse crop.

Check any soil tests and/or grower records, paying particular attention to the following soil characteristics:

- pH 5.2–8.0
- soil type—loams to self-mulching clays
- sodicity
- salinity/chloride
- bulk density
- potential waterlogging problems
- amount of stored soil moisture and received rainfall, and their potential impact on herbicide residues

Understand the crop management and harvest problems created by unlevelled paddocks and paddock obstacles such as sticks and stones.

3 P Matthews, H Marcellos (2003) Faba bean. Agfact P4.2.7. 2nd edn. NSW Department of Primary Industries, http://www.dpi.nsw.gov.au/__data/assets/pdf_file/0004/157729/faba-bean-pt1.pdf

Aim to direct-drill faba beans into standing cereal stubble. Crops reliably yield 10% higher when established this way. [4]

1.1.2 Avoid deep gilgai or heavily contoured country

Contoured country and undulating country with gilgais present two problems. First, uneven crop maturity occurs because of variation in soil-water supply. Melon-holes usually store more water than the mounds, and the crop in wetter areas often continues flowering and podding when the rest of the crop is already drying down. Similarly, contour banks retain more moisture after rain, and prolong crop maturity relative to the rest of the crop late in the crop cycle.

Second, high harvest losses occur and there is increased risk of dirt contamination in the header sample. Many dryland faba bean crops require the header front to be set close to ground level, and even small variations in paddock topography can cause large variations in cutting height across the header front and significant harvest losses. Contamination of the harvested sample with dirt and clods is difficult to avoid in undulating, gilgai country, and can cause a significant increase in grading losses and costs.

Foreign material must not exceed 3% by weight, of which ≤0.3% must be un-millable material (soil, stones and on-vegetable matter).

If faba beans are delivered that do not meet this export standard, they will need to be graded at a cost of A$15–25/t. [5]

1.1.3 Sticks, stones, clods of soil, ridged soil surface

Stones and sticks are a concern in either poorly or recently cleared country. Harvest losses increase dramatically if the front needs to be raised to avoid serious mechanical damage to the header. Small stones and wood fragments can also contaminate the seed sample and downgrade quality.

Cloddy or badly ridged paddocks are likely to cause contamination of the faba bean sample during harvest. Level the soil surface as much as possible, either during ground preparation or at sowing. Use of a roller after sowing can be helpful where you need to level the soil surface, and push clods of soil and small stones down level with the surface (Figure 3). [6]

Figure 3: *Stones can be a harvest hazard in beans, even in tall crops, unless the ground is rolled after sowing.*

Photo: W. Hawthorne, Pulse Australia

4 Northern Faba Bean—Best Management Practices Training Course. Pulse Australia 2014.

5 Northern Faba Bean—Best Management Practices Training Course. Pulse Australia 2014.

6 Northern Faba Bean—Best Management Practices Training Course. Pulse Australia 2014.

1.1.4 Bunching and clumping of stubble

Stubble bunching or clumping can occur when sowing into retained stubble, as a result of blockages during sowing. These mounds of stubble are often picked up in the header front, causing mechanical blockages and contamination of the sample if they contain excessive amounts of soil.

Management options for dealing with stubble clumping include:

- Use a no-till (disc) seeder or other seeder capable of handling heavy stubble.
- Modify existing air-seeders (tine shape and lifting some tines).
- Sow before soil and stubble become too wet.
- Use rotary harrows to spread and level stubble.
- Standing stubble can be slashed or burnt if sowing equipment with good trash flow is not available. [7]
- Kelly discs are often used immediately after sowing to level the paddock prior to applying the residual herbicides. [8]
- Planting between standing cereal stubble protects the young faba plants from early frosts and helps to prevent spread of viruses from thrips and aphids (Figure 4).

Figure 4: *Planting between standing cereal stubble protects the young faba bean plants from early frosts and helps to prevent spread of viruses from thrips and aphids.*

Photo: Drew Penberthy, Penagcon

1.1.5 Disease and paddock selection

Avoid sowing adjacent to faba bean stubble, particularly downwind. If possible, aim to separate the current faba bean crop from last year's bean stubble by a minimum of 500 m.

A break of at least 4 years between faba bean crops is recommended.

Growers who plan to sow more than one variety of faba beans should ensure at least 500 m between different varieties. Faba beans cross-pollinate, increasing the risk of breakdown of disease resistance and production of mixed seed types that are difficult to market.

Reduce disease risk by avoiding sowing adjacent to vetch crops or stubble. They may harbour *Botrytis fabae*, the primary cause of chocolate spot in faba bean. If this is

7 Northern Faba Bean—Best Management Practices Training Course, Pulse Australia 2014.

8 G Onus. Fababean Growing Program. Landmark Moree.

not possible, employ a management strategy appropriate for situations where there is a high risk of disease.

Ensure that the maximum plant-back periods for herbicides are adhered to, particularly for sulfonylurea and clopyralid. Herbicide residue may cause significant crop damage and weaken the plant's resistance to disease. [9]

1.2 Key requirements for faba beans

Faba beans prefer well-drained loam to clay soils with a pH in the range 5.4–8.0. They will not grow as well in light or acidic soils. They can grow in areas prone to waterlogging, and are the pulse most tolerant of waterlogging (Figure 5). However, they must be well nodulated and have foliar diseases controlled to survive prolonged, waterlogged conditions. There is a limit to their tolerance, and their growth is affected by waterlogging. Avoid stony ground, because the plants need to be harvested close to the ground.

Figure 5: *Faba beans prefer well-draining loam to clay soils but are considered the pulse most tolerant to waterlogging.*

Faba bean are moderately susceptible to hostile subsoils, with boron toxicity, sodicity and salinity perhaps causing patchiness in affected paddocks. Faba beans have very low exchangeable Al tolerance.

Tolerance to sodicity in the root-zone (to 90 cm) is: <5% ESP on the surface and <10% ESP in the subsoil (Mullen 2004) (see Table 1).

Broadleaf weeds and herbicide-resistant ryegrass can cause major problems in faba beans, and a careful management strategy must be worked out well in advance of sowing. It may be possible to control the weeds in the year prior to cropping. However, it is best to avoid paddocks with specific weeds that cannot be controlled by herbicides.

Foliar zinc (Zn), Mn and perhaps iron (Fe) may be needed where deficiencies of these micronutrients are known to occur. [10]

9 Northern Faba Bean—Best Management Practices Training Course. Pulse Australia 2014.

10 Northern Faba Bean—Best Management Practices Training Course. Pulse Australia 2014.

Table 1: *Pulse crop soil requirements.*

Crop	Soil type	Soil pH ($CaCl_2$)	Exchangeable aluminium (%)	Drainage tolerance and rating (1–5)	Sodicity in root-zone (90 cm) (ESP)
Lupin, narrow leaf	Sandy loams	4.2–6.0	20% tolerant	Sensitive (2)	<1 surface <3 subsoil
Lupin, albus	Sandy loams–clay loams	4.6–7.0	Up to 8%	Very sensitive (1)	<1 surface <3 subsoil
Field pea	Sandy loams–clays	4.6–8.0	Up to 5–10%	Tolerant (3)	<5 surface <8 subsoil
Chickpea	Loams–self mulching clay loams	5.2–8.0	Nil	Very sensitive (1)	<1 surface <5 subsoil
Faba bean	Loams–clay loams	5.4–8.0	Nil	Very tolerant (4)	<5 surface <10 subsoil
Canola	Loams–clay loams	4.8–8.0	0-5%	Tolerant (3)	<3 surface <6 subsoil
Lucerne	Loams–clay loams	5.0–8.0	Nil	Sensitive–tolerant (1–3)	<3 surface <5 subsoil

ESP, Exchangeable sodium percentage. Drainage tolerance: 5, no hardpans and good drainage (no puddles after 24 h from a 50-mm rain event); 1, hardpans—can aggravate waterlogging and cause artificial waterlogging

Source: C. Mullen (2004) NSW DPI Central NSW soils.

1.3 Paddock rotation and history

Implementation of the most suitable cereal–pulse–oilseed rotation requires careful planning. There are no set rules and a separate rotation should be devised for each cropping paddock.

The main aims should be sustainability and the highest possible overall profit. To achieve this, the rotation must be flexible enough to cope with key management strategies such as maintaining soil fertility and structure, controlling crop diseases, and controlling weeds and their seed-set.

The same pulse should not be grown in succession. Extreme care must be taken if growing the same crop in the same paddock without a spell of at least 3 years. Successive cropping with the same pulse is likely to result in rapid build-up of root and foliar diseases as well as weeds. Where possible, alternate different pulse crops in a continuous rotation with cereals.

Some farmers have adopted a pulse–wheat–barley sequence for their basic rotation. However, where a pulse and other crops can be grown, farmers are increasingly adopting a continuous pulse–cereal–oilseed–cereal rotation, e.g. beans–wheat–canola–barley. [11]

1.4 Benefits of faba beans as a rotation crop

1.4.1 Pulses and cereals

Pulses and cereal crops are complementary in a cropping rotation. The ways in which a crop affects following crops include well-recognised processes related to disease, weeds, rhizosphere microorganisms, herbicide residues, and residual soil water and mineral nitrogen (N). They may also include two recently discovered processes. One is growth stimulation following hydrogen gas released into the soil by the

MORE INFORMATION

Ground Cover: Faba bean potential as southern rotation option

11 GRDC (2008) Grain Legume Handbook. Update 7 February 2008. Grains Research & Development Corporation, https://grdc.com.au/uploads/documents/Index.pdf

legume–rhizobial symbiosis. The other is a drain on assimilates when its roots are strongly colonised by the hyphae of arbuscular mycorrhizal fungi (AMF) built up by a previous colonised host crop. (AMFs have also been known as vesicular arbuscular mycorrhizal or VAM.)

Pulses fix their own N_2, leaving available N in the soil for the following cereal crop. Pulses also play a vital role in controlling major cereal root diseases, particularly take-all.

The combination of higher soil N and reduced root diseases is cumulative and can result in a dramatic increase in subsequent cereal yields. The amount of N fixed is determined by how well the pulse crop grows, reflecting the effectiveness of nodulation, seasonal conditions, crop management, and the level of nitrate in the soil at sowing. Soil nitrate suppresses nodulation and N_2 fixation; hence, high soil nitrate means low N_2 fixation.

Numerous trials have clearly demonstrated the yield increases possible when pulses are included in a cropping rotation (see Tables 2, 3 and 4)

Some of the most significant early trial results came from Tarlee, South Australia, where intensive cropping rotations including pulses were continued for >10 years until herbicide resistance became a problem (see Table 2).

Much of the yield increase was directly associated with the control of cereal root diseases, including cereal cyst nematode and take-all. The weed-control measures used in the pulses successfully reduced grass populations, which also act as host to many cereal root diseases. However, herbicide resistance developed, highlighting the fact that sustainability requires more than improving soil fertility and disease control. [12]

Table 2: *Tarlee rotation trial (soil type: red brown earth).*

Rotation	Wheat yields (t/ha) (5-year average)
Fallow–wheat	2.20
Continuous cereal + nitrogen[A]	1.82
Pulse–wheat	2.45
Sown pasture–wheat	2.23
Volunteer pasture–wheat	1.99

Pulses grown were field pea, lupin and faba bean

[A] Nitrogen was applied at 40 kg/ha.

Source: Grain Legume Handbook.

Table 3: *Coonalpyn rotation trial (soil type: sand over shallow clay).*

Pulses were field pea, lupin and faba bean

Rotation	Wheat yields (t/ha)
Continuous wheat + nitrogen[A]	3.0
Volunteer pasture–wheat	2.2
Sown pasture–wheat	2.2
Pulse–wheat	3.7

A Nitrogen was applied at 30 kg/ha.

Source: Grain Legume Handbook.

12 Northern Faba Bean—Best Management Practices Training Course. Pulse Australia 2014.

Table 4: *Mundulla rotation trial (soil type: brown clay loam).*
Pulses were lupin (narrow leaf and albus), field pea and faba bean

Initial crop type	Second-year wheat yields			Third-year wheat yields		
	Rate of nitrogen (kg/ha):			Rate of nitrogen (kg/ha):		
	0	25	50	0	25	50
Pulse	4.75	4.95	4.99	2.71	3.23	3.48
Fallow	4.71	4.91	4.82	2.88	3.30	3.37
Pasture	3.69	4.22	4.27	2.85	3.21	3.28
Cereal	3.65	4.20	4.40	2.70	2.95	3.02

Source: Grain Legume Handbook.

1.4.2 Disease management and nitrogen benefits

Increased levels of plant-available N are only part of the story. Some of the increases in cereal yield can be attributed to the break effect of the legumes on soil- and stubble-borne diseases. Major cereal diseases in the northern grains region are shown in Table 5.

Table 5: *Major cereal diseases of the northern grains region and effectiveness of legumes as break-crops.*

Cereal disease	Causal agent	Crop legumes (chickpeas, faba beans, mungbeans, soybeans) as disease breaks
Crown rot	*Fusarium pseudograminearum*	Effective
Common root rot	*Bipolaris sorokiniana*	Effective
Yellow leaf spot	*Pyrenophora triticirepentis*	Effective
Take-all	*Gaeumannomyces graminis*	Effective
Fusarium head blight	*Fusarium graminearum*	Effective
Root lesion nematode	*Pratylenchus thornei, Pratylenchus neglectus*	Not particularly effective - all four crop legumes susceptible to *P. thornei*

From: D Herridge (2013) Managing legume and fertiliser N for northern grains cropping (GRDC)

All of the cereal diseases in Table 5, except root-lesion nematode (RLN), are caused by fungi. Soil-borne cereal pathogens reduce the health of the roots, subcrown internodes and crowns of plants, resulting in diminished ability of the plant to transport water and nutrients from the roots to the rest of the plant.

Crop legumes are generally effective disease breaks and are usually more effective than pasture leys because of the potential for grasses in the ley to provide alternative hosts for disease. The diseases cause yield loss of cereals, with estimates of losses varying with site, season, species and cultivar.

Wildermuth *et al.* (1997) suggested wheat yield losses of 10–20% from crown rot in the northern grainbelt. Other diseases, such as common root rot, yellow leaf spot and RLN, will add to that loss, with RLN alone estimated to cost northern grains region farmers about $50 million annually.

A reasonable estimate for the average disease-break effect of legumes in the northern grainbelt is 0.5 t/ha, equivalent to ~20% of average yield.

The combined N and disease-break effects of legumes are shown in a hypothetical set of data that describe wheat yields following either wheat or a legume, all grown in a relatively low-nitrate soil (Figure 6).

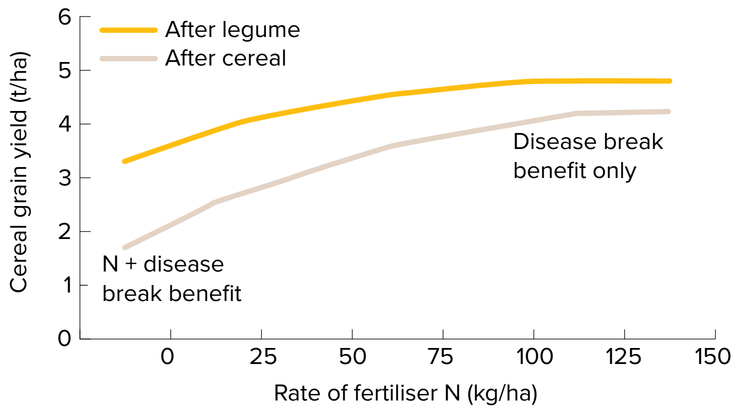

Figure 6: *Cereal yields following either a cereal or a grain legume, at increasing rates of fertiliser nitrogen (N). In this scenario, the yield differences are made up of a disease-break effect (0.5 t/ha) and an N effect, the latter ranging from zero at the highest rate of fertiliser N to 1.1 t/ha at nil fertiliser N.*

From: D Herridge (2013) Managing legume and fertiliser N for northern grains cropping. p. 35. GRDC

The wheat is fertilised with different rates of N to determine the fertiliser N equivalence, that is, how much additional fertiliser N is required for wheat after wheat compared with wheat after legume. At nil fertiliser N, the increased wheat yield after the legume is a combination of the N and disease-break effects. As the rate of fertiliser N is increased, the N benefit of the legume diminishes and the disease-break effect remains constant. At the high rates of fertiliser N, the rotational benefit of the legume may be entirely due to the disease-break effect.

In this hypothetical scenario, the fertiliser N equivalence of the legume benefit is about 60 kg N/ha. [13]

1.4.3 Controlling cereal root disease

Crown rot

Crown rot caused by the fungal pathogen *Fusarium pseudograminearum* is a major constraint to winter cereal production (wheat, barley and triticale) in Australia. The crown rot pathogen is stubble-borne and survives as mycelium (cottony growth) inside cereal and grass weed residues.

The starting levels of crown rot inoculum and the season in which break-crops are grown will influence their effectiveness. Hence, rotation to non-host winter pulse (chickpea, faba bean, field pea, lupin) or oilseed (canola or mustard) crops or to summer crops (sorghum, cotton, sunflowers, mungbean etc.) is a crucial component of an integrated disease management system (Figure 7). Break-crops allow natural microbial decomposition of cereal residues, which harbour the crown rot fungus.

The row spacing at which break-crops are sown likely influences their effectiveness in controlling crown rot. Research indicates that break-crops grown on row spacings of 30 or 38 cm rather than 50 or 100 cm provide more groundcover and will be more effective in reducing the inoculum of the crown rot fungus. [14]

Trials in the northern region have indicated that faba beans and canola are better break crops for crown rot than chickpeas.

MORE INFORMATION

Ground Cover: Fusarium head blight in the north

GRDC Update Paper: Managing crown rot through crop sequencing and row placement

GRDC Update Paper: Crown rot an update on latest research

13 Northern Faba Bean—Best Management Practices Training Course. Pulse Australia 2014.

14 Northern Faba Bean—Best Management Practices Training Course. Pulse Australia 2014.

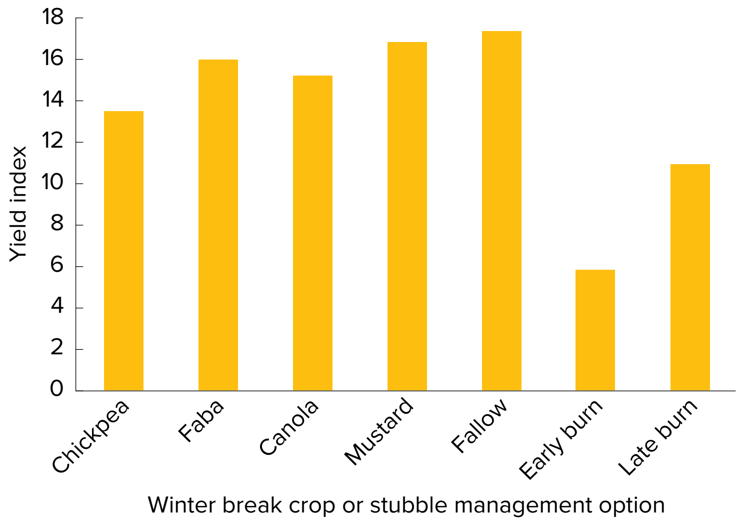

Figure 7: *Winter break-crop or stubble management options—yield indexed to continuous wheat.*

Source: NSW DPI. Crown rot management strategies, http://www.pulseaus.com.au/storage/app/media/crops/2006_Pulses-crown-rot-management.pdf

1.4.4 Quantifying break-crop yield increases

Yields of wheat grown after a broadleaf break-crop generally exceed yields of wheat grown after wheat or other cereals. The presumed reasons for the yield benefit vary between break-crops. They include reduced root and foliar disease, increased supply of soil water and mineral N, reduced assimilate loss to mycorrhizae and, after legumes, growth stimulation following hydrogen gas release.

Angus *et al* (2008) quantified the value of break-crops by compiling data from published experiments on the additional yield of wheat following oilseeds, pulses or alternative cereals grown in the previous year. Generally, yield increase was not proportional to yield, and the yield contribution of break-crops is best expressed in absolute terms, not percentage.

Break-crops improve the yield of subsequent wheat crops. For a 4 t/ha wheat crop, the additional yield after pulses was ranged from 1.81 t/ha (for lupin) to 1.10 t/ha (for field pea). For an oats break-crop it was 0.47 t/ha, and after canola and linseed it was 0.85 t/ha.

Data suggest that control of take-all and residual N after legumes are the largest benefits from break-crops (Table 6).

MORE INFORMATION

NSW DPI: Crown rot management strategies: http://www.pulseaus.com.au/storage/app/media/crops/2006_Pulses-crown-rot-management.pdf

MORE INFORMATION

GRDC Update Paper: Key outcomes arising from the crop sequence project

MORE INFORMATION

Ground Cover: New varieties and rotations rescue lost potential

Table 6: *Sources of the break-crop effect and estimates of their value at a wheat yield level of 4 t/ha.*

Mechanism for wheat yield increase	Additional wheat yield (t/ha)
Take-all suppression	0.5
Suppression of other root diseases	0.3
Net nitrogen benefit of canola	0.1
Hydrogen fertilisation by legumes	0.4
Suppression of AMF by non-host crops	0.0–0.1
Net nitrogen benefit of legumes	0.5

Hydrogen fertilisation is from increased soil hydrogen after legumes and is assumed at 10%; AMF, arbuscular mycorrhizal fungi

Source: Angus et al. 2008

Legumes such as lupin, chickpeas, field peas and faba beans offer the benefit of hydrogen fertilisation, which stimulates growth by 0–15% due to increased hydrogen in the soil. Estimates of the yield effect of hydrogen fertilisation by legumes are ~10%. [15]

1.4.5 Nitrogen fixation

A pulse crop does not necessarily add large quantities of N to the soil. The amount of N_2 fixed is determined by how well the pulse crop grows, reflecting the effectiveness of nodulation, seasonal conditions, crop management, and the level of nitrate in the soil at sowing. Soil nitrate suppresses nodulation and N_2 fixation. Thus, high soil nitrate means low N_2 fixation.

Pulses are usually able to fix sufficient N_2 from the air for their own needs, but a large amount is removed in the grain when crops are harvested.

Soil N levels following a pulse crop usually remain undepleted, so it is the available N that is high (see Table 7).

Where a pulse crop grows well but produces a poor yield, i.e. low harvest Index, the net result may be an increase in total soil N levels. Crops producing average or above average yields are likely to remove as much N as they produce.

Generally, then, soil N levels following a pulse crop are the result of a carryover effect of residual N rather than a net gain from the crop (see Table 7). In low-yielding cereal–pulse rotations, the pulse may provide enough N for the following crop. [16]

Quantifying nitrogen fixation

Turpin *et al* (2002) found that faba beans are more reliant on N_2 fixation than are chickpeas when grown under the same conditions of soil N supply. Early in crop growth, when soil N supply was high, faba beans maintained a higher dependence on N_2 fixation than chickpeas (45% v's 12%), fixed greater amounts of N_2 (57 *v.* 16 kg/ha), and used substantially less soil N (69 *v.* 118 kg/ha) (Figure 8).

In that study, soil-N sparing was observed. However, despite these differences in N_2 fixation and soil nitrate interactions, at the end of the growing season, there were no differences in soil nitrate levels between the chickpea, faba bean, and wheat plots. Grain yields of the two pulses were unaffected by soil-N supply (i.e. fertiliser N treatment).

Under the starting soil nitrate levels typical of many cropping soils (11–86 kg N/ha), faba bean and chickpea crops with high biomass will not spare significant amounts of soil N. With higher soil nitrate and/or smaller biomass crops with less N demand, nitrate sparing may occur, particularly with faba beans.

MORE INFORMATION

GRDC Update Paper: Legume effects on soil N dynamics - comparisons of crop response to legume and fertiliser N (Corowa)

15 Northern Faba Bean—Best Management Practices Training Course. Pulse Australia 2014.

16 Northern Faba Bean—Best Management Practices Training Course. Pulse Australia 2014.

Overall, Turpin *et al* (2002) found that faba beans fixed more N_2 than chickpeas. Values of N of the total plant including roots were 209–275 kg/ha for faba beans and 146–214 kg/ha for chickpeas. Values for percentage of the N that had been fixed were 69–88% for faba beans and 64–85% for chickpeas (Figure 9). Soil N balances, which combined crop N fixed as inputs and grain N as outputs, were positive for the legumes, with ranges 80–135 kg N/ha for chickpeas and 79–157 kg N/ha for faba beans, and negative for wheat (–20 to –66 kg N/ha). [17]

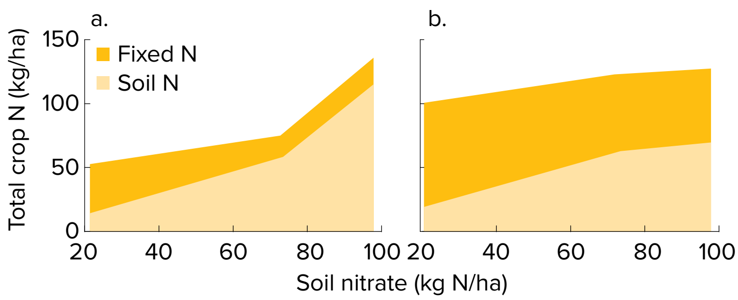

Figure 8: *Effects of soil N supply on soil-N use and N_2 fixation of (a) chickpeas and (b) faba beans for days 0–64 of growth. Soil N supply varied with fertiliser N treatment. These data supports the need for early and effective nodulation in faba bean.*

Source: Turpin et al. 2002

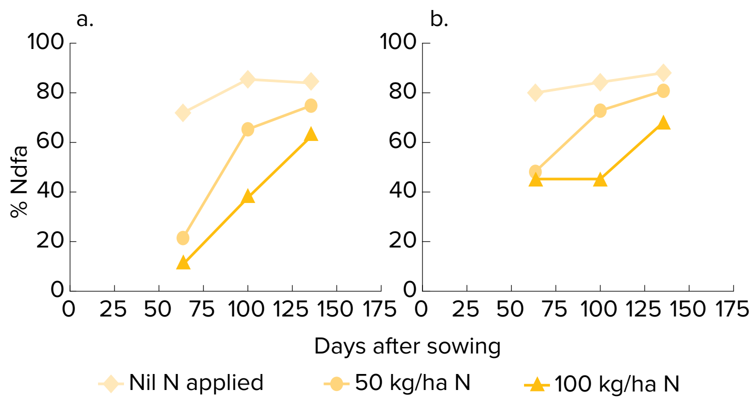

Figure 9: *Effects of available soil nitrogen (applied as N fertiliser) on the percentage of the N that was fixed (i.e. derived from the atmosphere; % Ndfa) over time for (a) chickpea and (b) faba bean.*

Source: Turpin et al. 2002

Nitrate-N benefit for following cereals

The nitrate-N benefit from chickpea and faba bean over a range of grain yields has been calculated from trials in northern Australia (Herridge *et al*. 2003) (Table 8). To understand N budgets for chickpeas and faba beans, it is important to understand the terminology:

17 Northern Faba Bean—Best Management Practices Training Course. Pulse Australia 2014.

- Total nitrogen fixed. The N fixed in both aboveground (shoots) and belowground (roots and nodules) biomass. With chickpea, 50% of total crop N is belowground; with faba bean, it is ~30%.
- Nitrogen balance. The difference between N inputs to the pulse crop (N_2 fixation + N applied) and N outputs (N harvested in grain or hay + N lost (volatilised) from the crop and soil).
- Nitrate-N benefit. The extra nitrate-N available at sowing in soil that grew a pulse crop in the previous season, compared with soil that grew a cereal crop.
- Harvest index (HI). For different crops, the relationship between shoot dry matter and grain yield (i.e. HI) may vary according to season and management. [18]

Table 7: *Nitrate-N benefit (kg N/ha) from chickpeas and faba beans over a range of grain yields.*

Grain yield (t/ha)	Shoot dry matter (t/ha)	Low soil nitrate at sowing (50 kg N/ha)			Moderate soil nitrate at sowing (100 kg N/ha)		
		N fixed	N balance	Nitrate-N benefit	N fixed	N balance	Nitrate-N benefit
Chickpeas							
1.0	2.4	31	–3	16	13	–21	4
1.5	3.6	74	22	28	47	–5	13
2.0	4.8	120	49	44	84	12	24
2.5	6.0	157	66	48	111	21	38
3.0	7.1	198	88	52	141	31	52
3.5	8.3	231	102	57	164	35	64
4.0	9.6	264	116	61	188	39	69
Faba beans							
1.0	2.8	49	12	15	39	2	3
1.5	4.2	83	25	26	68	10	11
2.0	5.6	120	40	41	100	21	22
2.5	6.9	158	58	45	133	33	36
3.0	8.3	196	75	49	167	45	49
3.5	9.7	234	92	53	202	60	60
4.0	11.1	274	111	57	237	74	64

Source: Grain Legume Handbook.

By understanding the development and measurement of crop biomass as well as the factors that influence HI, then better N and rotation management decisions can be made.

MORE INFORMATION

GRDC Update Paper: Fixing more nitrogen in pulse crops

1.5 Disadvantages of faba beans as a rotation crop

A disadvantage of faba beans is that they often struggle to provide an economic return as a 'stand-alone' crop. However, this disadvantage is usually minimised by the benefits they provide to other crops in the rotation. Often, economic benefits realised in the following crops can be attributed to the preceding faba beans.

Faba beans also provide limited stubble cover and may have implications for nematode populations.

Faba beans have few disadvantages; however, volunteers can appear after the crop is harvested. Diseases in wet years are also a concern. Spraying with a tow-behind

18 Northern Faba Bean—Best Management Practices Training Course. Pulse Australia 2014.

spray rig is also an issue later in the season because they grow so tall; a self-propelled spray rig or a plane is usually required after mid-flower.

1.6 Fallow management

The increased soil-water retention and decreased soil nitrate accumulation that occurs during a summer (pre-crop) fallow has been shown by the NSW Department of Primary Industries (NSW DPI) to improve the productivity and N_2 fixation of chickpeas and faba beans.

In NSW DPI rotation experiments involving faba beans, no-tilled soils contained 38 mm more water than cultivated soils at the end of the summer fallows, and 30 kg N/ha less nitrate. Shoot dry matter, plant N and crop N_2 fixed were, respectively, 5%, 12% and 14% higher in no-till crops. [19]

Paddocks for faba beans can be prepared using conventional or minimum cultivation as for other winter crops, but no-till or direct-drill methods are preferred, and are recommended in NSW. However, some soils may require cultivation prior to sowing to remove hardpans that inhibit healthy root development.

Management of the fallow after wheat or barley should start when the cereal is harvested. Leave straw at ~30 cm height and keep as intact as possible by restricting access to support traffic such as chaser bins. Repeated in-fallow herbicide applications should be done on tramlines to minimise damage to stubble. [20]

1.6.1 Fallow weed management

Effective weed management in faba beans involves planning at least a season before sowing. Few herbicides are registered for the control of broadleaf weeds, so select a paddock with low weed burden, or utilise the preceding crop and fallow to reduce weed numbers. Weed control mostly needs to be done in preceding cereal crops, combined with pre-emergent herbicides and vigorous plant stands.

For a list of registered herbicides, the annual NSW Agriculture Weed Control in Winter Crops is a useful guide. Consult the product label before using any herbicide.

Use of best management practices such as timely sowing, optimal plant population and adequate nutrition are valuable for weed management, because faba beans compete strongly once canopy closure has occurred. [21]

1.6.2 Fallow chemical plant-back effects

Plant-back periods are the obligatory times between the herbicide spraying date and safe planting date of a subsequent crop.

When planning weed-control programs in crops and fallow prior to faba beans, be cautious about the use of herbicides with damaging residues. Many of the Group B herbicides have long plant-back periods, up to 24 months for faba beans, which are prolonged on dry soils with pH($CaCl_2$) >6.5.

Some herbicides have a long residual. The residual is not the same as the half-life. Although the amount of chemical in the soil may break down rapidly to half of the original amount, what remains can persist for long periods, for example in sulfonylureas such as chlorsulfuron. Herbicides with long residuals can affect subsequent crops, especially if effective at low levels of active ingredient (such as the sulfonylureas). On the label, this will be shown by plant-back periods, which are

19 GRDC (2013) Nitrogen fixation and N benefits of chickpeas and faba beans in northern farming systems. GRDC Nitrogen Fixation Fact Sheet July 2013, http://www.grdc.com.au/Resources/Factsheets/2013/07/Nitrogen-fixation-and-N-benefits-of-chickpeas-and-faba-beans-in-northern-farming-systems

20 P Matthews, H Marcellos (2003) Faba bean. Agfact P4.2.7. 2nd edn. NSW Department of Primary Industries, http://www.dpi.nsw.gov.au/__data/assets/pdf_file/0004/157729/faba-bean-pt1.pdf

21 P Matthews, H Marcellos (2003) Faba bean. Agfact P4.2.7. 2nd edn. NSW Department of Primary Industries, http://www.dpi.nsw.gov.au/__data/assets/pdf_file/0004/157729/faba-bean-pt1.pdf

usually listed under a separate 'Plant-back' heading or under the 'Protection of crops etc.' heading in the 'General Instructions' section of the label. [22]

1.6.3 Herbicide residues in soil

Pulse growers need to be aware of possible herbicide residues because they can affect crop rotation choices or cause crop damage. Herbicide residues are more damaging where rainfall has been low. After a dry season, herbicide residues from previous crops could influence crop choice and rotations more than considerations of disease. The reverse occurs after a wet year.

Weed burden in the new crop will depend on the seed-set from previous year and residual herbicide efficacy.

Pulse crop types differ in their sensitivity to residual herbicides, so check each herbicide used against each pulse type.

MORE INFORMATION

Australian Pulse Bulletin: Residual herbicides and weed control

Residues of sulfonylurea herbicides can persist in some soils and can last for several years, especially in more alkaline soils and where there is little summer rainfall. The pulses emerge and grow normally for a few weeks and then start to show signs of stress. Leaves become off-colour, roots may be clubbed; plants stop growing and eventually die. Beans and vetches are more sensitive to Logran® (triasulfuron) than to Glean® (chlorsulfuron) residues, unlike other pulses. Faba beans are one of the least sensitive pulses to chlorsulfuron residues in soil. Refer to the labels for recommendations on plant-back periods for pulses following use of any herbicides. Be especially wary under conditions of limited rainfall since herbicide application.

Picloram (e.g. Tordon® 75-D) residues from spot-spraying can stunt any pulse crop grown in that area. This damage is especially marked in faba beans, where plants are twisted and leaves are shrunken (Figures 10 and 11). In severe cases, bare areas are left in the crop where this herbicide has been used, sometimes >5 years ago. Although this damage usually occurs over a small area, correct identification of the problem avoids confusion with some other problem such as disease.

In wheat–faba bean rotations, fallow and in-crop residual herbicides such as Broadstrike®, Eclipse®, Flame®, Grazon® DS, Lontrel® and metsulfuron (Ally®, Associate®, Lynx®, Harmony® M) should all be avoided, particularly during the summer fallow or weed control period (after November).

The use of long-term residual sulfonylurea herbicides such as Monza®, chlorsulfuron (Glean®, Lusta®) and Logran® should be avoided in wheat when re-cropping to faba beans. [23]

Figure 10: *Tordon® soil residues affecting faba bean. Note the stem distortion and severe leaf curl.*

Photo: Grain Legume Handbook

22 B Haskins (2012) Using pre-emergent herbicides in conservation farming systems. NSW Department of Primary Industries, http://www.dpi.nsw.gov.au/__data/assets/pdf_file/0003/431247/Using-pre-emergent-herbicides-in-conservation-farming-systems.pdf

23 Northern Faba Bean—Best Management Practices Training Course. Pulse Australia 2014.

Figure 11: *Previous year's Tordon® spot spray effect. Plants in the affected area are stunted.*

Photo: Grain Legume Handbook

1.7 Seedbed requirements

Rhizobia

Before European settlement, Australian soils lacked the rhizobia (N_2-fixing soil bacteria) needed for the pulse and pasture legumes now commonly grown in farming systems. However, after more than a century of legume cultivation, many soils have developed large and diverse communities of these introduced rhizobia.

Rhizobia become established in soils in several ways. Many were introduced as high-quality inoculants. Others arrived accidently with the movement of dust, soil and seed around the country, and some have evolved via genetic exchange with other bacteria in the soil. Because rhizobia are legume-specific and their persistence is affected by soil characteristics and cultural practices, their diversity, number and N_2-fixation capacity can vary greatly.

The legume history of a soil provides some guide. If a legume species, or one very similar to it, has not been grown in a paddock, it is unlikely that the rhizobia for that legume will be present in the soil in high numbers.

Conversely, where there is a recent history of well-nodulated legumes in a paddock, there is a reasonable chance the rhizobia that nodulated the legume will be in the soil.

Some extension materials suggest that inoculation is not necessary if the legume host has been grown in any of the previous 4 years. This simplistic rule fails to recognise that the level of nodulation of the previous crop can affect the current population of rhizobia in the soil, and that many soils are not conducive to the survival of large numbers of rhizobia because of factors such as extremes of soil pH and low clay content. In addition, the communities of rhizobia that develop under legume cultivation often become less effective N_2 fixers over time. [24]

It is wise to inoculate the faba beans each time they are planted to ensure effective nodulation; it is the cheapest and most effective N supplied into the farming system. Always inoculate the seed with the correct rhizobial strain regardless of paddock history.

Inoculate seed with correct rhizobium (Group F). This comes in various forms including freeze-dried vials, liquid vials and peat-based products. The vial products can be easily pumped and sprayed onto the seed. The peat products are usually mixed into a slurry with water and poured onto the stream of grain as it goes up

24 E Drew et al. (2012) GRDC Inoculating legumes: a practical guide. GRDC, http://www.grdc.com.au/GRDC-Booklet-InoculatingLegumes

MORE INFORMATION

Rhizobial inoculants Fact Sheet

the auger. Inoculation is usually done as the faba beans are augered into the air seeder cart. [25]

1.8 Soil moisture

1.8.1 Dryland

At sowing, faba beans need at least 150 mm of plant-available water (PAW), to a depth of 1 m. The crop requires average annual rainfall of 400 mm, or areas with irrigation. Faba beans have been grown in drier areas (350 mm); however, there are yield penalties.

Eighty mm of PAW is equivalent to about a 50% profile on a deep clay soil, and closer to a 75% profile on a loam soil. Faba beans have good tolerance of sodic and waterlogged soils, providing the sodicity or underlying structural problems do not greatly affect the water-holding capacity of the soil. [26]

1.8.2 Irrigation

Faba beans can be sown into pre-watered beds or hills, or into a dry seedbed. Dry sown seed should be watered-up as soon as possible to maintain the viability of the inoculum applied to the seed. Once watered up, and/or given reasonable rainfall in June and July, the crop may not need watering until early spring. [27]

1.8.3 Seasonal outlook

Growers and advisers now have a readily available online decision tool. CropMate was developed by NSW DPI and can be used in pre-season planning to analyse average temperature, rainfall and evaporation. It provides seasonal forecasts and information about influences on climate, such as the effect of Southern Oscillation Index (SOI) on rainfall. CropMate provides estimates of soil water and N, frost and heat risk, and gross margin analyses of the various cropping options.

Download CropMate from the App Store on iTunes at: https://itunes.apple.com/au/app/cropmate-varietychooser/id476014848?mt=8

Australian CliMate is a suite of climate analysis tools delivered on the web, and iPhone, iPad and iPod Touch devices. CliMate allows you to interrogate climate records, to ask questions relating to rainfall, temperature, radiation, and derived variables such as heat sums, soil water and soil nitrate, and well as El Niño Southern Oscillation status. It is designed for decision makers such as farmers whose businesses rely on the weather.

Download from the Apple iTunes store at https://itunes.apple.com/au/app/australian-climate/id582572607?mt=8 or visit http://www.australianclimate.net.au

One of the CliMate tools, '*Season's progress?*', uses long-term (1949 to present) weather records to assess progress of the current season (rainfall, temperature, heat sums and radiation) compared with the average and with all years. It explores the readily available weather data, compares the current season with the long-term average, and graphically presents the spread of experience from previous seasons.

Crop progress and expectations are influenced by rainfall, temperature and radiation since planting. *Season's progress?* provides an objective assessment based on long-term records:

- How is the crop developing compared to previous seasons, based on heat sum?
- Is there any reason why my crop is not doing as well as usual because of below-average rainfall or radiation?

25 G Onus. Fababean Growing Program. Landmark Moree.

26 R Brill (2011) Research reveals how to improve faba results. GRDC Ground Cover Issue 92, May–June 2011, http://www.grdc.com.au/Media-Centre/Ground-Cover/Ground-Cover-Issue-92-May-June-2011/Research-reveals-how-to-improve-faba-results

27 P Matthews, H Marcellos (2003) Faba bean. Agfact P4.2.7. 2nd edn. NSW Department of Primary Industries, http://www.dpi.nsw.gov.au/__data/assets/pdf_file/0004/157729/faba-bean-pt1.pdf

MORE INFORMATION

http://www.grdc.com.au/Research-and-Development/GRDC-Update-Papers/2013/07/Seasonal-climate-outlook-improvements-changes-from-historical-to-real-time-data

www.australianclimate.net.au

MORE INFORMATION

http://www.grdc.com.au/Research-and-Development/GRDC-Update-Papers/2013/07/Impact-of-stored-water-on-risk-and-sowing-decisions-in-western-NSW

- Based on season's progress (and starting conditions from HowWet-N?), should I adjust inputs?

For inputs, *Season's progress?* asks for the weather variable to be explored (rainfall, average daily temperature, radiation, heat sum with base temperatures of 0, 5, 10, 15 and 20°C), a start month and a duration.

As outputs, text and two graphical presentations are used to show the current season in the context of the average and all years. Departures from the average are shown in a fire-risk chart as the departure from the average in units of standard deviation. [28]

The Bureau of Meteorology has recently moved from a statistics-based to a physics-based (dynamical) model for its seasonal climate outlooks. The new system has better overall skill, is reliable, allows for incremental improvements in skill over time, and provides a framework for new outlook services including multi-week/monthly outlooks and the forecasting of additional climate variables. [29]

For a growing crop, there are two sources of water: first, the water stored in the soil during the fallow, and second, the water that falls as rain while the crop is growing. As a farmer, you have some control over the stored soil water; you can measure how much you have before planting the crop. Long-range forecasts and tools such as the SOI can indicate the likelihood of the season being wet or dry; however, they cannot guarantee that rain will fall when you need it. [30]

Faba bean varieties should be grown only in areas where the rainfall is >350 mm. Faba beans are not well suited to lower rainfall areas. They are very responsive to moisture, and will grow very short with pods close to the ground if moisture is severely limiting. In addition, faba beans do not tolerate hot conditions during flowering; hence, pod set can be poor and flowering terminated prematurely when hot conditions occur. Yield potential is therefore severely penalised by adverse hot and dry conditions during flowering.

Cool conditions are ideal for flowering and pod-set. Cool and wet conditions are more likely to stimulate foliar diseases if protection is not provided, and foliar disease can adversely affect seed-set and yield. Chocolate spot *(Botrytis fabae)* and, in some areas, rust (*Uromyces viciae*) are now highest priorities for control in medium- and high-rainfall areas.

Variety choice, crop hygiene, and fungicide choice and timing are all important in a management strategy for foliar diseases of faba bean.

HowWet?

HowWet? is a program that uses records from a nearby weather station to estimate how much PAW has accumulated in the soil and the amount of organic N that has been converted to an available nitrate during a fallow. HowWet? tracks soil moisture, evaporation, runoff and drainage on a daily time-step. Accumulation of available N in the soil is calculated based on surface soil moisture, temperature and soil organic carbon.

HowWet?:

- estimates how much rain has been stored as plant-available soil water during the most recent fallow period;
- estimates the N mineralised as nitrate-N in soil; and
- provides a comparison with previous seasons.

This information aids in the decision about which crop to plant and how much N fertiliser to apply.

28 Australian CliMate. Climate tools for decision makers. Managing Climate Variability R&D Program, www.australianclimate.net.au

29 J Sabburg, G Allen (2013) Seasonal climate outlook improvements changes from historical to real time data. GRDC Update Papers 18 July 2013, http://www.grdc.com.au/Research-and-Development/GRDC-Update-Papers/2013/07/Seasonal-climate-outlook-improvements-changes-from-historical-to-real-time-data

30 J Whish (2013) Impact of stored water on risk and sowing decisions in western NSW. GRDC Update Papers 23 July 2013, http://www.grdc.com.au/Research-and-Development/GRDC-Update-Papers/2013/07/Impact-of-stored-water-on-risk-and-sowing-decisions-in-western-NSW

Many grain growers are in regions where stored soil water and nitrate at planting are important in crop management decisions. This is particularly so for northern Australian grain growers with clay soils, where stored soil water at planting can constitute a large part of a crop's water supply.

Questions this tool answers:

- How much longer should I fallow? If the soil is near full, perhaps the fallow can be shortened.
- Given my soil type and local rainfall to date, what is the relative soil moisture and nitrate-N accumulation over the fallow period compared with most years? Relative changes are more reliable than absolute values.
- Based on estimates of soil water and nitrate-N accumulation over the fallow, what adjustments are needed to the N supply? [31]

Inputs

1. A selected soil type and weather station
2. An estimate of soil cover and starting soil moisture
3. Rainfall data input by the user for the stand-alone version of HowOften?

Outputs

4. A graph showing plant-available soil water for the current year and all other years and a table summarising the recent fallow water balance
5. A graph showing nitrate accumulation for the current year and all other years

Reliability

HowWet? uses standard water-balance algorithms from HowLeaky? and a simplified nitrate mineralisation based on the original version of HowWet? Further calibration is needed before accepting with confidence absolute value estimates.

Soil descriptions are based on generic soil types with standard organic carbon (C) and C/N ratios, and as such should be regarded as indicative only and best used as a measure of relative water accumulation and nitrate mineralisation. [32]

MORE INFORMATION

http://www.australianclimate.net.au/About/HowWetN

1.8.4 Weeds and paddock selection

Selection of the most appropriate paddock for growing faba beans requires consideration of several important factors, many of which relate to the modes of survival and transmission of pathogens such as chocolate spot.

- Rotation
  - » Develop a rotation of no more than 1 year of beans in 4 years.
  - » Plant beans into standing stubble of previous cereal stubble to protect against rain-splash of soil-borne spores, protect against erosion and reduce attractiveness of the crop to aphids (aphids may vector viruses).
  - » Consideration also needs to be given to previous crops that may host pathogens such as *Sclerotinia, Rhizoctonia* and *Phoma medicaginis*.
  - » *Ascochyta fabae* and *Botrytis fabae* are faba bean specific, whereas *Botrytis cinerea* has a wide host range including chickpeas.
  - » *Phoma medicaginis* var. *pinodella* can be hosted by lucerne, clover, field peas, lupins and chickpeas as well as *Phaseolus* spp.
- History of bean diseases
  - » Previous occurrence of soil-borne diseases (Sclerotinia stem rot, stem nematode or perhaps *Pratylenchus* nematodes) constitutes a risk for subsequent faba bean crops for up to 10 years.
  - » Plant at least 500 m (preferably more) distance from previous year's bean crop.

31 Australian CliMate. How Wet/N. Managing Climate Variability R&D Program, http://www.australianclimate.net.au/About/HowWetN

32 Australian CliMate. How Wet/N. Managing Climate Variability R&D Program, http://www.australianclimate.net.au/About/HowWetN

- Weeds
  - Almost all weeds host *Sclerotinia* spp.
  - Some of the viruses affecting faba beans also have wide host ranges. Weeds, particularly perennial legumes, host viruses (e.g. *Cucumber mosaic virus*) and their aphid and leafhopper vectors.
- Herbicide history
  - Have triazine, 'imi' or sulfonylurea herbicides been applied in the last 12 months?
  - The development of some diseases is favoured in herbicide-weakened plants.
  - The presence of herbicide residues in soil may cause crop damage and thus confusion over in-field disease diagnosis. [33]

1.9 Herbicide residues in soil

Residues from herbicides used in the current or previous crop could influence subsequent crop choice in rotations. Crop damage could occur if residues are ignored, particularly where rainfall has been minimal.

Pulse and other crop types differ in their sensitivity to residual herbicides, so check each herbicide used against each crop type. Choice of herbicide in cereal and oilseed crops may have to accommodate the planning of a pulse crop next in the rotation sequence. For example, 10 months may need to elapse before a chickpea crop can be grown after use of an imidazolinone ('imi') herbicide, and likewise, >24 months after chlorsulfuron has been applied on high pH soils.

Soil erosion

Pulses have slow early growth and consequently leave the soil more susceptible to the effects of wind and water erosion than do cereals. This highlights the benefits of stubble retention and limited tillage with pulses in the farming system.

Poor emergence is more likely with pulses on hard-setting soils. This can lead to a greater potential for soil erosion. Rolling after sowing a pulse crop can also leave some soils prone to erosion, and in these situations, post-emergent rolling is preferred if possible. [34]

1.10 Yield and targets

1.10.1 Yields

Constantly increasing production costs and increasing supplies of pulses mean that future success with these crops will depend on greater productivity per ha and per mm of rainfall.

It will be necessary to find and adopt the best management practices for the crop in relation to tillage, time of sowing, weed control and fertilising.

There is much room for improvement in these areas. Under ideal conditions, pulse crops should be able to produce 12–15 kg/ha of grain for every mm of growing season rainfall over 130 mm. By comparison, wheat can produce 20 kg/ha for every mm of rainfall over 110 mm (Figure 12).

Different pulses have varying yield potentials under different yielding situations, based on yield potential under adequate moisture or drought tolerance (Figure13).

33 Northern Faba Bean—Best Management Practices Training Course, Pulse Australia 2014.

34 Northern Faba Bean—Best Management Practices Training Course. Pulse Australia 2014.

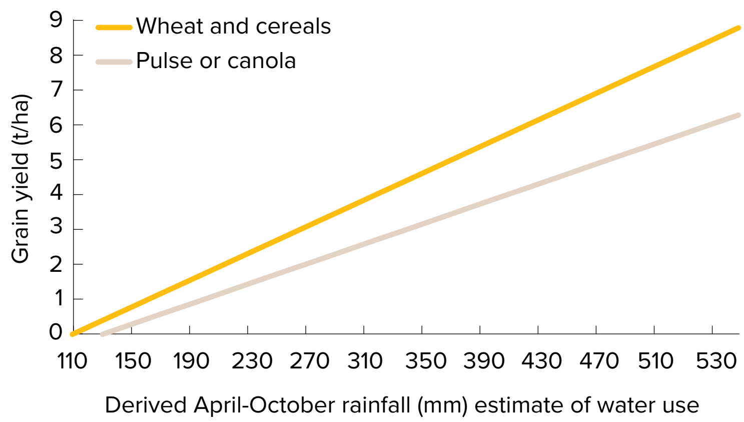

Figure 12: *Relationship of grain yield (t/ha) to estimated water use April–October. Pulses, 15 kg/ha.mm water available over 130 mm; cereals, 20 kg/ha.mm available over 110 mm.*

Source: Grain Legume Handbook, from French and Schultz model

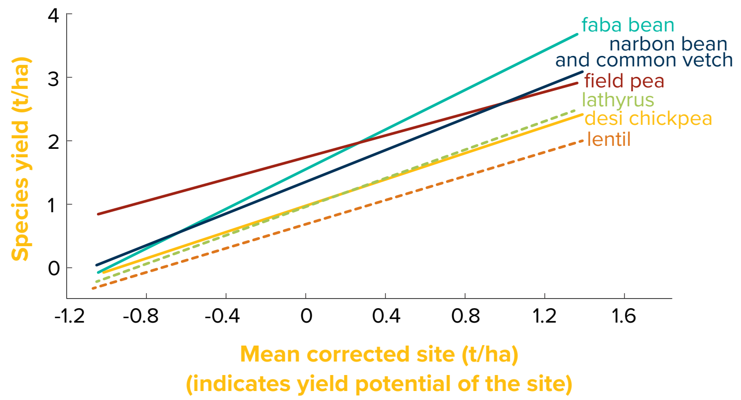

Figure 13: *Variation in grain yield of different grain legume species across sites with different yield potential in Western Australia.*

Adapted from K. Siddique et al. 1999

Ratio of water use to evaporation

The average pulse crop is subjected to an evaporation stress of 600–650 mm from sowing to harvest.

The best yields occur when water use by the crop is 0.7 times the evaporation level.

Temperature

One of the most critical factors affecting pulse yield is temperature. Temperature at flowering can be too high or too low for pollen survival, and hence fertilisation and pod-set.

Temperature minimum for pod-set ranges from –1.5°C to 15°C depending on crop species. Faba beans likely require temperatures ≥10°C (mean daily temperature) at flowering, which is similar to field peas, lentils, lupins and vetch, but lower than the 15°

required by chickpeas. Sunlight, and hence photosynthesis, is critical for pod-set in faba beans. At temperatures <–1.5°C, the bean plant tissue freezes.

High temperatures (>30°C) can cause flower abortion and cause flowering to cease, even with adequate soil moisture.

For maximum yield, flowering in faba bean and most other winter pulses should be completed by the week in which the average daily maximum temperature reaches 20°C. By comparison, the critical maximum temperature for wheat is 23°C and for chickpea 30°C.

The different pulse crops also need different amounts of time and cumulative temperature to go through various growth stages. Pulse crops will produce higher yields if they are sown early enough to allow them to finish flowering before the week of critical average daily maximum temperature.

Cumulative maximum daily temperature (CMDT) can be used to determine the start and end of flowering as well as maturity date. CMDT is calculated by the progressive addition of individual daily maximum temperatures (French *et al* 1979). Table 8 presents CMDTs that different crops need from sowing to reach flowering and harvest.

These dates can also be calculated from thermal units (also known as heat units, day-degrees, growing degree-days or GDD). The difference is that thermal unit degree-days are calculated by adding mean daily temperatures, and so use the average of daily minimum and maximum temperatures, whereas CMDT uses only the maximum temperature in its calculation.

Table 8: *Cumulative maximum daily temperatures (CMDT) from sowing to various crop growth stages.*

	Beginning of flowering	End of flowering	Harvest
Faba bean	1300	2200	3300
Field pea	1600	2400	3300
Lupin	1600	2400	3600
Chickpea and lentil			
Early cultivars	1600	2400	3200
Late cultivars	2000	2800	3400
Wheat	1900	2200	3300

Source: Grain Legume Handbook.

The use of CMDT makes it possible to work out the ideal sowing time for pulse crops in a particular area from meteorological information, using the accumulation of maximum daily temperatures with time (i.e. CMDT) and the week that critical flowering temperature occurs.

The sowing time for highest yield in each area can be worked out by defining either:

- when the week of 30°C for chickpea (20°C for other pulses) occurs; or
- when the average daily temperature is first warm enough (>15°C) for the crop to commence flowering and set pods.

Then having defined these dates, count back the CMDT days of cumulative temperature needed for the crop to develop from sowing to that date, using the CMDT units required by faba beans to achieve the start or end of flowering (Table 8).

Use of thermal units

Thermal unit data are used overseas for comparison between broadacre crops or varieties of their heat requirements to achieve particular growth stages. Thermal unit data are not commonly published or used in Australia for broadacre crops. However, thermal units are used in Australia in entomology and in weed management, for example. Thermal unit maps are published on the web for Canada and USA so that growers can know how the current season is progressing relative to average. Perhaps the concept should be more widely used in Australia.

1.10.2 Water Use Efficiency

Water Use Efficiency is the measure of a cropping system's capacity to convert water into plant biomass or grain. It includes the use of water stored in the soil and rainfall during the growing season.

Water Use Efficiency relies on:

- the soil's ability to capture and store water;
- the crop's ability to access water stored in the soil and rainfall during the season;
- the crop's ability to convert water into biomass; and
- the crop's ability to convert biomass into grain (HI).

Water is the principal limiting factor in rain-fed cropping systems in northern Australia. The objective of rain-fed cropping systems is to maximise the proportion of rainfall that crops use, and minimise water lost through runoff, drainage and evaporation from the soil surface and to weeds.

Rainfall is more summer-dominant in the northern region, and both summer and winter crops are grown. However, rainfall is highly variable and can range, during each cropping season, from little or no rain to major rain events that result in waterlogging or flooding.

Storing water in fallows between crops is the grower's most effective tool to manage the risk of rainfall variability, as in-season rainfall alone, in either summer or winter, is rarely enough to produce a profitable crop, especially with high levels of plant transpiration and evaporation. [35]

MORE INFORMATION

http://www.grdc.com.au/~/media/607AD22DC6934BE79DEAA05DFBE00999.pdf

1.11 Nematode status of the paddock

The primary RLN species, Pratylenchus thornei, costs the wheat industry A$38 million annually. [36] Including the secondary species, *P. neglectus*, RLN is found in three-quarters of paddocks tested. [37]

MORE INFORMATION

https://www.grdc.com.au/~/media/B4063ED6F63C4A968B3D7601E9E3FA38.pdf

http://www.soilquality.org.au/factsheets/root-lesion-nematode-in-queensland

1.11.1 Nematode testing of soil

Paddocks should be diagnosed for plant parasitic nematodes so that optimal management strategies can be implemented. Testing your farm will tell you:

- whether nematodes are present in your paddocks and at what density; and
- which species are present.

It is important to know which species are present because some crop-management options are species-specific. If a particular species is present in high numbers, immediate decisions must be made to avoid losses in the next crop to be grown. With low numbers, plans can be made to safeguard future crops. Learning that a paddock is free of these nematodes is valuable information because steps may be taken to avoid contamination. [38]

MORE INFORMATION

vGround Cover Supplement: Predicta B an identity kit for soil borne pathogens

MORE INFORMATION

Ground Cover: Single test improves stubble-borne disease management

Testing of soil samples taken before a crop is sown or while the crop is in the ground provides valuable information. Because there is a great deal of spatial variation in

35 GRDC (2009) Northern Region. Converting rainfall to grain. GRDC Water Use Efficiency Fact Sheet, http://www.grdc.com.au/~/media/607AD22DC6934BE79DEAA05DFBE00999.pdf

36 GM Murray, JP Brennan (2009) The current and potential costs from diseases of wheat in Australia. GRDC Report, https://www.grdc.com.au/~/media/B4063ED6F63C4A968B3D7601E9E3FA38.pdf

37 K Owen, J Sheedy, N Seymour (2013) Root lesion nematode in Queensland. Soil Quality Pty Ltd Fact Sheet, http://www.soilquality.org.au/factsheets/root-lesion-nematode-in-queensland

38 Queensland Primary Industries and Fisheries (2009) Root lesion nematodes—management of root-lesion nematodes in the northern grain region. Department of Agriculture, Fisheries and Forestry Queensland, http://www.daff.qld.gov.au/__data/assets/pdf_file/0010/58870/Root-Lesion-Nematode-Brochure.pdf

MORE INFORMATION

https://sites.google.com/site/crownanalyticalservices/home

http://www.sardi.sa.gov.au/products__and__services/entomology/diagnostic_services/predicta_b

http://www.daff.qld.gov.au/__data/assets/pdf_file/0010/58870/Root-Lesion-Nematode-Brochure.pdf

MORE INFORMATION

'Management of root-lesion nematodes in the northern grain region': http://www.daff.qld.gov.au/__data/assets/pdf_file/0010/58870/Root-Lesion-Nematode-Brochure.pdf

https://www.grdc.com.au/Research-and-Development/GRDC-Update-Papers/2013/07/Summer-crop-decisions-and-root-lesion-nematodes

MORE INFORMATION

GRDC Update Paper: Impact of crop varieties on RLN multiplication

nematode populations within paddocks, it is important to follow sampling guidelines to ensure accurate results.

1.11.2 Effects of cropping history on nematode status

Root-lesion nematode numbers build up steadily under susceptible crops and cause decreasing yields over several years. Yield losses >50% can occur in some wheat varieties, and up to 20% in some chickpea varieties. The amount of damage caused will depend on:

- the numbers of nematodes in the soil at sowing
- the tolerance of the variety of the crop being grown
- the environmental conditions

Generally, a population density of 2000 RLN/kg soil anywhere in the soil profile has the potential to reduce the grain yield of intolerant wheat varieties.

A tolerant crop yields well when high populations of RLN are present (the opposite is intolerance). A resistant crop does not allow RLN to reproduce and increase in number (the opposite is susceptibility).

Growing resistant crops is the main tool for managing nematodes. In the case of crops such as wheat or chickpea, choose the most tolerant variety available and rotate with resistant crops to keep nematode numbers at low levels. Information on the responses of crop varieties to RLN is regularly updated in grower and Department of Agriculture, Fisheries and Forestry Queensland planting guides. Note that crops and varieties have different levels of tolerance and resistance to *P. thornei* and *P. neglectus*. In the northern region, faba bean is resistant to *P. neglectus* and susceptible to *P. thornei.* [39]

Summer crops have an important role in management of RLN. Research shows when *P. thornei* is present in high numbers, two or more resistant crops in sequence are needed to reduce populations to low enough levels to avoid yield loss in the following intolerant, susceptible wheat crops. [40]

1.11.3 Faba beans and RLN

Preliminary results from Northern Grower Alliance (NGA) trials show there is no evidence of yield loss due to *Pratylenchus thornei* in faba beans.

Faba beans are broadly similar to chickpeas and bread wheat in building-up *Pratylenchus thornei* populations with all three crops rated as susceptible. To date, varietal differences in resistance have been minor but PBA Warda⊕ may be marginally less susceptible than Cairo⊕ and Doza⊕. In contrast, in both wheat and chickpeas there is a large varietal range in susceptibility. [41]

39 GRDC (2009) Northern region. Root lesion nematode dominates in the north. GRDC Plant Parasitic Nematodes Fact Sheet, http://www.grdc.com.au/uploads/documents/GRDC_NematodesFS_North_4pp.pdf

40 K Owen, T Clewett, J Thompson (2013) Summer crop decisions and root-lesion nematodes. GRDC Update Papers 16 July 2013, http://www.grdc.com.au/Research-and-Development/GRDC-Update-Papers/2013/07/Summer-crop-decisions-and-root-lesion-nematodes

41 R Daniel, Northern Grower Alliance pers comms 3014

Pre-planting

2.1 Faba bean types

The bean (*Vicia faba*) varieties grown in Australia can be divided into two types: the smaller, faba bean types, and the larger, broad bean types.

Colour, size, shape and texture are important attributes in marketability of faba beans.

The requirements of faba beans in terms of size and colour vary between importing countries and according to the end use:

- The predominant colour for international trade is beige or buff, and colour is largely genetically determined and highly heritable.
- Size can vary according to variety.
- Size can also be influenced by the region (rainfall, soil type, etc.) where it is grown and by the season.
- Colour can also be influenced by environment in which the crop is grown, post-harvest handling, time in storage and storage method.

Faba beans have large flat seeds, which are predominantly a beige colour. The seed size can vary from 35 to 100 g/100 seeds according to the variety being grown, the region and season.

Within the faba bean types, several market categories have emerged for Australian growers:

- the traditional, medium-seeded faba bean markets, where seed size and uniformity (50–70 g/100 seeds) is important to attract market interest;
- a large-seeded class (70–90 g/100 seeds) that is sold into bulk Kabuli markets; and
- a small-seeded (35–50 g/100 seeds) class, originally exported for human consumption markets but now considered too small in all but a few niche markets ('Fiord' size).

When choosing a faba bean type, factors that influence the gross margin and risks with each variety must be considered. [1]

MORE INFORMATION

GRDC Update Paper: Profitable integration of pulses in farming systems

2.2 Choosing a variety

When selecting a variety, the season length, seed size with reference to sowing machinery, disease tolerance, seed availability and markets need to be considered.

Varietal resistance to chocolate spot (*Botrytis fabae*) is extremely important because this disease is a potential problem with faba beans in higher rainfall areas, irrigated crops or wetter years. Current varieties do not offer good resistance, and so a strategic foliar fungicide program is essential in most areas. Improvement in varietal resistance is being developed, however, and breeding lines that offer better long-term prospects will eventually be released.

Some faba bean varieties available to growers have limitations with regard to agronomic adaptation and marketability, and they will not suit all areas or situations. When choosing varieties to grow, consider their susceptibility to chocolate spot and rust, along with yield potential, price potential, marketing opportunities, maturity timing, lodging resistance and other agronomic features relevant to your growing

1 Northern Faba Bean—Best Management Practices Training Course. Pulse Breeding Australia 2014.

MORE INFORMATION

Variety Management Packages (VMPs) available at www.pulseaus.com.au

PBA Warda⒫ VMP

MORE INFORMATION

www.nvtonline.com.au

region. Rust is a major disease in the northern region, especially in mild, wet springs when the disease can spread very quickly; a strategic foliar fungicide program is also imperative.

Fungicide (Dithane®, active ingredient mancozeb) is usually applied as the crop approaches canopy closure to protect the lower leaves from rust. Sometimes this initial fungicide can be included with the grass weed herbicide. Depending on the seasonal conditions, e.g. continued wet conditions, a further fungicide application may be needed. [2]

When comparing yields between varieties, growers need to be aware that under high pressure of chocolate spot or moisture stress, more susceptible varieties are more likely to suffer greater yield loss than less susceptible varieties. [3]

2.3 Varietal performance and ratings yield

Faba beans are grown across the subtropical environments of northern New South Wales and southern Queensland. Faba bean varieties have specific traits to deal with different growing conditions in each zone, such as lengths of growing season or presence of diseases. A variety with a highly specific trait such as disease resistance may not yield as well as another variety bred specifically for yield, but the resistance trait will diminish risk. Varietal selection is a matter of weighing up how yield *v.* risk will affect gross margins.

Grains industry productivity depends on the continued deployment of new technologies, including the adoption of new varieties with superior yield and useful disease-resistance characteristics.

National Variety Trials (NVT) initiative collects the most relevant varieties for each region and tests them alongside the elite lines from breeding programs. To view trials in your region, visit the interactive map of NVT faba bean trials. For more information on the NVT, visit the NVT website.

Most new varieties are protected by Plant Breeders' Rights (PBR) and/or end-point royalties (EPR).

Seed of varieties with PBR protection can be bought only from the owner, commercial partner/licensee or an agent (seed merchant) authorised by the owner. Purchase seed of a PBR cultivar in the name(s) of the entity or entities in which you intend to deliver the product. Retain invoices to prove that you have entitlement to that seed and the crop produced.

Once purchased, growers can maintain seed of a variety with PBR protection to satisfy their seed requirements for the following seasons. Farmers can sell the products of a protected variety for commercial use as feed or food, unless bound by a 'closed loop' or other contract. Farmers cannot sell, trade, or give away the variety for seed. Farmer-to-farmer trading of seed without authorisation from the owner will make them liable for prosecution.

Commercial marketing arrangements between the owners and the licensee can vary between crops and varieties. Farmers must be aware of the conditions of the marketing arrangements. [4]

2.4 Area of adaptation

Faba bean varieties are bred for, and selected in, a range of environments. Hence, individual varieties have specific areas of adaptation for maximised yield and reliability. Specific adaptation of a variety depends on rainfall, geography, temperatures, disease pressure, and soil types at the site of cropping.

2 G Onus. Fababean Growing Program. Landmark Moree.

3 Northern Faba Bean—Best Management Practices Training Course. Pulse Australia 2014.

4 Northern Faba Bean—Best Management Practices Training Course. Pulse Australia 2014.

The national pulse production area has been categorised by Pulse Breeding Australia (PBA) into five regions based on rainfall and geographic location (see Figure 1 below):

- Region 1, low rainfall tropical
- Region 2, medium rainfall, subtropical
- Region 3, low rainfall, subtropical
- Region 4, medium–high rainfall, Mediterranean–temperate
- Region 5, low–medium rainfall, Mediterranean–temperate

These regions cross state borders, and are target zones for national breeding and variety evaluation. Breeding trials and NVT results help to indicate specific adaptation even within a region. Some variety releases have been specific for northern Australia (Doza⟑ and PBA Warda⟑). Other varieties have been found to be better adapted to specific parts of regions (e.g. PBA Rana⟑ and PBA Kareema⟑ in southern high-rainfall areas).

The area of adaption is specified for each variety so that potential users are aware of the best fit. [5]

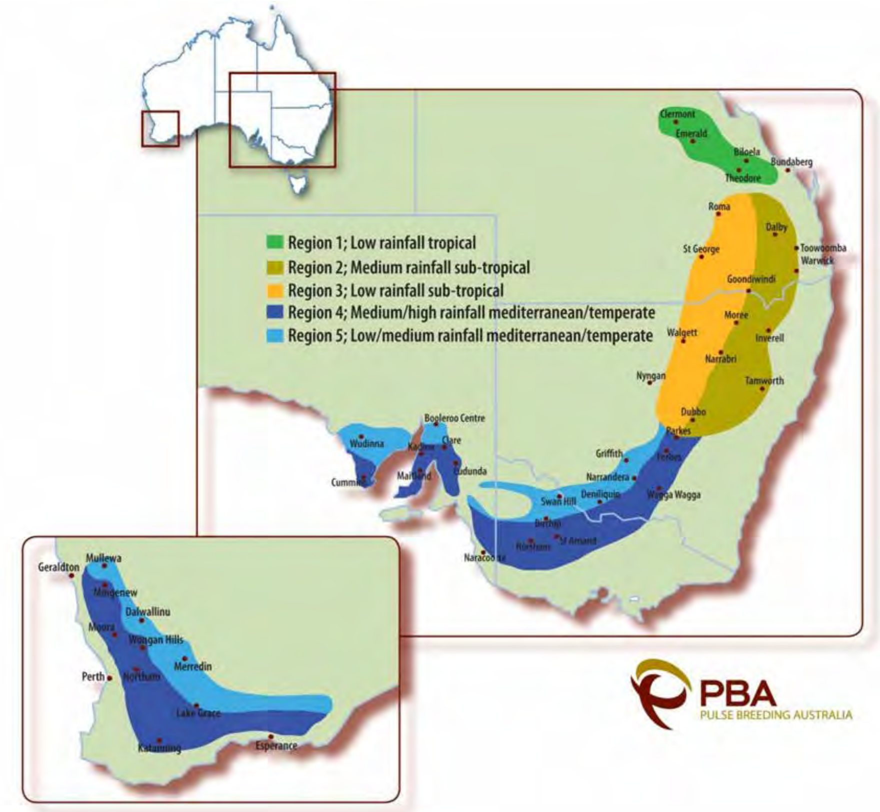

Figure 1: *PBA regions used to describe variety area of adaptation.*

2.5 Quality traits

Variety choice will be influenced by market acceptability and susceptibility to factors that downgrade grain quality, especially disease (Table 1). Small beans such as the old variety Fiord are less acceptable in major export markets. Medium–small beans (e.g. PBA Warda⟑) are sought because of their size and light colour. Medium-sized beans (e.g. Cairo⟑) and broad, large beans (e.g. Aquadulce) remain acceptable because of their size and colour.

5 Northern Faba Bean—Best Management Practices Training Course. Pulse Australia 2014.

Although seed size and colour are factors influencing quality, and these are largely determined by genetics, sound management from seeding to delivery can affect quality downgrading caused by shrivelling, seed discoloration, breakage and insect damage. Discoloured and small, shrivelled faba beans may result not only in seed being downgraded from human consumption but also in poor emergence and vigour for next year's crop. [6]

Seed staining in beans is caused by:

- genetics—natural ageing, and high tannin grains are more likely to discolour
- late rain on maturing or mature crops
- Ascochyta blight—susceptible varieties are more prone to discoloration
- exposure due to pod splitting—commonly caused by chocolate spot infection
- frost
- other diseases—Pea seed-borne mosaic virus (PSbMV) and Broad bean stain virus (BBSV)
- poor storage conditions, including high moisture or exposure to sunlight

Table 1: *Summarised yield data and disease traits across faba bean varieties and sites using NSW DPI, PBA and NVT trials from 2008–2015.*

Variety	PBR	Maturity	Seed colour	Seed size (g/100 seeds)	Disease: Ascochyta	Disease: Chocolate spot	Disease: Rust	Yield North east: Yield as % of Cairo(D %	No. Trials	Yield North west: Yield as % of Cairo(D %	No. Trials	Yield South east: Yield as % of Farah(D %	No. Trials	Yield South west irrigated: Yield as % of Farah(D %	No. Trials
								Cairo(D = 2.78 t/ha		Cairo(D = 2.16 t/ha		Farah(D = 2.82 t/ha		Farah(D = 4.20 t/ha	
Cairo(D	yes	mid–late	buff	50–75	VS	VS	MS	100	29	100	48	91	3	–	–
Doza(D	yes	early	light buff	40–60	VS	MS	MR-R	105	29	104	48	93	16	95	3
Farah(D	yes	mid	light buff	60–75	R–MR	S	S	–	–	–	–	100	31	100	9
Fiesta VF	no	mid	buff	60–75	MR–MS	S	S	101	17	100	25	101	31	100	9
Fiord	no	early–mid	buff	33–55	MS	VS	S	98	20	99	30	95	11	–	–
Nura(D	yes	mid	light buff	50–65	R–MR	MS	MS	88	11	89	10	97	31	95	9
PBA Nasma(D	yes	early	beige to brown	61–79	S	MS	MR	112	28	110	46	104	16	–	–
PBA Rana(D	yes	mid–late	light buff	75–90	R	MS	MS–MR	–	–	–	–	106	6	94	9
PBA Samira(D	yes	mid	light buff	60–80	R	MS	MS	–	–	–	–	95	31	101	5
PBA Warda(D	yes	early	beige to brown	58–70	S	MS	MR–R	100	30	108	49	98	15	102	4
PBA Zahra	yes	mid-late	light buff	65–85	MR	MS	S	–	–	–	–	106	16	101	5

VS, very susceptible; S, susceptible; MS, moderately susceptible; MR, moderately resistant; R, resistant; –, insufficient data

Source: NSW Department of Primary Industries Winter crop variety sowing guide 2016.

6 W Hawthorne (2008) Faba beans—for quality markets, Australian Pulse Bulletin No.14. Pulse Australia, http://pulseaus.com.au/storage/app/media/crops/2008_APB-Faba-beans-quality-markets.pdf

2.6 Northern faba bean varieties

Cairo⚐

Released for the northern region and superior to Fiord and Barkool for yield, seed size and quality, Cairo⚐ also had better rust resistance and tolerance to stem collapse from frost (Figure 2). It is now outclassed for yield and rust resistance by Doza⚐ and PBA Warda⚐. It is not generally recommended for southern regions where Ascochyta blight and chocolate spot are major problems. Released in 2004. Area of adaptation: Regions 2 and 3.

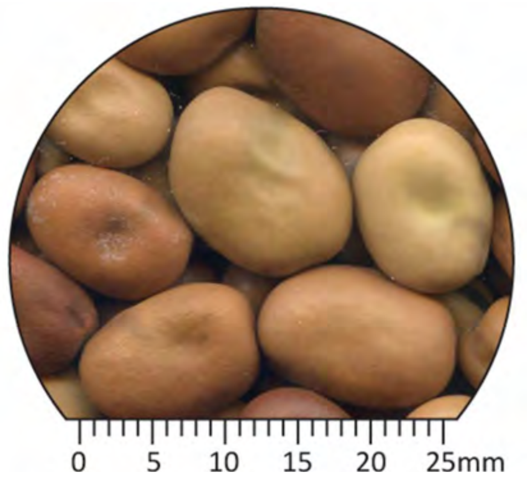

Figure 2: *Cairo⚐. Released: 2004. Seed size: 55–75 g/100.*

PBA Nasma⚐

PBA Nasma⚐ is an early maturing variety, similar to PBA Warda⚐. It is well adapted to the growing season in northern New South Wales and southern Queensland. This variety is not recommended for southern New South Wales where Ascochyta blight and chocolate spot are significant diseases.

Extensive yield evaluation of PBA Nasma⚐ in northern New South Wales, at Pulse Breeding Australia (PBA) and National Variety Trial (NVT) sites, shows that its yield is on average 3% greater than PBA Ward⚐. This yield advantage has been obtained in both rain fed and irrigated trials. PBA Nasma⚐ is suggested as an alternative to PBA Warda⚐ for growers in northern New South Wales and southern Queensland who are targeting larger seed size for premium markets.

Variety PBA Nasma⚐ is moderately resistant to faba bean rust, the major fungal disease in northern New South Wales and southern Queensland and is moderately susceptible to chocolate spot. It has a similar level of tolerance to BLRV as that of PBA Warda⚐, which will benefit growers in areas prone to virus infection. PBA Nasma⚐ is susceptible to Ascochyta blight, but this is not considered to be a major disease in northern New South Wales. Released in spring 2015. Area of adaptation: Regions 2 and 3.

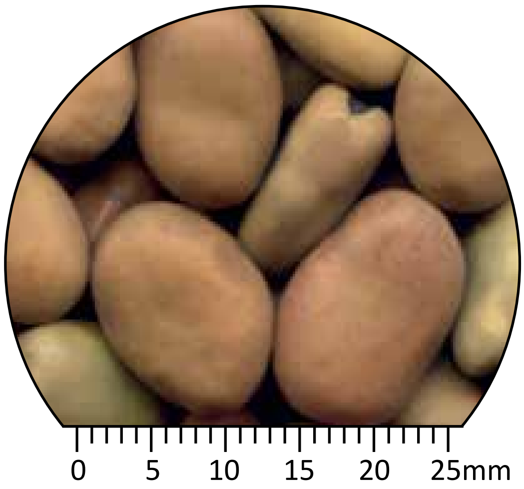

Figure 3: *PBA Nasma⒟*

Doza⒟

Doza⒟ (SP01040) is a medium-sized faba bean released for the subtropical environments of northern New South Wales and southern Queensland (Figure 4). Early flowering enables it to better adapt to warmer spring temperatures, along with higher yielding and improved rust resistance over Cairo⒟. Seed size is slightly smaller but uniformity of seed size and a light buff seed coat is a significant improvement for this region. It has good resistance to 'hockey stick' and stem collapse from frost, which is an important trait in this environment. It exhibits reasonable resistance to chocolate spot but is very susceptible to Ascochyta blight, and consequently not likely to have a large role in southern Australia. Released in 2008. Area of adaptation: Regions 2 and 3.

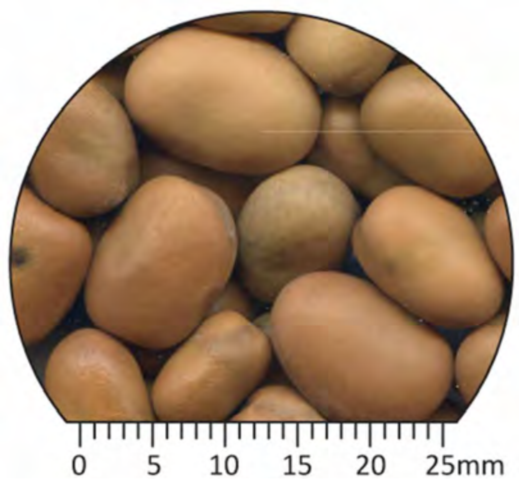

Figure 4: *Doza⒟. Released: 2008. Seed size: 35–55 g/100.*

PBA Warda⒟

Released for the northern region, PBA Warda⒟ is superior to Doza⒟ for yield, seed size and disease resistance (Figure 5). It is expected to replace Doza⒟ and Cairo⒟ in these regions. This variety is less suited to southern and western regions because of its susceptibility to Ascochyta blight and its poorer yields.

Variety PBA Warda⒟ is moderately resistant–resistant to rust, equivalent to Doza⒟, and has a higher level of tolerance to *Bean leafroll virus* (BLRV) than Doza⒟. It has similar flowering and maturity time to Doza⒟, but bigger and more uniform seed size. Released in 2012. Area of adaptation: Regions 2 and 3.

MORE INFORMATION

Ground Cover: Northern expansion stretches to Egypt

Long-term yield data for these varieties in NVT assessments are presented in Figure 6.

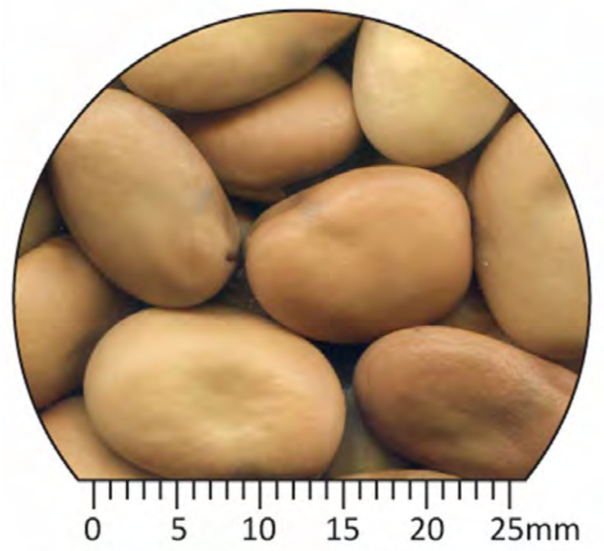

Figure 5: *PBA Warda⚖. Released: 2012. Seed size: 55–75 g/100.*

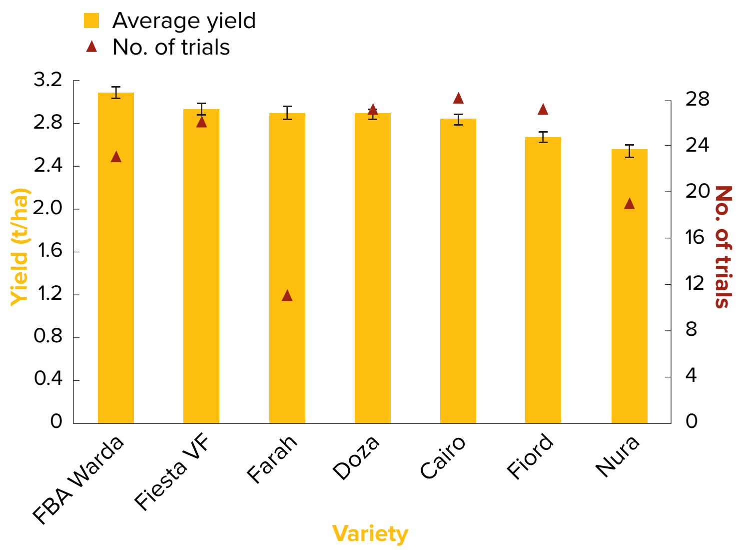

Figure 6: *National Variety Trial (NVT) adjusted average long-term yield report 2005–12 for north-eastern New South Wales.*

http://www.nvtonline.com.au/google-maps/2012/Faba%20BeanMaNE.pdf

MORE INFORMATION

http://www.dpi.nsw.gov.au/agriculture/broadacre/guides/winter-crop-variety-sowing-guide

2.6.1 Faba bean variety agronomic traits

A summary of agronomic traits for the three varieties Dozaⓓ, Cairoⓓ and PBA Wardaⓓ is provided in Table 2.

Table 2: *Faba bean agronomic traits.*

Variety	Maturity	Seed colour	Seed size (g/100)	Height	Ascochyta blight		Chocolate spot	Rust	Cercospora	PSbMV seed staining
					Foliage	Seed				
Dozaⓓ	Very early	Buff	40–60	Medium	VS	VS	MS	MR–R	S	–
Cairoⓓ	Early	Buff	50–70	Med.–tall	VS	VS	VS	MS	–	–
PBA Wardaⓓ	Very early	Buff	50–70	Medium	S	S	MS	MR–R	S	–
PBA Nasmaⓓ	Very early	Buff	60-80	Medium	S	S	MS	MR-R	S	–

These varieties are protected by PBR. VS, Very susceptible; S, susceptible; MS, moderately susceptible; MR, moderately resistant; R, resistant

Source: Pulse Breeding Australia.

2.6.2 Faba bean variety seed availability

Access details for the four varieties Dozaⓓ, Cairoⓓ, PBA Wardaⓓ and PBA Nasmaⓓ are shown in Table 3.

Table 3: *Availability of faba bean varieties.*

Variety	PBR	Licensee or agency	Commercial partner	Seed supplying agents	Telephone	EPR ($/t incl. GST) and market restriction
Cairoⓓ	Yes	DPI NSW	Viterra	Seedmark	1800 112 400	$3.30, none
Dozaⓓ	Yes	DPI NSW	Viterra	Viterra	1800 018 205	$3.63, none
PBA Wardaⓓ	Yes	University of Adelaide	Seednet	Seednet	(03) 5381 0406	$3.85, none
PBA Nasmaⓓ	Yes	University of Adelaide	Seednet	Seednet	1800 018 205	$3.85, none

EPR, End-point royalties

MORE INFORMATION

See Variety Central www.varietycentral.com.au

2.7 CropMate VarietyChooser

CropMate VarietyChooser (Figure 7) is a free iPhone app decision tool developed by NSW Department of Primary Industries to help farmers choose varieties of faba beans, barley, canola, chickpeas, field peas, lupins, oats, triticale and wheat. Choose variety characteristics and desired disease resistance levels, and see comparative yield trials for your region to narrow down your choices and see details of each variety.

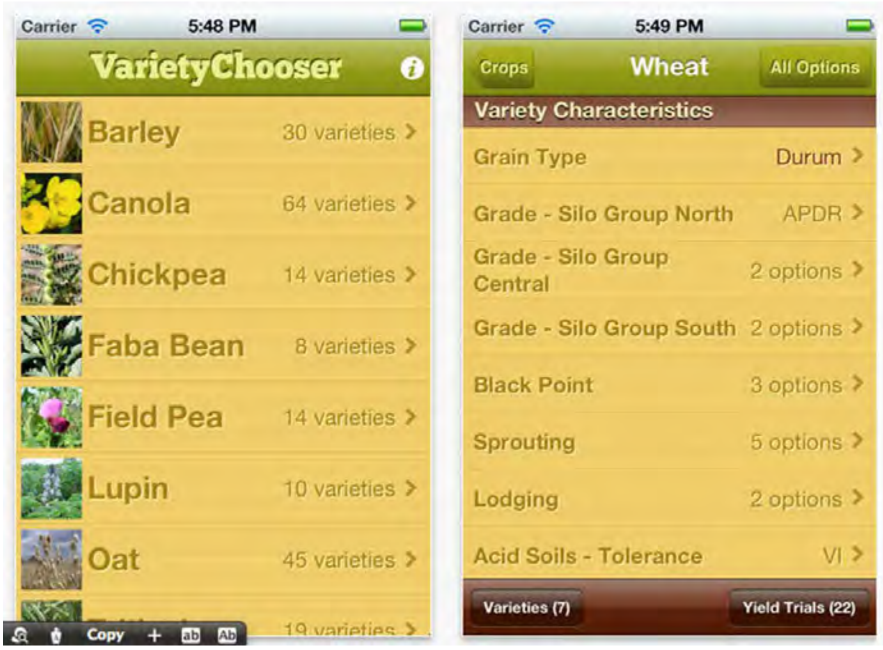

Figure 7: *Screenshots of the CropMate VarietyChooser.*

MORE INFORMATION

https://itunes.apple.com/au/app/cropmate-varietychooser/id476014848?mt=8

2.8 Seed quality

High-quality seed is essential to ensure the best start for your crop. Grower-retained seed, if not tested, may be of poor quality with reduced germination and vigour, as well as being infected with seed-borne pathogens.

- All seed should be tested for quality including germination and vigour.
- If grower-retained seed is of low quality, then consider purchasing registered or certified seed from a commercial supplier. Always ask for a copy of the germination report regardless of the source.
- Careful attention should be paid to the harvest, storage and handling of seed intended for sowing.
- Calculate seeding rates in accordance with seed quality (germination, vigour and seed size).

Good establishment with correct plant density and good seedling vigour is important to maximise yields of pulse crops. A targeted density can only be achieved by having quality seed with good vigour and a known germination percentage to accurately calculate seeding rates. A slight variation in seed size due to seasonal conditions or an incorrect germination percentage can make a significant difference in the final plant density.

Many seed buyers are unaware that the minimum germination requirement for certified pulse seed is 70%, compared with 80% in cereal grains, and is far less than the 90% or more often obtained in pulse seed. Test results must be made available under the Seeds Act, and Australian Seeds Federation guidelines; ensure that you receive a copy.

Problems with seed quality often occur when the crop is not harvested under ideal moisture or seasonal finishing conditions. A sharp seasonal finish, a wet harvest or delayed harvest can have a big effect on seed quality, as can poor insect control during the podding stage of the crop.

Low germination rates and poor seedling vigour can cause slower and uneven emergence, which can result in sparse establishment and a weak crop. The crop can also be more vulnerable to virus infection, fungal disease and insect attack, and less competitive with weeds. Any of these can result in significantly lower yields.

The large size or fragile nature of pulse seed, particularly faba bean, Kabuli chickpea and lupin, makes them more vulnerable to mechanical damage during harvest and handling. This damage is not always obvious, and can be reduced by slowing header drum speed and opening the concave, or by reducing auger speed and lowering the flight angle and fall of grain. Rotary harvesters and belt conveyers are ideally suited to pulse grain. They can reduce seed damage that often results in abnormal seedlings, which germinate but do not develop further.

Under ideal conditions, abnormal seedlings may emerge but will lack vigour, making them vulnerable to other rigours of field establishment. Factors such as low temperature, disease, insects, seeding depth, soil crusting and compaction are more likely to affect the establishment of weak seedlings. Abnormal seedlings that do emerge are unlikely to survive for long, and those that do survive are likely to have reduced biomass and make little or no contribution to the final yield. [7]

2.8.1 Grower-kept sowing seed

The best area of a paddock should be selected and marked out well before harvest. Choose areas where weeds and diseases are absent and the crop is vigorous and healthy and likely to mature evenly and have good grain size. Also select areas at least 500 m away from other faba bean varieties, to reduce cross-pollination and hence contamination. Seed from this area should be harvested first, ideally at 11–13% moisture to avoid low-moisture grain that is susceptible to cracking.

If desiccation is required, do not use glyphosate to treat the area that will be kept for seed, because it will severely affect the germination, normal seed count and vigour. Read the glyphosate label.

Seed-borne diseases can lower germination levels. Specialist laboratories can conduct tests for the presence in seed of a number of diseases, such as Ascochyta blight and botrytis (chocolate spot or grey mould) in faba bean and chickpea, *Cucumber mosaic virus* (CMV) in narrow leaf lupin, and bacterial blight in field pea.

Seed with poor germination or high levels of seed-borne disease should not be sown. The cheaper cost of retaining this seed will often be offset by higher sowing rates needed and the potential risk of introducing further disease into the crop.

The only way to assess accurately the germination rate, vigour and disease level of seed is to have it tested.

2.8.2 Safe storage of seed

Retained seed must be stored correctly to ensure that its quality is maintained. Ideal storage conditions for pulses are at ~20°C and 12.5% moisture content.

Faba beans may be stored in sheds, bunkers and silos. They do not suffer from pea weevil infestations; therefore, a sealed silo is usually not necessary. [8]

As with other grains, faba bean seed quality can deteriorate in storage, and the most rapid deterioration occurs under conditions of high temperature and moisture. Crops grown from seed stored under these conditions may have poor germination and emergence.

It is best not to store faba beans in bunkers or in 'sausage bags' for any length of time, because pockets of moisture can quickly lead to black, mouldy grain, which can contaminate the remainder of product. Black, mouldy grain can also taint the sample with an unpleasant odour, rendering it unacceptable for consumption. [9]

Reducing moisture and temperature increases longevity of the seed, although storage at very low moisture contents (<10%) may render faba bean more vulnerable

7 Northern Faba Bean—Best Management Practices Training Course. Pulse Australia 2014.

8 Victoria DEPI (2013) Growing faba bean. Note AG0083. Department of Environment and primary Industries, State Government of Victoria, http://www.depi.vic.gov.au/agriculture-and-food/grains-and-other-crops/crop-production/growing-faba-bean

9 W Hawthorne (2008) Faba beans—For quality markets. Australian Pulse Bulletin No.14. Pulse Australia http://pulseaus.com.au/storage/app/media/crops/2008_APB-Faba-beans-quality-markets.pdf

to mechanical damage during subsequent handling. See Table 4 for an example with chickpea.

Table 4: *Effect of moisture content and temperature on storage life of chickpea seed.*

Storage moisture (%)	Storage temperature (°C)	Longevity of seed (days)
12	20	>200
	30	500–650
	40	110–130
15	20	700–850
	30	180–210
	40	30–50

Note: Most sowing seed will need to be stored for a period of ≥180 days
Source: Ellis et al. 1982.

Storage at >13% moisture under Australian conditions is not recommended. Reducing temperature in storage facilities is the easiest method of increasing seed longevity. Not only will it increase the viable lifespan of the seed, it will slow the rate at which insect pests multiply in the grain.

To reduce temperature in grain silos:

- Paint the outside of the silo with white paint. This reduces storage temperature by as much as 4–5°C and can double the safe-storage life of grains.
- Aerate silos with dry, ambient air. This option is more expensive, but in addition to reducing storage temperatures, it is effective in reducing moisture of seed harvested at high moisture content.
- Heat drying of faba bean sowing seed should be limited to temperatures <40°C. [10]

2.8.3 Handling bulk seed

The large size, awkward shape and fragile nature of many pulses means they need careful handling to prevent seed damage. Seed grain, in particular, should be handled carefully to ensure good germination.

Plan to ensure so that handling can be kept to a minimum to reduce damage between harvest and seeding.

Augers with steel flighting can damage pulses, especially larger seeded types such as faba beans. This problem can be partly overcome by slowing down the auger. Augers with large flight clearances will cause less damage to large grains.

Tubulators or belt elevators are excellent for handling pulses, with little or no damage occurring. Cup elevators are less expensive than tubulators and cause less damage than augers. They have the advantage of being able to work at a steeper angle than tubulators. However, cup elevators generally have lower capacities.

Auguring from the header should be treated with as much care as later during handling and storage, because it has the same potential for grain damage.

Combine loaders that throw or sling, rather than carry the grain, can cause severe damage to germination.

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2.9 Seed testing

2.9.1 Germination testing

Germination tests can be conducted by a simple home test (see next section, 2.10), or ideally by sending a representative sample to seed-testing laboratories for germination and vigour tests. For faba beans, chickpeas, lupins, field peas and vetch, the sample size required is 1 kg for every 25 t of seed. For lentils, take 1 kg for each 10 t of seed.

Sampling should be random and include numerous subsamples to give best results. It is easier and more accurate to take numerous samples while seed is being moved out of the seed cleaner, storage or truck or by sampling from numerous bags if stored this way.

Do not sample from within a silo; this is dangerous for the operator, and it is difficult to obtain a representative sample because samples are taken from the bagging chute. Mix subsamples thoroughly and take a composite sample of 1 kg. Failure to sample correctly or test your seed could result in poor establishment in the field.

If an issue is suspected with kept grain, it is wise to get a sample tested early. Testing prior to grading and seed treatment could give a big saving if the quality is found to be unsatisfactory, and it enables more time to source replacement seed. If the germination and vigour are below optimal, or marginal, or the crop was weather-damaged at harvest, it is advisable to have it re-tested closer after storage, handling and grading have occurred.

2.9.2 Vigour testing

In years of drought or a wet harvest, seed germination can be affected, but more importantly, seedling vigour can also be reduced. Poor seedling vigour can impact heavily on establishment and early seedling growth. This can often occur under more difficult establishment conditions such as deep sowing, crusting, compaction, and wet soils or when seed treatments have been applied. Some laboratories also offer a seed vigour test when doing their germination testing. Otherwise conduct your own test by sowing seeds into a soil tray that is kept cold (<20°C) and observing not only the germination but also speed and uniformity of emergence and any abnormal shoot and root development.

Vigour represents the rapid, uniform emergence and development of normal seedlings under a wide range of conditions. Several different tests are used by seed laboratories to establish seed and seedling vigour.

2.9.3 Accelerated ageing vigour test

Accelerated ageing estimates longevity of seed in storage. It is now also used as an indicator of seed vigour and has been successfully related to field emergence and stand establishment. This tests seed under conditions of high moisture and humidity. Seeds with high vigour withstand these stresses and deteriorate at a slower rate than those with poorer vigour. Results are reported as a percentage, and the closer the accelerated ageing number is to the germination result, the better the vigour. Results are expressed as a percentage normal germination after ageing (vigorous seedlings). [11]

2.9.4 Conductivity vigour test

The conductivity test measures electrolyte leakage from plant tissues and is one of two International Seed Testing Association (ISTA) recommended vigour tests. Conductivity test results are used to rank vigour lots by vigour level.

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Information is interpreted for field pea as follows:

- <25 µS/cm.g. Nothing to indicate seed is unsuitable for early sowing or adverse conditions.
- 25–29 µS/cm.g. Seed may be suitable for early sowing, but there is some risk of poor performance under adverse conditions.
- 30–43 µS/cm.g. Seed is not suitable for early sowing especially under adverse conditions.
- >43 µS/cm.g. Seed is not suitable for sowing.

It is important to have a germination test done as well, because a conductivity test cannot pick up all seed-borne chemical and pathogen scenarios.

2.9.5 Cool germination and cold tests

A cool or cold test is used to evaluate the emergence of a seed lot in cold, wet soils, which can cause poor field performance. The cold test simulates adverse field conditions and measures the ability of seeds to emerge. It is the most widely used vigour test for many crops, and is one of the oldest vigour tests.

This test can:

- Evaluate fungicide efficacy.
- Evaluate physiological deterioration resulting from prolonged or adverse storage, freezing injury, immaturity, injury from drying or other causes.
- Measure the effect of mechanical damage on germination in cold, wet soil.
- Provide a basis for adjusting seeding rates.

This test usually places the seed in cold temperatures (5–10°C) for a time, which is then followed by a period of growth. Then the seed is evaluated relative to normal seedlings according to a germination test. Some laboratories also categorise the seedlings further into vigour categories and report both of these numbers.

2.9.6 Tetrazolium test (TZ) as a vigour test

The TZ test is used to test seed viability, but is also useful as a rapid estimate of vigour of viable seeds. It is conducted in the same manner as a germination test, but viable seeds are evaluated more critically into categories of:

- High vigour. Staining is uniform and even, tissue is firm and bright.
- Medium vigour. Embryo completely stained or embryonic axis stained in dicots; extremities may be unstained; some overstained–less firm areas exist.
- Low vigour. Large areas of non-essential structures unstained; extreme tip of radicle unstained in dicots; tissue milky, flaccid and over stained.

Results have shown good relationships with field performance, and are useful for pulses.

2.9.7 Other

Another example of a vigour test used by some Australian laboratories is to test germination at 7°C for 12–20 days in the dark and under low-moisture conditions. If seed vigour is acceptable, then this germination result should be within 10% of the regular germination test.

2.9.8 Weed contamination testing

Sowing seed free of weeds cuts the risk of introducing new weeds. It also reduces the pressure on herbicides, especially with increasing herbicide resistance. Tests for purity of a seed sample, including the amount and type of weed seed contamination, can be conducted if requested.

2.9.9 Disease testing and major pathogens identified in seed tests

Seed-borne diseases such as CMV in lupin and lentil, and Ascochyta blight in chickpea, faba bean and lentil, pose a serious threat to yields. Seed-borne diseases can strike early in the growth of the crop when seedlings are most vulnerable and can result in severe plant losses and hence lower yields.

Testing seed before sowing will identify the presence of disease and allow steps to be taken to reduce the risk of disease. If disease is detected, the seed may be treated with a fungicide before sowing or a clean seed source may be used (Table 5).

For a disease test, 1 kg of seed is required, except for anthracnose (lupin) which requires 2 kg. [12]

Table 5: *Major pathogens identified in seed tests on faba bean.*

Pathogen	Disease
Botrytis fabae	Chocolate spot
Ascochyta fabae	Ascochyta blight
Ditylenchus dipsaci	Stem nematode
BBSV	Broad bean stain virus

Refer to GrowNotes Faba bean 6—Disease management. Check test number against the laboratories that do seed tests

Laboratories that will test for some or all of the above diseases include:

SARDI Field Crops Pathology
GPO Box 379, Adelaide, SA 5001
Telephone (08) 8303 9384
Facsimile (08) 8303 9393
Web: www.sardi.sa.gov.au/diagnostic_services/Crop_diagnostics

Futari Consulting (Qld) Pty Ltd
P.O. Box 7135
South Toowoomba
Qld 4350
Ph: (07) 4697-5340
Email: Ken@futariqld.com.au

2.10 Performing your own germination and vigour test

A laboratory seed test for germination should be carried out before seeding to calculate seeding rates. However, a simple preliminary test on-farm can be done in soil after harvest or during storage. Results from a laboratory germination and vigour test should be used in seeding rate calculations.

For your own germination test, use a flat, shallow seeding tray about 5 cm deep. Place a sheet of newspaper on the base to cover drainage holes. Use clean sand, potting mix or a freely draining soil. Testing must be at a temperature <20°C, so doing it indoors may be required. Randomly count out 100 seeds per test, but do not discard any damaged seeds.

After the tray has been filled with soil, sow 10 rows of 10 seeds in a grid at the correct seeding depth (Figure 8). Do this by placing the seed on the levelled soil surface and gently pushing each in with a pencil marked to the required depth. Cover seed holes with a little more soil and water gently.

Alternatively, place a layer of moist soil in the tray and level it to the depth of sowing that will be required. Place the seeds as 10 rows of 10 seeds in a grid on the seedbed formed. Then uniformly fill the tray with soil to the required depth of seed coverage

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(i.e. seeding depth). Ensure that the soil surface is uniformly levelled, and water gently if required.

During the test, keep the soil moist but not wet. Overwatering will result in fungal growth and possible rotting. After 7–14 days, the majority of viable seeds will have emerged. Count only normal, healthy seedlings. The number of normal and vigorous seedlings that you count will be the germination percentage.

This germination test is partly a form of inbuilt vigour testing because it is done in soil. To further establish vigour under more adverse conditions, a second germination test done under colder or wetter conditions could be used as a comparison to the normal germination test done at the same time. [13]

Figure 8: *Doing your own germination test.*

Photo: E. Leonard, AgriKnowHow

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Planting

MORE INFORMATION

Australian Pulse Bulletin: Pulse inoculation techniques

3.1 Inoculation

Pulses have the ability to fix their own nitrogen (N_2) from the air via nodules on their roots if specific N_2-fixing bacteria (rhizobia) are available (Figure 1).

Faba beans tend to nodulate freely, but agronomists will often suggest inoculation as cheap insurance against poor nodulation performance, especially in acid soils. Inoculating legume seed or soil at sowing provides a large number of effective rhizobia around the emerging legume root to optimise nodulation and N_2 fixation.

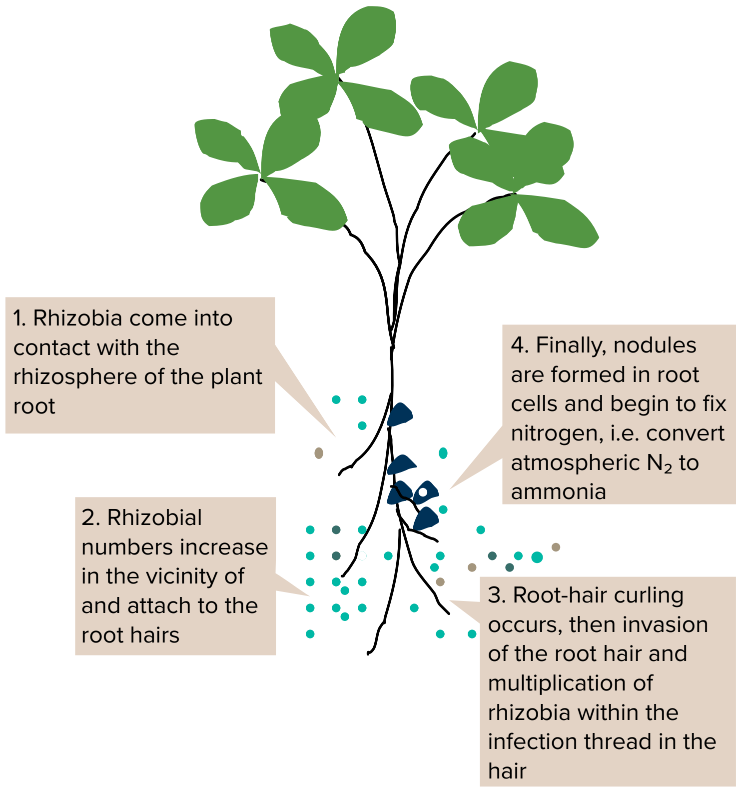

Figure 1: *Schematic representation of the process of nodulation.*

Source: D Herridge (2013) Managing legume and fertiliser N for northern grains cropping. p. 30. GRDC, https://grdc.com.au/uploads/documents/Managing-N-for-Northern-Grains-Cropping.pdf

The strain of rhizobia used to inoculate faba bean, WSM1455, is common to field peas, vetches and lentils. Field peas and vetches are placed under Inoculant Group E, for which both the WSM1455 and SU303 rhizobial strains can be used. Faba beans and lentils are in Group F, which only responds to the use of WSM1455.

Inoculation with the correct rhizobial strain is essential for effective nodulation in some soil types and situations.

High levels of background rhizobia are often common in commercial faba bean crops, and so they nodulate well. However, these native strains do not always provide fully effective nodulation or N_2 fixation. Improvements in nodulation and N_2 fixation can be improved by inoculating with the strain of rhizobia suited to faba bean.

Rotation lengths of 4–5 years are recommended between successive faba bean crops as a disease management strategy (i.e. for Ascochyta blight). At this re-cropping interval in some more 'hostile' situations (e.g. acid soils), it us unlikely that sufficient levels of Group F rhizobia will survive for effective nodulation.

The Group F rhizobia are regarded as an 'aggressive nodulator'. This effectively means that nodulation will be successful in meeting the crops N requirements provided:

- Inoculants are handled and stored in a manner that will ensure bacterial survival, i.e. they should be kept cool.
- Growers adopt effective inoculation practices on-farm.
- Inoculated seed is planted into moisture within 12 h of treatment—the sooner the better, as fungicide seed dressings and warm temperatures can affect survival of the bacteria.

Group F rhizobia are extremely sensitive to the level of available nitrate-N in the soil.

While high levels of nitrate-N have no significant effect on both the initial formation and number of nodules, they do markedly reduce both nodule size and activity.

Nodules remain inactive until the soil nitrate supply is exhausted (ineffective nodules remain white inside from the absence of leghaemoglobin). Effective N_2-fixing nodules, on the other hand, are rusty red or pink inside (Figure 2).

Figure 2: *Active nodules have a pink centre.*

Photo: G. Cumming, Pulse Australia

Growing faba beans on long fallows or in a situation with high residual N (e.g. after cotton) will substantially reduce N_2 fixation.

Where the host legume plant is grown infrequently in the cropping rotation, re-inoculation can be beneficial. Use of a commercial inoculant will ensure that nodulation is prompt, nodules are abundant, and the strain of rhizobia forming the nodules is effective at fixing N_2.

When the legume germinates, the rhizobia enter the plant's roots, multiply rapidly and form a nodule. Effective nodule formation and function requires good growing conditions, the appropriate rhizobia and a host plant (Figure 3). [1]

1 Northern Faba Bean—Best Management Practices Training Course. Pulse Australia 2014.

Figure 3: *Well-nodulated faba bean roots.*

Source: D Herridge (2013). Managing legume and fertiliser N for northern grains cropping. p. 29. GRDC, https://grdc.com.au/uploads/documents/Managing-N-for-Northern-Grains-Cropping.pdf

3.1.1 When to inoculate

The WSM1455 rhizobia have been widely distributed following decades of cultivation of its host species, particularly field peas and vetch. Combined sowings of field peas, faba beans and lentils are ~600,000 ha/year. Spread and survival of the rhizobia has also been assisted by vetch, which is broadly naturalised and is sown as a forage–green manure crop.

Although the rhizobia have been widely distributed, their moderate sensitivity to soil acidity means that their populations are sometimes below what is needed for optimal nodulation. Rhizobial numbers may be suboptimal or rhizobia may be absent where soil pH is <6.0, even where there has been a recent history of the legume host.

Growth and yield of crops grown on red soils in northern New South Wales (NSW) have been increased by seed inoculation, but responses on black soils of the Liverpool Plains have been mixed. [2] Trials at Coonamble and Walgett in 2009 found no response to inoculant application at those trial sites (heavy clay soils), likely due to rhizobial survival from naturalised vetch populations and possibly the movement of rhizobia in floodwater.

However, it is not possible to be sure that the rhizobia are present across a whole paddock or region, so inoculation with Group F inoculant is recommended. [3]

If the paddock has previously grown the legume (or one from the same inoculant group), the number of rhizobia remaining in the soil will be affected by the time since the legume was last grown, the type of rhizobia, and soil pH and texture (Figure 4). Field pea and faba bean rhizobia (Groups E and F) survive well in neutral to alkaline soils with good texture (loams or clays). A response to inoculation is less likely on

2 P Matthews, H Marcellos (2003) Faba bean. Agfact P4.2.7. 2nd edn. NSW Department of Primary Industries, http://www.dpi.nsw.gov.au/agriculture/broadacre/winter-crops/pulses/beans/faba-bean

3 GRDC (2010) Faba beans for the Central West and Northwest Plains Regions of NSW. GRDC Update Papers 6 September 2010, http://grdc.com.au/Research-and-Development/GRDC-Update-Papers/2010/09/FABA-BEANS-FOR-THE-CENTRALWEST-AND-NORTHWEST-PLAINS-REGIONS-OF-NSW

these soil types if these crops have been grown in the paddock in the previous four years. If soil pH is <6.0, the crop is best inoculated, especially on light-textured soils.

MORE INFORMATION

http://www.grdc.com.au/GRDC-Booklet-InoculatingLegumes

http://www.grdc.com.au/GRDC-FS-RhizobialInoculants

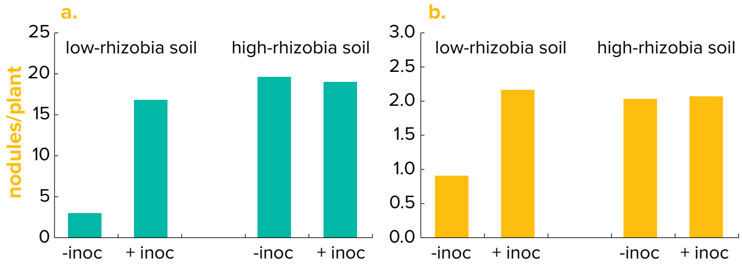

Figure 4: *Effects of inoculation on (a) nodulation and (b) grain yield of faba bean in low-rhizobia and high-rhizobia soils. Data aggregated from 18 experiments in the National Rhizobium Program (NRP) across Western Australia, Victoria and New South Wales during 1997–2003.*

Source: GRDC Rhizobial inoculants Fact Sheet, http://www.grdc.com.au/GRDC-FS-RhizobialInoculants

3.1.2 Inoculant types

A diverse range of inoculant products with different methods of application is available (Table 1, Figure 5), including:

- Becker Underwood (Nodulaid™). Peat and liquid inoculants, applied as a slurry/powder/liquid to the seed or 'in-furrow' to the soil and peat granular inoculants (Nodulator™), to be applied in-furrow to the soil.
- New-Edge Microbials (EasyRhiz™). Freeze-dried inoculants made up into a liquid and applied to the seed or in-furrow by water injection into the soil.
- ALOSCA Technologies (ALOSCA®). Dry clay (bentonite) granular inoculants, applied in-furrow to the soil.
- Brushmaster (Inoculeze™). Peat inoculants in a 'tea bag' extract applied to the seed just before sowing with a special applicator.
- Novozymes Australia (N-Prove™). Peat-based inoculant, applied as a slurry/powder/liquid to the seed or in-furrow to the soil. Also available are in-furrow granular formulations to be applied to the soil in the seed furrow.

The inoculant type will depend on product availability, relative cost, and efficacy, ease of use and machinery availability. Granular products vary and may be dry or moist, uniform, variable, powdery, coarse or fine.

Table 1: *Rhizobial inoculants available for use in Australia.*

Manufacturer	Brand	Formulation	Application
Becker Underwood	Nodulaid™	Peat	Slurry on seed; slurry/liquid in furrow
	Nodulaid™	Liquid	On seed; in furrow
	Nodulator™	Clay granule	In furrow
	BioStacked®	Peat (rhizobia) plus liquid (*Bacillus subtilis*)	Slurry on seed; slurry/liquid in furrow
New-Edge Microbials	EasyRhiz™	Freeze-dried	Liquid on seed; liquid in furrow
	Nodule N™	Peat	Slurry on seed; slurry/liquid in furrow

Manufacturer	Brand	Formulation	Application
Novozymes Biologicals Australia	N-Prove®	Peat	Slurry on seed; slurry/liquid in furrow
		Peat granule	In furrow
	TagTeam®	Peat (rhizobia) plus (*Penicillium bilaii*)	Slurry on seed; slurry/liquid in furrow
	TagTeam®	Peat granule (rhizobia) plus (*Penicillium bilaii*)	In furrow
ALOSCA Technologies	ALOSCA®	Clay granule	In furrow
Brushmaster	Inoculeze™	Peat	'Tea extract' on seed via an applicator

Source: D Herridge (2013). Managing legume and fertiliser N for northern grains cropping (GRDC).

Figure 5: *Different forms of rhizobia. Left to right: EasyRhiz® freeze dried, Nodulator® granules, Alosca® granules, N-Prove® granules and Nodulaid® peat inoculant.*

Photo: M. Denton, formerly Vic DPI

Figure 6 shows nodule development with peat and granular inoculants, and Figure 7 the effect of level of inoculant, both in acid soils.

Figure 6: *Faba beans on acid soil inoculated with peat inoculant showing few nodules (left panel) compared with those inoculated with granular inoculant (right panel). Note that nodulation is still less than would be experienced on more neutral or alkaline soils*

Photo: W. Hawthorne, Pulse Australia

Figure 7: *Faba beans on acid soil inoculated at different rates of inoculant. Plots inoculated with low numbers of rhizobia show as yellow, poorly nodulated plants with less biomass.*

Photo: W. Hawthorne, Pulse Australia

3.1.3 Newer inoculation methods

With new inoculants types and technologies, an appreciation is needed of each type's strengths and limitations. Rhizobial survival becomes more important under more 'difficult' circumstances, for example, placement in dry soil, prolonged dry soil conditions, use of a seed treatment of fungicide or trace elements, and acidic soil. Survival is associated with the degree of protection the rhizobia have against drying or adverse conditions. Ease of inoculant application is increasingly important and needs to be accounted for in costing. [4]

3.1.4 In-furrow water injection

Injection of inoculants mixed in water is becoming a more common practice. It can be used where machines are set up to apply other liquids at seeding, such as liquid N or phosphorus. See Figures 8–11 for photos of liquid injection set-ups on seeding equipment. Figure 11 shows the liquid stream.

Water injection of inoculant requires at least 40 L water/ha, and is better with more water. The slurry–water suspension is sprayed under low pressure into the soil in the seed row during seeding. Benefits of the new inoculants over peat are that they mix more readily, and do not have the requirement for filtering out peat. Compatibility of the inoculant with trace elements is not yet known, but cautious is advised, because water pH is critical, and trace element types, forms and products behave differently between products and inoculants groups.

4 Northern Faba Bean—Best Management Practices Training Course, Pulse Australia. 2014.

Figure 8: *A seeding bar setup with Atom Jet narrow points, gang press wheels and liquid injection for either inoculum or trace element application during sowing.*

Photo: W. Hawthorne, Pulse Australia

Figure 9: *Tanks mounted on the seeding bar for liquid injection of rhizobia or trace elements during seeding. Agitation is required. Note the tubes and manifold. Inoculum must be applied under low pressure only. Some machines have their tanks set up as a separate, trailed tanker.*

Photo: W. Hawthorne, Pulse Australia

Figure 10: *A disc seeder set up with Yetter trash clearing wheels and tubing for liquid injection of inoculum or trace elements during sowing. Note also the closer, to cover the seeding slot and act like a press-wheel from the side.*

Photo: W. Hawthorne, Pulse Australia

Figure 11: *In-furrow liquid injection: Note the droplets from liquid injection, which can be used for inoculating pulses or applying liquid trace elements.*

Photo: W. Hawthorne, Pulse Australia

3.1.5 Granular inoculants

Granular inoculants are applied like fertiliser as a solid into the seed furrow, near to the seed or below. They avoid many of the compatibility problems that rhizobia have with fertilisers and fungicides. They also eliminate the need to inoculate seed before sowing. Granular inoculant may also be better where dry sowing is practiced or when sowing into acidic soils, because the rhizobia survive better than on seed. A third, small seed box is required to apply granular inoculum (Figure 12). This is because rhizobial survival is jeopardised if the granular inoculum is mixed with fertiliser. If it is mixed with the seed, then distribution of both seed and inoculum is affected, causing poor and uneven establishment and/or patchy nodulation.

Granules contain fewer rhizobia per gram than peat-based inoculants, so they must be applied at higher application rates. The size, form, uniformity, moisture and rate of application of granules differ between products. Depending on product or row-spacing sown, rates can vary from 2 to 10 kg/ha to deliver comparable levels of nodulation.

Figure 12: *An 'after-market' third box fitted to a Flexicoil box to enable application of granular inoculum. Note that granular inoculum cannot be applied mixed with the seed (uneven distribution of seed and/or inoculums occurs). Rhizobia survival is severely jeopardised if granular inoculum is applied mixed with fertiliser.*

Photo: W. Hawthorne, Pulse Australia

3.1.6 Inoculant and fungicide compatibility

Caution should be used when treating pulse seed with a fungicide. Some insecticide and seed treatments can also cause problems. See Table 2 for an example with chickpea. Check the inoculant and chemical labels for compatibility of the inoculant and fungicide or insecticide seed treatments, and the planting window (time) for either sequential or simultaneous application of seed treatments and seed-applied inoculants.

Table 2: *Effects of seed dressings on plant growth and nodulation in chickpea.*

Treatment	Fresh weight (g)			Height (cm)	Nodulation score
	Shoot	Root	Total		
Nil	106	142	248	47	1.0
Inoculum only	130	244	374	57	4.5
Inoculum plus thiram	103	182	285	55	1.8
Inoculum then thiram	119	208	327	58	3.2
Thiram then inoculum	117	212	329	55	3.8
Inoculum plus metalaxyl	106	173	279	54	1.8
Inoculum then metalaxyl	114	207	321	59	3.3
Metalaxyl then inoculum	113	206	319	55	3.6
l.s.d. ($P = 0.05$)	19	33	31	9	0.6

Source: T. Bretag, formerly DPI Victoria.

3.1.7 Compatibility with trace elements

Rhizobia can be compatible with some specific trace element formulations, but many are not compatible for rhizobial survival. Mixing of inoculants with trace elements should only occur if the trace element formulation being used has been laboratory-tested against the rhizobial type (Table 3).

Table 3: *Rhizobial compatibility with different trace element (TE) products after 24 h of tank mixing.*

TE formulation	Inoculant strain (by crop)				
	Field peas	Faba beans	Chickpeas	Lupins	Soybean
Manganese 1	×	×	×	✓	✓
Manganese 2	✓	✓	✓	✓	✓
Zinc 1	×	×	×	×	✓
Zinc 2	×	×	×	×	✓
Zinc 3	×	×	×	×	✓
Zinc 4	×	✓	×	✓	✓
Zinc 5	×	✓	×	✓	✓

Note the differences between inoculant types for a given TE product, as well as differences between TE products with a given inoculant
Source: Becker Underwood Pty Ltd.

3.1.8 Inoculation checklist

- When purchasing inoculants:
- Check the expiry date on packet.
- Note how it been has been stored.
    - » Packets should be stored at ~4°C.
    - » Do not freeze (below 0°C) or exceed 15°C.
- Choose Group F faba bean inoculum.
- Prepare slurry and apply in the shade. Avoid exposure to high temperatures (>30°C), direct sunlight, and hot winds.
- Accurately meter adhesive slurry onto the seed. Too much water means sticky seeds and blockages in the seeder.

- Avoid high-speed mixing in augers.
- Sow inoculated seed immediately. Never delay more than 12 h.
- Check air-seeders for excessively high temperatures in the air stream. Temperatures >50°C will kill the rhizobia. [5]

3.1.9 Rating nodulation and nitrogen fixation (effectiveness)

The amount of N_2 fixed is strongly correlated with nodule rating (0–5) as detailed in the photo standards outlined in the TopCrop publication 'Growers guide to assessing nodulation in pulse crops'.

When using this rating system, plants should be gently dug from the soil and the root system rinsed in water before scoring the level of nodulation.

Obvious signs of nodulation should be visible by 6 weeks after sowing (even in high soil nitrate situations).

Rate the level of nodulation using the photo standards provided (see Figure 13). This is based on nodule number and position on the root system.

The pattern of nodules on the root system should be observed. Nodules on the main taproot clustered near the seed are an indication that nodulation occurred because of the inoculation process. These are referred to as 'crown nodules'.

If there are no crown nodules but nodules on the lateral roots, it is more likely that they have formed from native soil bacteria that are usually less effective at fixing N_2, even in faba beans.

Nodules on both the crown and lateral branches indicate that inoculation was successful and that bacteria have spread in the soil. The faba bean rhizobia are not very 'aggressive' and do not spread more than very short distances in the soil.

Inspect nodules for nitrogen-fixation activity by assessing their internal 'pink' (leghaemoglobin) colour. The best method is to slice a few nodules open with a razor blade or sharp knife and examine their colour.

Young nodules are usually white and need to develop. White nodules can also indicate the wrong bacteria in the nodule, and these will not fix N_2. Effective nodules are a rusty red or pink inside, and these are usually actively fixing N_2. Effective red nodules can sometimes turn green when a plant is under water, disease or other stress, or is suffering from nutrient deficiencies. These do not fix N_2, but they can change back to red and begin to fix again if the stress is relieved without too much damage being done. Black nodules are usually dead or dying. These are often seen as the crop matures, or after a crop has suffered severe waterlogging. [6]

MORE INFORMATION

http://www.grdc.com.au/uploads/documents/3%20Seeding.pdf

3.1.10 Key for assessing nodulation in winter pulse crops

Scores from 0 to 5 are based on nodulation number and distribution, where 0–1 is inadequate nodulation, 2–3 is adequate nodulation, and 4–5 is good nodulation (Figure 13).

5 Northern Faba Bean—Best Management Practices Training Course Pulse Australia 2014.

6 Northern Faba Bean—Best Management Practices Training Course. Pulse Australia 2014.

(a) Score 0: taproot, absent; lateral, absent.

(b). Score 1: taproot, few-medium; lateral, absent-few

(c) Score 2: taproot, medium; lateral, absent-low.

(d) Score 3: tap root, medium-high; lateral, low.

(e) Score 4: taproot, high; lateral, medium.

(f) Score 5: taproot, high; lateral, high.

Figure 13: *Visual key for nodulation scores.*

Source: TopCrop 'Growers guide to assessing nodulation in pulse crops'

Points to note:

- Where plant available soil-N is low, the crop relies heavily on good nodulation for its N supply. A score of 4–5 is desirable.
- Where plant-available N is high, nodulation may be partly inhibited, and the crop will depend mainly on the soil for N supply.
- A high score indicates that the crop will yield well and conserve soil N for use by a following crop.
- A low score suggests that the crop will yield poorly and deplete soil N.

3.1.11 Storing inoculants

For maximum survival, peat inoculant should be stored in a refrigerator at ~4°C until used. If refrigeration is not possible, store in a cool, dry place away from direct sunlight. Granules and other forms also need to be stored in a cool place out of direct sunlight. Do not store an opened inoculum packet, as it will deteriorate rapidly.

Discard the inoculant after the expiry date shown because the rhizobia population may have dropped to an unacceptable level.

3.1.12 Inoculum survival

Moist peat provides protection and energy while the unopened pack is being stored. Rhizobia can dry out and lose viability once applied to seed and not in moist soil. Granular inoculant forms may not dry out as quickly, and most peat inoculants now contain an adhesive, which delays drying and increases survival of the rhizobia. Use a peat–slurry mix within 24 h and sow seed inoculated with peat slurry as soon as possible or store for up to 3 days in a cool place, away from sunlight.

With non-peat based inoculants, such as freeze-dried rhizobia, it is recommended that treated seed should be sown within 5 h of inoculation.

Lime pelleting is not usual practice with pulse crops, and especially with large-seeded types such as faba bean. If the inoculum is incorporated into lime-pelleted seed, it may survive at cool room temperatures for up to a week.

If inoculated seed is sown into dry soil, the sticker assists in survival of rhizobia until rain, but inoculum viability rapidly diminishes over time in warm, dry soil temperatures. It is difficult to provide guidelines to survival times; however, it is best to sow as close to a rain front as possible. The rhizobia will survive for longer in granules than when applied to seed. Hence, when dry-sowing pulses, granular inoculant is preferred over peat and liquid-injection methods.

Nodulation failure after dry-sowing of inoculated seed is more likely if the soil has no naturalised rhizobia present.

Dry-dusting the peat inoculant into the seed box is not an effective means of either applying or retaining rhizobia uniformly on seed. Under some conditions, rhizobial death is so rapid where dry-dusting is used that no rhizobia are alive by the time the seed reaches the soil.

MORE INFORMATION

Soil acidity holds back pulse potential

3.1.13 Applying inoculant

Most commercial inoculants contain a pre-mixed sticker. When mixing the slurry, do not use hot or chlorinated water. Add the appropriate amount of the inoculant group to the solution and stir quickly. Mix into a heavy paste with a small amount of water prior to adding to the main solution. Read the inoculant label before adding any approved insecticides, fungicides, herbicides, detergents or fertilisers into the slurry (see below: 3.2 Seed treatments). Add the inoculant suspension (slurry) to the seed and mix thoroughly until all seeds are evenly covered. A small amount of fine lime can be added after mixing is complete to help dry the seed and prevent tackiness. If adding lime use only calcite lime; agricultural lime is too coarse. Do not use builders lime, hydrated lime or slaked lime—they will kill the rhizobia. [7]

MORE INFORMATION

http://www.grdc.com.au/uploads/documents/3%20Seeding.pdf

Slurry can be applied to the seed using:

1. A cement mixer. This is practical for small lots only unless a cement truck is used.
2. Through an auger (see Figure 14). Make sure the auger is turning as slowly as possible. Reduce the height of the auger to minimise the height of seed-fall. Perhaps add a slide, e.g. tin, to the outlet end of the auger to stop seed from falling and cracking. Meter the slurry in, according to the flow rate of the auger (about a 250-g packet per 100 kg seed). If the auger outlet is out of reach, e.g.

7 Northern Faba Bean—Best Management Practices Training Course. Pulse Australia 2014.

under a field bin, then use some poly water pipe to run the slurry into the auger. A clean drench pack fixed to a dropper makes a good funnel into the poly pipe.

3. Through a tubulator. Use of a tubulator reduces the risk of damaging the seed, but its mixing ability is not as effective as an auger. Apply the slurry in a similar fashion as with an auger.

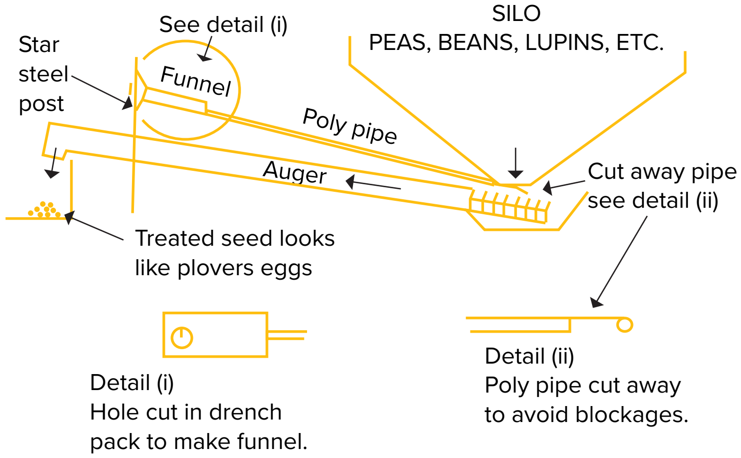

Figure 14: *Applying inoculum through an auger.*

Source: Grain Legume Handbook, http://www.grdc.com.au/uploads/documents/3%20Seeding.pdf, p. 3: 4

MORE INFORMATION

Ground Cover: Aphids – to spray or not to spray

3.2 Seed treatments

Fungicide seed dressings are not normally required for faba bean in the northern cropping zone. If a fungicide dressing is to be used, caution is required because of incompatibility between some fungicides and the living bacteria used for inoculations. Some insecticide and seed treatments can also cause problems. Check the inoculant and chemical labels for compatibility of the inoculant and fungicide or insecticide seed treatments. [8]

3.3 Crop establishment

MORE INFORMATION

Ground Cover: Avoiding stubble trouble

3.3.1 Stubble retention

Presence of stubble can increase water infiltration and slow moisture loss through evaporation. With standing stubble, lower wind speeds at the soil surface and cooler soil temperatures assist in reducing evaporation, hence increasing soil moisture storage for sowing and afterwards. Winter crops in southern cropping areas are dependent on incident rainfall. Stubble retention ensures that more of this moisture is captured and retained as stored soil moisture for the pulse to benefit. Stubble retention also helps to retain some of the deeper moisture left from summer rains, provided weeds are controlled.

The value of stubble presence to pulse production in drier areas or during drier years has been very apparent with pulses in southern Australia in recent dry years. Stubble retention provides an earlier sowing opportunity than stubble burning, because of preservation of soil moisture in the soil surface (Figures 15 and 16). Stubble retention combined with the ability to sow earlier, perhaps sowing into wider row spacing and achieving greater harvestable height with less lodging, has allowed pulse growers to produce a pulse crop in years that would otherwise have been disastrous.

8 GRDC (2008) Grain Legume Handbook. GRDC, https://grdc.com.au/uploads/documents/Index.pdf

Figure 15: *Beans sown into cereal stubble.*

Photo: W. Hawthorne, Pulse Australia

Figure 16: *Beans sown into cereal stubble establish well and lose less soil moisture than those sown into bare soil.*

Photo: W. Hawthorne, Pulse Australia

Table 4: *Effect of stubble retention and fungicide regime on faba bean grain yield (t/ha) at Rupanyup 2011.*

	Grain yield (t/ha)	
	Standing stubble	Burnt stubble
Total disease control: (fortnightly carbendazim + chlorothalonil)	4.7	3.9
Carbendazim × 3 (early, mid, late flowering)	4.5	3.7
Carbendazim × 2 (early and late flowering)	4.1	3.4
Nil fungicide	3.5	3.0
l.s.d. (*P* = 0.05)	0.21	0.22

Separate but adjacent trials were used for stubble treatments
Source: J. Brand, Southern Pulse Agronomy.

In trials at Rupanyup, there were large differences between stubble treatments. Overall grain yield in the standing stubble trial averaged 20% more than in the burnt stubble trial. Maturity of the plots in the standing stubble was up to 2 weeks later than in the burnt stubble. Response to fungicide regimes across varieties was similar in both trials. Compared with the fortnightly regime of total disease control, average yield loss was ~5%for Carbendazim × 3, 12% for Carbendazim × 2, and 23% for the nil fungicide treatment (Table 4).

The relative response of varieties to stubble treatment did not appear to be related to the disease score. Varieties with highest disease scores did not show significantly greater yield loss in the nil treatment than varieties with lowest disease scores. In the standing stubble trial, average disease scores (range 2.7–4.2) were less than in the burnt stubble trial (range 3.1–5.1). Differences were particularly evident in the susceptible variety Farah⒟, which, in the nil fungicide treatment, had scores of ~7 in the burnt stubble trial and 5 in the standing stubble trial.

Average height to the lowest pod in standing stubble (average 32.3 cm) was greater than in the burnt stubble (average 26.1 cm).

Table 5: *Effect of stubble retention and fungicide regime on faba bean grain yield (t/ha) at Lake Bolac (Vic) 2011.*

	Grain yield (t/ha)	
	Slashed stubble	Burnt stubble
Total disease control (fortnightly carbendazim + chlorothalonil)	3.2	3.4
Carbendazim × 3 (early, mid, late flowering)	3.1	3.2
Carbendazim × 2 (early and late flowering)	2.85	3.05
Nil fungicide	2.5	2.65
l.s.d. (*P* = 0.05)	0.21	0.23

Separate but adjacent trials were used for stubble treatments S
ource: J. Brand, Southern Pulse Agronomy.

Effect of stubble retention on faba bean grain yield at the high-rainfall site at Lake Bolac in 2011 was minimal (Table 5). Rainfall during the summer meant that soil moisture profiles were at, or near, field capacity at sowing.

Average grain yields were slightly higher (3–7%) on burnt stubble. Burnt stubble had higher average disease levels (range 4.9–7.6) than those beans on slashed stubble (range 3.5–7.0). Disease, predominately rust, resulted in grain yield losses of 5–35% depending on variety.

There were clear differences in the susceptibility of varieties to the disease present, and this negatively correlated with grain yield. The variety with the lowest disease scores had the lowest grain yield loss in the nil fungicide treatment. [9]

MORE INFORMATION

GRDC Update paper: Faba beans for acidic soils in southern NSW - yields and time of sowing effects

MORE INFORMATION

Ground Cover: Faba bean foray into the north takes hold

MORE INFORMATION

GRDC Update Paper: Chickpea and faba bean agronomy ideal row spacing and populations

MORE INFORMATION

Minimising frost damage in pulses

3.3.2 Time of sowing

Aim to sow in the earlier part of the sowing window to maximise yield potential. The preferred sowing window in the northern region is typically during April, extending into the first 2 weeks of May for the higher rainfall, longer growing regions of the Liverpool Plains. Avoiding frost or cold conditions during flowering can be important, particularly in areas with long growing seasons where sowing time may also need to be delayed to avoid chocolate spot.

Faba beans show a marked response to time of sowing, with crops sown 'on time' having an excellent chance of producing very high yields. Crops sown earlier or later than recommended will often suffer reduced yields (Figure 17).

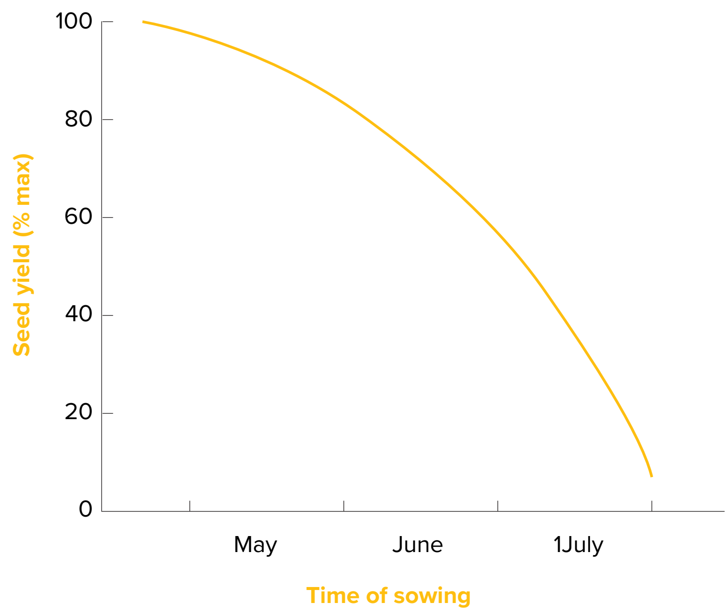

Figure 17: *Influence of delay in sowing on yield of faba beans in northern New South Wales.*

Source: Faba bean Agfact P4.2.7, 2nd edn 2003. p. 7

Water Use Efficiency is commonly in the range 8–12 kg grain/ha.mm for sowings made during the preferred sowing window. This drops to 4–6 kg/mm for very late or very early sowings.

Sowings made prior to the recommended sowing window tend to be more vegetative and suffer from:

- poor early pod set because of low light or low temperatures (10°C) at commencement of flowering
- higher risk of chocolate spot at flowering and through podding
- crops more pre-disposed to lodging
- increased frost risk at flowering and early podding
- high water use prior to effective flowering and earlier onset of moisture stress during flowering and podding

9 Northern Faba Bean—Best Management Practices Training Course. Pulse Australia 2014.

- increased risk of Ascochyta blight, chocolate spot and rust in susceptible varieties

Late-planted crops are more likely to suffer from:

- high temperatures and moisture stress during flowering and podding
- greater native budworm pressure
- fewer branching and flowering sites, unless plant population is increased
- shorter plants and lower podset, which is more difficult to harvest

To achieve maximum yields, critical management factors such as weed control and seedbed preparation must be planned to allow crops to be sown as close as possible to the ideal sowing dates.

These ideal sowing dates should ensure that all pulse crops:

- finish flowering before being subjected to periods of heat stress (generally when maximum day temperatures over 1 week average ≥25°C); and
- flower over an extended period to encourage better podset and produce sufficient growth to set and fill an adequate number of pods.

However, sowing must not be too early, otherwise:

- Flowering may be during a frost period.
- Growth may be excessive, resulting in crop lodging and dramatically increasing the likelihood of fungal disease in the medium–high rainfall districts.
- Conditions at seeding time may not be suitable for controlling broadleaved weeds with recommended herbicides, resulting in weedy crops.

In other words, there can be a significant difference between the optimum sowing time (for maximum potential yields) and the ideal sowing time (reducing yield loss factors).

The ideal seeding time for pulses depends largely on where the crops are being grown (Figure 18). Key factors include rainfall and the date of risk periods such as frost and critical heat stress. Soil type and fertility can also influence crop growth. With all pulses, adequate soil moisture at seeding time is essential.

On acidic soils of southern NSW:

- Sow faba bean from 20 April to 15 May on acidic soils of southern NSW.
- Sowing earlier than the above dates can result in excessive lodging and disease risk.
- Sowing later lowers yield and produces shorter plants affecting harvestability.
- Choice of sowing time is far more important than choice of variety. [10]

Optimum temperature for growth is in the range 15–25°C, with flowering ideally occurring from July to late September. Flowering may start in June if sown early in northern NSW and may extend to mid-October in southern NSW. High temperatures and hot, dry winds during flowering will reduce yield. Severe frosts following mild weather often cause elongating stems to develop a bent stick ('hockey stick') appearance, blackening of leaf margins and abortion of flowers and pods in some varieties. [11]

Faba bean seedlings are tolerant of frost but can still be affected.

Faba bean seeds can germinate in soil as cold as even 5°C, but emergence will be slow. Seedling vigour will be greater if soil temperatures are at least 7°C.

10 GRDC (2015) Faba beans for acidic soils in southern NSW - yields and time of sowing effects. GRDC Update Papers 28 July 2015, https://grdc.com.au/Research-and-Development/GRDC-Update-Papers/2015/07/Faba-beans-for-acidic-soils-in-southern-NSW

11 P Matthews, D McCaffery, L Jenkins (2013) Winter crop variety sowing guide NSW DPI Management Guide. NSW Department of Primary Industries, http://www.dpi.nsw.gov.au/agriculture/broadacre/guides/winter-crop-variety-sowing-guide

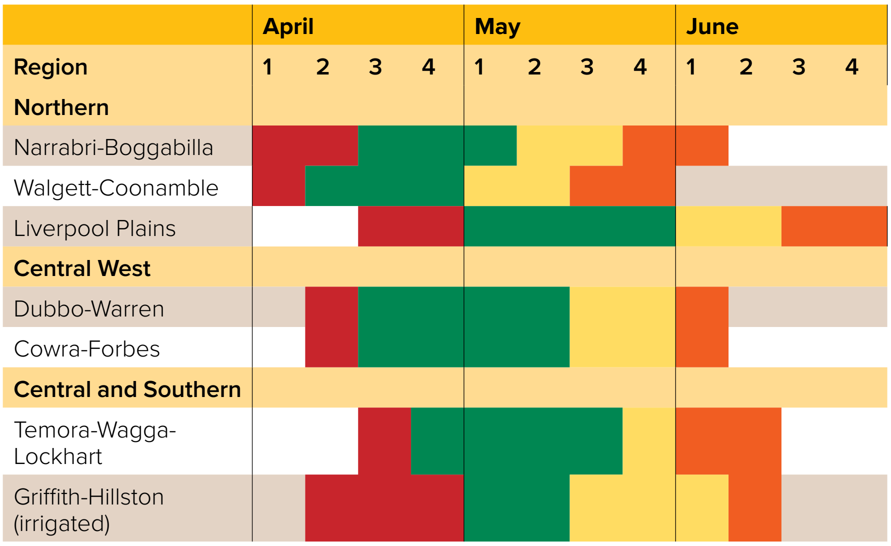

Figure 18: *Suggested sowing times for faba bean in New South Wales.*

Source: Winter crop variety sowing guide, NSW DPI Management Guide 2013, http://www.dpi.nsw.gov.au/agriculture/broadacre/guides/winter-crop-variety-sowing-guide

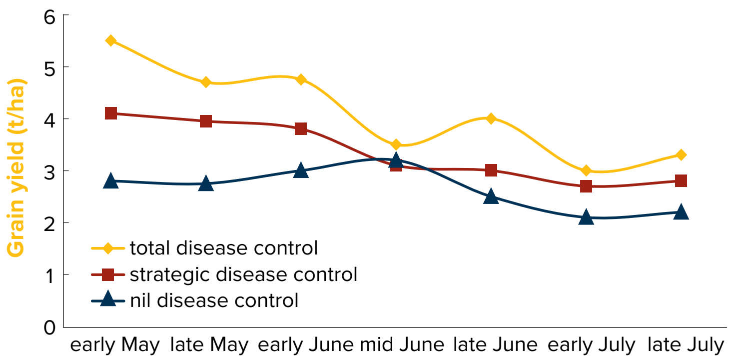

Figure 19: *Interaction between sowing date and fungicidal disease control on grain yield (t/ha) at Struan (South Australia), with a chocolate spot susceptible variety (Fiord).*

Source: Grain Legume Handbook

In low-rainfall areas, faba beans must be sown early. Hot winds in spring cause beans to wilt, stop flowering and prematurely ripen. Compacted soils that do not allow root penetration exaggerate this effect. Sowing also needs to be earlier in wetter areas, soils of lower fertility or acidic condition, or where excessively tall growth of beans is unlikely.

Ultimately, the use of varieties with resistance to chocolate spot will enable earlier sowing in most areas. In the interim, wider row spacing (skip row or wider) is being used in early sowings to delay canopy closure and so lessen disease risk. Fungicidal disease control can have a greater effect on improving yield of earlier sown than mid or later sown crops (Figure 19).

Limited post-emergence broadleaf weed control is available in beans; therefore, it is important to consider achieving good weed control in view of the desire for early sowing.

In the late 2000s, growers in north-western NSW experimented with sowing faba beans in late March–early April, often with considerable success. A trial was set up at Trangie Agricultural Research Centre in 2009 to test two released and four unreleased varieties across a range of sow times (Figure 20). [12]

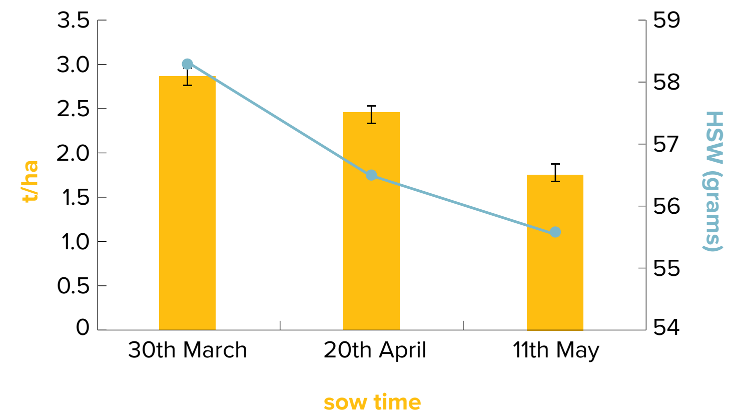

Figure 20: *Effect of sowing time on yield and 100-seed weight of faba beans at Trangie Agricultural Research Centre, 2009.*

Source: http://grdc.com.au/Research-and-Development/GRDC-Update-Papers/2010/09/FABA-BEANS-FOR-THE-CENTRALWEST-AND-NORTHWEST-PLAINS-REGIONS-OF-NSW#sthash.26gEqmle

As shown in Figure 20, yield (averaged across all varieties) was highest from the early sowing time (2.87 t/ha), with yield decreasing significantly for the second sowing time (2.46 t/ha), and again for the third sowing time (1.76 t/ha). Hundred-seed weight (which generally correlates to grain size) was also significantly greater from the early sowing than the later sowings.

Previous recommendations have pointed to sowing faba beans from about 25 April in the Macquarie Valley, and from about 10 April for the Coonamble–Walgett regions. Despite this, commercial crops and trials (albeit limited) in the past 2–3 years have had best results when planted in late March–early April. Based on these recent results, there is potential to move the sowing window forward ~15 days for both regions, provided producers are willing to accept the increased risk of frost and diseases (especially rust and viruses). However, the newer varieties such as Doza⦇D⦈ and PBA Warda⦇D⦈ are quicker in maturity and, hence, should be sown in the traditional planting window for best results.

Further research and commercial experience in the coming seasons will seek to determine more clearly optimal sowing times for the region.

3.4 Seeding rates

Seeding rates (kg/ha) for faba beans vary with the size of the seed being sown (Table 6).

Faba bean plant populations in the northern region should target 12–25 plants/m^2, meaning a typical seeding rate of 120–160 kg/ha depending on variety and seed weight.

Not all seeds are equal—some grow better than others. Before deciding on a seeding rate take a representative sample, have it sized and then germination- and vigour-tested (see GrowNotes Faba beans 2. Pre-planting).

MORE INFORMATION

http://www.dpi.nsw.gov.au/archive/agriculture-today-stories/ag-today-archives/september-2011/broadleaf-weed-trial-in-faba-beans

MORE INFORMATION

Faba bean foray into the north takes hold

12 GRDC (2010) Faba beans for the central-west and north-west plains regions of NSW. GRDC Update Papers 6 September 2010, http://grdc.com.au/Research-and-Development/GRDC-Update-Papers/2010/09/FABA-BEANS-FOR-THE-CENTRALWEST-AND-NORTHWEST-PLAINS-REGIONS-OF-NSW

Seeding rates can have a significant effect on crop yields (Figure 21). Be aware of the very large differences in seed size between varieties and the impact that variable seasons can have on grain size of even the same variety.

When determining a seeding rate, consider plant populations and not just kg seed per ha. In other words, the kg rate should be adjusted to achieve a target population of plants based on seed size and germination percentage.

Calculating seeding rates

Seeding rate for the target plant density can be calculated using germination percentage, 100-seed weight and establishment percentage:

$$\text{Seeding rate (kg/ha)} = \frac{(\text{100 seed weight (g)} \times \text{target plant population per m}^2 \times 1000)}{(\text{germination\%} \times \text{estimated establishment\%})}$$

Example:
100-seed weight = 60 g
Target plant density = 25 plants/m^2 (i.e. 250,000 plants/ha)
Germination % = 90
Estimated establishment % = 95% (90–95% is a reasonable estimate, unless sowing into adverse conditions)

Seeding rate (kg/ha) = (60 × 25 × 1000) ÷ (90 × 95) = 175 kg/ha

To determine your seed weight, weigh 100 seeds (g). If you have seeds per kg from a laboratory test, this can be easily converted to 100-seed weight, as follows:

100-seed weight = (1000 ÷ no. of seeds per kg) × 100

NOTE: Optimum plant populations vary with the location grown, the variety sown and the pulse crop being sown.

MORE INFORMATION

http://www.dpi.nsw.gov.au/agriculture/broadacre/guides/winter-crop-variety-sowing-guide

Table 6: *Seeding rate (kg/ha) required for 20 and 30 plants per m^2 for a range of faba bean varieties and sizes at 100% germination and 90% establishment.*

Seeding rates	Average 100 seed weight (g)	Seed rate (kg/ha) 20 pl/m^2	Seed rate (kg/ha) 30 pl/m^2
Establishment %		90	90
Doza⦸	50 (40–60)	111	166
Fiesta VF, Farah⦸, Cairo⦸, Nura⦸	60 (50–75)	133	200
PBA Warda⦸	64 (58–69)	142	212

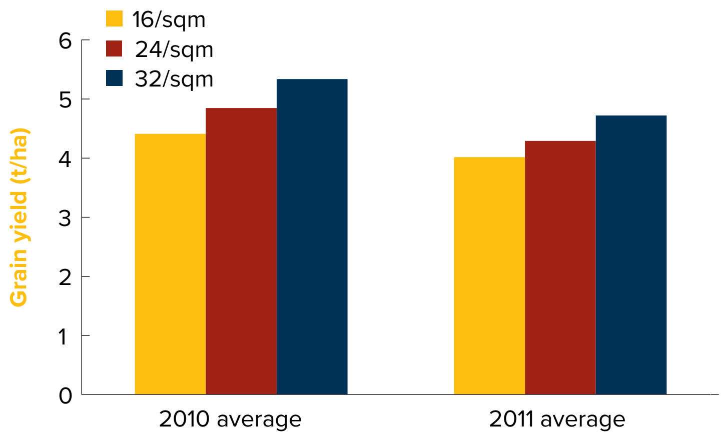

Figure 21: *Effect of plant density on average grain yield (t/ha) across four faba bean genotypes and two seeding dates at Bool Lagoon (South Australia) in 2010 and 2011; l.s.d. (P = 0.05) = 0.20 t.*

Source: M. Lines, Southern Pulse Agronomy Project

MORE INFORMATION

Northern Winter Pulse Agronomy (Walgett 2015): https://grdc.com.au/Research-and-Development/GRDC-Update-Papers/2016/02/Northern-Winter-Pulse-Agronomy-Walgett-2015

GRDC Update Paper: Faba bean density experiments 2015 (Northern Winter Pulse Agronomy)

MORE INFORMATION

GRDC Update Paper: Effect of seed size at sowing on grain yield of PBA Nasma⒟ faba bean

Faba bean – variety x plant density experiments

Faba bean, variety x density, experiments were conducted at three locations across northern NSW in 2015. Three varieties were sown; Doza⒟, PBA Warda⒟ and the new line PBA Nasma⒟. Four target plant densities were examined; 10, 20, 30 and 40 plants/m^2. All five trials were grown under dryland cropping conditions.

The three lines selected represent the two preferred commercial lines (Doza⒟ and PBA Warda⒟) and the new large seeded line PBA Nasma⒟. The difference in seed size for these commercial lines is shown in Figure 22 where PBA Nasma⒟, on average, has seed that is 40% larger than Doza⒟.

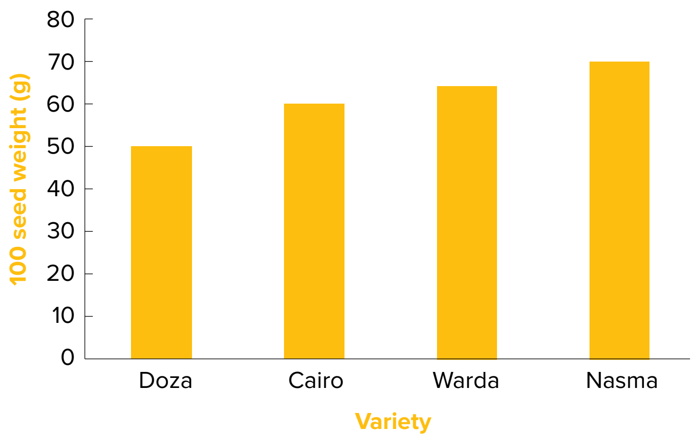

Figure 22: *Average 100 seed weight (g) for selected faba bean varieties. Varieties Doza⒟, Cairo⒟, Warda⒟ and Nasma⒟ shown in the graph above are protected under the Plant Breeders Rights Act 1994.*

Source: GRDC 2016

For grain yield, there were no significant interactions between variety and plant density, only main effects (see Table 7). PBA Warda⒟ and PBA Nasma⒟ out yielded

Doza⍱ at Coonamble, with no significant difference in varieties at Bullarah or Cryon (Table 7). Grain yield had a significant response to plant density at Cryon, plateauing at 20 plants/m^2.

Table 7: *Faba bean grain yield (kg/ha) for the main effects, variety and plant density at three locations in 2015.*

	Grain yield (kg/ha)		
Variety	**Bullarah**	**Coonamble**	**Cryon**
Doza⍱	1602 a	2900 b	1547 a
Warda⍱	1687 a	3280 a	1700 a
Nasma⍱	1685 a	3452 a	1686 a
	Grain yield (kg/ha)		
Plant density (plants/m^2)	**Bullarah**	**Coonamble**	**Cryon**
10	1498 a	3376 a	1373 b
20	1670 a	3411 a	1772 a
30	1768 a	3246 a	1673 a
40	1666 a	3270 a	1745 a

Values with the same letter are not significantly different P=0.05

Source: GRDC 2016

Limited data from the first year of trial results in 2015 suggests that for northern and western sites 20 plants/m^2 is a preferred target plant density for faba beans.

At present, there is no evidence to suggest that seed size at sowing has an impact on grain yield in cultivar PBA Nasma⍱. [13]

3.4.1 Row spacing

There is a trend towards wider row spacing with pulses, especially faba beans. Wider row and 'skip' row pulses (30–54 cm) must be part of an overall system. Stubble retention, preferably standing stubble, is considered essential with wide rows, where retaining soil moisture and ensuring adequate weed control is required. Use of wider row spacing is part of an overall system of production and it should not be considered in isolation. Yield comparisons in research trials can vary depending on the system and location, and there is no one solution that fits all situations.

Reasons for choosing wider rows with pulses vary with location and operator, but key drivers are the combination of:

- yield and yield consistency
- better stubble clearance and other sowing practicalities
- improved Water Use Efficiency (drought tolerance)
- minimise disease risk and easier management
- desire to sow pulses early
- weed control through minimised soil disturbance
- herbicide application options between the rows

If row spacing is doubled, the seeding rate per row must be doubled if the same plant density is to be maintained. This is significant for seeders with one seed meter per row, but relatively unimportant in air seeders where one meter supplies all.

MORE INFORMATION

GRDC Update Paper: Impact of row spacing on chickpea fababean and mungbean

MORE INFORMATION

Southern Pulse Bulletin – Wider Row Pulses and Stubble Systems

MORE INFORMATION

Australian Pulse Bulletin: Wide row pulses and stubble retention

13 A Verrell, L Jenkins (2016) Effect of seed size at sowing on grain yield of PBA Nasma⍱ faba bean. GRDC Update Papers, https://grdc.com.au/Research-and-Development/GRDC-Update-Papers/2016/02/Effect-of-seed-size-at-sowing-on-grain-yield-of-PBA-Nasma-faba-bean

MORE INFORMATION

GRDC Update Paper: Impact of row spacing on chickpea and faba bean

MORE INFORMATION

GRDC Update Paper: Chickpea and faba bean agronomy ideal row spacing and populations

3.4.2 Row spacing trial results

Northern region data are currently being generated however trials on the Darling Downs showed narrow row spacing (25–50 cm) consistently yielded higher than wider row spacings (75 cm and above) for faba beans. [14]

This effect was seen across 2 years and differing seasons and environments. Row spacing has a larger effect on yield than plant population.

In 2006 at Roseworthy, South Australia, a dry-season faba bean sown into standing cereal stubble showed an increase in yield relative to the conventional 18-cm sowing arrangement. By contrast, there was a small yield penalty growing cereals on wide rows. These results provide some confidence that wide-row cropping could be used for the management of difficult-to-control weeds with inter-row herbicide application without compromising crop yield and profitability.

There were differences between crop species in their yield response to the different row spacing treatments (Figure 23). Grain yield of faba bean increased significantly at 36-cm (24%) and 54-cm (20%) spacing relative to 18-cm row spacing, which yielded 0.79 t/ha. The penalty in grain yield for cereals in 36-cm rows was only 2% for barley and 5% for wheat. However, this yield penalty increased to >20% when row spacing increased to 54 cm in cereals.

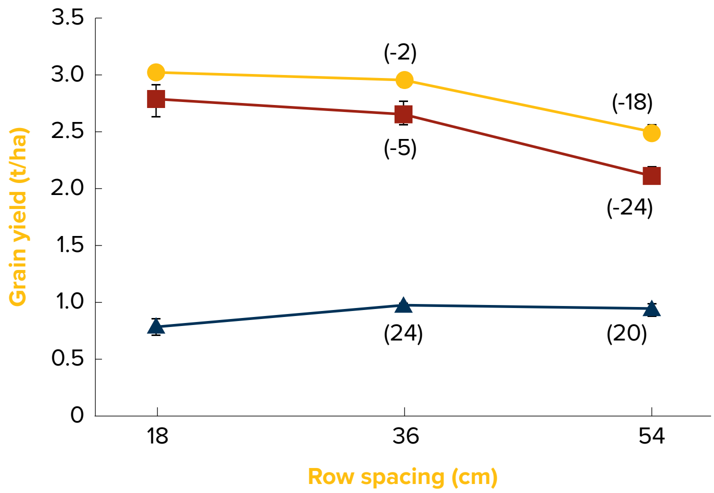

Figure 23: *Yield response of Pugsley wheat, Sloop SA barley and Fiesta faba bean grown on row spacings of 18, 36 and 54 cm sown into standing cereal stubble at Roseworthy (South Australia) in 2006. Values in parentheses are relative grain yield (%) compared with 18-cm spacing.*

Source: Kleeman and Gill 2008

Water use by wheat and barley over the growing season was unaffected by row spacing; however, both were more effective than faba bean at extracting soil water (Figure 24). Faba bean used 50 mm less water than cereals, which was related to its inability to extract water below 85 cm depth and its failure to dry soil below 20% volumetric water content. This additional soil water could be of benefit to the following wheat crop in dry seasons if it could be stored in the profile until the next growing season.

14 R Raymond, R Rachaputi (2016) Faba bean agronomy: Ideal row spacing and time of sowing. GRDC Update Papers, https://grdc.com.au/Research-and-Development/GRDC-Update-Papers/2016/03/Faba-bean-agronomy-Ideal-row-spacing-and-time-of-sowing.

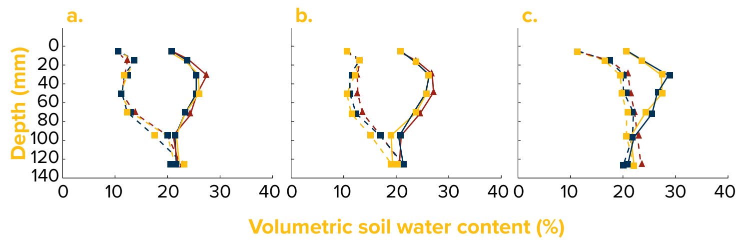

Figure 24: *Change in volumetric soil water with depth from May (—) to October (– – –) for (a) Pugsley wheat, (b) Sloop SA barley and (c) Fiesta faba bean at three different row spacings (18, 36 and 54 cm) at Roseworthy in 2006.*

Source: Kleeman and Gill 2008

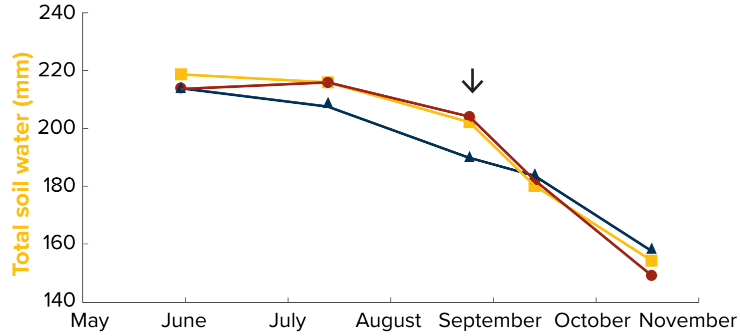

Figure 25: *Change in total soil water for Fiesta faba bean at three different row spacings (18, 36 and 54 cm) during the 2006 growing season. Arrow indicates start of flowering. (Source Kleeman and Gill 2008)*

Faba beans grown in wider rows used 10–15 mm less water between the rows during the early vegetative phase than the crop grown at 18-cm row spacing (Figure 25), deferring some of the water use until its reproductive phase. This is in contrast to wheat and barley. Change in water-use pattern may have contributed to the increased pod density and subsequent grain yield responses observed in faba bean in wider rows (Figures 26, 27, 28).

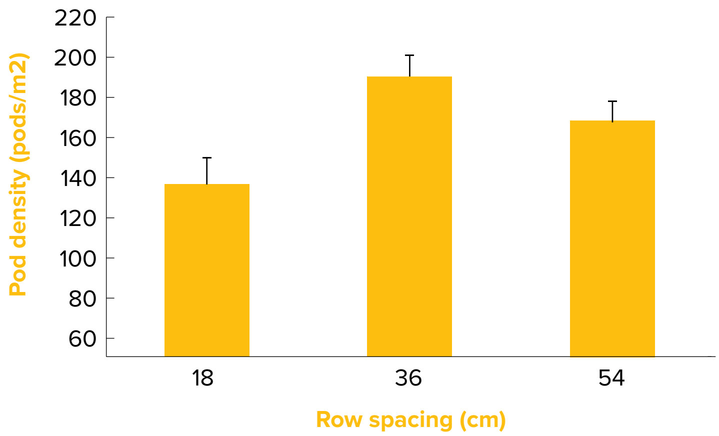

Figure 26: *Effect of row spacing on pod density (pods/m^2) of Fiesta faba bean at Roseworthy in 2006.*

Source: Kleeman and Gill 2008

Figure 27: *Wide ('skip') rows are starting to be used in faba beans.*

Photo: W. Hawthorne, Pulse Australia

Figure 28: *Wide ('skip') rows in faba beans allow easier sowing into heavy cereal stubbles, assist in weed control, promote better pod set and delay canopy closure to assist in disease control and fungicide application.*

Photo: W. Hawthorne, Pulse Australia

MORE INFORMATION

BJ Scott, P Martin, GP Riethmuller (2013) Row spacing of winter crops in broad-scale agriculture in southern Australia. Graham Centre Monograph No. 3, https://www.csu.edu.au/research/grahamcentre/publications/monograph/row-spacing-monograph

S Kleeman, G Gill (2008) Row spacing, water use, and yield of wheat (*Triticum aestivum*), barley (*Hordeum vulgare*) and faba bean (*Vicia faba*). Australian Agronomy Conference, http://www.regional.org.au/au/asa/2008/poster/agronomy-landscape/5752_kleemannsgl.htm

3.4.3 Sowing depth

Faba beans have a hypogeal pattern of emergence (they leave their cotyledons below the soil surface) and therefore are able to emerge from deeper in the soil than plants with an epigeal emergence pattern (e.g. lupins) (Figure 29). Faba beans are also large-seeded and produce a relatively strong seedling, which further enable seedlings to emerge from deeper in the soil (Table 8).

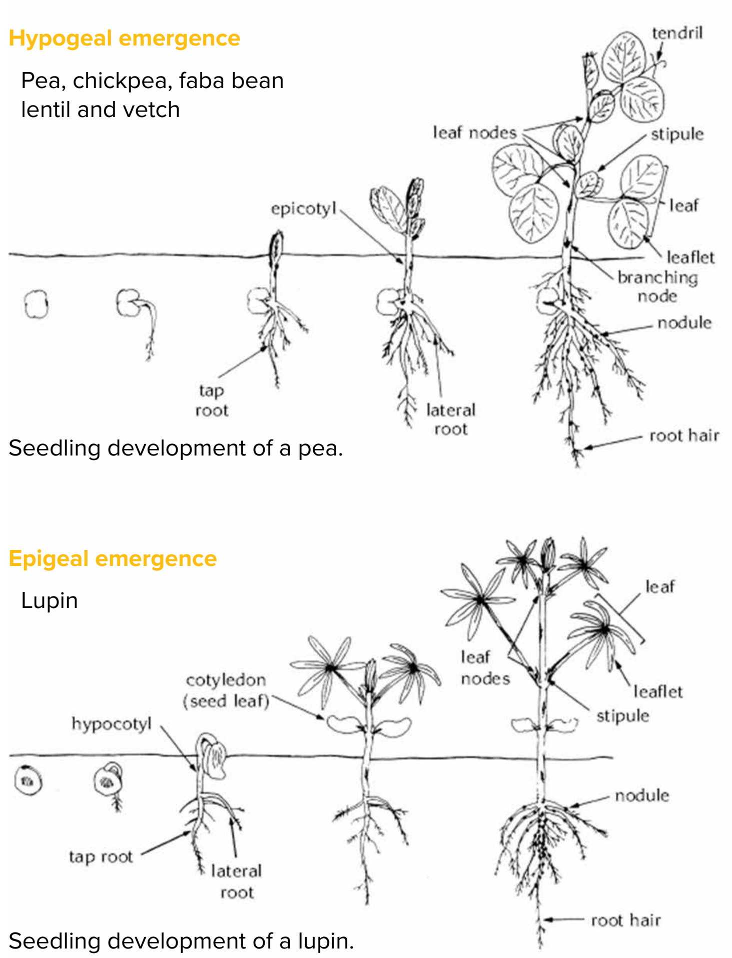

Figure 29: *Epigeal versus hypogeal emergence patterns.*

Source: GRDC Grain Legume Handbook—Seeding, http://www.grdc.com.au/uploads/documents/3%20Seeding.pdf

Sowing depth of pulse seed needs to be varied to take into account crop type, soil type, herbicide used, diseases likely to be present, and soil temperature at sowing time, i.e. how long the crop will take to emerge. Lighter textured soils can be more prone to herbicide leaching in wet winters; hence, deeper sowing in sandier soils is often recommended if applying a pre-emergent herbicide. The deepest sowings tend to be in sandy soil with warm soil temperatures and if dry-sowing. The shallowest sowings will be in heavy soils with cold soil temperatures or late sowing; however, there are exceptions.

Table 8: *Sowing depth ranges (cm) for pulses.*

Crop	General recommended sowing depth range
Chickpeas	3–5 cm
Faba beans	5–8 cm
Lentils	2–6 cm
Lupins	1–3 cm
Peas	3–5 cm
Vetch	3–5 cm

Note that if applying a pre-emergent herbicide the greater depth should be used

Figure 30: *Faba beans are much more tolerant of deeper sowing than are lupins, because of their hypogeal emergence. The lupins shown were sown too deep (greater than 5 cm). Note the stunted first true leaf and lack of early vigour.*

Photo: Grain Legume Handbook

There is a maximum depth at which the pulse crop can be safely sown to avoid poor establishment and lower seedling vigour (Figure 30). Sowing seed outside the suggested range (see Table 8) will delay emergence and slow seedling growth. Actual sowing depth should be shallower on clay soils and hard-setting soils and deeper on sands. Generally, lupins are least tolerant of deep sowing; lentils, field pea, chickpea and vetch are intermediate; and beans are the most tolerant.

Burying seed too deep to chase seedbed moisture for early sowing is not recommended, particularly because weed control, establishment and possibly nodulation is more likely to be poor. Deeper sowing may be needed in some districts to reduce the damage caused by birds and mice.

In the northern region, faba beans are often planted deep (up to 15–18 cm into the soil) early in the planting window to ensure they go into good soil moisture to get an even establishment. Following planting, the paddock often has Kelly discs (or some leveling implement) put across it to help level the soil surface, which seals the planting slots to stop the clay soils drying out down to the seed and prepares the paddock for harvest, because the crop is often harvested close to the ground.

In northern NSW, planting is typically 7.5–15 cm, and in recently, growers have planted at 20 cm.

Sowing depth and herbicide interaction

Pulses can be more tolerant of some herbicides if shallow sowing is avoided. For example, faba beans are less affected by simazine applied either pre-sowing or post-sowing pre-emergent if they are sown deeper.

The actual depth of sowing will depend on the soil type. Herbicides leach deeper in sands than in clay soils. Some herbicides leach more than others, and heavy rain onto a dry soil surface, particularly on a sand, is worst.

Leaving the soil ridged increases the risk of post-sowing, pre-emergent herbicide washing into the furrow, especially on sands. As pre-sowing applications of herbicide may be less effective in the furrows, a split herbicide application is suggested to ensure effective weed control while avoiding the risk of herbicide damage.

Deep sowing

Deep sowing of faba beans and chickpeas is used in northern Australia to sow into dry surface but wet subsurface moisture. Faba beans can be sown at depth to 15 cm if needed. Deep-sowing or moisture-seeking techniques can be used to ensure timely planting when the soil surface is still dry. The large seed size makes faba beans very suitable for this type of planting system. Deep sowing also allows more time in which to apply a knockdown herbicide prior to crop emergence.

MORE INFORMATION

Pulse Australia Northern Pulse Bulletin 'A growers guide to deep planting chickpea': http://www.pulseaus.com.au/growing-pulses/bmp/chickpea/deep-seeding

3.5 Irrigation

Irrigating faba beans with either full or supplementary irrigation is practiced in Australia where it is economical when grown in rotation with other winter and summer crops. Management requirements for irrigated faba beans are the same as for dryland crops. Faba beans do have a greater sensitivity to foliar diseases under irrigation. Their greater sensitivity to waterlogging under irrigation needs to be considered. Even waterlogging for a short time can result in severe losses, particularly if the crop is stressed (from herbicides, disease, moisture, etc.).

MORE INFORMATION

GRDC Update Paper: Crop sequencing for irrigated double cropping within the Murrumbidgee Valley region

3.5.1 Principles

There are a number of factors to consider when choosing irrigated faba bean production as an option:

- Avoid heavy clay or dense soil types (bulk density >1.5) or those that do not drain freely and are subject to waterlogging.
- Select fields with good irrigation layout such as beds or hills and relatively good grades.
- Border-check layouts steeper than 1 : 800 grade are suitable provided there are short runs and free-draining soils that can be irrigated quickly and do not remain saturated.
- Irrigation can be used in activating and incorporating a number of pre-emergent herbicides.

Irrigation management

- Pre-irrigate to fill the moisture profile prior to planting all faba bean crops unless this has already been achieved by rainfall.
- Watering up can be achieved on beds, rows and under sprinkler irrigation, but is not recommended for border-check layout unless moisture was insufficient to achieve a uniform germination.
- As a rule, in crop irrigation should start early when there is a deficit of 30–40 mm and ~60–70% of field capacity. Moisture scheduling is more important than growth stage.

- Irrigations should also commence prior to flowering to prevent moisture stress and high temperatures affecting yield, quality and grain size.
- For furrow irrigation, water every second row to avoid waterlogging. Doubling up siphons can increase water flow and reduce irrigation time.
- Aim to have watering completed in less than 8 h, and have good tail-water drainage to avoid waterlogging.
- Avoid irrigation if there is likelihood of rain soon after.
- Faba beans are more sensitive to waterlogging during their reproductive stage (flowering, podding). Spring irrigations usually do not pose a risk to crops on beds or rows, however crops on border-check layout with heavy soil types or long runs may be at risk with this practice. If in doubt, do not water.
- Sprinkler irrigation is ideally suited to growing pulses as there is very little risk of waterlogging even during flowering and pod-fill; however, there may be a need for greater disease control against chocolate spot, rust or Ascochyta blight because of more frequent wet conditions. [15]

3.5.2 '*Faba Check*' findings

From 2000 to 2004, NSW Department of Agriculture (now Department of Primary Industries) conducted '*Faba Check*' monitoring of irrigated bean crops in southern NSW. *Faba Check* in southern NSW showed growers and their advisors the way forward in terms of crop management and identified the main factors for success of local irrigated crops. Main lessons learnt were:

Paddocks and layout

- Check soil pH, because faba beans do not like acid soils with pH <5.2 (in $CaCl_2$).
- Do not grow on freshly land-formed paddocks, particularly if there are big cut-and-fill areas.
- Only grow on your best soil types.
- Be aware of potential damage from herbicide residues, particularly from boom spray contamination.
- Irrigation layout is one of the most important factors for the final spring irrigation. Faba beans performed best on bed layouts, with waterlogging in spring a potentially serious issue on contour layouts (Table 8).
- Good weed control in previous crops is highly beneficial.

Sowing

- Calibrate seeders after inoculating to get the correct plant population.
- Check capabilities of seeders; seed size can be an issue for some, often causing blockages or resulting in low plant populations per m^2. It is not advisable to grade out the large seed before sowing.
- Sowing with a spreader (broadcasting) and then harrowing gives variable results leading to poor establishment. Some seed is buried too deep or left sitting on the surface.
- Do not sow too early; crops sown before May can suffer from lodging. Sowing early to mid-May helps to avoid the problem and maximises yield potential.

Crop management

- Growers need make every effort to achieve optimum plant populations.
- Pay close attention to plant nutrition.
- Lodging can prove an issue at harvest and can be worse on beds because plants are harder to pick up from furrows. It is then important to be harvesting one way.
- Thrips can be a problem at flowering, but the benefits of treating them are unclear and control may not be worth it.

15 Northern Faba Bean—Best Management Practices Training Course. Pulse Australia 2014.

- Budworm (*Helicoverpa*) control is required.

Disease control

- Keep up to date with disease prevention with strategic use of fungicides.
- Even in a dry year, 4 or 5 fungicide sprays may still be required.
- It is best that build-up of disease during winter is effectively prevented and that protection against disease in the spring is provided before each watering when the canopy humidity and disease risk is high.
- Strategic fungicide applications adopted by district growers are outlined below:
  - An application 4–6 weeks after the crop has emerged, targeting mainly *Ascochyta* and more recently *Cercospora*.
  - Number of later applications will depend on the level of disease in the crop and seasonal conditions. Applications throughout the most active growth period must target chocolate spot, but fungicide choice or mix need match the diseases likely present.
  - Final application of fungicide targets rust and *Ascochyta*.

Irrigation

- Timely spring irrigations are important.
- Be able to minimise moisture stress with optimum irrigation layouts.
- Hot conditions experienced during September–October can impact, especially in dry seasons. Crops on beds may require 2 or 3 spring irrigations, after being watered up.
- The move towards more suitable layouts for faba beans has been beneficial, with a higher proportion of crops now grown on beds rather than flat.
- *Faba Check* results in 2003 showed that 82% of beans were on beds and 18% on border-check, with only a small percentage on contours.
- Use of more suitable layouts has given growers flexibility in spring and removes the waterlogging risk, particularly after the last spring irrigation.
- Table 8 shows the break-up of irrigation layout and yields in *Faba Check* from 2000 to 2003.
- *Faba Check* data showed an average Water Use Efficiency of 12.5 kg grain/mm water for faba beans grown on beds, compared to an average of 9.98 kg grain/mm water for those grown on border-check.

Rotation benefits

- Growers need be aware of the benefits that faba beans provide to following wheat crops.

Additional keys to successful irrigated faba bean production

- Faba beans needs to be put in context with other crops; they require a higher level of management input than other winter crops.
- Benchmarking crops against others in the district helped growers to see where improvements in their management systems could be made in order to achieve higher yields and better quality.

Table 9: *Irrigation layout and yield from 'Faba Check' 2000–03.*

Year	Irrigation layout yield (t/ha)			
	Beds	Border-check	Contour	Other
2000	4.57	3.87	3.29	-
2001	4.37	4.04	3.72	3.7
2002	N/A	N/A	N/A	N/A
2003	5.16	3.77	–	–
Average	4.7	3.89	3.51	

N/A, no 'Faba Check' data for 2002; Other, sprinkler irrigation

Source: Faba Check Reports 2000, 2001 and 2003.

Table 9 shows that faba beans grown on beds consistently outperformed faba beans grown on any other layout. *Faba Check* results also showed that the Water Use Efficiency of faba beans grown on beds is higher than of faba beans grown on border check.

The same growers seem to be consistently achieving high yields of 5–6 t/ha for faba beans. Keys to success have been their regular adoption of best management practices in paddock selection, layout selection, good weed, insect and disease control, and spring irrigation requirements. [16]

3.6 Pulses and herbicide damage

Pulses can be affected by application of some post-emergent broadleaf and grass herbicides applied at label rates. Crop effects can be a reduction in plant biomass or N_2 fixation and lower yields. Lower rainfall regions with >250 mm annual rainfall and with sandy calcareous soils are at most risk of experiencing herbicide damage. For example, a single application of some Group A grass herbicides to peas grown at Waikerie (South Australian Mallee) reduced nodulation by 50%, which resulted in a reduction in N_2 fixation of ~50% and no N-benefit to the system for the following crop. A significant reduction in N_2 fixation can mean the difference between a positive and negative economic benefit from a pulse crop, particularly in low-rainfall situations.

The severity of herbicide effects on pulses varies with seasonal conditions and location. When considering pulses as an option in low-rainfall regions, growers should identify the prime reason for choosing a pulse in rotation. If weed and disease control are a priority, a potential decrease in N_2 fixation may be less of a concern. Growers should adopt an integrated weed management (IWM) approach to reduce weed populations on-farm and spray strategically to reduce the number of herbicide applications required in a pulse crop.

Pulses can be damaged by soil-active herbicides, either from leaching into the root-zone or from herbicide residues.

3.7 Sowing and handling hints

The large size, awkward shape and fragile nature of many pulses means that they need careful handling to prevent seed damage. The bigger the grain, the easier it is to damage. Seed grain, in particular, should be handled carefully to ensure good germination and vigour.

Plan ahead so that handling can be kept to a minimum to reduce damage between harvest and seeding.

16 Northern Faba Bean—Best Management Practices Training Course. Pulse Australia 2014.

Handling bulk seed

Augers with screen flighting can damage pulses, especially larger seeded types. This damage can be partly overcome by slowing down the auger. Augers with large flight clearances will cause less damage to large grains.

Tubulators or belt elevators are excellent for handling pulses, as little or no damage occurs. Cup elevators are less expensive than tubulators and cause less damage than augers. They have the advantage of being able to work at a steeper angle than tubulators. However, cup elevators generally have lower capacities.

Auguring from the header should be treated with as much care as later handling and storage, because it has the same potential for grain damage.

Combine loaders that throw or sling, rather than carry the grain, can cause severe damage to seed and germination.

If inoculating faba bean seed during handling, there is less mixing and poorer seed coverage when using tabulators and elevators than with augers.

3.8 Seeding equipment

Success with pulses may depend on the type of sowing equipment used. The large size of pulses can make sowing with conventional seeders very frustrating.

If the seeder is not suitable for sowing a particular pulse (usually larger seeded types) in standard form there are several options available.

The machine may be adapted by minor modifications such as:

- modifying the metering mechanism with manufacturer-supplied optional parts
- modifying seed tubes to reduce blockages, particularly on older machines
- modifying or replacing dividing heads on airseeders (see Figure 31).

Most pulse seeding problems are related to seed metering and the transfer from seed meter to soil. These problems are caused by the large size of some pulses and the high seeding rates generally used.

Faba beans can be sown with a standard airseeder or conventional combine, but care is needed, because seeds tend to bridge over the outlets, causing very uneven sowing. This difficulty can be eliminated by filling the box to only one-third or one-half capacity or by fitting an agitator.

Faba beans can also cause problems in some combines, but airseeders with adequate metering rollers can sow them successfully if the airflow is adequate.

Airseeders

Air seeders that use peg-roller metering systems (Napier, Shearer) will handle grain up to the size of smaller faba beans without problems, because of the banked metering arrangement. The optional rubber star roller will be necessary for larger seeds.

Airseeders using metering belt systems (Fusion, Alfarm, Chamberlain–John Deere, New Holland) can meter large seed at high rates with few problems.

Airseeders with large or very coarse, single-fluted rollers cannot meter faba beans >18 mm without modifications to the metering roller. Consult a machinery dealer about possible modifications.

On some airseeders, the dividing heads may have to be modified because there is too little room in the secondary distributor heads to allow seeds to flow smoothly. Figure 30 shows a standard secondary distributor head (on the left) and a conversion to suit Connor–Shea airseeders. The conversion head increased the bore from 23 to 41 mm. Four larger hoses replace the original eight, and row spacings are increased from 150 to 300 mm. This conversion allows large seeds to be sown easily.

Significant levels of seed damage can be caused in air-seeders by excessive air pressure, so take care to use only enough air to ensure reliable operation.

Figure 31: *Conversion heads, such as this one for a Connor–Shea air seeder, allow large seeds such as faba beans and Kabuli chickpeas to be sown with ease.*

Source: Grain Legume Handbook

Combine seeders

Combines with fluted roller feeds have few problems feeding seed of <15 mm down to the metering chamber. Combines with peg-roller and seed-wheel feeds will sow grains up to the size of faba beans without problems, providing adequate clearances are used around the rollers. Smaller faba beans such as Fiord can be metered with the more aggressive seed wheel system, but peg rollers are best replaced with 'rubber stars' for larger faba beans.

Combines with internal force-feed seed meters perform well on small seeds but cannot sow seed >9 mm because of bridging at the throat leading to the seed meter. The restricted internal clearance in this type of design can damage larger seeds.

3.8.1 Seeder and tine comparisons

The key functional or mechanical issues that arise with establishing all crops, especially pulses, are to ensure that the seeding equipment has, or enables:

- Adequate seeding mechanism to handle the pulse seed without damaging it or bridging or blocking, especially when larger seeded types are being sown.
- Adequate sizes of seed and fertiliser tubes and boots to prevent seed blockages and bridging during sowing.
- Ability to sow into stubbles and residues without blockages.
- Sufficient down-pressure to penetrate the soil, sow at the desirable depth, and place all seeds at a uniform depth.
- Ability to cover the seeds so that good seed-to-soil contact or moisture vapour ensures rapid germination.
- Compaction of the soil as required, by press-wheels (Figure 32) or closers. Otherwise, a prickle chain, Kelly discs or roller are required afterwards for many pulses.

- Ability to disturb the soil to the degree required. This means no disturbance in no-till with disc sowing. It may also mean having sufficient soil throw to incorporate herbicides such as trifluralin. This can be achieved by using either aggressive discs or narrow point set-ups in no-till, or full disturbance in more conventional or direct-drill systems.

Inability to achieve adequate plant establishment is one of the bigger problems faced by pulse growers, and it leads to a multitude of other problems. Many different seeding mechanisms or openers are available to pulse growers. Narrow points are widely used in minimum or no-tillage, but there are many different points that can be used. Likewise, with disc seeders (Figure 33), many different types are now available, and they differ greatly in their soil disturbance and soil throw, as well as their ability to handle trash and sticky conditions.

A comparison of the critical functions for seed drills and no-till is shown in Table 10. For interpretation of the functions listed in Table 10 it should be noted that:

- With tines, the slot created is different depending on the type of tine used. Some create a vertical slot, others a 'V', whereas the inverted 'T' (or 'baker boot') (Figure 34) leaves a slot with a narrow entrance and wider trench underneath. These tines perform differently in some functions.
- Residues need to be handled in all conditions, not just when dry.
- 'Hairpins' (stubble is pressed into the slot by the disc ahead of the seed) need to be avoided by placing seeds away from stubble.
- Vertical slots tend not to self-close, especially in wet, clay soils.
- Ability for openers to follow ground surface variation is critical for uniform depth of sowing (Figure 35).
- Springs cannot apply consistent down-force on openers throughout a range of soil conditions.
- Banding of fertiliser away from the seed is important for crop establishment, particularly when high rates or high-analysis products are applied and the seed is in a narrow opening slot.
- Tines handle stones, but bring them up, requiring rolling to press them back again.
- The seeding mechanism of the seeder must be able to handle pulses, which are larger seeded than cereals and oilseeds. Hoses, distributor heads and boots must be able to handle pulses without blockages or bridging. This is especially true for larger seeded types such as faba beans or Kabuli chickpeas.
- Table 10 does not list as a function deep working to assist in rhizoctonia control. This was a weakness of early disc drills compared with narrow points with deep openers. Many newer discs are addressing this issue, including using opening coulters and rippled discs. [17]

17 Southern/Western Faba and Broad Bean—Best Management Practices Training Course—Module 4: Agronomy 2013. GRDC.

Figure 32: *One of several seeding mechanisms for uniform sowing depth using the press-wheel for depth control.*

Photo: W. Hawthorne, Pulse Australia

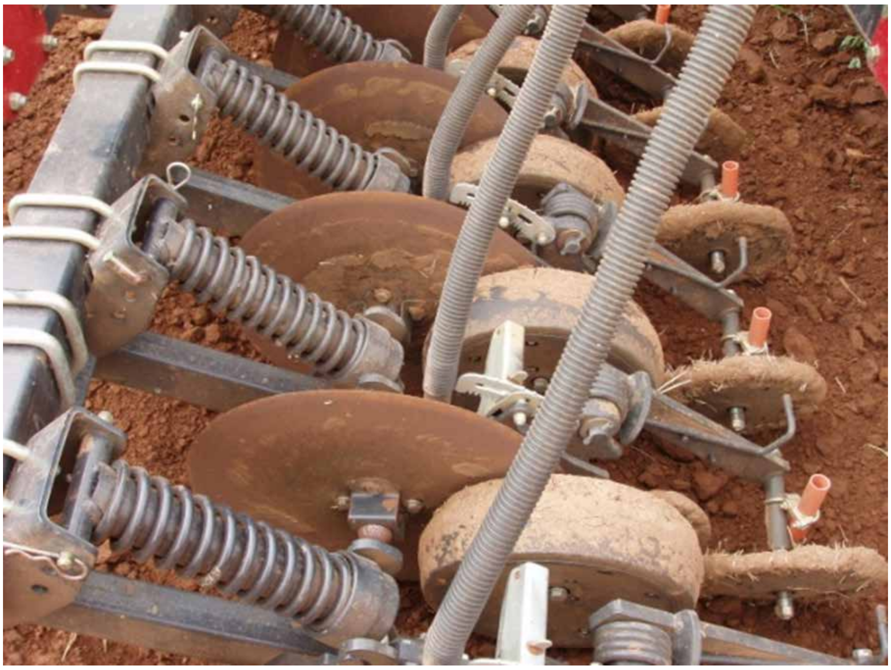

Figure 33: *A Case IH SDX-40 single-disc drill.*

Photo: W. Hawthorne, Pulse Australia

Figure 34: *A primary precision seeder fitted with hydraulic breakout for consistent penetration. Also fitted are narrow points that form an 'inverted-T' slot and are capable of deep or side placement of fertiliser.*

Photo: W. Hawthorne, Pulse Australia

Figure 35: *The DBS system parallelogram for uniform seeding depth and deep placement of seed or fertiliser.*

Photo: W. Hawthorne, Pulse Australia

Table 10: *Comparison scores of no-till openers by function (after Baker 2010).*

Function	Narrow point	Wide point	Sweep	Double disc	Single disc	Slanted disc	Combined winged tine and disc
Mechanically handle heavy residues without blockage	2	1	1	4	4	4	5
Leave 70%+ of original residue in place after drill has passed	3	2	2	5	4	4	5
Trap moisture vapour in the seeding slot in dry soils using residues as slot cover	3	2	3	1	2	4	5
Avoid placing seeds in 'hairpins'	5	5	5	1	2	2	5
Maximise in-slot aeration in wet soils[A]	3	4	3	1	3	3	5
Avoid in-slot soil compaction or smearing in wet soils[A]	1	1	3	1	5	5	5
Maximise soil–seed contact, even in greasy or 'plastic' conditions	4	3	4	3	3	4	5
Self-close the seeding slots	2	1	3	2	3	4	5
Mitigate slot shrinkage when soils dry out after sowing[A]	3	5	5	1	2	4	5
Individual openers faithfully follow ground-surface variations	2	1	2	2	4	2	5
Individual openers have a larger than normal range of vertical travel	2	1	1	2	2	1	5
Maintain consistent down-force on individual openers	3	1	1	2	3	3	5
Openers seed accurately at shallow depths[A]	2	1	1	2	2	1	5
Opener down-force auto-adjusts to changing soil hardness	1	1	1	1	1	1	5
Simultaneously band fertiliser with, but separate from, the seed	5	5	5	1	2	3	5
Ensure that fertiliser banding is effective with high-analysis fertilisers	5	5	51	1	1	2	5
Able to handle sticky soils[A]	5	5	4	1	3	3	2
Able to handle stony soils[A]	4	3	1	4	4	2	4
Avoid bringing stones to the surface[A]	1	1	1	5	5	3	5
Functionality unaffected by hillsides[A]	5	5	4	5	2	1	5
Minimal adjustments required when moving between soil conditions	3	3	3	4	1	1	5
Ability to maintain most critical functions at higher speeds of sowing	3	1	1	4	3	3	5
Wear components are self-adjusting	5	5	5	3	2	2	5
Design life of machine matches that of the tractors that pull it	4	4	4	2	2	2	5
Low wear rate of soil-engaging components	5	4	4	2	3	3	3
Wear components, including bearings, are cheap and easily replaced	5	5	4	2	2	2	4
Requires minimal draft from tractor	4	3	2	5	4	3	3
Proven, positive impact on crop yield	3	2	2	1	3	4	5
Total score (maximum = 140)	93	80	80	68	77	76	131
Rating score as % of maximum possible	66	57	57	49	55	54	94

Rating basis: 1 = poor, 5 = excellent. Combination is otherwise known as the Cross SlotTM or Bio Blade

Source: CJ Baker (2010). SANTFA 12th Annual Conference pp. 7–13.

A Functions that may be deleted in some circumstances, but all other functions are more universal.

NOTE that Table 10 is a broad GUIDE ONLY. Scores given in the table are subjective and may vary with individual openers, etc. You may use your own scores for each function and not count those that are not relevant in your situation. Neither pure disc nor pure tine openers rate highly over all functions in this scoring. Disc openers rated lowest (49–55%), and of the tines (57–66%), narrow points were the best. Best was the combination of winged tine and disc, known as the Bio Blade or Cross Slot™ (94%). It allegedly combines the best attributes of pure disc openers with t he best attributes of pure tine openers, and has some unique features. Its weaknesses included a lesser ability to handle 'sticky' soils, its horse power requirement, and its wear rate of soil-engaging components.

Plant growth and physiology

4.1 Introduction

Vicia faba, also known as the faba bean, broad bean, fava bean, horse bean, field bean, bell bean, Windsor or tic bean, is a species of bean (Fabaceae) native to North Africa and south-western Asia, and extensively cultivated elsewhere including Australia.

It is grown as a winter annual in warm temperate and subtropical areas. Hardier cultivars grown in the Mediterranean region can tolerate winter temperatures of –10°C without serious injury, whereas the hardiest European cultivars can tolerate up to –15°C (Robertson *et al.* 1996).

Although usually classified in the same genus *Vicia* as the vetches, some botanists treat it in a separate monotypic genus *Faba*.

In much of the English-speaking world, the name ‘broad bean’ is used for the large-seeded cultivars grown for human food, while ‘horse bean’ and ‘field bean’ refer to cultivars with smaller seeds used for either animal feed or human food. Their strong flavour is preferred in some human foods, such as falafel. The term ‘fava bean’ (from the Italian fava, meaning ‘broad bean’) is often used in English-speaking countries such as the USA, but the term ‘broad bean’ is the most common name in the UK.

There is some variation in the way that faba beans have been classified botanically. Based on seed size, two subspecies of *Vicia faba* have been recognised, *paucijuga* and *faba* (Muehlbauer and Tullu 1997). The latter (*faba)* has been subdivided into *Vicia faba* var. *minor* with small rounded seeds (1 cm long), *Vicia faba* var. *equina* with medium-sized seeds (1.5 cm) and *Vicia faba* var. *major* with large broad flat seeds (2.5 cm). Taxonomically, the crop belongs to Section *Faba* of the Genus *Vicia*.

Cubero (1973) had previously suggested four subspecies, namely: *Vicia faba* ssp. *minor, Vicia faba* ssp. *equina, Vicia faba* ssp. *major,* and *Vicia faba* ssp. *paucijuga*. According to Cubero (2011) now, the correct name of the family is Fabaceae*,* faba beans belonging to the subfamily Faboideae and tribe Fabeae*,* but paradoxically to the genus *Vicia*.

The scientific classification is: Kingdom Plantae*;* Division Magnoliophyta*;* Class Magnoliopsida*;* Order Fabales*;* Family Fabaceae*;* Tribe Vicieae*;* Genus *Vicia;* Species *Vicia faba.* [1]

4.2 Key to growth stages

The key is based on counting the number of nodes on the main stem.

Uniform growth stage descriptions were developed for the faba bean plant based on visually observable vegetative and reproductive events.

The vegetative stage is determined by counting the number of developed nodes on the main stem, above ground level. The last node counted must have its leaves unfolded (Figure 1).

1 Northern Faba Bean—Best Management Practices Training Course 2014. Pulse Australia.

The reproductive stages begin when the plant begins to flower at any node. The standard description of the development of a faba bean plant aids faba bean research planning and communication and assists extension recommendation of timing of cultural practices.

Germination is hypogeal, with the cotyledons remaining below the soil surface. This enables it to emerge from sowings as deep as 25 cm. In drier regions, faba beans are sown deep, because surface moisture is often inadequate to enable crop germination and establishment. The node at which the first leaflet arises from the main stem above the soil is counted as node one. A node is counted as developed when leaves are unfolded and flattened out. Scale leaves at the base of the plant and close to the ground are not counted as true nodes.

In faba beans, alternate primary branches ('tillers') usually originate from the base just above ground level (usually 1–5 primary branches on the main stem, depending on variety and growing conditions).

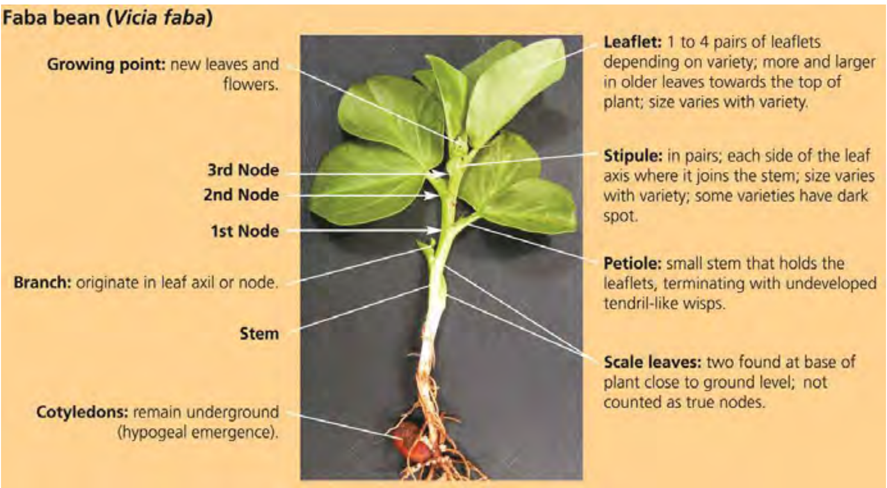

Figure 1: *Faba bean early growth stages.*

Source: Weeds in Winter Pulses (2004), CRC for Australian Weed Management

Nodes are counted from the point at which the first true leaves are attached to the stem.

Faba bean varieties generally exhibit either indeterminate or semi-determinate growth habits. The terminal bud of an indeterminate plant is always vegetative and keeps growing. Vegetative growth continues even as the plant switches to reproductive mode and flowering begins. For a semi-determinate growth habit, vegetative growth continues initially after the plant switches to reproductive mode and flowering begins, but can terminate before moisture becomes limiting. Australian faba bean varieties are semi-determinate (Figure 2); determinate lines have been bred (Figure 3).

Flower terminals develop from the auxiliary bud at the base of each node, with flowering commencing at approximately the 6th–10th node, depending on the variety, location and time of sowing. Faba bean flowers are white with some purple or black markings. Flowers are borne on a peduncle that arises from nodes. Flowers are both self-pollinated and cross-pollinated. [2]

The growth stages of faba beans are described in Figure 4 and Table 1.

2 Northern Faba Bean—Best Management Practices Training Course 2014. Pulse Australia.

Figure 2: *An Australian semi-determinate faba bean type that is typical of our current varieties.*

Photos: W. Hawthorne, Pulse Australia

Figure 3: *A breeding line that is determinate. No new growth appears above the pods.*

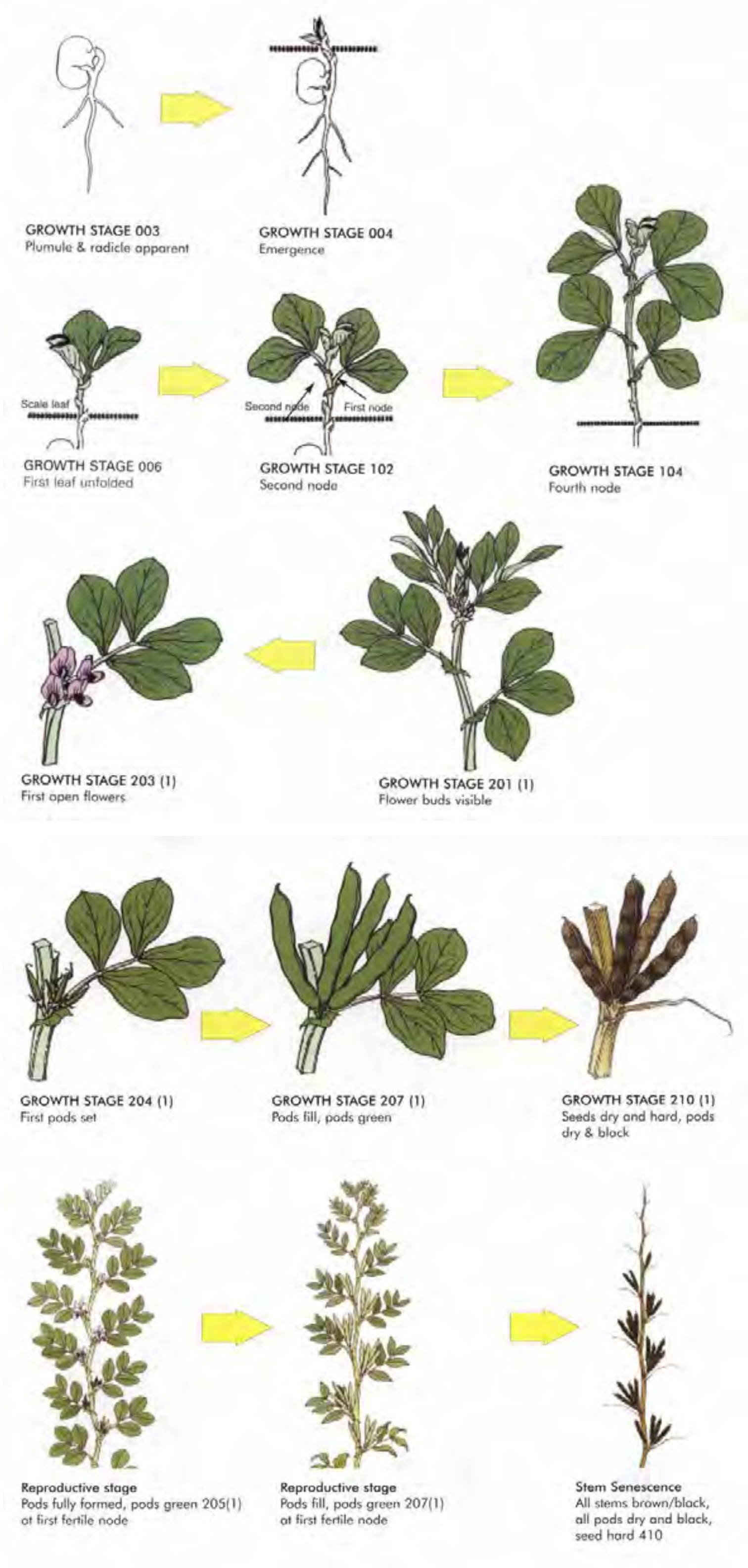

Figure 4: *Stages in the development of the faba bean (Vicia faba).*

Source: PGRO, UK

Table 1: *Growth stages of a faba bean plant.*

Development phase	Growth stage (GS)	Description
00 Germination and Emergence	GS 000 Dry seed GS 001 Imbibed seed GS 002 Radicle apparent GS 003 Plumule and radicle apparent GS 004 Emergence GS 005 First leaf unfolding GS 006 First leaf unfolded	
10 Vegetative	GS 101 First node GS 10(X) X node GS1(N) N, Last recorded node	First leaf fully unfolded with one pair leaflets X, leaf fully unfolded with more than one pair of leaflet N, any number of nodes on the main stem with fully unfolded leaves according to cultivar
20 Reproductive	GS 201 Flower buds visible GS 203 First open flower GS 204 Pod set GS 205 Green pods fully formed GS 207 Pod fill GS 209 GS 210 Dry seed	First buds visible and still green First open flowers on fist raceme First pods visible at first fertile node Small immature seeds within Seeds maximum size fill pod cavity Seeds rubbery, pods still pliable turning black Pods dry and black, seed dry and hard
30 Senescence	GS 301 10% pods dry and black GS 305 50% pods dry and black GS 308 80% pods dry and black, some upper pods green GS 309 90% pods dry and black, desiccation stage GS 310 All pods dry and black, seed hard	
40 Stem senescence	GS 401 10% stem brown/black or most stem green GS 405 50% stem brown/black or 50% stem green GS 410 All stems brown/black, all pods dry and black, seed hard	

Source: PGRO, UK.

For populations, vegetative stages can be averaged if desired. Reproductive stages should not be averaged.

A reproductive stage should remain unchanged until the date when 50% of the plants in the sample demonstrate the desired trait of the next reproductive (R) stage. The timing of a reproductive stage for a given plant is set by the first occurrence of the specific trait on the plant, without regard to position on the plant. [3]

4.3 Crop development

Crop duration is highly correlated with temperature such that crops will take different times from sowing to maturity under different temperature regimes. The concept of thermal time is the mechanism used to represent a crop's requirement to accumulate a minimum time for development through each essential growth stage (e.g. vegetative or reproductive growth). Consequently, crops growing under low air temperatures generally require more time to develop than crops growing at warmer temperatures.

Progress to flowering in faba beans is significantly influenced by temperature and can be described by the accumulation of thermal time ((max T° – min T°)/2, assuming a base temperature of 0°C) (Ellis *et al*. 1988; McDonald *et al.* 1994).

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Thermal time is also referred to as heat units, degree-days or growing degree-days. The base temperature for calculating thermal time for faba bean is 0°C. Once a certain number of degree-days are reached (accumulated), flowering commences, but the actual number of thermal units required varies with the location, photoperiod and variety. Similarly the end of flowering is controlled by thermal unit accumulation.

When sufficient heat units have been accumulated, the plant will enter its reproductive phase and start flowering. It is at this point that the stress tolerance of faba bean tolerance is significantly reduced. Low light or low average daily temperatures (probably <10°C) can cause flower abortion. Sub-zero temperatures can cause flower, pod and seed abortion, and severe frost can cause vegetative distortion total defoliation and death. Temperatures >30°C can also cause flower loss and water stress.

Faba beans are most sensitive to water logging at flowering, with a similar response to low light or low temperatures with flower and pod abortion and leaf senescence. Sowing date and canopy closure are other factors that can impact on pod-set and yield.

The phenology of most crops can be described using nine phases:

i. Sowing to germination.
ii. Germination to emergence.
iii. A period of vegetative growth after emergence, called the basic vegetative phase (BVP), during which the plant is unresponsive to photoperiod.
iv. A photoperiod-induced phase (PIP), which ends at floral initiation.
v. A flower development phase (FDP), which ends at 50% flowering.
vi. A lag phase prior to commencement of grain-filling. This period is relatively short in faba bean, but in chickpeas can be up to 2 months in some cases under cool temperature conditions (<15°C average daily temperature) that inhibit pod set and pod growth.
vii. A linear phase of grain-filling.
viii. A period between the end of grain-filling and physiological maturity.
ix. A harvest-ripe period prior to grain harvest.

These stages of development are generally modelled as functions of temperature (phases i–viii) and photoperiod (phase iv).

Faba beans are a medium duration crop, usually beginning flowering within 29 –96 days of sowing, depending on photoperiod and temperature. Faba beans are either day-neutral or long-day requiring, depending on variety. European germplasm is generally more photoperiod-sensitive. A day length of >12 hours might be required for them to flower under southern Australian conditions while Mediterranean types flower under much shorter days (Stoddard 1993).

Photo-thermal response of flowering in faba beans over the range of environments normally experienced by the crop may be described by the equation: $1/f = a + bt + cp$, where f is the number of days from sowing to first flower, t is the mean temperature and p is the photoperiod. The values of the constants a, b and c vary between genotypes and provide the basis for screening genotypes for sensitivity to temperature and photoperiod (Ellis *et al* 1988; McDonald *et al* 1994). [4]

4.3.1 Flowering and fruit development

If every flower on every faba bean plant produced a pod and each of those pods produced three seeds, the yield potential of the crop would be ~38–43 t/ha (Patrick and Stoddard 2010). However, 4 t/ha is a more realistic figure. The explanation is in the amount of sunlight hitting the leaves adjacent to open flowers for the following three days. Those leaves photosynthesise and produce sugars that feed the flowers. If there is no or very little photosynthesis, then there are insufficient assimilates to

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sustain the flowers. Necessity for sunlight to improve podset has implications for time of sowing, sowing rate and for row spacing in faba bean.

Figure 5: *Flowering faba bean.*

Photo: Drew Penberthy, Penagcon

It is not unusual for <20% of the flowers set by faba beans to develop into pods (Figure 5). Faba beans are both self- and cross-pollinated, so poor podset cannot always be blamed on the absence of bees. In some circumstances, lack of bee or pollinator activity, due to either absence of bees or environmental factors might reduce yield. A high proportion of the flowers that a bean crop sheds have been pollinated.

Fewer pods per node are set at lower nodes for an early sown crop. At a low seeding rate, more pods are set per node at lower nodes, whereas at higher sowing rates pods are more evenly distributed along the stem (Figure 6). This means that matching the variety with the time of sowing and sowing rate is particularly important with faba beans. Using a high seeding rate with early sown crops produces dense, vigorously growing crops early in the season that shade the flowers, reducing pod set and therefore the yield potential.

Figure 6: *Distribution of pods depends on seeding rate.*

Photo: Drew Penberthy, Penagcon

Lack of sunlight is a major factor in determining the level of podset in some environments, such as the winter-rain Mediterranean climate. Total radiation, rainfall, evaporation, temperature, humidity and wind strength have all been investigated, but the amount of radiation hitting the flower from when it opens and for the following 3 days is the main contributing factor (Stoddard 1993). Plant density is also an important factor in podset. Stoddard (1993) states that the primary determinant of whether a flower would be retained was weather during the 4 days from anthesis; incident light and rainfall accounted for >55% of the variation in the retention of flowers within a genotype. Availability of assimilate at the time of pod-setting is critical for the development of adequate yield.

There are significant differences between varieties for time between producing first flower and first podset, and this contributes to the variation in podset between varieties. The old variety Barkool sets a pod very soon after producing a flower. There is a delay of several days between the flower and the production of a pod in the variety Fiesta. Consequently, there is a significant difference in podset between Barkool, Fiord and Fiesta, even though they all begin flowering at about the same time.

Weight of individual seeds is more uniform along a stem for an early sown than for a late-sown crop, which has more small seeds towards the plant top.

Opportunity exists to breed varieties with better pod retention, and cultural practices contributing to competition and plant shading should be investigated.

Flowering commences at the appropriate node on the main stem and lower branches and proceeds acropetally (from the base to the apex of the plant) at intervals averaging at least 5–7 days between successive nodes along each branch. The node of the first flower, and the interval between successive nodes, vary depending on the month, season, variety and sowing time. Duration between nodes is particularly slow during vegetative and early reproductive stages (≥7 days) in winter, but shorter than this interval during spring.

At any location, seasonal variations in temperature can bring about a significant shift in flowering times for the same time of sowing (i.e. +10 days to the values quoted later in the section). In general, warmer temperatures hasten development, as reflected in thermal-time calculations.

Once flowers begin to develop and fertilisation has occurred, the pods remain erect and beneath the leaf canopy. Pods only bend and point downward when seeds are near maturity in some bean varieties. The pod can contain 3–8 ovules, of which most usually develop into seeds. The bulk of the yield is found on the lower flowering nodes of the main stem and basal branches.

Faba beans are like other cool-season legumes in their susceptibility to extreme hot or cold conditions, especially at flowering. In chickpeas, the average day/night temperature is critical for flowering and podset, rather than any specific effects of maximum or minimum temperatures (Singh 1996). This is not necessarily so with faba beans. If there is a critical mean or average daily temperature for faba beans to flower, in most current varieties it would be <10°C.

Unlike in chickpeas, low temperatures with faba beans are not known to cause pollen sterility. In chickpeas, if the average daily temperature falls below 15°C, pollen abortion occurs because the pollen becomes sterile and reproductive structures do not develop. Flowers that may develop below this temperature contain infertile pollen. In faba beans, poor light and hence lack of photosynthates lead to poor podset.

Once true flowers are produced in faba beans, a period of cool weather or lack of sunlight for three days can cause flower or pod abortion to varying degrees (Figure 7). Frosts can have an impact.

At Turretfield Research Centre, Rosedale, South Australia, Fiesta always flowers 90 ± 3 days after sowing with a mid-May sowing. Hence, it commences flowering in temperatures that average 11.4°C (maximum 16.5°C, minimum 6.3°C) (Figure 8).

If moisture and temperature conditions are favourable, additional crop growth, node production, flowering and crop height occurs until flowering ceases (Figure 9). Hot conditions (maximum temperatures >30°C) or lack of moisture causes flowering, and hence additional crop growth, to cease.

If the crop is able to continue to grow taller as it flowers, it will use more soil water. Water-use efficiencies will decline under such circumstances.

Note that the impacts of low air temperatures will be moderated by topography and altitude, so there will be warmer and cooler areas in undulating country.

In faba beans, selection of sowing date is a trade-off between:

- early sowing with high yield potential in those years where excessive frosts are avoided; and
- delayed sowing with lower yield potentials to ensure flowering occurs in warmer temperature and sunlight conditions, but before temperatures become excessive or moisture stress sets in.

The pods of faba beans are green and leathery, maturing to be blackish-brown, with a dense downy internal surface. Modern cultivars developed for human food use have pods 15–25 cm long and 2–3 cm thick. Each pod contains 3–8 seeds; round to oval, usually flattened and up to 20–25 mm long, 15 mm broad and 5–10 mm thick. [5]

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Figure 7: *Faba bean with poor pod set. Note the pedicel indicating lost flowers at each node above and below the single pod.*

Photo: W. Hawthorne, Pulse Australia

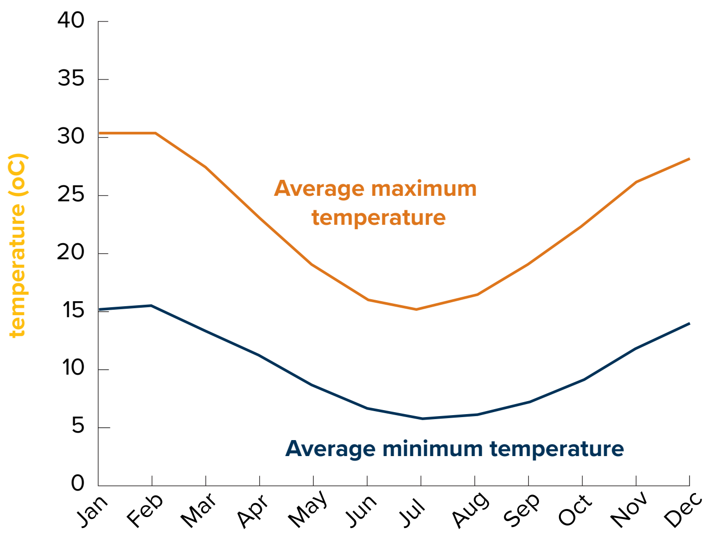

Figure 8: *Minimum and maximum daily temperature averages by month at Roseworthy, South Australia.*

Source: CropMate

Figure 9: *Faba bean with excellent podset, but note the need for fungicide protection of flowers (and leaves) in a disease-risk situation.*

Photo: W. Hawthorne, Pulse Australia

4.4 Growth and development

Faba beans, being legumes, belong to the botanical family of Leguminosae. They are semi-erect annuals with medium-fibrous roots (Figure 10). Worldwide, three main types of *Vicia fabae* are cultivated, and are classified based on seed size. Faba beans, horse beans and broad beans are all are grown in temperate regions and are large-seeded relative to many other pulses.

In European countries, there are winter- and spring-sown beans. In Australia we grow what are internationally considered Mediterranean-type beans (Patrick and Stoddard 2010). Spring beans flower over an extended period and do not ripen in southern Australia.

Faba bean types are mainly consumed whole (canned product), split for dhal, crushed for falafel or turned into flour.

Faba bean seed contain about 25% protein, 10% fat and 55% carbohydrates.

Figure 10: *A display of faba bean plants at various stages of development.*

Photo: W. Hawthorne, Pulse Australia

4.4.1 Emergence

Under optimum moisture and temperature conditions, faba bean seeds imbibe water relatively quickly and germinate within a few days provided temperatures are >0°C. Unlike lupins, faba bean seedlings have hypogeal emergence, that is, their cotyledons (embryonic leaves) remain underground inside the seed coat while providing energy to the rapidly growing roots and shoots.

Emergence occurs 7–30 days after sowing, depending on soil moisture, temperature conditions and depth of sowing. Growth of the shoot (plumule) produces an erect shoot and the first leaves are scales. The first true leaves have a single pair of leaflets (i.e. two leaflets), and from the 5th to 8th node, leaves have two or three pairs of leaflets. The development of multiple pairs of leaflets per leaf generally corresponds with development of the first flower bud.

When placed in a moist environment, the seed goes through three stages of water uptake during germination as it imbibes water (Mares 2005), as follows.

Phase 1 is water movement into the grain, imbibition, which occurs because the moisture content in the soil is greater than that in the seed. The seed swells. Water enters primarily at the hilum end of the grain where it was originally attached to the funiculus and nutrient-conducting tissues of the plant. There is also some minor movement of water through the seed coat. Water uptake into the embryo (germ) proceeds very rapidly, depending on the soil moisture content, to the point that normal cellular processes (metabolism, cell division, etc.) can occur. Seed moisture needs to reach ~35% dry weight before germination can occur in wheat. Too much water can impede germination by restricting diffusion of oxygen to the seed. All seeds, whether viable or non-viable, dormant or non-dormant, go through this phase 1 process.

Phase 2 is when there is minimal uptake of water, and it extends through to the first visible signs of germination. The major metabolic events required to prepare the seed for germination occur during phase 2 only in viable and non-dormant seeds. These changes are conserved if the seed is dried, and the seed can remain dry for considerable period without significant reduction in viability or germination potential. When these seeds are re-wetted, they again rapidly imbibe and show accelerated germination as the phase 2 duration is markedly shortened.

Phase 3 is associated with visible germination and subsequent growth (Figure 11). As part of this growth, there is rapid uptake of water again and new metabolic activity, including the start of mobilisation of stored food reserves in the endosperm. Visible germination starts with rupture of the seed coat over the germ and the protrusion of the shoot and radicle. As this process advances, the seedling becomes increasingly vulnerable to damage through drying, and there is a reducing capacity to regenerate following re-wetting.

Until the establishment of green leaves, the seedling is dependent on the stored food reserves in the endosperm. During the early stages of germination, the embryo produces gibberellic acid, which triggers the synthesis of enzymes that ultimately lead to the production of sugars and amino acids required by the growing seedling. [6]

Implications of this information are that:

- Seeds that are sown into marginal moisture and have imbibed some moisture may have either dried down or not taken up sufficient moisture to germinate. These 'primed' seeds will germinate quickly when the soil is again wetted up, as part of the germination process had commenced.
- Seed with a cracked seed coat can allow direct access of water and microorganisms into the stored starch and protein reserves in the endosperm.
- Seed with a cracked seed coat may imbibe moisture too quickly and impede oxygen diffusion into the seed.

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- If there has been pre-harvest sprouting, it may have limited effects on germination percentage when tested at harvest, but will cause a decline in germination percentage, germination vigour and seed viability during storage. [7]

Figure 11: *Germinating bean seed.*

Leaves

Leaves in faba beans are alternate along the branch. Each leaf is 10–25 cm long, pinnate and consists of 2–7 leaflets each up to 8 cm long and of a distinct glaucous grey–green colour (Figure 12). Leaflets are not serrated. Unlike most other members of the *Vicia* genus, it is without tendrils or with rudimentary tendrils.

Leaflets fold and become limp in dry, hot conditions to minimise transpiration. Canopy development in faba beans is quite rapid, especially during early sown and warmer winter conditions.

The entire surface of the leaflets is free of fine hairs (trichomes). [8]

Figure 12: *Nura⦷ faba bean plants showing alternate leaves along the branch, with multiple leaflets on each leaf. Note chocolate spot incidence and loss of lower leaves.*

Photo: W. Hawthorne, Pulse Australia

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Roots

Faba beans have a robust taproot with profusely branched secondary roots that increase in size near the soil surface as the season develops. The root systems are strong, but do not always penetrate to depth (Figure 13).

Faba bean roots can leave moisture at depth late in the season, and this can result in a reduced ability to withstand dry conditions. Root growth is most rapid before flowering but will continue until maturity under favourable conditions. Faba beans are susceptible to hard pans, and prefer deep, well-structured soils so that roots can penetrate deeply. Subsoil constraints, such as soil chloride in excess of ~800 mg/kg soil in the top 60 cm, will restrict root growth and water availability.

At Pinery, South Australia, with soils showing chloride levels >1000 mg/kg in the top 100 cm, there was a significant relationship between yield and salt tolerance.

As well as their role in water and nutrient uptake, faba bean roots develop symbiotic nodules with the rhizobial bacteria *Rhizobium leguminosarum* bv. *Viciae*, a species capable of fixing atmospheric nitrogen (N_2) (Figure 14). The plant provides carbohydrates for the bacteria in return for N_2 fixed inside the nodules.

These nodules are visible within about a month after plant emergence, and eventually form slightly flattened, fan-like lobes. Almost all nodules are confined to the top 30 cm of soil and 90% are within 15 cm of the surface. When cut open, nodules actively fixing N_2 have a pinkish centre (Figure 15). Nitrogen fixation is highly sensitive to waterlogging; hence, faba beans need well-aerated soils.

Waterlogging and drainage

Faba beans are considered tolerant of waterlogging. They will survive despite periods of waterlogging, especially in cool conditions of winter. However, waterlogging will reduce yields. Irrigated faba beans grown at Kerang on drained soils (tile drains at 1.0 m) yielded 4.2 t/ha, whereas the undrained crop yielded 2.7 t/ha when sown on raised beds and 1.9 t/ha where sown into a conventionally laser levelled bay (Drew 1994). The watertable was maintained at about 1.0 m below the soil surface for the season on drained soils, but on undrained soils, it was 0.1–0.3 m from the surface until September, and then fell away to be 0.8–0.9 m by the end of November.

Figure 13: *Faba bean usually has a robust, but not deep, taproot system.*

Photo: W. Hawthorne, Pulse Australia

Figure 14: *Nodulated roots.*

Figure 15: *Active nodules have pinkish centre.*

Photo: G. Cumming, Pulse Australia

Soil nitrate and temperature effects on nodulation

Nitrate in the soil can delay nodulation, decrease nodule number and decrease nodule activity (Herdina and Salisbury 1989); bean seedling growth and nodulation were poorer at 10°C than at either 15°C or 20°C. Nodulation was markedly reduced by the low temperature, and it is likely to be slow in the field when the soil temperature is low (10°C) as may occur after a late sowing. The known yield advantage of early planting of faba bean may in part be due to better nodulation under warm (15°C) soil conditions (Herdina and Salisbury 1989).

Root mass and penetration

Faba bean roots do not penetrate to the same soil depths as those of wheat or barley (Gill and Kleeman 2008). In their study, extractable water through the soil to 130 cm depth showed small differences due to row spacing in May but larger ones due to crop type in October. Water use by wheat and barley over the growing season was unaffected by row spacing; however, both cereals were more effective than faba bean at extracting soil water. In contrast to the cereals, faba bean used 50 mm less water, which was related to its inability to extract water below 85 cm depth and its failure to dry soil below 20% volumetric water content. This additional soil water could be of benefit to the following wheat crop in dry seasons if it could be stored in the profile until the next growing season.

Faba bean roots do not produce as much biomass as chickpea or wheat roots (Figure 16). [9]

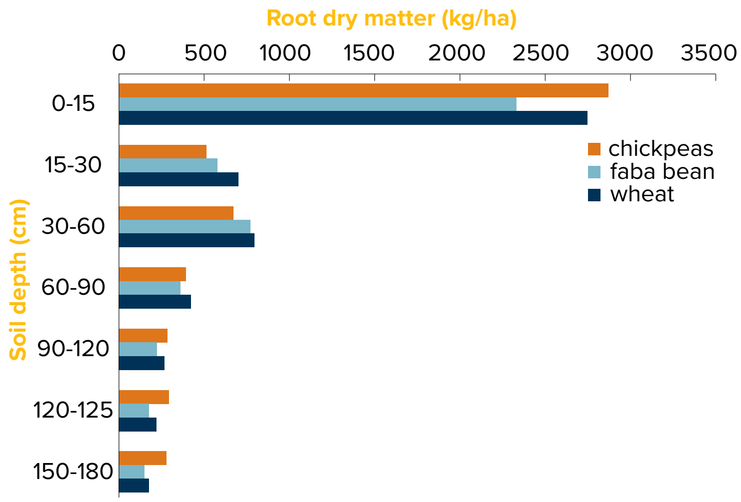

Figure 16: *Root biomass (kg/ha) at each soil depth of chickpea, faba bean, and wheat.*

Source: Turpin et al. 2002

4.4.2 Stem and branches

Vicia faba is an annual with rigid, erect plants, ideally 0.5–1.8 m tall, with stout, hollow but erect stems of a square cross-section.

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Figure 17: *Maturing, well-podded faba bean plants showing their basal branching habit and multiple-podding nodes.*

Photo: W. Hawthorne, Pulse Australia

Primary branches, starting from ground level, grow from buds at the lowest nodes or plumular shoot as well as the lateral branches of the seedling (Figure 17). These branches are thick, strong and woody, and determine the general appearance of the plant. Height achieved by the main stem and branches depends on soil moisture or rainfall conditions, length of growing season and variety.

Unlike lupins and some other pulses, there are no secondary or tertiary branches that develop from the main stem or branches.

Pollination

Faba beans are allogamous, or have a mixed mating system, with both cross-pollination and self-pollination, but require insect pollinators to maximise seed set. If low numbers of bees are present, introducing commercial pollinating bees through the crop in a grid of at least 2 hives/ha can increase yield by 30–100%.

Apiarists must manage hives as ‘pollinators’, not honey producers, placing hives throughout the crop, not in a paddock corner (Figures 18 and 19). Bees must be removed or housed when insecticide or fungicide is used.

Growers must tolerate beehives through the crop but will see a yield benefit to pay for the pollination service. Apply and time chemical use wisely, use integrated pest management (IPM) and communicate intentions with the apiarist. [10]

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Figure 18: *Bee hives need to be strategically placed within the crop and well managed to ensure adequate pollination.*

Photo: W. Hawthorne, Pulse Australia

Figure 19: *Placing multiple hives in a corner of the paddock does not effectively pollinate the whole crop.*

Photo: W. Hawthorne, Pulse Australia

Pollination trials

All pulse crops are open-pollinated to varying degrees, which means in order to achieve seed-set, pollen must be transferred between flowers. Mechanisms such as wind can achieve pollen transfer or cross-pollination, but the most effective method is utilising insects to carry the pollen from one flower to the next. Several insects will do this, including bees, lacewings, flies and even ants. Because of the density of flowers in a pulse crop and the short flowering period, the number of insects required to pollinate the crop effectively is far beyond what can naturally occur. Therefore, the most effective way to increase the number of insects in the crop is to introduce honeybees.

The role of the forager bee is primarily to collect food for the hive. Bees collect two different foods, pollen, which is used to feed their young (brood), and nectar, which is converted into honey to feed the adults. As the bees collect pollen, and to a lesser degree nectar, they transfer pollen from one flower to the next and inadvertently fertilise the crop.

Trials are being conducted across South Australia employing a technique of hive management that is used in other parts of the world but only just starting to be adopted commercially in Australia. This more intensive form of hive management uses a technique that creates an overwhelming demand in the hive for pollen. Hives are serviced every fortnight to maintain the demand. This technique significantly increases the proportion of forager bees collecting pollen. The overwhelming demand for pollen means that the bees travel to the closest source of pollen and this reduces the distance they travel from the hive. Trials indicated that the flight of the bees was restricted to around 200–300 m from the hive. This means that, in order to achieve effective pollination, precise placement and density of hives is crucial for uniform pollination.

Why is this different?

Apiarists currently supply hives that contain a significantly greater amount of stored honey and pollen than the hives managed with this new technique. As a result, there is not a large immediate demand in the hive for pollen and nectar, because the bees have stores to sustain the hive for some time. With reduced demand in the hive for pollen and nectar, the bees will travel further from the hive to find preferable areas to forage. This might include gullies that are warmer and protected from wind within the crop, or alternative flora such as flowering Mallee trees. The bees may travel up to 5 km to find alternative flora. Due to the lack of demand in the hive for pollen, bees often selectively forage on the easiest to reach flowers in the crop, usually on the top of the canopy. This leaves many flowers in the lower part of the canopy untouched, meaning that they do not set seed and drop off. By placing an immediate demand in the hive for pollen, the bees will visit every flower in the crop, including the older flowers and flowers in the lower part of the canopy.

Trials conducted in 2007 and 2008 across South Australia have indicated that yield increases of up to 50% may be easily achieved with the addition of the managed hives to pulse crops (Figure 20). Trials have mainly focused on beans, but funding has been sourced to investigate other crop types and their yield responses to managed pollination.

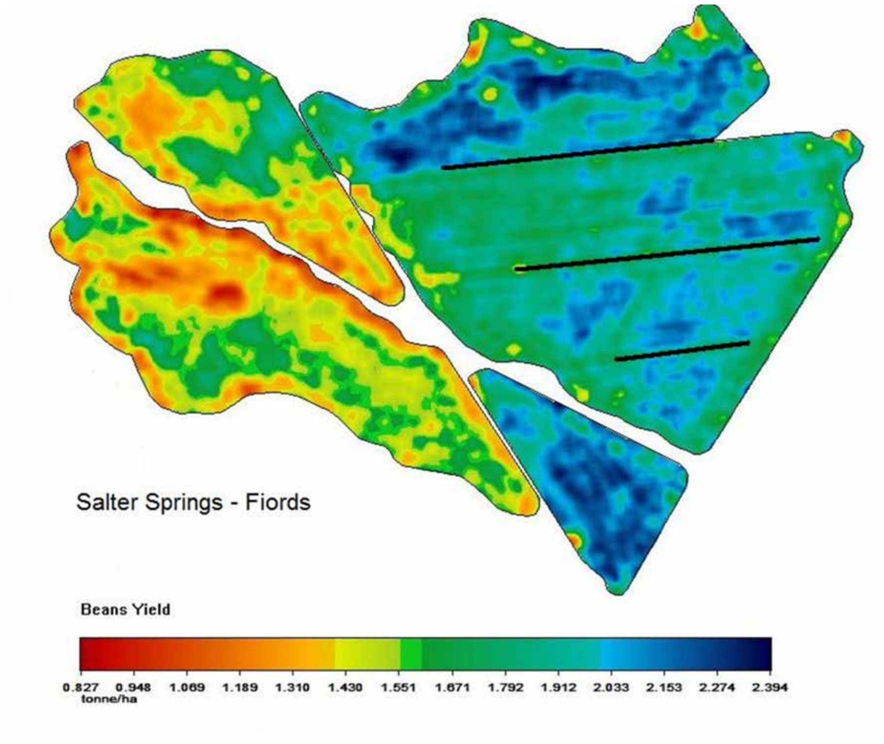

Figure 20: *Yield map of Fiord faba beans showing increased yield where beehives had been strategically placed through the crop (top right side, black lines).*

Source: Danny Le Fevure, formerly Ag Consulting Company

Climatic requirements for flowering

The timing of flowering is an important trait affecting the adaptation of crops to low-rainfall, Mediterranean-type environments (such as southern Australia). Seed yields of many crops in these areas have been increased by early sowing, the development of early flowering varieties and use of stubble-retention systems to maximise moisture use efficiency.

Apart from daylight, the three major factors affecting flowering in faba bean are temperature, daylength, and drought. Temperature is generally more important than daylength. Flowering is invariably delayed under low temperatures but more branching occurs.

Progress towards flowering is rapid during long days, whereas under short daylengths, flowering is delayed but never prevented. However, some faba bean varieties are less sensitive to daylength than others. This has enabled breeders to identify improved varieties that flower early in our short-day, winter growing season in southern Australia.

Faba beans are like many other cool season pulses in that they are reasonably tolerant of cold conditions, even at flowering. Unlike chickpeas, some advantage can be derived from early flowering, despite increased flower and pod abortion at lower temperatures. There are, however, temperature and daylight limits that constrain photosynthesis.

In many parts of southern Australia, mean daily temperatures fall below 10°C during winter. This is not necessarily an impediment to flowering or podset unless frosts occur. Faba bean producers in high-rainfall areas do complain about poor early podset with early sowing; however, poor light in dense canopies, and hence low photosynthesis, is likely the major cause, often in conjunction with low levels of pollinator activity and possible chocolate spot incidence on flowers.

In many well-grown faba bean crops, podset does not occur until temperatures rise in August–September, when there is also more sunlight and less wind and rain (for pollinator activity). More consistent podset and seed-filling then commences. Disease incidence in flowers (i.e. chocolate spot) is implicated in poor podset in some situations, and thus, many faba bean growers consider fungicide protection of early flowers important. When temperatures rise and environmental conditions improve, pods can develop quickly, within 3–6 days. Even after flowers develop into pods, periods of low temperature and poor conditions may result in abortion of seeds or whole pods before filling commences.

In addition to the effects of cold described above, sub-zero temperatures in winter can damage leaves and stems of the plant. This occurs particularly in northern Australia. These severe frosts can cause a characteristic 'hockey-stick' bend in the stem (Figure 21). However, beans have some ability to recover from this damage by being able to regenerate new branches in severe cases. New growth occurs from the base of the frost-affected plants if moisture conditions are favourable.

Figure 21: *Severe vegetative frost can cause bends like a hockey stick in faba bean stem and branches in northern Australia.*

Photos: G Cumming, Pulse Australia

Frosts can also cause flower, pod and seed abortion. Pods at a later stage of development are generally more resistant to frost than flowers and small pods (Figure 22), but may suffer some mottled darkening of the seed coat (Figure 23).

Frost will normally affect the smallest pods first, even though they are the higher pods on the plant. Similarly, pod abortion induced by moisture stress is normally also noted on the last formed pods in the upper parts of the plant. Visual symptoms of frost and moisture stress damage to pods are, however, quite different.

In southern Australia, frost or low minimum temperatures (<5°C) during the reproductive stage will not physically damage the crop as might occur in northern Australia (Figure 21). There may be a slight leaf tipping on upper leaves to indicate a frost has occurred.

Frost during early flowering that affects early podset can be compensated for later by subsequent pods that set higher up the plant, provided the seasonal conditions are favourable to fill them.

Figure 22: *Frost can cause flower or pod abortion (usually smaller pods). Damage to the seed depends on the size of the pod or seed and the severity of the frost.*

Photo: W. Hawthorne, Pulse Australia

Figure 23: *Frost can cause seed staining from 'burning' the seed coat next to the pod wall.*

Photo: W. Hawthorne, Pulse Australia

Maximum temperatures >30°C in spring may also reduce yield in faba beans, causing flower abortion, cessation of flowering and a reduction in the time available for seed-filling. Faba beans are considered one of the least tolerant of the winter pulses to moisture stress (drought) and high temperatures.

On the other hand, high levels of humidity and low light also reduce podset in faba beans. [11]

Tolerance to low temperature

Some varieties of faba bean released in the northern region have been bred for their tolerance to frosts during the vegetative growth stage. This tolerance in the varieties PBA Warda⚲, Cairo⚲ and Doza⚲ means less death of stems and 'hockey-stick', symptoms from the severe frosts seen in northern Australia, but not in southern areas. Current varieties grown in southern Australia (e.g. Fiesta, Farah⚲, Nura⚲ and PBA Rana⚲) are susceptible to severe vegetative frost damage when grown in northern Australia.

Tolerance to frost at either vegetative or reproductive stages is not a breeding priority in southern Australia. However, improved early podset under conditions of low temperatures and low light is a breeding priority.

In other parts of the world, 'spring faba bean' crops are sown after winter. 'Winter faba bean' crops are sown before winter and are able to survive under snow. Winter varieties tolerate freezing conditions and can be sown in autumn, survive over winter, and are ready to grow, flower and set pods when temperatures rise in spring and summer. [12]

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Flowering, podding and seed development

Flowers are large, borne on short pedicels in clusters of 1–5 on each axillary raceme, usually from the node where flowering commences. There can be up to 15 flowering nodes in well-grown faba beans in Australia; 1–4 pods develop from each flower cluster. Growth is largely indeterminate. Flowers are 1.0–2.5 cm long, with five petals, the standard petal white, the wing petals white with a black spot (not deep purple or blue) and the keel petals white (Figure 24).

Figure 24: *Faba bean flowers are not completely white, because of the tannins that occur in their seeds. Only tannin-free faba beans lack anthocyanin, hence only they produce white flowers.*

Photo: W. Hawthorne, Pulse Australia

About 30% of the plants in a population are cross-fertilised and the main insect pollinators are honeybees in Australia. Bumblebees are not present in mainland Australia.

The development of flowers and then of seeds are key processes in the formation of yield in faba beans, as in other grain legumes.

Mediterranean-type faba beans as grown in Australia do not have a high vernalisation requirement (McDonald *et al* 1994). Winter faba beans, however, generally have a quantitative vernalisation requirement, allowing flowering to occur at a lower node than in unvernalised plants. Some germplasm is day-neutral; other germplasm is long-day with a critical day length between 9.5 and 12 h.

Progress toward flowering follows a conventional thermal-time model. For commercial faba bean varieties, ~830–1000 degree-days (>0°C) is required for the onset of flowering, but this varies with location, time of sowing and variety. Optimum temperature of flowering is 22–23°C.

Flowers may abscise from the crop because of:

- lack of pollination
- proximal flowers on the same raceme being fertilised
- vegetative–reproductive competition for assimilate
- stresses such as drought

Seed-filling in the retained pods proceeds through well defined, pre-storage and storage phases, described in detail by Patrick and Stoddard (2010). During the pre-storage phase, cell expansion occurs mostly in the endosperm and seed coat while the embryo is in a cell-division phase.

Growth in faba beans is often described as indeterminate. This means that branch and leaf (or vegetative) growth continues as the plant switches to a reproductive mode and initiates flowering. Hence, there is often a sequence of leaf, flower bud, flower and pod development along each branch.

The duration of vegetative growth before flowering is dependent on many factors, as discussed earlier.

There can be an early period of ineffective flowering, during which podset does not occur. In warmer environments, this period is minimal, but in colder temperate environments, it can be as long as 30 days.

Pollination takes place after the flower bud opens. Faba beans have a mixed mating system with both self- and cross-pollination. Faba bean pollen is very heavy and sticky and is not is not released into the air. Virtually all cross-pollination is via insect transfer of the pollen. The rate of cross-pollination in a faba bean crop is typically 30%, but varies with environmental conditions, presence of insect vectors and variety.

Faba bean plants generally produce many flowers; however, a large proportion (~80–90%) does not develop into pods, depending upon the variety, sowing date and other environmental conditions (Figures 25–28). Some pods that set do not progress to fill seeds either.

Figure 25: *Flower raceme indicates flowers that did not set pods.*

Photo: W. Hawthorne, Pulse Australia

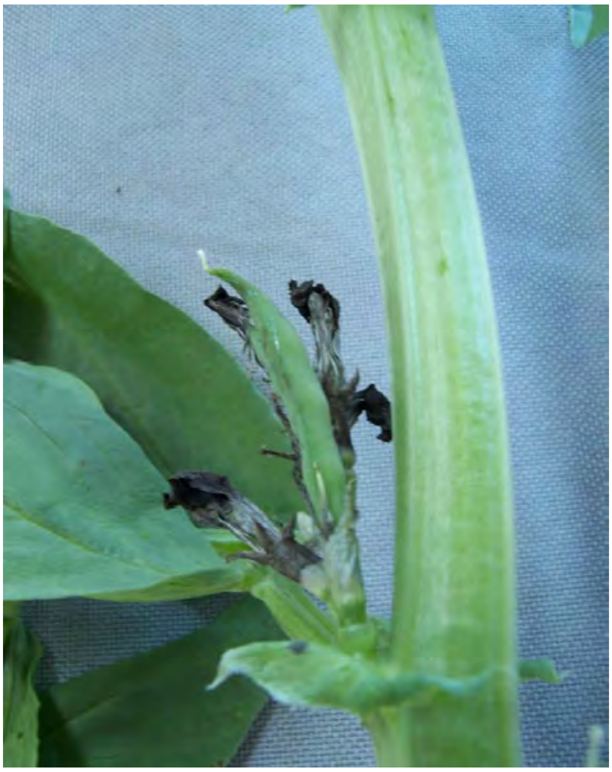

Figure 26: *Faba bean pod and dead flowers that when removed may show small pods.*

Photo: W. Hawthorne, Pulse Australia

Figure 27: *Faba bean branches showing small pods, pods that have formed but not developed and flower raceme left after flower abscission without setting pods.*

Photo: W. Hawthorne, Pulse Australia

Figure 28: *Faba bean canopy showing full flowers*

Photo: W. Hawthorne, Pulse Australia

Under favourable temperature and soil moisture conditions, the time taken from fertilisation of the ovule (egg) to the first appearance of a pod (pod set) is about 6 days. The seed then fills over the next 3–4 weeks. The developing pod stands above its subtending leaf. It may become too heavy (e.g. in broad bean) and then hang below the flowering node for harvest. After podset, the pod wall grows rapidly for the first 10–15 days, while seed growth mainly occurs later.

Faba bean pods vary greatly in size between varieties because of varying seed sizes. Pod size is largely unaffected by the environment. Seed-filling and subsequent seed size are highly dependent on variety, number of seeds set and weather conditions.

Seed are characteristically oval and flat, sometimes with a ridged, dimpled or smooth seed coat. Seed colour varies between varieties from white (tannin-free) to light tan/green (commercial varieties), brown (aged beans), even purple or black (specific lines). Kernel colour is yellow. Seed numbers vary from one to eight per pod, and not every ovule in a pod necessarily develops. [13]

4.4.3 Erectness

Faba beans are prone to lodging, 'necking' or both, which are two different processes. Either way the end result is a crop that is no longer erect and becomes more difficult to harvest.

Lodging is the condition when the stems bend and the crop is less erect as it becomes taller late in the season (Figure 29). Taller (e.g. early sown) and dense crops are more prone to lodging than shorter, thinner crops. Strong winds and rain can cause lodging. There are varietal differences in erectness, and disease (Ascochyta blight in particular) in the stem can also make a crop more prone to lodging. Chocolate spot becomes more severe in lodged crops, and penetration of foliar fungicide into the canopy becomes more difficult.

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Necking occurs in beans under strong wind conditions, and seems more pronounced when the crop is under moisture stress. The stem bends over sharply (virtually snapping) at about pod height, and so the upper part of the plant either dies or becomes less able to assist in grainfill (Figure 30). Sometimes there is plant recovery from necking, and the growing points turn to grow upright again (Figure 31). These plants then appear to have stems that are bent into an 'S'-shape. These plants are often considered lodged.[14]

Figure 29: *Faba bean crops can be subject to lodging, often severe, when the stem bends gently. Dense, tall crops, windy conditions and disease can make the crop more prone to lodging.*

Photo: W. Hawthorne, Pulse Australia

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Figure 30: *Faba bean can be subject to 'necking' when the stem bends sharply to be virtually snapped off. Hot winds and moisture stress make the crop more prone to 'necking'.*

Photo: W. Hawthorne, Pulse Australia

Figure 31: *Faba beans that shows some mild 'necking' when the stems have bent but not so as to appear snapped off. In such cases, there is recovery, and plants appear to have bent stems and are often considered lodged.*

Photo: W. Hawthorne, Pulse Australia

Maturity

Soon after the development of pods and seed-filling, senescence of subtending leaves begins. If there is plenty of soil moisture and maximum temperatures are favourable for growth, flowering and podding will continue on the upper nodes.

However, as soil moisture is depleted or if temperatures increase, flowering ceases and eventually the whole plant matures. This is typical of pulse crops and annual plants in general.

In northern New South Wales, flowering ceases and plants ripen in response to temperature increase even though there could be adequate of soil moisture.

Faba beans are unlike chickpeas, which can tolerate high temperature if there is adequate soil moisture. Hence, chickpea is normally one of the last pulse crops to mature in Mediterranean-type environments.

As leaves begin to senesce, there is a rapid re-translocation of dry matter from leaves and stems into the seeds.

Under mild moisture stress, faba bean and most winter pulses other than chickpea are incapable of accumulating solutes (sugar, proteins and other compounds) in their cells. Stomatal conductance and low levels of photosynthesis are therefore not maintained in these winter pulses, but are in chickpea via a process known as osmoregulation.

In southern Australia, faba bean crops can reach maturity 180–220 days after sowing, depending on the sowing date, variety, and a range of environmental factors including temperature (Figure 32). Faba beans are ready to harvest when >90% of the stems and pods lose their green colour and become black (Figure 33). At this point, seeds are usually hard but do not rattle when the plant is shaken as occurs in chickpea and lentil.

Figure 32: *Mature, well-podded faba beans before their pods and stem dry for harvest.*

Photo: W. Hawthorne, Pulse Australia

Figure 33: *Mature faba beans are black, and in this photo have been desiccated (front and right) for earlier maturity and harvest compared with that allowed to mature naturally (centre).*

Photo: W. Hawthorne, Pulse Australia

Pulses can be desiccated or windrowed pre-harvest to enable earlier harvest and to dry out green weeds, although growers in northern New South Wales have moved away from this practice. Timing of desiccation is based on crop stage, and is similar to or later than that for windrowing.

Potential dangers of premature desiccation are the presence of excessive green cotyledons in the sample, staining of the seed coat and small seed, all of which create marketability problems.

Windrowing or desiccation of bean crops can commence when the majority of seeds are physiologically mature. This is assessed as being when the hilum (scar-like area where the seed attaches to the pod) is turning black on the seeds in the upper most pods. At this stage the upper pods are still bright green, and green leaf is still present, but the lowest pods are starting to turn black and have seeds with completely black hilums. If windrowing is delayed beyond this stage, it needs to be done in cool and moist conditions otherwise pod loss can become unacceptable. [15]

For more information on frost in faba beans please see Section 14.

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Nutrition and fertiliser

A balance of soil nutrients is essential for profitable yields. Fertiliser is commonly needed to add the essential nutrients phosphorus (P), potassium (K), sulfur and zinc. Lack of other micronutrients may also limit production in some situations.

Knowing the nutrient demand of crops is essential in determining nutrient requirements. Soil testing and nutrient audits assist in matching nutrient supply to crop demand. [1]

5.1 Declining soil fertility

The natural fertility of cropped agricultural soils is declining over time, and so growers must continually review their management programs to ensure the long-term sustainability of high quality grain production. Paddock records, including yield and protein levels, fertiliser test strips, crop monitoring, and soil and plant tissue tests all assist in the formulation of an efficient nutrition program.

Pasture leys, legume rotations and fertilisers all play an important role in maintaining and improving the chemical, biological and physical fertility of soils, fertilisers remain the major source of nutrients to replace those removed by grain production. Fertiliser programs must supply a balance of the required nutrients in amounts needed to achieve a crop's yield potential. The higher yielding the crop, the greater the amount of nutrient removed. Increasing fertiliser costs means growers are increasing pulses within their crop rotation and even the use of ley pastures to complement their fertiliser programs and possibly boost soil organic matter.

5.1.1 Soil organic matter

Soil organic matter (SOM) is a critical component of healthy soils and sustainable agricultural production. Growers understand that crops grown in healthy soils perform better and are easier to manage. Soil organic matter is '*all of the organic materials found in soils irrespective of its origin or state of decomposition*' [2] that is anything in or on the soil of biological origin, alive or dead. It is composed mainly of carbon (approximately 60%) as well as a variety of nutrients (including nitrogen, phosphorus and sulfur). It is difficult to actually measure the SOM content of soil directly so we measure the soil organic carbon (SOC) content and estimate SOM through a conversion factor:

Soil organic matter (%) = organic carbon (%) × 1.72

It is important to understand the role of plants in the SOM cycle. Photosynthesis is the process by which plants take in carbon dioxide (CO_2) from the atmosphere, combine with water taken up from the soil, and utilising the energy from the sun, form carbohydrate (organic matter) and release oxygen (O_2). This is the start of the SOM cycle. When the leaves and roots (carbohydrate) die they enter the soil and become SOM. These residues are decomposed by soil organisms which provides them with the energy to grow and reproduce. The SOM cycle is a continuum of different forms (or fractions) with different time frames under which decomposition takes place. Over time SOM moves through these fractions; particulate, humic and resistant fractions. As SOM decomposes carbon is released from the system along with any nutrients that are not utilised by the microorganisms. These nutrients are then available for plants

1 P Matthews, D McCaffery, L Jenkins (2013) Winter Crop Variety Sowing Guide. NSW Department of Primary Industries, http://www.dpi.nsw.gov.au/aboutus/news/all/2013/2013-wcvsg

2 JA Baldock, JO Skjemstad (1999) Soil organic carbon/Soil organic matter. In KI Peverill, LA Sparrow, DJ Reuter (eds). Soil analysis: An interpretation manual. CSIRO Publishing, Collingwood Australia.

to utilise. Eventually a component of these residues will become resistant to further decomposition (resistant fraction Figure 1).

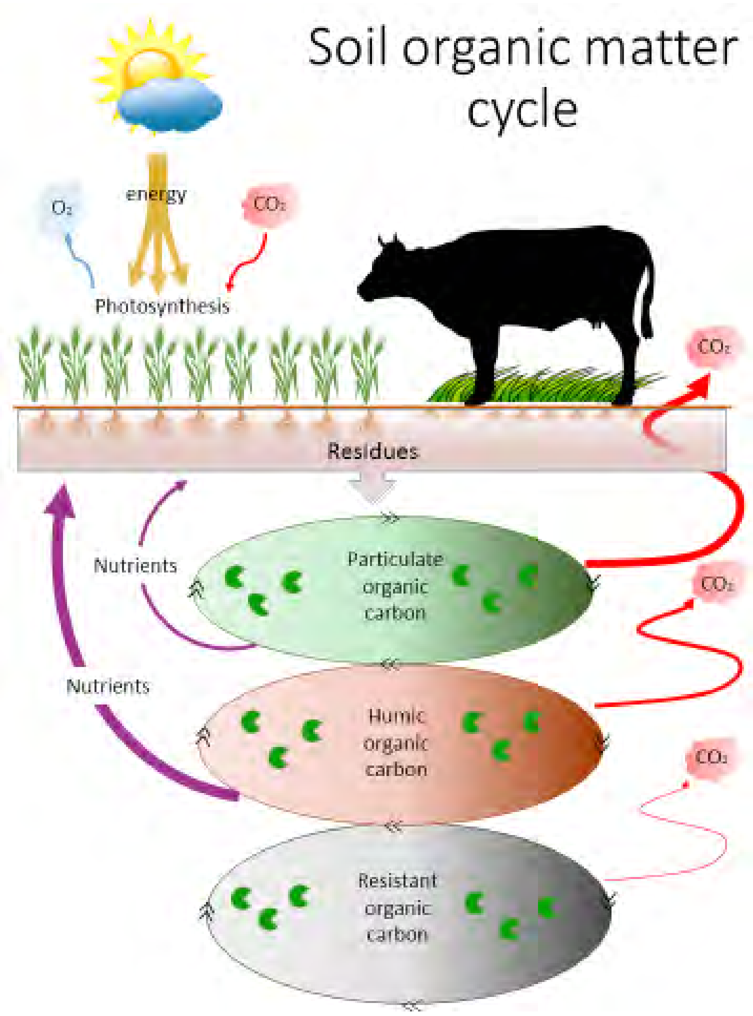

Figure 1: *Organic matter cycle*

Source: J Gentry, DAF

Organic matter is fundamental to several of the physical, chemical and biological functions of the soil. It helps to ameliorate or buffer the harmful effects of plant pathogens and chemical toxicities. It enhances surface and deeper soil structure, with positive effects on infiltration and exchange of water and gases, and for keeping the soil in place. It improves soil water-holding capacity and, through its high cation-exchange capacity, prevents the leaching of essential cations such as calcium (Ca), magnesium (Mg), potassium (K) and sodium (Na). Most importantly, it is a major repository for the cycling of nitrogen and other nutrients and their delivery to crops and pastures.

Australian soils are generally low in SOM. Initial SOM levels are limited by dry matter production (and so climate) for each land type/location. SOM levels have declined under traditional cropping practices. On-farm measures (sampled 2012–15) from over 500 sites in Queensland and northern New South Wales confirm that soil organic matter, measured as soil organic carbon, declines dramatically when land is cleared and continuously cropped. This decline affects all soils and land types but is most dramatic for the brigalow-belah soils because their starting organic carbon levels are so high (Figure 2). [3]

3 DAF (2016) Queensland Grains Research – 2015. Regional Research Agronomy Network. Department of Agriculture, Fisheries and Forestry Queensland, pp. 112 – 117, http://www.moreprofitperdrop.com.au/wp-content/uploads/2016/08/RANsTrials2015-screen.pdf

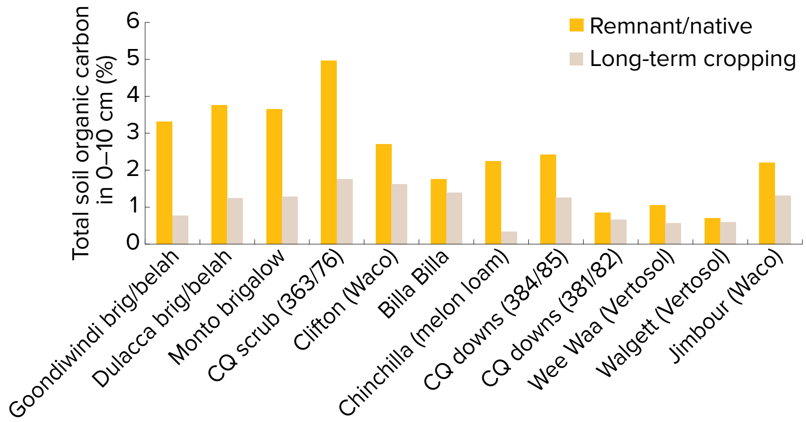

Figure 2: *The decline of soil organic carbon in long-term cropping systems 4*

Declining levels of SOM have implications for soil structure, soil moisture retention, nutrient delivery and microbial activity. However, probably the single most important effect is the decline in the soil's capacity to mineralise organic nitrogen (N) to plant-available N. Past research (1983) has shown that N mineralisation capacity was reduced by 39–57%, with an overall average decline of 52% (Figure 3). [5] This translated into reduced wheat yields when crops were grown without fertiliser N.

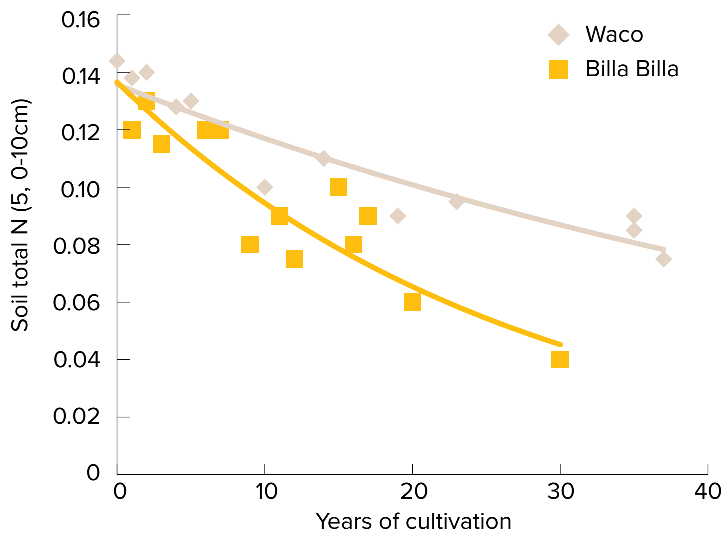

Figure 3: *Graph of decline in soil total N with years of cropping. The decline was greater for the Billa Billa soil (clay content 34%) than the Waco soil (clay content 74%)*

Source: based on Dalal & Mayer (1986a,b) [6]

4 DAF (2016) Queensland Grains Research – 2015. Regional Research Agronomy Network. Department of Agriculture, Fisheries and Forestry Queensland, pp. 112 – 117, http://www.moreprofitperdrop.com.au/wp-content/uploads/2016/08/RANsTrials2015-screen.pdf

5 RC Dalal, RJ Mayer (1986) Long term trends in fertility of soils under continuous cultivation and cereal cropping in southern Queensland. II. Total organic carbon and its rate of loss from the soil profile. Australian Journal of Soil Research 24, 281–292.

6 RC Dalal, RJ Mayer (1986) Long term trends in fertility of soils under continuous cultivation and cereal cropping in southern Queensland. II. Total organic carbon and its rate of loss from the soil profile. Australian Journal of Soil Research 24, 281–292.

5.1.2 Current situation

Soil organic carbon levels are simply a snapshot of the current balance between inputs (e.g. plant residues and other organic inputs) and losses (e.g. erosion, decomposition) constantly happening in each soil and farming system. The decline over time is overwhelmingly driven by the extent of fallowing in our farming systems. Most fallow rain in the northern region (as much as 75–80% in a summer fallow) is lost as runoff or evaporation. This wasted rain does not grow dry matter to replenish the organic matter reserves in the soil. However, increasing moisture in the fallowed soil continues to support microbial decomposition. This helps accumulate available nitrogen for the next crop, but reduces soil organic carbon. The soil organic matter and carbon levels will continue to decline until they reach a new lower level that the dry matter produced by the new farming system can sustain. Put simply,

'Crops may make more money than trees and pastures, but do not return as much dry matter to the soil.'

Total soil organic carbon levels vary within a paddock, from paddock to paddock and from region to region. Comprehensive sampling was under taken throughout the northern region, with over 900 sites sampled and analysed for total organic carbon at 0–10 cm depth. These results varied enormously across sites. The average was 1.46% however it varied from under 0.5% to over 5% (Figure 4). [7] A selection of these data from representative soil types throughout the northern grains region clearly indicates how soil carbon levels can be significantly different due to soil type (Figure 5). [8]

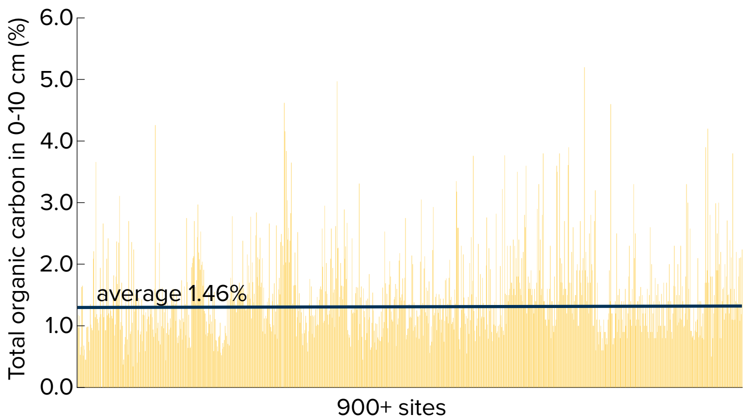

Figure 4: *Soil organic carbon levels on mixed farms within the GRDC Northern Region 9*

7 DAF (2016) Queensland Grains Research – 2015. Regional Research Agronomy Network. Department of Agriculture, Fisheries and Forestry Queensland, pp. 112 – 117, http://www.moreprofitperdrop.com.au/wp-content/uploads/2016/08/RANsTrials2015-screen.pdf

8 DAF (2016) Queensland Grains Research – 2015. Regional Research Agronomy Network. Department of Agriculture, Fisheries and Forestry Queensland, pp. 112 – 117, http://www.moreprofitperdrop.com.au/wp-content/uploads/2016/08/RANsTrials2015-screen.pdf

9 DAF (2016) Queensland Grains Research – 2015. Regional Research Agronomy Network. Department of Agriculture, Fisheries and Forestry Queensland, pp. 112 – 117, http://www.moreprofitperdrop.com.au/wp-content/uploads/2016/08/RANsTrials2015-screen.pdf

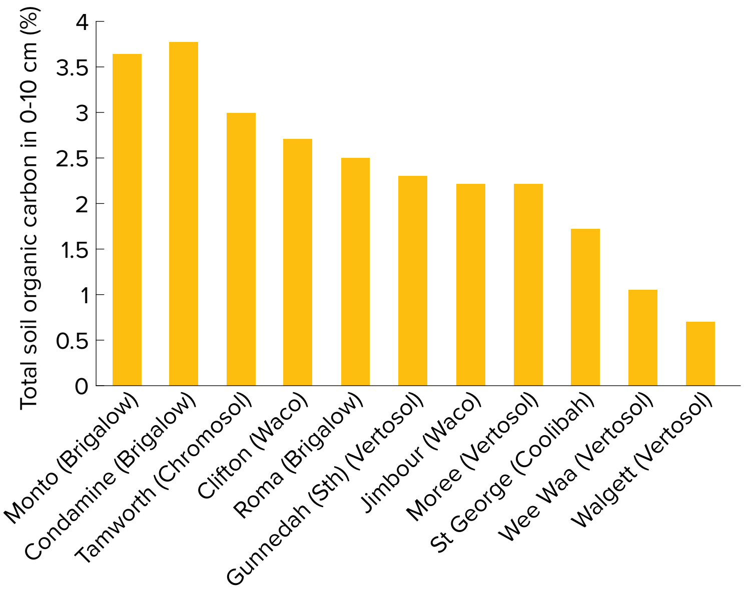

Figure 5: *Impact of land-type on total soil carbon levels (0–10 cm) across northern region 10*

5.1.3 Options for reversing the decline in soil organic matter

Soil organic matter is an under-valued capital resource that needs informed management. Levels of SOC are the result of the balance between inputs (e.g. plant residues and other organic inputs) and losses (e.g. erosion, decomposition, harvested material) in each soil and farming. [11] So maximising total dry matter production will encourage higher SOC levels, and clearing native vegetation for grain cropping will typically reduce SOC and SOM levels. [12]

Modern farming practices that maximise Water Use Efficiency for extra dry matter production are integral in protecting SOM. Greater cropping frequency, crops with higher yields and associated higher stubble loads, pasture rotations and avoiding burning or baling will all help growers in the northern region to maintain SOM.

Research in the past has shown the most direct, effective means of increasing SOM levels is through the use of pastures, however these pasture have to be productive. A grass only pasture will run out of N especially in older paddocks, which is normally the reason why these paddocks are retired from cropping. As a result, a source of nitrogen is required to maximise dry matter production, this can be supplied via a legume or N fertiliser. The rotation experiments of I. Holford and colleagues at Tamworth, NSW and R. Dalal and colleagues in southeast Queensland provide good evidence of this (Table 1).

The greatest gains in soil carbon and nitrogen, relative to the wheat monoculture, were made in the 4-year grass–legume ley, with increases of 550 kg total N/ha and 4.2 t organic C/ha. The chickpea–wheat rotation fared no better than the continuous wheat system. The shorter (1–2-year) lucerne and annual medic leys resulted in marginal increases in soil organic C and N (Table 1).

10 DAF (2016) Queensland Grains Research – 2015. Regional Research Agronomy Network. Department of Agriculture, Fisheries and Forestry Queensland, pp. 112 – 117, http://www.moreprofitperdrop.com.au/wp-content/uploads/2016/08/RANsTrials2015-screen.pdf

11 FC Hoyle, JA Baldock, DV Murphy (2011) Soil organic carbon: Role in rainfed farming systems. In PG Tow, I Cooper, I Partridge, C Birch (eds). Rainfed farming systems. Springer, pp. 339–361.

12 RC Dalal, RJ Mayer (1986) Long term trends in fertility of soils under continuous cultivation and cereal cropping in southern Queensland. II. Total organic carbon and its rate of loss from the soil profile. Australian Journal of Soil Research 24, 281–292.

Clearly, time and good sources of both carbon and nitrogen are required to build up SOM, which is exactly what the 4-year grass–legume ley provided. Nitrogen was supplied via N_2 fixation by the lucerne and annual medic in the pasture, with most of the carbon supplied by the grasses, purple pigeon grass and Rhodes grass. There were no inputs of fertiliser nitrogen in any of the treatments in Table 1. [13]

Table 1: *Effects of different rotations on soil total N and organic C (t/ha) to 30 cm and as gain relative to continuous wheat.*

Rotation	Wheat crops	Soil total N		Organic C	
		0-30 cm	Gain	0-30 cm	Gain
Grass/ legume ley 4 years	0	2.91	0.55	26.5	4.2
Lucerne ley (1-2 years)	2-3	2.56	0.20	23.5	1.2
Annual medic ley (1-2 years)	2-3	2.49	0.13	23.1	0.8
Chickpeas (2 years)	2	2.35	0.00	22.0	0.0
Continuous wheat 4 years	4	2.36	-	22.3	-

Source: Hossain et al. 1996a.

Further research was initiated in 2012 to identify cropping practices that have the potential to increase or maintain soil organic carbon and soil organic matter levels at the highest levels possible in a productive cropping system. Paired sampling has shown that returning cropping country to pasture will increase soil carbon levels (Figure 6). However, there were large variations in carbon level increases detected, indicating not all soil types or pastures preform the same. Soil type influences the speed by which carbon levels change, i.e. a sandy soil will lose and store carbon faster than a soil high in clay. As too does the quality and productivity of the pasture, maximising dry matter production by ensuring adequate nutrition (especially in terms of nitrogen and phosphorus) will maximise increases in soil carbon over time. Current research in Queensland being undertaken by the Department of Agriculture, Fisheries and Forestry (DAF) is indicating that the most promising practice to date to rebuild soil carbon stocks, in the shortest time frame, is the establishment of a highly productive pasture rotation with annual applications of nitrogen fertiliser, however, adding an adapted legume is also effective. [14]

13 D Herridge (2011) Managing legume and fertiliser N for northern grains cropping. Revised 2013. GRDC, https://grdc.com.au/uploads/documents/Managing-N-for-Northern-Grains-Cropping.pdf

14 DAF (2016) Queensland Grains Research – 2015. Regional Research Agronomy Network. Department of Agriculture, Fisheries and Forestry Queensland, pp. 112 – 117, http://www.moreprofitperdrop.com.au/wp-content/uploads/2016/08/RANsTrials2015-screen.pdf

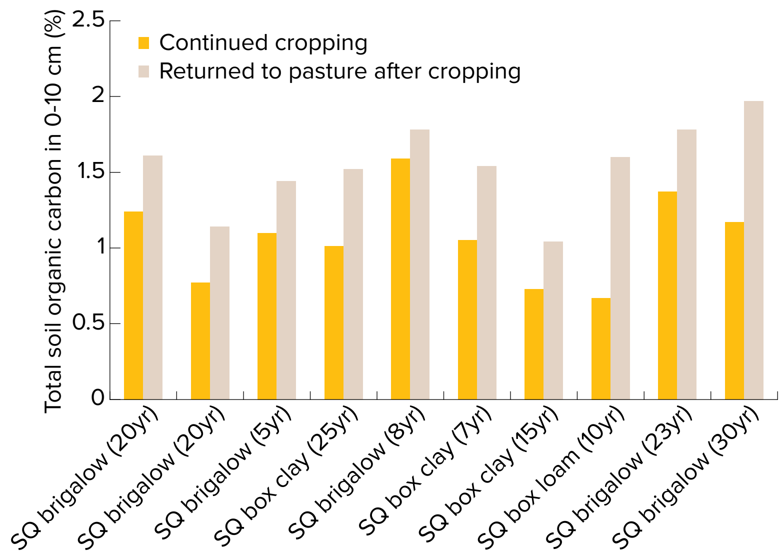

Figure 6: *Total organic carbon comparisons for croplands resown to pasture 15*

Impact of fertiliser N inputs on soil

If the rates of fertiliser N are sufficiently high, the effects can be positive. In the Warra experiments, both soil organic C and total N increased marginally (3–4%) over an 8-year period when no-till, continuous wheat, fertilised at a rate of 75 kg N/ha, was grown. This is in contrast with decreases of 10–12% in soil organic C and N in the non-fertilised, continuous wheat and chickpea–wheat plots. The result was much the same in NSW Department of Primary Industries experiments in northern NSW. At the Warialda site, for example, SOM increased during 5 years of cropping but only where fertiliser N had been applied to the cereals.

It is clear from the above examples that building SOM requires N. It works in two ways. First, the fertiliser or legume N produces higher crop/pasture yields and creates more residues that are returned to the soil. Then, these residues are decomposed by the soil microbes, with some eventually becoming stable organic matter or humus. The humus has a C/N ratio of about 10:1, i.e. 10 atoms of C to 1 atom of N. If there are good amounts of mineral N in the soil where the residues are decomposing, the C is efficiently locked into microbial biomass and then into humus.

If, on the other hand, the soil is deficient in mineral N, then more of the C is respired by the soil microbes and less is locked into the stable organic matter. [16]

5.2 Crop removal rates

Balancing inputs

A balance-sheet approach to fertiliser inputs is a good starting point for considering the amount of fertiliser to apply to your faba bean crop. Other factors such as soil type, paddock history, soil test and tissue analysis results, as well as your own experience, affect the choice of fertiliser to be used.

The nutrients removed by 1 t of grain by the various pulses is shown in Table 1. Actual values may vary by 30% or sometimes more, due to the differences in soil fertility,

15 DAF (2016) Queensland Grains Research – 2015. Regional Research Agronomy Network. Department of Agriculture, Fisheries and Forestry Queensland, pp. 112 – 117, http://www.moreprofitperdrop.com.au/wp-content/uploads/2016/08/RANsTrials2015-screen.pdf

16 D Herridge (2011) Managing legume and fertiliser N for northern grains cropping. Revised 2013. GRDC, https://grdc.com.au/uploads/documents/Managing-N-for-Northern-Grains-Cropping.pdf

varieties and seasons. For example, the P per tonne removed by faba bean grain can vary from a low 2.8 kg on low fertility soils to 5.4 kg on high fertility soils.

From the Table 2, it can be seen that a 3 t/ha crop of faba beans will remove (on average) 12 kg/ha of P. This, then, is the minimum amount of P that needs to be replaced. Larger quantities may be needed to build up soil fertility or overcome soil fixation of P.

Table 2: *Nutrient removed by 1 t of grain.*

	N	P	K	S	Ca	Mg	Cu	Zn	Mn
Grain			**(kg)**				**(g)**		
Pulses									
Chickpea (Desi)	33	3.2	9	2.0	1.6	1.4	7	34	34
Chickpea (Kabuli)	36	3.4	9	2.0	1.0	1.2	8	33	22
Faba bean	41	4.0	10	1.5	1.3	1.2	10	28	30
Lentil	40	3.9	8	1.8	0.7	0.9	7	28	14
Lupin (sweet)	53	3.0	8	2.3	2.2	1.6	5	35	18
Lupin (white)	60	3.6	10	2.4	2.0	1.4	5	30	60
Field pea	38	3.4	9	1.8	0.9	1.3	5	35	14
Cereals									
Wheat	23	3.0	4	1.5	0.4	1.2	5	20	40
Barley	20	2.7	5	1.5	0.3	1.1	3	14	11
Oats	17	3.0	5	1.6	0.5	1.1	3	17	40

Source: Grain Legume Handbook.

Soil types vary in their nutrient reserves. For example, most black and red soils have sufficient reserves of K to grow many crops. However, the light, white sandy soils which, on soil test, have <50 µg/g (bicarbonate test) of K will respond to applications of K fertiliser. On some of the more highly sodic soils, K levels need to be higher to counteract the amount of sodium in the soil profile. Other soils may have substantial nutrient reserves that vary in availability during the growing season or are unavailable because of the soil's pH. This is often the case with micronutrients. Foliar sprays can be used in these cases to correct micronutrient deficiencies.

Nutrient budgeting

Even a simple nutrient budget, such as shown in Table 3, requires careful interpretation.

Table 3: *An example nutrient budget.*

Year	Crop	Yield (t/ha)	Nutrients removed (kg/ha)			
			N	P	K	S
2006	Faba bean	2.2	90	8.8	22	3.3
2007	Wheat	3.8	87	11.4	15	5.7
2008	Barley	4.2	84	11.3	21	6.3
2009	Chickpea	1.8	59	5.8	16	3.6
Total			**320**	**37.3**	**74**	**18.9**
	Fertiliser	**Rate (t/ha)**	**Nutrients applied (kg/ha)**			
			N	**P**	**K**	**S**
2006	0 : 20 : 0 (NPK)	50	0	10	0	1
2007	18 : 20 : 0 (NPK)	70	12.6	14	0	1
2008	18 : 20 : 0 (NPK)	70	12.6	14	0	1
	Urea	60	27.6	0	0	0
2009	0 : 16 : 0 : 20 (NPKS)	80	0	12.8	0	16
		Total	**52.8**	**50.8**	**0**	**19**
Balance			**–267.2**	**+13.5**	**–74**	**0**

Source: GRDC Grain Legume Handbook.

Nitrogen: The deficit of 267 kg needs to be countered by any N_2 fixation that occurred. This may have been 50 kg/ha per legume crop. It still shows that the N status of the soil is declining and should be increased by using more N in the cereal phase. Nitrogen fixation and application for faba beans is detailed below (see 5.5 Fertiliser).

Phosphorus: The credit of 13 kg will be used in the soil in building P levels, hence increasing soil fertility. No account was made for soil fixation of P.

Potassium: Because most Australian soils have ample K, drawing down the levels without replacing K is legitimate. However, some Australian cropping soils (usually white sandy soils) are showing responses to K, and applications should be considered to replace the K used by the crop.

Sulfur (S): The S inputs and removals are in balance.

Other nutrients such as zinc (Zn) and copper (Cu) can be included in a nutrient-balancing exercise. This is a useful tool for assessing the nutrient requirements of a cropping rotation; however, it needs to be considered in conjunction with other nutrient management tools such as soil and tissue testing, soil type, soil fixation and potential yields.

There are many fertilisers available to use on pulses. For the best advice, check with your local fertiliser reseller or agronomist.

5.3 Soil testing

It is a common belief that a soil or plant tissue test will show how much nutrient is required by the plant, but this is not so. A soil test will show only that, at a certain soil concentration, the plant will or will not respond to that nutrient. These tests are specific for both the soil type and the plant being grown.

MORE INFORMATION

http://www.grdc.com.au/Research-and-Development/Major-Initiatives/More-Profit-from-Crop-Nutrition

http://www.publish.csiro.au/pid/5352.htm

MORE INFORMATION

http://grdc.com.au/Resources/Factsheets/2013/11/Better-fertiliser-decisions-for-crop-nutrition

www.grdc.com.au/GRDC-FS-SoilTestingN

https://grdc.com.au/uploads/documents/Managing-N-for-Northern-Grains-Cropping.pdf

Experience suggests that the only worthwhile soil tests will be for P, K, organic matter, soil pH and soil salt levels. [17]

In northern cropping soils, nutrient deficiencies other than N are a relatively recent development. Consequently, less research has been conducted into nutrients in these soils and for the many crop types grown in northern cropping systems than in other regions. Most research has been done in wheat and barley.

For instance, research has highlighted that N applications can be wasted, even on cropping soils that have low N availability, if the levels of other nutrients such as K, P and S are not adequate. The importance of subsoil layers for nutrients such as P and K is not yet reflected in the limited soil test-crop response data available.

Researchers are currently using rough rules of thumb to help interpret P and K soil tests in terms of likely fertiliser responsiveness on northern region Vertosols. These values will be refined as more nutrient information becomes available during the second phase of the Grains Research and Development Corporation (GRDC) 'More Profit from Crop Nutrition' (MPCN) program.

5.3.1 Types of soil test

It is important to understand how faba beans will respond to different soil types and the background levels of nutrients required for the coming season requirements.

Appropriate soil tests for measuring soil extractable or plant-available nutrients in the northern cropping region are:

- bicarbonate-extractable P (Colwell-P), to assess easily available soil P
- acid-extractable P (BSES-P), to assess slower release soil P reserves and the build-up of fertiliser residues (not required annually)
- exchangeable K
- KCl-40 extractable S or monocalcium phosphate (MCP)-S
- 2 M KCl extractable mineral N, to provide measurement of nitrate-N and ammonium-N

The more consideration we give to all of the activities that contribute to the nutrient-management process (Figure 7), the better the outcome we will get from soil and plant testing. Testing may not provide a useful contribution if one or more of these activities is not done well. [18]

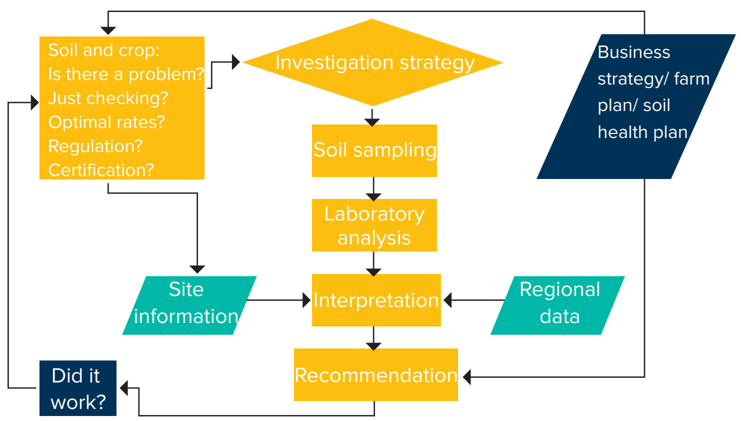

Figure 7: *Nutrient management flow chart.*

17 GRDC (1998) Nutrition. Grain Legume Handbook. GRDC, http://www.grdc.com.au/uploads/documents/4%20Nutrition.pdf

18 Northern Faba Bean—Best Management Practices Training Course 2014. Pulse Australia.

5.4 Nutrition

Too little or too much of a nutrient, or incorrect proportions of nutrients, can cause nutritional problems. If the condition is extreme, plants will show visible symptoms that can sometimes be identified. Visual diagnostic symptoms are readily obtained and provide an immediate evaluation of nutrient status. Visual symptoms do not develop until a major effect on yield, growth or development has occurred; therefore, damage can be done before there is visual evidence.

Healthy plants are more able to ward off disease, pests and environmental stresses, leading to higher yields and better grain quality. A plant tissue analysis can be important in detecting non-visible or subclinical symptoms, and in fine-tuning nutrient requirements. This is particularly helpful where growers are aiming to capitalise on available moisture.

Tissue tests also help to identify the cause of plant symptoms that are expressed by plants but not readily attributable. Technology is enabling quicker analysis and reporting of results to enable foliar- or soil-applied remedies to be used in a timely manner for a quick crop response.

Identifying nutrient deficiencies

Many nutrient deficiencies may look similar:

- Know what a healthy plant looks like in order to recognise symptoms of distress.
- Determine what the affected areas of the crop look like. For example, are they discoloured (yellow, red, brown etc.), dead (necrotic), wilted or stunted.
- Identify the pattern of symptoms in the field (patches, scattered plants, crop perimeters).
- Assess affected areas in relation to soil type (pH, colour, texture) or elevation.
- Look at individual plants for more detailed symptoms such as stunting, wilting and where the symptoms are appearing (whole plant, new leaves, old leaves, edge of leaf, veins, etc.).

If more than one problem is present, typical visual symptoms may not occur. For example, water stress, disease or insect damage can mask a nutrient deficiency. If two nutrients are simultaneously deficient, symptoms may differ from those when one nutrient alone is deficient. Micronutrients are often used by plants to process other nutrients, or work together with other nutrients, so a deficiency of one may look like a deficiency of another. For instance, molybdenum (Mo) is required by pulses to complete the N_2-fixation process.

MORE INFORMATION

http://www.publish.csiro.au/sr/SR9820265

Nutrient types

Plant nutrients are categorised as either macronutrients or micronutrients (also called trace elements or trace amounts).

Macronutrients are those elements that are needed in relatively large amounts. They include N, P and K, which are the primary macronutrients, with calcium (Ca), magnesium (Mg) and S considered secondary. Higher expected yields of crops for grain or forage will place greater demand on the availability of major nutrients such as P, K and S. Nitrogen, P and at times sulfur are the main nutrients commonly lacking in Australian soils. Others can be lacking under certain conditions. Each pulse type is different, has different requirements for nutrients, and may display different symptoms.

A balance sheet approach to fertiliser inputs is often a good starting point when determining the amount and type (analysis) of fertiliser to apply. A soil test, paddock history, soil type, and personal or local experience can all help. Tissue analysis can be helpful in identifying any deficiencies once the crop is growing, and can assist in fine-tuning nutrient requirement even when deficiency symptoms are not visible.

Micronutrients are those elements that plants need in small amounts, such as iron (Fe), boron (B), manganese (Mn), Zn, copper (Cu), chlorine (Cl) and Mo.

Both macro- and micronutrients are taken up by roots and they require certain soil conditions for uptake to occur:

- Soil must be sufficiently moist to allow roots to take up and transport the nutrients. Plants that are moisture-stressed from too little or too much (saturation) moisture can often exhibit deficiencies even though a soil test may show these nutrients to be adequate.
- Soil pH affects the availability of most nutrients and must be within a particular range for nutrients to be released from soil particles. On acid soils, aluminium (Al) and Mn levels can increase and may restrict plant growth, usually by restricting the rhizobia and thus the plant's ability to nodulate.
- Soil temperature must be within a certain range for nutrient uptake to occur. Cold conditions can induce deficiencies such as of Zn or P.

The optimum range of temperature, pH and moisture can vary for different pulse species. Thus, nutrients may be physically present in the soil, but not available to those particular plants. Knowledge of a soil's nutrient status (soil test) pH, texture, history and moisture status can be useful for predicting which nutrients may become deficient. Tissue tests can help to confirm the contents of individual nutrients in the plant. [19]

5.4.1 Balancing inputs

If the nutrients (P, N, Zn, etc.) that are removed in grain from the paddock are not replaced (via fertiliser), then crop yields and soil fertility will decline.

This means that fertiliser inputs must be matched to expected yields and soil type. The higher the expected yield and therefore nutrient removal, the higher the fertiliser input, particularly for the major nutrients (i.e. P, K and S).

For example, P removed by faba bean grain can vary from a low 2.8 kg/t on low-fertility soils to 5.4 kg/t on high-fertility soils.

5.4.2 Nutrient budgeting

Nutrient budgeting is a simple way to calculate the balance between nutrient removal (via grain) and nutrient input (via fertiliser).

For an accurate guide to nutrient removal, use analysis of grain grown on your farm. The best picture emerges when several years of a rotation are budgeted.

Because P is the basis of soil fertility and hence crop yields, all fertiliser programs are built on the amount of P needed. Table 4 shows examples of P rates required, and the rates of various fertilisers needed to achieve this.

There is a recent trend to use 'starter' fertilisers such as mono-ammonium phosphate (MAP) and di-ammonium phosphate (DAP) on pulses. Some growers are concerned that use of N on their pulse crop will affect nodulation; this will not occur with the low rates of N supplied by MAP or DAP. In fact, early plant vigour is often enhanced on low-fertility soils, and yield increases have been gained. [20]

19 Northern Faba Bean—Best Management Practices Training Course 2014. Pulse Australia.

20 Northern Faba Bean—Best Management Practices Training Course 2014, Pulse Australia.

Table 4: *Fertiliser application rate ready-reckoner (all rates are kg/ha) for some phosphate fertilisers used on pulses.*

P rate	Superphosphate Single 8.6% P		Superphosphate Gold Phos 10 18% P		Superphosphate Triple 20% P		Legume Special 6 : 16 : 0 : 10 (NPKS)			MAP 10 : 22 : 0 (NPS)		DAP 18 : 20 : 0 (NPS)		Grain Legume Super 0 : 15 : 0 : 7 (NPKS)	
	Fert.	S	Fert.	S	Fert.	S	Fert.	N	S	Fert.	N	Fert.	N	Fert.	S
10	116	13	50	5	45	0.7	62	4	6	46	5	50	9	69	5
12	140	15	67	7	60	0.9	75	4	8	55	6	60	11	83	6
14	163	18	78	8	70	1.1	87	5	9	64	6	70	13	97	7
16	186	20	89	9	80	1.2	99	6	10	73	7	80	14	110	8
18	209	23	100	10	90	1.4	112	6	11	82	8	90	16	124	9
20	223	25	111	11	100	1.5	124	7	12	91	9	100	18	138	10
22	256	28	122	12	110	1.7	137	8	14	100	10	110	20	152	11
24	279	31	133	13	120	1.8	149	8	15	110	11	120	22	166	12

5.4.3 Detecting nutrient deficiencies

Soil tests are specific for both the soil type and the plant being grown (Table 5). The most useful soil tests are for P, K, organic matter, soil pH and salt levels. A test for S has now been developed. The pulse crops can have different requirements for K; hence, they have different soil test K critical levels.

Table 5: *Adequate levels (µg/g) for various soil test results.*

Nutrient	Test used		
Phosphorus			
	Colwell	Olsen	
Sand	20–30	10–15	
Loam	25–35	12–17	
Clay	35–45	17–23	
Potassium			
	Bicarb.-extractable	Skene	Exchangeable K
Sand	50	50 100	Not applicable
Other soils	100	–	0.25 cmol(+)/kg
Sandy loam	–	–	–
Faba bean	100–120	–	–
Field pea	70–80	–	–
Lupin	30–40	–	–
Canola	40	–	–
Cereals	30	–	–
Sulfur			
	KCl		
Low	5		
Adequate	8		

Source: Grain Legume Handbook.

Plant tissue testing can also be used to diagnose a deficiency or monitor the general health of the pulse crop. Plant tissue testing is most useful for monitoring crop health, because the yield potential can be markedly reduced by the time noticeable symptoms appear in a crop.

Several companies perform plant tissue analysis and derive accurate analytical concentrations; however, it can be difficult to interpret the results and determine a course of action. As with soil tests, different plants have different critical concentrations for a nutrient, and in some cases varieties can vary in their critical concentrations.

Table 6 lists the plant analysis criteria for faba beans. These should be used as a guide only, and plant tissue tests should be used for the purpose for which they have been developed. Most tests diagnose the nutrient status of the plants only at the time they are sampled, and cannot reliably indicate the effect of a particular deficiency on grain yield.

Table 6: *Critical nutrient levels for faba beans at flowering.*

Nutrient	Plant part	Critical range
Nitrogen (%)	YOL	4.0
Phosphorus (%)	YOL	0.4
Potassium (%)	YML	1.0
Calcium (%)	YML	0.6
Magnesium (%)	YML	0.2
Sulfur (%)	Whole shoot	0.2
Boron (mg/kg)	YOL	10
Copper (mg/ka)	YML	3.0–4.0
Manganese (mg/kg)	YML	<40
Zinc (mg/kg)	YOL	20–25

YOL, Youngest open leaf blade; YML, youngest mature leaf. Any nutrient level below the critical range will be deficient; any level above will be adequate

5.4.4 Diagnosing nutrient disorders

Table 7 summarises the symptoms of nutrient deficiencies in faba bean leaves of various ages.

Table 7: *Key to nutrient deficiencies in faba beans.*

Symptom	Old to middle leaves						Middle to new leaves					New leaves to terminal shoots					
Deficiency:	**N**	**P**	**S**	**K**	**Mg**	**Zn**	**N**	**Mg**	**Mn**	**Zn**	**B**	**Mn**	**Fe**	**Zn**	**Cu**	**Ca**	**B**
Chlorosis (yellowing)																	
Complete	x		x									x#	x				x#
Mottled	x	x	x		x					x	x						
Interveinal					x						x						
On margins			x		x												
Necrosis (tissue death)																	
Complete		x				x											
Distinct areas (including spotting)				x		x		x	x		x	x		x			
Margins													x			x	
Tips				x		x			x			x		x	x		
Pigmentation within necrotic (yellow) or chlorotic (dead) areas																	
Purple	x	x	x	x		x		x	x	x		x				x	
Dark green		x									x						
Brown		x	x						x		x	x	x	x			
Red					x						x			x			
Malformation of leaflets																	
Rolling in of margin				x				x					x			x	x
Wilting		x													x		
Twisting									x			x			x		x
Malformation of leaves																	
Cupping	x						x								x		
Umbrella formation								x			x						
Malformation of stems and roots																	
Internode shortening											x			x			x
Petiole collapse																x	
Root distortion											x		x			x	x

#, Mild

Source: Symptoms of nutrient disorders: faba beans and field peas. (Snowball and Robson 1991).

5.4.5 Nutrient toxicity

Soil pH has an effect on the availability of most nutrients. Occasionally, some nutrients are so available that they inhibit plant growth. For example on some acid soils, Al and Mn levels may restrict plant growth, usually by inhibiting the rhizobia and so the plants ability to nodulate (Table 8, Figure 8).

Table 8: *Pulse reactions to nutrient toxicities.*

	Boron	Aluminium	Manganese
Chickpeas	Sensitive	Very sensitive	Very sensitive
Faba beans	Tolerant	Sensitive	Sensitive
Lentils	Very sensitive	Very sensitive	Very sensitive
Lupins	Very sensitive	Tolerant	Tolerant
Field peas	Sensitive	Sensitive	Sensitive

Lentils and lupins are not usually grown on alkaline–high boron soils

Figure 8: *Similarity of visual toxicity symptoms of manganese (left), boron (centre) and phosphorus (right) in old and middle leaves of faba bean.*

Photo: A. Robson

5.4.6 Boron toxicity

Boron toxicity occurs on many of the alkaline soils of the southern cropping areas. The most characteristic symptom of boron toxicity in pulses is chlorosis (yellowing), and if severe, some necrosis (death) of leaf tips or margins (Figure 9). Older leaves are usually more affected. There appears to be little difference in reaction between current varieties of faba beans.

Shallow (0–10 cm) and deep (10–90 cm) soil tests can be a good guide to the suitability of some soils for growing faba beans and to the toxicities that may affect plant growth and rooting depth.

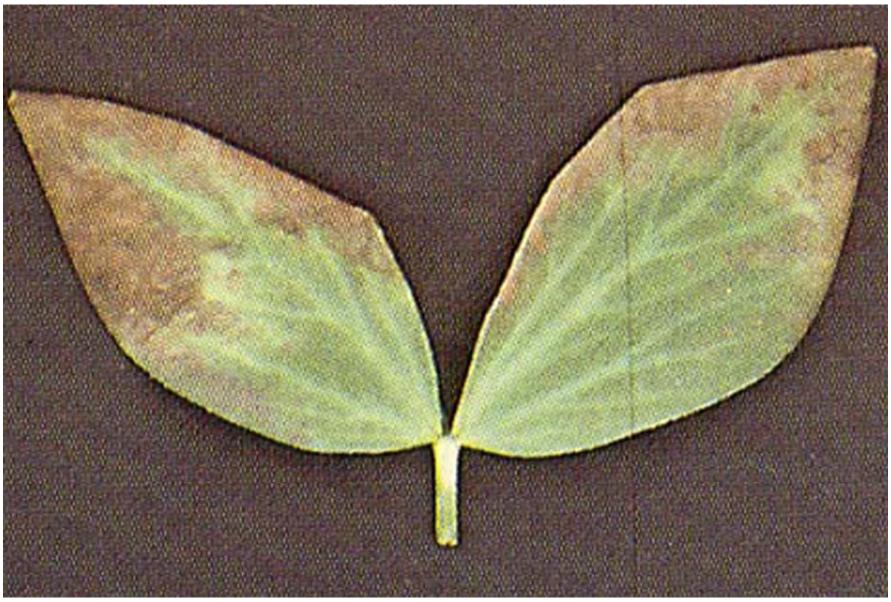

Figure 9: *Boron toxicity in old and middle faba bean leaves.*

Photo: A Robson

5.4.7 Manganese toxicity

Manganese toxicity can occur in well-nodulated faba beans grown on soils of low pH.

Symptoms

Symptoms appear on new leaves first and can then develop in middle-age and older leaves, the opposite to other toxicities such as Mn or P. Small purple spots appear from the margins on young leaves, and in slightly older leaves take on a reddish colouration (Figure 10).

Figure 10: *Manganese toxicity in young leaves (left) and in middle-age leaves (right) of faba bean.*

Photos: A. Robson

5.4.8 Aluminium toxicity

Aluminium toxicity can develop in faba beans that are well nodulated but grown on soils of low pH.

Visual symptoms

There are no visual symptoms of Al toxicity in faba beans other than delayed germination and plants appearing miniature and dark green. Roots are extremely stunted, with many laterals appearing dead. Symptoms may be confused with P deficiency. [21]

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5.5 Fertiliser

5.5.1 Overview

Faba beans have a high P requirement. Phosphorus should be applied at rates of at least 12 and up to 22 kg/ha for this crop. On black soils of pH >8, Zn deficiencies can be caused by these high P rates. Zinc can be applied either with the fertiliser at sowing or as a foliar spray.

Faba beans appear more susceptible to K deficiency than other pulses such as peas and, especially, lupins.

Fertiliser recommendations for faba beans, as with most pulses, tend to generic, with an over-reliance on the recommendation of MAP-based starter fertilisers across nearly all situations. This is often based more on convenience and availability, rather than meeting the specific nutrient requirements of the crop.

Fertiliser recommendations need to be more prescriptive, and should take into account:

- soil type
- rotation (fallow length and impact on arbuscular mycorrhizae fungi (AMF) levels)
- yield potential of the crop
- plant configuration (row spacing, type of opener and risk of'seed burn')
- soil analysis results
- effectiveness of inoculation techniques

Molybdenum and cobalt (Co) are required for effective nodulation and should be applied as needed.

Soil P levels influence the rate of nodule growth. The higher the P level the greater the nodule growth.

MAP or DAP fertilisers can be used because fertilisers containing N in small amounts (5–15 kg N/ha) are not harmful to nodulation and can be beneficial by extending the early root growth to establish a stronger plant.

Excessive applied N will restrict nodulation and reduce N_2 fixation. High background levels of soil N can have similar effects or delay nodulation until N levels are depleted.

Inoculated seed and acidic fertilisers should not be sown down the same tube. The acidity of some fertilisers will kill large numbers or rhizobia. Neutralised and alkaline fertilisers can be used.

Acid fertilisers include:

- superphosphates (single, double, triple)
- fertilisers with Cu and/or Zn included
- MAP (also known as 11 : 23 : 0 and Starter 12)

Neutral fertilisers include:

- Super Lime

Alkaline fertilisers include:

- DAP (also known as 18 : 20 : 0)
- starter NP
- lime

5.5.2 Pulses and fertiliser toxicity

All pulses can be affected by fertiliser toxicity. Lupins are especially susceptible to higher rates of P fertiliser, which are toxic to lupin establishment and nodulation if drilled in direct contact with the seed at sowing.

Drilling 10 kg/ha of P with the seed at 18-cm row spacing through 10-cm points rarely causes problems. However, changes in sowing techniques to narrow sowing points or disc-seeders with minimal soil disturbance, and wider row spacing, have increased rates of fertiliser (all of which concentrate the fertiliser near the seed in the seeding furrow) and increase the risk of toxicity.

The effects are also increased in highly acidic soils, sandy soils and where moisture conditions at sowing are marginal. Drilling concentrated fertilisers to reduce the product rate per hectare does not reduce the risk.

The use of starter N (e.g. DAP) banded with the seed when sowing pulse crops may reduce establishment and nodulation if higher rates are used. On sandy soils, up to 10 kg/ha of N at 18-cm row spacing can be safely used. On clay soils, do not exceed 20 kg/ha of N at 18-cm row spacing.

Deep banding of fertiliser is often preferred for lupins, or else broadcasting and incorporating, drilling pre-seeding or splitting fertiliser applications so that a lower rate or no P is in contact with the seed.

5.5.3 Nitrogen

Fertilisation with N is unnecessary for faba beans, because the crop can meet its N needs through biological N_2 fixation in nodules formed on the roots, unless a nodulation failure has occurred.

On the other hand, soil nitrate inhibits legume nodulation and N_2 fixation. At low nitrate levels of <50 kg N/ha in the top 1.2 m of soil, the legume's reliance on N_2 fixation is generally high. As soil nitrate levels increase, legume nodulation and N_2 fixation become increasingly suppressed. However, the suppression effect is much less pronounced on faba beans than chickpeas.

Deficiency symptoms

First sign of N deficiency in faba beans is a general paleness of the whole plant, even before a reduction in plant growth. There may be a cupping of the middle to new leaves. With time, a mottled chlorosis of old leaves slowly develops with little sign of necrosis (Figures 11 and 12).

Check for nodulation and for whether nodules are fixing N_2 (nodule colour), to confirm suspected N deficiency from visual plant symptoms.

Figure 11: *Nitrogen deficiency—plants show signs of stunting, yellowing and poor growth relative to well-nodulated plants.*

Photo: W. Hawthorne, Pulse Australia

Figure 12: *When plants show signs of stunting, yellowing and poor growth, check nodulation and nodule colour to confirm nodulation failure and nitrogen deficiency.*

Photo: W. Hawthorne, Pulse Australia

Some situations where N fertiliser may warrant consideration include:

- The grower is unwilling to adopt recommended inoculation procedures.
- Late or low fertility situations, where rapid early growth is critical in achieving adequate height and sufficient biomass to support a reasonable grain yield (Table 9).

Table 9: *Nitrogen balance.*

Total plant dry matter (t/ha)	Total shoot dry matter yield (t/ha)	Grain yield (t/ha) 40% HI	Total crop nitrogen requirement (2.3% N) kg/ha	Nitrogen removal in grain (kg/ha)
1.75	1.25	0.5	40	17
3.50	2.50	1.0	80	33
5.25	3.75	1.5	120	50
7.00	5.00	2.0	160	66
8.75	6.25	2.5	200	83
10.50	7.50	3.0	240	100

HI, Grain harvest index—grain yield as a percentage of total shoot dry matter production (averages ~40%

Faba bean grain contains about 40 kg N/t.

5.5.4 Phosphorus

Deficiency symptoms

Symptoms of P deficiency take time to develop because of initial seed reserves of P. When symptoms start to appear, large differences in growth are apparent and smaller leaves compared with P-adequate plants. Visual symptoms appear first on the oldest pair of leaves as a mildly mottled chlorosis over much of the leaf. These symptoms could be confused with N or S deficiency, but middle and new leaves remain a healthy green, so the whole plant does not appear pale.

As symptoms on old leaves develop, round purple spots may appear within areas of dark green in an otherwise mildly chlorotic leaf (Figure 13).

Note that faba beans are deemed very responsive to P fertiliser, but Zn status must be adequate to achieve a P response. [22]

Figure 13: *Symptoms of phosphorus deficiency in old leaves of faba bean. Note the spotting within darker green areas of an otherwise mildly chlorotic leaf.*

Photo: A. Robson

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5.5.5 Potassium

Deficiency symptoms

Older leaflets show symptoms first, and initially growth is stunted compared with other parts of the paddock, eg in old stubble rows. Older leaves show a slight curling and then a distinct greying of leaf margins, eventually dying (Figures 14–19).

Figure 14: *Potassium deficiency in faba beans. Note the necrosis of leaf margins and purple blotching.*

Photo: Grain Legume Handbook

Figure 15: *Potassium deficiency in faba bean (left and middle, alongside a plant with adequate K taken from the same paddock but from within old cereal stubble rows from the harvester.*

Photo: W. Hawthorne, Pulse Australia

Figure 16: *Potassium deficiency in Faba bean leaflet.*

Photo: A. Robson

Figure 17: *Potassium deficiency in faba beans. Note loss of lower leaves and general poorer height and vigour compared with K-adequate plants from the same paddock shown in Figures 18 and 19.*

Photo: W. Hawthorne, Pulse Australia

Figure 18: *Faba beans with adequate potassium taken from the same paddock as Figures 17 and 19, but from within old header rows of canola stubble.*

Photo: W. Hawthorne, Pulse Australia

Figure 19: *Potassium deficiency in faba beans shows up as poorer strips between old header rows from canola stubble (centre right of shovel and far left). Healthy strips are where canola stubble was left by the harvester (centre left of shovel and far right). See Figures 17 and 18.*

Photo: W. Hawthorne, Pulse Australia.

Responses to K are unlikely on most black earths and grey clays; K fertilisers may be warranted on red earths (Ferrosols) but should be based on soil analysis.

Fertiliser responses are likely where soil test levels using the ammonium acetate test fall below:

- 0.25 cmol(+)/kg of exchangeable K on black earths and grey clays
- 0.40 cmol(+)/kg of exchangeable K on red earths and sandy soils

Applying 20–40 kg K/ha banded 5 cm to the side of, and below, the seed line is recommended where soil test levels are critically low.

Alternatively, blends such as Crop King 55 (NPK, 13 : 13 : 13) may be considered at rates of 80–120 kg/ha where K levels are marginal.

5.5.6 Sulfur

Deficiency symptoms

Youngest leaves turn yellow, and plants are slender and small (Figure 20).

Certain soil types are prone to S deficiency, e.g. some basaltic, black earths. On these soils with marginal S levels, deficiency is most likely to occur in double-crop situations where available S has become depleted to very low levels, for example when double-cropping faba beans after high-yielding sorghum or cotton crops.

Soil sampling to a depth of 60 cm is the recommended procedure to test for S. A soil analysis of available sulfate-S below 5 mg/kg (MCP test) indicates a likely response. Below 3 mg/kg is considered critically low.

Application of 5–10 kg S/ha will normally correct an S deficiency. Where soil P levels are adequate, a low rate of gypsum is the most cost-effective, long-term method of correcting S deficiency. Granulated sulfate of ammonia is another effective option where low rates of N are also required.

Figure 20: *Sulfur deficiency in faba beans shows up as chlorosis of leaf edges (left photo) and can progress to necrosis within those chlorotic areas (right photo).*

Photos: A. Robson

5.5.7 Zinc

Note that faba beans are deemed very responsive to Zn fertiliser, but P status must be adequate to achieve a Zn response.

Deficiency symptoms

Plants are small; the areas between veins turn yellow, becoming yellower on the lowest leaves. Maturity can be delayed (see Figures 21–25).

Faba beans are considered to have a relatively high demand for Zn, but have evolved highly efficient mechanisms for extracting Zn from the soil (similar to the previous discussion on P).

Foliar application of Zn is relatively common, often fitting in with herbicide or early fungicide applications.

There is a lack of Australian and overseas research on Zn responses in faba bean. Zn fertiliser recommendations are conservatively based on a general recommendation used for all crops, based on DTPA analysis of soil samples 0–10 cm:

- <0.8 mg/kg on alkaline soils
- <0.3 mg/kg on acid soils

AMF can be extremely important to Zn nutrition in faba beans, and responses can be expected in situations where AMF levels have become depleted after long fallows (>8–10 months).

Pre-plant treatments

Severe Zn deficiency can be corrected for 5–8 years with a soil application of zinc sulfate monohydrate of 15–20 kg/ha, worked into the soil 3–4 months before sowing.

Zinc is not mobile in the soil and needs to be evenly distributed over the soil surface, and then thoroughly cultivated into the topsoil.

In the first year after application, the soil-applied zinc sulfate monohydrate may be not fully effective and a foliar Zn spray may also be required.

Seed treatments

Zinc seed treatments may be a cost-effective option where soil P levels are adequate but Zn levels are likely to be deficient.

Broadacre Zinc (Agrichem)

Contains 650 g Zn/L and is applied as 4 L product /t seed. Pre-mix with 1 L water prior to application.

To minimise damaging effects on the rhizobia, Broadacre Zinc treatment needs to be applied first and then allowed to dry before applying the inoculum.

Broadacre Zinc is compatible with either Thiraflo or P-Pickel T®, and the two products can be mixed to treat faba bean seed in the one operation, should it be required.

Teprosyn Zn (Phosyn)

Contains 600 g Zn/L and is applied as 4 L product/t seed (pre-mix with 2–3 L water to assist coverage).

Apply inoculum first and allow to dry before applying the Teprosyn.

Fertilisers applied at sowing

A range of phosphate-based fertilisers contain, or can be blended with, a Zn additive.

Foliar zinc sprays

A foliar spray of 1.0 kg zinc sulfate heptahydrate + 1.0 kg urea + 1200 mL of a non-ionic wetter (1000 g/L) in at least 100 L water/ha will correct a mild deficiency. One or two sprays will need to be applied within 6–8 weeks of emergence.

Hard water (high in carbonate) will produce insoluble sediment (zinc carbonate) when the zinc sulfate is dissolved, with the spray mix turning cloudy. Buffer back with L1-700 or Agri Buffa if only hard water is available. Zinc oxide products are highly alkaline with pH 9.5–10.5.

Figure 21: *Zinc deficiency in faba beans.*

Photo: Grain Legume Handbook

Figure 22: *Zinc-deficient faba beans (left) and those with adequate Zn applied as solid fertiliser at seeding or earlier foliar application (right).*

Photo: Grain Legume Handbook

Figure 23: *Zinc-deficient faba beans (far left and centre right) are paler and poorer grown than those with adequate Zn applied (centre left).*

Photo: Grain Legume Handbook

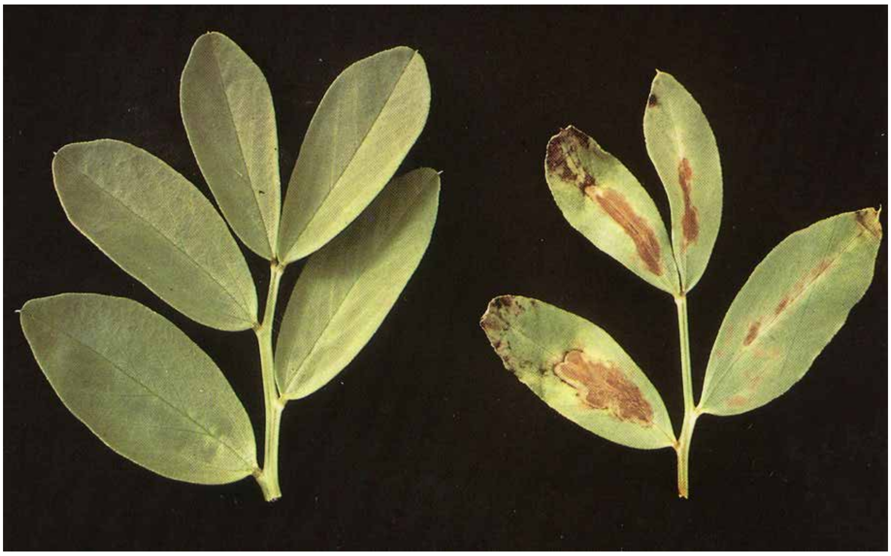

Figure 24: *Zinc-deficient middle leaves of faba bean (right).*

Photo: A. Robson

Figure 25: *Zinc-deficient leaves of faba bean—oldest to youngest (left to right).*

Photo: A. Robson

5.5.8 Iron

Iron deficiency can be confused with Mn and Mg deficiency. Iron is strongly immobile in plants.

Deficiency symptoms

Yellowing between leaf veins can progress to completely yellow plants (Figures 26 and 27). Contrast in colour between old and new leaves is much stronger with Fe deficiency than Mn deficiency.

Figure 26: *Iron deficiency showing in faba beans in wheel tracks.*

Photo: W. Hawthorne, Pulse Australia

Figure 27: *Bean varieties have different tolerances to Iron deficiency. Aquadulce (between the pegs) is more tolerant, but not immune compared to many other faba beans (e.g. left).*

Photo: Grain Legume Handbook

MORE INFORMATION

For detailed descriptions and images of nutrient deficiencies 'Faba bean: The Ute Guide', available from the GRDC book shop on the GRDC website

Occurrence and treatment

Iron deficiency is observed occasionally on alkaline, high pH soils. It is usually associated with a waterlogging event following irrigation or heavy rainfall, and is attributed to interference with Fe absorption and translocation to the foliage.

Symptoms include a general yellowing of young leaves, which can develop in severe cases to distortion, necrosis and shedding of terminal leaflets (pinnae).

A mixture of 1 kg/ha of iron sulfate + 2.5 kg/ha of crystalline sulfate of ammonia (not prilled) + 200 mL non-ionic wetter/100 L water has been successfully used to correct Fe deficiency.

The addition of sulfate of ammonia will improve absorption of Fe, with a significantly better overall response.

Cultivars exhibit marked differences in sensitivity to iron chlorosis, and major problems with Fe deficiency have largely been overcome through the efforts of the plant breeders. Whereas Tyson was highly sensitive to Fe deficiency, most current varieties are considered tolerant to all but extreme situations.

Iron deficiency symptoms tend to be transient, with the crop making a rapid recovery once the soil begins to dry out.

5.5.9 Manganese

Deficiency symptoms

Deficiency appears in new leaves, which first show mild chlorosis, followed by small dead spots or purple spotting at each side of the mid-rib and lateral veins. The leaves can turn yellow and die. See Image 4.22 to Image 4.25.

Some plants may have only a few brown spots on unopened new growth, where-as in other plants symptoms may extend to middle leaves and range from blackened tops of leaves and new growth to purple necrosis over much of the leaf (Figures 28–29).

Figure 28: *Manganese deficiency (right) in middle leaves of faba bean.*

Photo: A. Robson

Figure 29: *Manganese-deficient faba bean new leaves as they are opening (right).*

Photo: A. Robson

Figure 30: *Manganese-deficient faba bean new leaves and new growth.*

Photo: A. Robson

Figure 31: *Manganese-deficient faba bean middle leaf.*

Photo: A. Robson

Occurrence and treatment

Manganese deficiency is observed occasionally on alkaline, high pH soils. It is usually associated with a drier, fluffy soil conditions, for example rolled areas or wheel tracks in a paddock may appear healthy while the remainder shows Mn deficiency.

5.5.10 Copper

Copper has a role in cell wall constituents of plants.

Deficiency symptoms

Copper deficiency does not appear until flowering; hence, there is little effect on vegetative growth. The first symptom of Cu deficiency is an apparent wilting and rolling of the leaflet ends of fully opened leaves. Such symptoms of wilting are seen in other plants with Cu deficiency. Wilting symptoms are followed by a partial un-opening of new leaflets, which in some cases appear puckered and kinked over towards the leaf ends. If the deficiency is severe, wilting of fully formed leaves develops into a 'withertip', as often seen in Cu-deficient wheat. Tips of each leaflet become pale green with a dried-up appearance, and then become twisted and necrotic (Figure 32 and 33).

Flowering is not delayed in faba bean as it is in field peas, and flowers appear quite normal, but few pods and seeds form.

Figure 32: *Copper deficiency in faba bean new leaves showing 'withertip'.*

Photo: A. Robson

Figure 33: *Copper deficiency in faba bean new leaves (left) and fully opened leaves (right) showing 'withertip'.*

Photo: A. Robson

5.5.11 Molybdenum

Deficiency symptoms

Leaves are pale green and mottled between veins, with brown scorched areas developing rapidly between veins.

Molybdenum-deficient plants may contain high nitrate-N levels resulting from the inhibition of nitrate reduction to ammonia. The presence of high nitrate levels in a chlorotic, apparently N-deficient plant is thus evidence for Mo deficiency.

5.5.12 Boron deficiency

As with Ca, B has a dramatic effect on the root system of faba bean.

Deficiency symptoms

Roots become brown with lateral extremities showing shortening and thickening. The first leaf symptoms are a reduction in growth with a waxy look and a darkening of colour. This is followed by a folding back of these leaves in an umbrella fashion, leaving the leaflet folded over and twisted. Stem internode length is shortened. As the deficiency progresses, middle leaves develop a mottled chlorosis that forms between the veins (Figure 34).

Figure 34: *Boron-deficient leaves (youngest to older: right to left) of faba bean, with B-adequate leaf (left).*

Photo: A. Robson

As B becomes deficient, the vegetative growing point of the affected plant becomes stunted or deformed, or disappears. When this occurs, apical dominance of the growing point ceases to exert control over lateral shoot development. Thus, a proliferation of side shoots can occur resulting in a 'witches broom' condition. Deformed flowers are a common plant symptom of B deficiency. Many plants may respond by reduced flowering and improper pollination as well as thickened, curled, wilted and chlorotic new growth.

5.6 Arbuscular mycorrhizae fungi

The symbiotic relationships between some soil fungi and plant roots are known as arbuscular mycorrhizae (AMF; or vesicular-arbuscular mycorrhizae, VAM). These AMF can help plants to take up nutrients such as P and Zn from the soil and fertiliser. AMF colonise and build up on the faba bean root system. The fungi produce hyphae that colonise the root and then grow out into the soil (much further than root hairs). Phosphorus and Zn are taken up by the hyphae and transported back for use by the plant. AMF can build up to levels five times higher on chickpea root systems than on wheat.

Crops such as faba beans, chickpeas, safflower and linseed have a high AMF dependency and promote AMF build-up. Winter cereals and field peas are less AMF-dependent, but do allow AMF to build up. Canola, lupins and extended fallow do not host AMF, so AMF levels are reduced under these crops in rotation.

Faba beans are considered to have high crop requirement for P, and economic fertiliser responses to P are common. Therefore, AMF can be important in faba bean production and fertiliser responses.

Uptake of P can become far more inefficient in winter crops with:

- soils with critically low P levels (<6 mg P/kg) and no history of P fertiliser application; and.
- long-fallow situations with low AMF levels (≥10 months).

Products containing AMF are available as seed treatments, often in association with other seed enhancers, which in combination can give the most potent means to ensure a highly successful AMF spore inoculation. An example is Seed Enhancer™VAM from Ferti-Tech Australia Pty Ltd.

http://www.fertitech.com/site/DefaultSite/filesystem/documents/FTA%20Ferti%20Seed%20Enhancer%20VAM.pdf

High AMF situations

Where AMF levels are moderate–high (double-crop situations or short, 6-month fallows from wheat), consistent responses to applied phosphate fertiliser are more likely where soil bicarbonate-P levels fall below 6 mg/kg and are critically low.

Low AMF situations

Levels of AMF become depleted as fallow length is increased, or after crops such as canola or lupin, which do not host AMF growth (Table 10).

Where there are low levels of AMF (long fallows of >8–12 months), faba beans are expected to be very responsive to applied P and Zn. Faba beans will likely show a marked growth response to starter fertilisers, which likely translates into a positive yield response, depending on growth and onset of terminal drought stress in spring.

Table 10: *Effect of fallow length on arbuscular mycorrhizae (AMF) spore survival and maize yield with and without phosphorus + zinc.*

Fallow duration (months)	AMF spores (no./g soil)	Maize yield	
		–(P + Zn)	+(P + Zn)
21	14	2865	4937
11	26	3625	3632
6	44	5162	4704

Source: J. Thompson (1984).

5.7 Nutrition effects on following crop

5.7.1 Nitrogen

Northern grain growers sowed ~450,000 ha of chickpeas and 30,000 ha of faba beans in 2012, resulting in the fixation of ~35,000 t of N, worth A$55 million in fertiliser N equivalence. [23]

Agricultural legumes fix large quantities of N_2. Globally, the 185 million ha of crop legumes and >100 million ha of pasture and fodder legumes fix ~40 million t of N_2 annually (Herridge *et al.* 2008).

This represents a huge saving of fertiliser N that would otherwise need to be applied, and has positive economic and environmental consequences. Assuming 80% conversion of fertiliser N into plant N, the 40 million t of biologically fixed N_2 has a fertiliser-N equivalence of 50 million t, or about 50% of current global inputs of nitrogenous fertilisers. The nominal annual value of the fixed N_2 is about $63 billion (assuming cost of fertiliser N of $1.25/kg).

The situation for Australian agriculture is equally impressive. The 23 million ha of legume-based pastures are estimated to fix ~2.5 million t of N_2 annually, based on average production of 3.0 t/ha of legume biomass and rates of N_2 fixation of 110 kg N/ha (Table 11). Nitrogen fixation by the crop legumes is estimated at <0.2 million t annually. Using the assumptions above, the economic value of the N_2 fixed by legumes in our agricultural systems is >$4 billion annually.

23 GRDC (2013) Nitrogen fixation and N benefits of chickpeas and faba beans in northern farming systems. Northern Region. GRDC Nitrogen Fixation Fact Sheet, http://www.grdc.com.au/~/media/A16EDF6798064F419597DDFBC0B365E1.pdf

Table 11: *Estimates of the amounts of N_2 fixed annually by crop legumes in Australia.*

Legume	%Ndfa	Shoot DM[1] (t/ha)	Shoot N (kg/ha)	Root N_2 (kg/ha)	Total crop N (kg/ha)	Total N fixed[3] (kg/ha)
Soybeans	48	10.8	250	123	373	180
Lupins	75	5.0	125	51	176	130
Faba beans	65	4.3	122	50	172	110
Field peas	66	4.8	115	47	162	105
Peanuts	36	6.8	190	78	268	95
Chickpeas	41	5.0	85	85	170	70
Lentils	60	2.6	68	28	96	58
Mungbeans	31	3.5	77	32	109	34
Navy beans	20	4.2	105	43	148	30

%Ndfa, % of legume N derived from N_2 fixation

1 DM = dry matter
2 Root N = shoot N x 0.5 (soybeans), 1.0 (chickpeas) or 0.4 (remainder)
3 Total N fixed = %Ndfa x total crop N

Source: Primarily Unkovich et al. (2010). From D Herridge (2013) Managing Legume and Fertiliser N for Northern Grains Cropping (GRDC).

The major crop legumes in the northern grains region are chickpeas and faba beans. Local N_2 fixation data for the two legumes are consistent with the national data. In the NSW Department of Primary Industries (DPI) long-term farming systems experiments, faba beans fixed about 20% more N_2 than chickpeas (Table 12). Rates of N_2 fixation were less in on-farm surveys than in the experimental plots, but the differences between faba beans and chickpeas were consistent with faba beans fixing about 70% more N_2 than chickpeas.

Table 12: *Comparisons of N_2 fixation and yields of chickpeas and faba beans in crop-rotation experiments and on-farm surveys in northern New South Wales.*

	Soil sowing		Shoot		N_2 fixation	
Crop	Water (mm)	Nitrate (kg N/ha)	DM (t/ha)	N (kg/ha)	%Ndfa	Crop N fixed (kg/ha)
Long-term experiments[A]						
Faba beans	171	106	5.56	124	71	123
Chickpeas	171	95	5.21	98	53	105
On-farm surveys[B]						
Faba beans	163	54	4.57	121	60	100
Chickpeas	158	58	3.73	79	38	60

A Means of 18 site/years/tillage treatments; soil water and nitrate to depth of 1.2m (unpublished data of W. Felton, H. Marcellos, D. Herridge, G. Schwenke and M. Peoples)

B Means of 15 farmer crops; soil water and nitrate to depth of 0.9m (Schwenke et al. 1998)

Source: D Herridge (2013) Managing Legume and Fertiliser N for Northern Grains Cropping. GRDC.

Legume growth is the major driver of legume N_2 fixation (Figure 35). In the Australian environment, growth is mostly determined by the amount of water that the crop or pasture can access. Farmers cannot control the weather but they can optimise their management to capture and store the greatest amount of water in the soil, to keep soil nitrate levels as low as possible and to provide the legume with ideal, stress-free growing conditions.

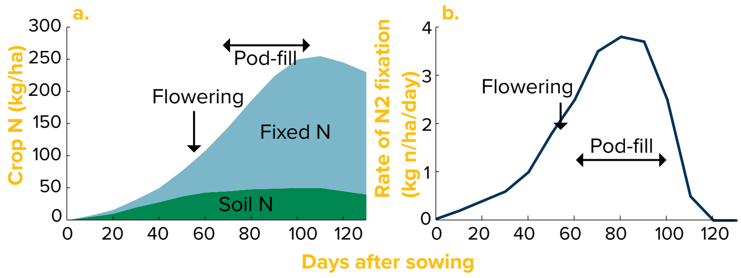

Figure 35: *Typical patterns of nitrogen accumulation and N_2 fixation by annual crop legumes. In (a), total crop N is shown to have two sources, soil N and fixed N, and the bulk of N accretion occurs after flowering. In (b), rates of N_2 fixation are shown to peak at 4 kg N/ha.day during mid-podfill, then decline as the crop matures.*

Source: D Herridge (2013) Managing Legume and Fertiliser N for Northern Grains Cropping. GRDC

Data from NSW DPI long-term rotation experiments in northern NSW show that no-till methods improve the productivity and N_2 fixation of chickpeas and faba beans. This is primarily due to increased soil-water retention and decreased soil nitrate accumulation during the summer (pre-crop) fallow.

In rotation experiments involving chickpeas, no-till soils had 35 mm more water available at sowing than cultivated soils and less nitrate-N by 15 kg N/ha (Table 13). The extra soil water resulted in about 16% more growth and the decreased nitrate-N increased the dependence of the chickpea crops on N_2 fixation (55% *v.* 44%). Total crop N_2 fixed was 43% higher (107 kg N/ha) in no-tilled chickpeas than in cultivated chickpeas (75 kg N/ha).

Similar results were achieved in trials with faba beans. No-tilled soils contained 38 mm more water than cultivated soils at the end of the summer fallows and less nitrate-N by 30 kg N/ha. Shoot dry matter, shoot N and crop N_2 fixed were 5%, 12% and 14%, respectively, higher in no-till crops.

Table 13: *Effects of tillage on soil water and nitrate-N at sowing, and chickpea and faba bean growth, grain yield and N_2 fixation.*

	Soil sowing (1.2m depth)		Shoot		N_2 fixation	
Tillage	**Water (mm)**	**Nitrate (kg N/ha)**	**DM (t/ha)**	**N (kg/ha)**	**% crop N from N_2 fixation**	**Crop N fixed (kg/ha)** [B, D]
Chickpeas[A]						
No tillage	144	71	5.4	95	55	107
Cultivated	109	86	4.7	82	44	75
Faba beans[B]						
No tillage	213	88	5.8	126	68	122
Cultivated	175	118	5.5	113	66	107

[A] means of 21 site/years of experiments
[B] Crop N calculated as shoot N x 2
[C] means of 9 site/years of experiments
[D] Crop N calculated as shoot N x 1.4

Source: Nitrogen Fixation Fact Sheet, GRDC 2013, http://www.grdc.com.au/~/media/A16EDF6798064F419597DDFBC0B365E1.pdf.

Benefits of nitrogen fixation

Crop legumes are usually grown in rotation with cereals, and the benefits to the system are measured in terms of increased soil total and plant-available (nitrate) N and grain N and yield of the subsequent cereal crop, all relative to a cereal–cereal sequence.

The N available to the cereal is a combination of the N mineralised as part of the decomposition of legume residues and soil humus and from applied fertiliser N. A fourth source of N is the mineral N not used by the legume during its growth, but spared. The residue N that is not released as mineral N remains in the soil as organic matter (Figure 36).

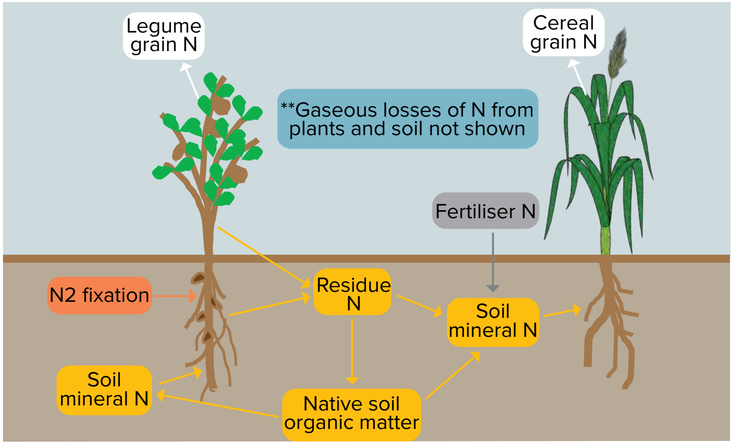

Figure 36: *Nitrogen cycling through a grain legume to the following cereal crop. Gaseous losses of N are not shown, nor are potential leaching losses. All of the flows of N are facilitated by the action of the soil biota.*

Source: D Herridge (2013) Managing Legume and Fertiliser N for Northern Grains Cropping. GRDC

Much research has now demonstrated that cereals grown after crop legumes commonly yield 0.5–1.5 t grain/ha more than cereals grown after cereals without fertiliser N. To generate equivalent yields in the cereal–cereal sequence, research has also shown that 40–100 kg fertiliser N/ha needs to be applied.

Results from more than a decade (60 sites × years) of chickpea–wheat rotation experiments conducted by NSW DPI researchers at North Star from 1989 to 1991 showed the clear financial and agronomic advantages that accrued from the legume. The research found:

Wheat following chickpeas outyielded wheat after wheat by an average of 0.7 t/ha in NSW trials and by 0.6 t/ha in Queensland trials. Wheat grain protein was increased by an average of 1 percentage point in NSW and 1.4 percentage points in Queensland.

Where water was not limiting, the yield benefit was >1.5 t/ha.

Nitrate supply was the major factor in the increased wheat yields. In NSW there was, on average, 35 kg more nitrate-N/ha in the top 1.2 m of soil after chickpeas than after wheat.

Chickpea yields were, on average, ~85% of unfertilised wheat and ~70% of N-fertilised wheat.

In the first year, chickpeas, unfertilised wheat (wheat 0N) and N-fertilised wheat (wheat 100 N) were grown in a soil with a moderate level of nitrate-N at sowing. The chickpeas fixed 135 kg N/ha and produced far more residue-N (133 kg N/ha) than either wheat crop (20–55 kg N/ha). The chickpea residues were also richer in N, with a C : N ratio of 25 : 1 compared with C : N ratios of 44 : 1 (wheat 100N) and 50 : 1 (wheat 0N) for the wheat residues.

The low C:N ratio of the chickpea residues meant that 16 kg mineral (ammonium and nitrate) N/ha was released into the soil during residue decomposition during the summer fallow. The wheat residues immobilised 21 to 22 kg mineral N/ha because additional N was needed by the break-down organisms for decomposition to occur. [24]

Table 14: *N and yield benefits of a chickpea-wheat rotation compared with unfertilised or N fertilised wheat-wheat. Values are the means of no-tillage and cultivated treatments at two sites in northern NSW.*

	Chickpeas - wheat 0N*	Wheat 0N - wheat 0N	Wheat 100N - wheat 0N**
Year 1 (chickpeas of wheat)	**Chickpeas**	**Wheat (0N)**	**Wheat (100N)**
Soil nitrate at sowing (kg N/ha, 1.2m depth)	67	67	67
Fertiliser N applied (kg N/ha)	0	0	100
Grain yield (t/ha)	2.3	2.3	3.2
Crop N fixed (kg/ha)	135	0	0
Residue N (kg/ha)	133	20	55
Residue C:N	25:1	50:1	44:1
Est. mineralisation or immobilisation (kg N/ha)	+16	-22	-21
Year 2 (wheat only)	**Wheat (0N)**	**Wheat (0N)**	**Wheat (0N)**
Sowing soil nitrate (kg N/ha, 1.2m depth)	102	53	74
Grain yield (t/ha)	2.8	1.7	1.8

* Wheat 0N = unfertilised wheat
** Wheat 100N = N fertilised wheat

Source: Nitrogen Fixation Fact Sheet, GRDC 2013, http://www.grdc.com.au/~/media/A16EDF6798064F419597DDFBC0B365E1.pdf.

5.8 References

2013 Winter Crop Variety Sowing Guide. NSW DPI

A.D. Robson, editor, (1993). "Zinc in soils and plants". Proceedings of the International Symposium on 'Zinc in Soils and Plants' held at The University of Western Australia, 27–28 September, 1993

Grain Legume Handbook. 2008, GRDC

Hashemabadi , Davood (2013). "Phosphorus fertilisers effect on the yield and yield components of faba bean". Annals of Biological Research, 2013, 4 (2):181-184

Herridge, D (2013). Managing Legume and Fertiliser N for Northern Grains Cropping – GRDC

GRDC (2013) Nitrogen fixation and N benefits of chickpeas and faba beans in northern farming systems. Northern Region. GRDC Nitrogen Fixation Fact Sheet, http://www.grdc.com.au/~/media/A16EDF6798064F419597DDFBC0B365E1.pdf

Southern/Western Faba and Broad Bean – Best Management Practices Training Course. Module 3 – Varieties. 2013, Pulse Breeding Australia

24 GRDC (2013) Nitrogen fixation and N benefits of chickpeas and faba beans in northern farming systems. Northern Region. GRDC Nitrogen Fixation Fact Sheet, http://www.grdc.com.au/~/media/A16EDF6798064F419597DDFBC0B365E1.pdf

Weed control

VIDEOS

http://www.grdc.com.au/Media-Centre/Media-News/North/2013/05/Harvest-weed-seed-control-key-to-overcoming-resistance

MORE INFORMATION

http://ahri.uwa.edu.au/wp-content/uploads/2015/11/Michael-Walsh_HWSC_compressed.pdf

http://www.grdc.com.au/~/media/25C653C167C24A9A98C3451DFD16506C.pdf

http://www.grdc.com.au/uploads/documents/GRDC_HerbicideCard.pdf

http://www.dpi.nsw.gov.au/agriculture/pests-weeds/weeds/publications/nhrr

http://www.dpi.nsw.gov.au/__data/assets/pdf_file/0006/155148/herbicide-resistance-brochure.pdf

Weeds are estimated to cost Australian agriculture A$2.5–4.5 billion per annum. For winter cropping systems alone, the cost is $1.3 billion, equivalent to ~20% of the gross value of the Australian wheat crop. Consequently, any practice that can reduce the weed burden is likely to generate substantial economic benefits to growers and the grains industry. See more at: www.grdc.com.au/weedlinks. [1]

Weed control is essential if crops are to make full use of stored summer rainfall, and in order to prevent weed seeds from contaminating the grain sample at harvest. Weed management should be planned well before planting and options considered such as chemical and non-chemical control. [2]

The Grains Research and Development Corporation (GRDC) supports integrated weed management. Download the Integrated Weed Manual.

Weed control is important, because weeds can:

- rob the soil of valuable stored moisture
- rob the soil of nutrients
- cause issues at sowing time, restricting access for planting rigs (especially vine-type weeds such as melons, tarvine or bindweed, which wrap around tines)
- cause problems at harvest
- increase moisture levels of the grain sample (green weeds)
- contaminate the sample
- prevent some crops being grown where in-crop herbicide options are limited, i.e. broadleaf crops
- be toxic to stock
- carry disease
- host insects

6.1 Integrated weed management in faba bean

Good weed control management is vital to successful and profitable crop production. Yield losses caused by weeds can vary enormously from almost negligible to a complete loss.

Weeds lower crop yields by competing for soil moisture, nutrients, space and light. They can also carry diseases and viruses that can infect crops. This competition reduces grain yield and quality, and can impede harvesting. Some weeds can restrict cropping options because herbicides for control are sometimes limited. Thoroughly investigate which weed species are likely to germinate in a paddock before sowing crops and determine the availability of suitable herbicide options.

Weed control is a numbers game, and growers should aim to reduce weed numbers and keep them low with an ongoing management program. A weed-management program should make the most of rotations and hence opportunities to use selective herbicides from a different herbicide group in each crop in the rotation to reduce weed presence in the following crop. Care should be taken in planning a cropping rotation to avoid herbicide resistance, or growing a crop that may become a 'weed',

1 GRDC (2005) Integrated weed management: the mini manual. Weed Links, GRDC, www.grdc.com.au/weedlinks

2 QDAF (2012) Wheat—planting information. Department of Agriculture, Fisheries and Forestry, Queensland, http://www.daff.qld.gov.au/plants/field-crops-and-pastures/broadacre-field-crops/wheat/planting-information

MORE INFORMATION

http://www.dpi.nsw.gov.au/__data/assets/pdf_file/0007/431269/Fleabane-management-in-crop-rotations.pdf

http://www.dpi.nsw.gov.au/agriculture/broadacre/guides/ngrt-results

For further information on resistance management strategies refer to Integrated Weed Management Manual on the following websites: www.croplifeaustralia.org.au

www.glyphosateresistance.org.au

MORE INFORMATION

www.croplifeaustralia.org.au

www.glyphosateresistance.org.au

www.weedsmart.org.au

http://www.youtube.com/playlist?list=PL2PndQdkNRHGRipNhkDYN2dJWAY1-oH9W

Ground Cover: SA trial assesses different weed strategies

GRDC Update Paper: Herbicides for control of clethodim-resistant annual ryegrass

or lead to uncontrolled weeds that cannot be controlled with selective herbicides in the subsequent crop.

An integrated weed-management system (IWM) system combining all available methods is the key to successful control of weeds (Table 1).

In-crop weed control

A wide range of pre-emergent and early post-emergent herbicides is available for grass weed control in faba bean. With broadleaf weeds, post-emergent options are very limited. Weeds should be removed from crops early, and certainly no later than 6 weeks after sowing if yield losses are to be minimised. Yield responses will depend on weed species, weed and crop density and seasonal conditions. The stage of growth of the weed and the crop are vital factors to consider when planning the use of post-emergent herbicides. Read herbicide labels carefully for these details and information on the best conditions for spraying.

Herbicide resistance

Herbicide resistance continues to develop and become more widespread. It is one of the biggest agronomic threats to the sustainability of our cropping systems. However, this problem can be managed through good crop rotations, rotating herbicide groups, and by combining both chemical and non-chemical methods of weed control.

In general, options for broadleaved weed control with selective herbicides in faba beans are limited, compared with the treatments available for use in cereal crops. [3]

Table 1: *Weed control options for integrated weed management (IWM).*

	Herbicidal	Non-herbicidal
Crop phase	• Crop topping in pulse/legume crops • Knockdown herbicides, e.g. double-knock strategy before sowing • Selective herbicides before and/or after sowing, but ensure escapes do not set seed • Utilising moderate resistance-risk herbicides • Delayed sowing (as late as spring in some cases) with weeds controlled in the interim • Brown manure crops	• Rotate crops • Rotate varieties • Grow a dense and competitive crop • Cultivation • Green manure crops • Delay sowing • Cut crops for hay/silage • Burn stubbles/windrows • Collect weed seeds at harvest and remove or burn • Destroy weed seeds harvested (use of Harrington seed destructor)
Pasture phase	• Spray topping • Winter cleaning • Selective herbicides but ensure escapes do not set seed	• Good pasture competition • Hay making or silage • Cultivated fallow • Grazing

Keep yourself informed and be pro-active in the prevention and management of herbicide resistance.

3 Southern/Western Faba & Broad Bean—Best Management Practices Training Course. Module 5—Weed Management. 2013. GRDC/Pulse Australia.

Crop rotation

A well-managed rotation in each paddock, which alternates pastures, broadleaf and cereal crops, is a very useful technique for controlling weeds. For example, grass weeds are more easily and cheaply controlled chemically in broadleaf crops, whereas broadleaf weeds are much easier to control in cereal crops. Good crop rotation management can substantially reduce the cost of controlling weeds with chemicals.

Pulses grown in rotation with cereal crops offer opportunities to control grassy weeds easily with selective herbicides that cannot be used in the cereal years. An effective kill of grassy weeds in pulse crops will reduce root disease carryover and provide a 'break crop' benefit in following cereal crops. Grass-control herbicides can control most grassy weeds in pulses. Volunteer cereals can also be controlled with some of these herbicides.

Good agronomic practice

Use of weed-free seed (preferably registered or certified) and sowing on time with optimal plant populations and adequate nutrition all contribute to good weed control management. Some crops and varieties are more competitive against weeds than others. All weeds growing in a paddock should be controlled before the crop emerges. Large weeds that have not been controlled prior to or by the sowing operation prove most difficult and often impossible to remedy with in-crop herbicides.

Timely cultivation

Timely cultivation is a valuable method for killing weeds and preparing seedbeds. Some growers use varying combinations of mechanical and chemical weed control to manage their fallows or stubbles. Increasing numbers of growers are using knockdown herbicides instead of cultivation for fallow commencement, as well as pre-planting weed control in the autumn. These practices are providing clear benefits to soil structure, as well as more timely and effective weed control.

6.2 Specific weed issues for faba beans

Problem weeds or issues in faba beans that require special attention or are difficult to fully control include:

- Annual ryegrass that is resistant to group A products ('dims' and 'fops'), particularly where high rates of clethodim are required.
- Annual ryegrass that is resistant to trifluralin.
- Crop topping cannot always be conducted in a timely manner to be safe for the beans and at the optimum stage for preventing ryegrass seed set. These late germinations of weeds (e.g. ryegrass, brome grass) would safely be prevented from setting seed by crop-topping in many earlier maturing pulses.
- Snail and other medic.
- Wild radish. There are no safe post-emergent treatments available.
- Hoary cress, soursob and tares.
- Faba beans are reasonably poor competitors with weeds initially because of slow germination, low plant populations and an extended period before ground is covered at canopy closure. [4]

MORE INFORMATION

GRDC Update Paper: Managing resistant ryegrass in break crops and new herbicides for resistant ryegrass

4 Southern/Western Faba & Broad Bean—Best Management Practices Training Course. Module 5—Weed Management. 2013. GRDC/Pulse Australia.

6.3 Herbicide performance

Cha racteristics that determine herbicide performance and activity are:

- herbicide uptake—how and where the chemical is taken up by the plant
- herbicide solubility—how readily it dissolves or leaches in soil water
- herbicide adsorption—how much is lost by binding to the soil
- herbicide persistence—how long it lasts on the soil, affected by:
  - volatility, i.e. loss to the atmosphere
  - leaching potential, i.e. amount lost below the root-zone
  - decomposition by light

Understanding these factors will assist in ensuring more effective herbicide use. For best performance, pre-sowing and pre-emergence herbicides should be placed in the top 0–7.5 cm of soil. They must enter the germinating weed seedling in order to kill it. These herbicides can be mixed in by cultivation, rainfall or sprinkler irrigation, depending on the herbicide.

Poor herbicide efficacy can occur under dry conditions at application. Some soil-active herbicides (e.g. Terbyne® or simazine) can damage faba beans where wetter conditions favour greater activity and leaching.

6.4 Herbicide damage in pulse crops

The risk of crop damage from herbicide application should be balanced against the potential yield loss from weed competition. In heavy weed infestations, some herbicide crop damage can be tolerated, as it is easily offset by the yield loss avoided by removing competing weeds.

If herbicide is applied to dry soils, the risk of movement and crop damage is increased greatly after rainfall, particularly if the soil is left ridged and herbicide washes into the seed row. Incorporation by sowing (IBS) may be more appropriate in dry conditions, or a split application to minimise risk. Post sowing pre-emergent (PSPE) herbicides should be applied to moist soil regardless of the sowing time.

Herbicides move more readily in soils with low organic matter, and with more sand, silt or gravel. Herbicide movement is much less in soils with higher organic matter and higher clay contents. Damage from leaching is also greater where herbicides are applied to dry, cloddy soils than to soils that have been rolled and are moist on top from recent rainfall.

The relative leaching potentials presented in Table 2 show that metribuzin leaches at almost three times the rate of simazine and seven times the rate of diuron.

Table 2: *Relative leaching of some soil-active herbicides (where 1 is the least leaching).*

Chemical	Example of product	Leaching index
Pendimethalin	Stomp®	1
Trifluralin	Treflan®	1
Diuron	Diuron 900DF	2
Prometryn	Prometryn 900DF	3–4
Simazine	Simazine 900 WDG	5
Metolachlor	Dual®	6
Atrazine	Atrazine 900 WG	10
Metribuzin	Lexone®, Sencor®	14

The relative tolerance of the crop type and variety will also affect crop damage from these herbicides. For example, lupins are more tolerant to simazine than are the other pulses. For more specific details on soil-active herbicides and the risk of crop damage in your cropping situation, seek advice from an experienced agronomist. [5]

MORE INFORMATION

The Royal Botanic Gardens Plant Identification & Botanical Information Service:
http://www.rbgsyd.nsw.gov.au/plant_info/identifying_plants/plant_identification_service

6.5 Planning your weed control strategy

1. Know your weed species. Ask your local adviser or service provider, or use the Sydney Botanic Gardens plant identification service, which is free in most cases (see link).
2. Conduct in-crop weed audits prior to harvest to know which weeds will be problematic the following year.
3. Ensure that seed is kept from a clean paddock.
4. Have a crop-rotation plan that considers not just crop type being grown but also the weed control options this crop system may offer, e.g. grass control with triazine-tolerant (TT) canola.

6.6 Herbicides explained

6.6.1 Residual *v.* non-residual

Residual herbicides remain active in the soil for an extended period (months) and can act on successive weed germinations. Residual herbicides must be absorbed through the roots or shoots, or both. Examples of residual herbicides include imazapyr, chlorsulfuron, atrazine and simazine.

The persistence of residual herbicides is determined by a range of factors including application rate, soil texture, organic matter levels, soil pH, rainfall/irrigation, temperature and the herbicide's characteristics.

Persistence of herbicides will affect the enterprise's sequence, such as a rotation of crops, e.g. wheat–barley–chickpeas–canola–wheat.

Non-residual herbicides, such as the non-selective paraquat and glyphosate, have little or no soil activity and they are quickly deactivated in the soil. They are either broken down or bound to soil particles, becoming less available to growing plants. They also may have little or no ability to be absorbed by roots.

MORE INFORMATION

https://grdc.com.au/Resources/Publications/2014/07/Integrated-Weed-Management-Manual

6.6.2 Post-emergent and pre-emergent

These terms refer to the target and timing of herbicide application. Post-emergent refers to foliar application of the herbicide after the target weeds have emerged from the soil, whereas pre-emergent refers to application of the herbicide to the soil before the weeds have emerged. [6]

6.7 Crop damage caused by herbicides

Symptoms of crop injury from herbicides do not always mean that a grain yield loss will occur. Recognition of crop injury symptoms allows the cause of the injury to be identified and possibly prevented in future crops. The type of injury depends on how the herbicide works in the plant, the site and seasonal conditions.

Herbicide injury may be obvious (e.g. scorched leaves) or it may be more subtle (e.g. poor establishment or delayed maturity). Herbicide crop-injury symptoms can easily be confused with symptoms produced by other causes, such as frost, disease or nutrition.

5 Southern/Western Faba & Broad Bean—Best Management Practices Training Course. Module 5—Weed Management. 2013. GRDC/Pulse Australia.

6 GRDC Integrated weed management, Section 4: Tactics for managing weed populations, http://www.grdc.com.au/~/media/A4C48127FF8A4B0CA7DFD67547A5B716.pdf

MORE INFORMATION

'Field crop herbicide injury: The Ute Guide' and 'Faba bean: The Ute Guide'. Both are available from: http://www.grdc.com.au/Resources/Bookshop

Care should be taken when using crop oils and penetrants with herbicides, as these can increase the uptake of active chemicals and exceed crop tolerance. Always follow the herbicide label.

Pulse crops can be severely damaged by some herbicides present as soil residues from previous applications, contaminants in spray equipment or spray drift onto the crop or by incorrect use of the herbicide.

Herbicide efficacy and crop safety of the new crop can suffer if the soil is dry at application time.

Taking some general precautions can help to reduce the likelihood of crop damage with residual herbicide use:

- Do not apply if rain is imminent.
- Maintain at least 7.5–10 cm soil coverage.
- Avoid leaving a furrow or depression above the seed that could allow water (and chemical) to concentrate around the seed/seedling.
- Avoid leaving an exposed, open slot over the seed with disc-openers and avoid a cloddy, rough tilth with tined openers.

Damage to faba beans from various herbicides is depicted in Figures 1–20.

Figure 1: *Crops grown on lighter soils are more prone to simazine (Group C) damage.*

Photo: A. Mayfield, Grain Legume Handbook

Figure 2: *High rates of simazine can damage faba beans, lower leaves turn black and die back from the edge.*

Photo: A. Mayfield, Grain Legume Handbook

Figure 3: *Herbicide damage affecting emergence and survival of seedlings.*

Photo: W. Hawthorne, Pulse Australia

Figure 4: *Damage on headland where higher rate on inside of spray boom when turning.*

Photo: W. Hawthorne, Pulse Australia

Figure 5: *Bean seedlings affected by Lontrel® residue (Group I) in soil.*

Photo: W. Hawthorne, Pulse Australia

Figure 6: *Beans are susceptible to Tordon® or Lontrel® residue in soil. Note the stem distortion and severe leaf curl.*

Photo: A. Mayfield, Grain Legume Handbook

Figure 7: *Trifluralin (Group D) injury (left) causing stunted growth. It can also cause development of multiple growing points.*

Photo: C. Preston, Univ. of Adelaide

Figure 8: *Trifluralin injury (left) in the field, causing stunted growth.*

Photo: A. Mayfield, Grain Legume Handbook

Figure 9: *Damage (left) from Dual Gold® (metachlor, Group K).*

Photo: C. Preston, Univ. of Adelaide

Figure 10: *Chemical leaf spotting from oils in a Group A herbicide applied post-emergent. Note that spots are numerous, small, irregular in shape and differ on top and bottom sides of leaf.*

Photo: R. Kimber, SARDI

Figure 11: *Group A chemical leaf spotting on lower leaves after application of a grass herbicide. Do not confuse this with Cercospora or ascochyta leaf diseases.*

Photo: R. Kimber, SARDI

Figure 12: *Leaf spotting caused by MCPB herbicide (Group I) can be confused with ascochyta and chocolate spot infections in beans.*

Photo: A. Mayfield, Grain Legume Handbook

Figure 13: *Spinnaker damage (Group B).*

Photo: W. Hawthorne, Pulse Australia

Figure 14: *Symptoms of Brodal® (diflufenican, Group F) damage, white–pale yellow leaves with yellow blotches.*

Photo: A. Mayfield, Grain Legume Handbook

Figure 15: *.2,4-D (Group I) spray drift causing narrow leaves with crinkled edges.*

Photo: A. Mayfield, Grain Legume Handbook

Figure 16: *Damage from Lontrel® drift (Group I).*

Photo: T. Bray, formerly Pulse Australia

Figure 17: *Leaf spotting from spray droplets of Affinity® (carfentrazone, Group G).*

Photo: C. Preston, Univ. of Adelaide

Figure 18: *Leaf spotting from spray droplets of paraquat (Group L).*

Photo: C Preston, Univ. of Adelaide

Figure 19: *Leaf damage and plant set-back from post-emergent application of Spray.Seed® (paraquat plus diquat, Group L).*

Photo: W. Hawthorne, Pulse Australia

Figure 20: *Group M. Limp leaves and yellowing after glyphosate application. Young leaves are stunted and twisted.*

Photo: C. Preston, Univ. of Adelaide

6.7.1 Tolerance of faba bean varieties to herbicides

At present there are no post-emergent herbicide options for faba beans.

Faba varieties do differ in their herbicide tolerance, depending on season, soil type and rate of application. Herbicide labels generally do not reflect these subtleties.

PBA Rana(D shows performance similar to all current varieties of faba beans at label recommended rates of registered herbicides based on visual observations from National Variety Trials (NVT) and Pulse Breeding Australia (PBA) breeding trials conducted on a range of soil types.

Herbicide tolerance trials in South Australia (alkaline sandy loam soils) show that herbicides commonly used in faba beans can be used with some degree of safety or

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risk. Nura⫽ has exhibited greater sensitivity to imazethapyr (e.g. Spinnaker®) in some herbicide-tolerance trials in South Australia. However, all varieties exhibit some yield loss to imazethapyr (Table 3).

In South Australian herbicide-tolerance trials (2000–10) as reported by NVT, simazine applied post-emergence can be more damaging than when applied PSPE, especially with the variety Farah⫽. Simazine does have a narrow safety margin or some yield loss (to 21%) at standard rates.

Raptor® (imazamox) has a narrow safety margin in all faba bean varieties. It can be applied under APVMA permit. Field experience is that damage is more severe under moisture stress and conditions of slow growth. It should be considered a salvage option more so than a routine application.

Diuron has been safe in Farah⫽ and Nura⫽ over seven or eight trials, but check current registration status with broadacre crops.

Severe seasonal effects on herbicide activity occur, so work is ongoing to validate findings under differing seasonal conditions. See Variety Management Packages (VMPs) at www.pulseaus.com.au, and the NVT website http://www.nvtonline.com.au. [7]

Table 3: *Faba bean herbicide tolerance as reported by NVT, South Australia.*

Variety	Years	Diuron® (diuron)	Simazine		Lexone® (metribuzin)	Spinnaker® (imazathapyr)	Raptor®A (imazamox)	Terbyne® (terbuthylazine)
		2000–10	2000–10	2001–08	2003–10	2000–10	2003–10	2009–10
Farah⫽	2002–08	Safe (7)	Narrow (1/7)	6–18% (3/7)	Safe (6)	28–39% (2/3)	Narrow (3/6)	–
Fiesta	2000–07	Narrow (1/8)	18% (1/8)	21% (1/7)	S (5)	11–32% (2/8)	Narrow (4/5)	–
Fiord	2000–02	Narrow (1/3)	Narrow (2/3)	Narrow (1/2)	–	18–30% (2/3)	–	–
Nura⫽	2003–10	Safe (8)	Narrow (1/8)	Narrow (1/6)	Safe (8)	10–53% (4/8)	Narrow (8/8)	Safe (2)
Rate		1.0 L/ha	1.5 L/ha	1.5 L/ha	280 g/ha	85 g/ha	45 g/ha	1.0 kg/ha
Application		PSPE	PSPE	6 weeks	PSPE	PSPE	3–4 leaf	PSPE

Safe, No significant yield reductions at recommended rates or higher in 2+ trials (no. of trials in parentheses); Narrow, narrow margin, significant yield reductions at higher than recommended rate in 1+ trials (X of Y trials in parentheses), but not at recommended rate; X%, percentage yield reduction (warning), significant yield reduction at recommended rate in 1 trial only; X–Y%, percentage range yield reductions (warning), significant yield reductions at recommended rate in 2+ trials

A Denotes use under APVMA permit. This use is not endorsed by this data and no responsibility will be taken for its interpretation.

MORE INFORMATION

http://www.dpi.nsw.gov.au/archive/agriculture-today-stories/ag-today-archives/september-2011/broadleaf-weed-trial-in-faba-beans

6.7.2 Contamination of spray equipment

The importance of cleaning and decontaminating spray equipment for the application of herbicides cannot be over-stressed. Traces of sulfonylurea herbicides (such as chlorsulfuron, metsulfuron or triasulfuron) and carfentrazone (Affinity®) in spray equipment can cause severe damage to faba beans and other legumes when activated by grass control herbicides (Table 4).

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Table 4: *Product labels usually detail decontamination and cleaning procedures for each product.*

Herbicide	Rate of agent/100 L water	Instructions for cleaning and decontamination
Roundup® CT, Roundup PowerMAX™, glyphosate, Raptor®, Flame®, Spinnaker®, Sniper®, Wipe Out® Plus, Sickle® 520, Precept®, Velocity®	Clean water (Spraymate®), Absolute Boomer®	Rinse thoroughly several times with clean water before use.
Hormone type, salt or amine formulations (2,4-D amine, MCPA amine, 2,4-DB, dicamba)	2 L household ammonia (Spraymate®), Ammonition®	Thoroughly agitate and flush a small amount of solution through the system and let stand in sprayer overnight. Flush and rinse with clean water several times before use.
Hormone type, ester formulations 2,4-D ester, MCPA ester, Paragon®, Midas®	500 g washing soda (chrystaline sodium carbonate) + 4 L kerosene + 125 g powdered detergent (Spraymate®), 2 L Ammonition®	Rinse the inside and outside of the tank and flush a small amount through the system for 15–20 min. Let stand for at least 2 h or overnight preferably. Flush and rinse before use.
Atrazine, simazine	125 g powdered detergent (Spraymate®), Absolute Boomer®	Rinse with clean water before and after using the solution.
Sulfonylurea herbicides Glean®, Logran®, Ally®, Logran® B-power, Hussar® OD, Tackle®, Lynx®, Lonestar®, Atlantis® OD	300 mL fresh household chlorine bleach containing 4% chlorine or 300 mL BC-45 Spray Equipment Cleaning Agent (Spraymate®) per 100 L water with agitation. Absolute Boomer® or CC49®	1.Drain and flush the tank, hoses and boom with clean water for 10 min. 2. Fill the tank with clean water and add the chlorine bleach. Flush the boom and allow to stand for 15 min then drain. 3. Repeat step 2. 4. Nozzles, screens and filters should be removed and cleaned separately.
Broadstrike™, Eclipse® 100 SC, Lontrel™, Grazon™ DS, Victory®, Fightback®, Conclude™, Crusader™, Torpedo™	500 mL liquid detergent DynamoMatic®, or 500 g of the powder equivalent such as Surf®, Omo®, 1 L Absolute Boomer®	Flush the system, then quarter-fill the tank with water and add the detergent. Start the pump and circulate for at least 15 min. Drain the whole system. Remove and clean the filters, screens and nozzles with clean water and allow to drain.
Herbicides for grass control in broadleaf crops and pastures such as Verdict™ (520 g/L)	500 mL liquid alkali liquid detergent such as Surf®, Omo®, DynamoMatic®, or 500 g of the powder equivalent.1 L Absolute Boomer®	If broadleaf herbicides, particularly sulfonylureas (such as Glean®, Logran®), have been used in the spray equipment at any time prior to grass herbicides such as Verdict™, particular care should be taken to follow the directions for cleaning and decontamination on the label of the relevant broadleaf herbicide. Before spraying cereals, maize, sorghum or other sensitive crops, wash the tank and rinse after use. Completely drain the tank and wash filters, screens and nozzles. Drain and repeat the procedure twice. To decontaminate, wash and rinse the system as above, quarter-fill the tank, add the detergent and circulate through the system for at least 15 min. Drain the whole system. Remove filters, screens and nozzles and clean separately. Finally, flush the system with clean water and allow to drain.
Affinity®	100 g of alkali detergent, e.g. Omo® or Spree® 1 L Absolute Boomer®	1. Drain sprayer tank and system and thoroughly rinse the inside of the sprayer tank with clean water. Remove and clean all filters and nozzle strainers. Flush through sprayer system. 2. Half-fill the tank with clean water and add alkali detergent. Fill the tank to capacity and operate the sprayer for a minimum of 15 min. 3. Drain the sprayer system and rinse the tank with clean water and flush through the system. Remove and check all filters and nozzle strainers and clean if necessary.

Spray-tank contamination of small quantities of sulfonylurea herbicides such as Glean® and Logran® can be extremely damaging to crops such as pulses, canola and other oilseed crops as well as legume pastures. Grass-control herbicides such as Verdict™, Fusilade® Forte, Correct®, Select®, Targa® and Sertin® can be extremely damaging to winter and summer cereals

Nufarm Spraymate® Tank and Equipment Cleaner can also be used to decontaminate spraying equipment.

NOTE: Rinse water should be discharged into a designated disposal area, or if this is unavailable, onto unused land away from plants and water sources.

6.7.3 Spray drift

When applying pesticides, the aim is to maximise the amount reaching the target and to minimise the amount reaching off-target areas. This results in:

- maximum pesticide effectiveness
- reduced damage and/or contamination of off-target crops and areas

In areas where various agricultural enterprises co-exist, conflicts can arise, particularly from the use of pesticides.

Pulse crops can be severely damaged by some hormone herbicide sprays, such as 2,4-D ester, drifting into the crop. This can happen when these sprays are applied nearby in very windy or still conditions, especially where there is an inversion layer of air on a cool morning.

When using these herbicides, spray when there is some wind to mix the spray with the crop. Do not use excessively high spray pressure, which will produce very fine droplets that are more likely to drift onto a neighbouring pulse crop.

All pesticides are capable of drift. There is a moral and legal responsibility to prevent pesticides from drifting and contaminating or damaging neighbours' crops and sensitive areas (Figure 21). [8]

Figure 21: *Glyphosate spray drift from the road verge on the left. Note the barrier effect of the tall weeds on the fence line.*

Photo: G. Bardell, Nufarm

6.8 Legal considerations of pesticide use

Information on the registration status, rates of application and warnings related to withholding periods, occupation health and safety (OH&S), residues and off-target effects should be obtained before making decisions on which herbicide to use. This information is available from the State Department Chemical Standards Branches, chemical resellers, APVMA and the pesticide manufacturer.

Some of the legal issues surrounding herbicide usage are considered here, but it by no means exhaustive. Specific questions should be followed up with the relevant staff from your local State Department.

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Registration

Users should be aware that all herbicides go through a registration process, where they are normally authorised (registered) by the Australian Pesticide and Veterinary Medicine Authority (APVMA) for use:

- against specific weeds
- at specific rates of product
- in prescribed crops and situations
- where risk assessments have been evaluated that these uses are:
  - » effective (against the weed, at that rate, in that crop or situation)
  - » safe in terms of residues not exceeding the prescribed maximum residue level (MRL)
  - » not a trade risk

Labels

A major outcome of the registration process is the approved product label, a legal document, that prescribes the pest (weed) and crop situation where a product can be legally used, and how.

SDS

Material Safety Data Sheets are also essential reading. These document the hazards posed by the product, and the necessary and legally enforceable handling and storage safety protocols.

Permits

In some cases, a product may not be fully registered but is available under a Permit with conditions attached, which often require the generation of further data for eventual registration.

APVMA

The national body in charge of administering these processes is called the APVMA (the Australian Pesticides and Veterinary Medicines Authority) and is based in Canberra.

Details of product registrations and permits are available via the APVMA's website www.apvma.gov.au.

Always read the label

Apart from questions about the legality of such an action, the use of products for purposes or in manners not on the label involves potential risks. These risks include reduced efficacy, exceeded MRLs and litigation.

Be aware that herbicide-use guidelines on the label are there to protect product quality and Australian trade by keeping residues below specified MRLs. Residue limits in any crop are at risk of being exceeded or breached where herbicides:

- are applied at rates higher than the maximum specified;
- are applied more frequently than the maximum number of times specified per crop;
- are applied within the specified withholding period (i.e. within the shortest time before harvest that a product can be applied); or
- are not registered for the crop in question.

6.9 Getting best results from herbicides

Successful results from herbicide application depend on numerous interacting factors. Many of the biological factors involved are not fully understood, and are out of your control, so give careful attention to the factors that you can control.

Annual weeds compete with cereals and broadleaf crops mainly when the crops are in their earlier stages of growth. Weeds should be removed no later than 6 weeks after sowing to minimise losses. Early post-emergence control nearly always results in higher yields than treatments applied after branching in broadleaf crops.

Points to remember for the successful use of herbicides:

- Plan the operation. Check paddock sizes, tank capacities, water availability and supply.
  - » Do not spray outside the recommended crop growth stages; damage may result.
- Carefully check crop and weed growth stages before deciding upon a specific post-emergent herbicide.
- Read the label. Check to make sure the chemical will do the job. Note any mixing instructions, especially when tank-mixing two chemicals.
- Follow the recommendations on the label.
- Conditions inhibiting plant cell growth, such as stress from drought, waterlogging, poor nutrition, high or low temperatures, low light intensity, disease or insect attack, or a previous herbicide application, are not conducive to maximum herbicide uptake and translocation.
- Use good quality water, preferably from a rainwater tank. Water quality is very important.
  - » Hard, dirty or muddy water can reduce the effectiveness of some herbicides.
- Use good equipment checked frequently for performance and output.
- Use sufficient water to ensure a thorough, uniform coverage regardless of the method of application.
- Check boom height with spray pattern operation for full coverage of the target.
- Check accuracy of boom width marking equipment.
- Check wind speed.
  - » A light breeze helps herbicide penetration into crops.
  - » Do not spray when wind is strong (>10–15 km/h).
- Do not spray if rain is imminent or when heavy dew or frost is present.
- Calculate the amount of herbicide required for each paddock and tank load. Add surfactant where recommended.
- Select the appropriate nozzle type for the application.
- Beware of compromising nozzle-types when tank-mixing herbicides with fungicides or insecticides.
- Be aware of spray conditions to avoid potential spray drift onto sensitive crops and pastures, roadways, dams, trees, watercourses or public places. Note: all chemicals can drift.
- After products such as Atlantis®, chlorsulfuron, Hussar®, metsulfuron or triasulfuron have been used in equipment, it is essential to clean the equipment thoroughly with chlorine before using other chemicals. After using Affinity®, Broadstrike® or Eclipse® decontaminate with liquid alkali detergent.
- Seek advice before spraying recently released pulse varieties, which may differ in their tolerance to herbicides. Information on herbicide tolerance is available on the variety management package for the variety.
- Keep appropriate spray records for each spray operation. [9]

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6.10 Weed control requires a planned approach

Faba beans can mature too late in some extended seasons, so crop-topping (see section 6.13.2 Crop-topping) may have to be delayed or done before physiological maturity, risking yield and quality losses.

Faba beans can be relatively slow to emerge but with rapid early growth even during the colder winter months. Consequently, they are poor competitors with weeds early. Even moderate weed infestations can cause large yield losses and harvest problems.

Risk with crop-topping or inability to be able to crop-top to prevent weed seed-set is one reason producers give for not growing faba beans in southern Australia. Broadleaf weed control options post-emergence are very limited in faba beans, and this is another common reason producers cite for not growing them.

The weed-control strategy for growing a successful faba bean crop depends on substantially reducing the viable weed seedbank in the soil before the crop emerges, because post-emergence weed-control options are limited.

Selecting paddocks that are relatively free, or carry a low burden, of grass and broadleaf weeds is very important.

Broadleaf weeds need to be heavily targeted in the preceding crop and or fallow. Always assess the risk of broadleaf weeds prior to planting. This should be based on:

- grower experience
- the previous crop and herbicides used
- an assessment of winter weeds germinating in the fallow prior to planting

Paddocks with a severe broadleaf or grass weed problem should be avoided.

6.10.1 Weed competition in faba beans

Preventing increases in herbicide-resistant ryegrass populations during the faba bean phase of rotations is essential for maximum crop yield and sustainable cropping systems in southern Australia. Preventing weed seed-set in beans is the aim for most faba bean growers. Faba beans are reasonable competitors against ryegrass and other weeds early, but are at a relatively low plant population; hence, weeds can grow without necessarily inhibiting early development of the beans. If weeds are present, then later in the season they can affect yield and become a nuisance by setting seed, often necessitating desiccation to enable harvest.

Yield loss in faba beans caused by weed presence has not been recorded in research trials. Impact of weed seed-set and carryover to subsequent years may be more significant than yield loss *per se*, especially where weeds such as ryegrass or late broad-leafed weeds are present and not controlled.

6.10.2 Knockdown herbicides

The most important part of the weed-control strategy is to control the majority of weeds before seeding, either by cultivation or with knockdown herbicides such as glyphosate or Spray.Seed®

A technique used with varying success by growers has been to sow faba bean and then use a knockdown herbicide tank-mixed with a pre-emergent herbicide to control germinating weeds before the crop has time to emerge. Faba bean crops may take up to 28 days to emerge under cool, drying soil conditions, but under favourable warm, moist soil conditions, faba bean may emerge after 7–10 days. Growers considering this option should sow deeper (10–15 cm) and carefully check their paddocks for the emergence of the faba bean immediately before spraying. Done well, this can be an effective weed-control option.

6.10.3 Pre-emergent herbicides

These herbicides are primarily absorbed through the roots, but there may also be some foliar absorption (e.g. Terbyne®). When applied to soil, best control is achieved when the soil is flat and relatively free of clods and trash. Although most pre-emergent herbicides are suitable for use in high stubble-load paddocks, modern labels will suggest adequate control with 50% ground cover. Sufficient rainfall (20–30 mm) to wet the soil through the weed root-zone is necessary within 2–3 weeks of application. Best weed control is often achieved from a post-sowing application, because rainfall gives the best incorporation. Mechanical incorporation is less uniform and so weed control may be less effective. If applied pre-sowing and sown with minimal disturbance, incorporation will essentially be by rainfall after application. Weed control in the sowing row may be less effective because a certain amount of herbicide will be removed from the crop row.

Weed control

The absence of cost-effective and safe post-emergent herbicides effectively limits broadleaf weed control options in faba beans to a small number of pre-emergent herbicides. The efficacy of most of these chemicals is very dependent on rainfall soon after application, and consequently, inconsistent or partial weed control can result under drier conditions.

The pre-emergent herbicides will not adequately control large weed populations by themselves, and so they need to be used in conjunction with paddock selection, crop rotation and pre-seeding weed control.

Which pre-emergent herbicide to use is a question that can only be answered after assessing such factors as weed spectrum, soil type, farming system and local experience.

Refer to the complete product label for directions for use, rates and weeds controlled and conditions for best results.

Crop safety

The safety to pulse crops is due in part to chemical tolerance of the crop, in part to ensuring the seed is below the treated soil, and to ensuring no wash of herbicide into the seeding furrow.

Pre-sowing application is possible with some products and is often safer than post-sowing application, because the sowing operation removes a certain amount of the herbicide from the crop row. Higher rates can often be used pre-sowing, but in both cases the rate must be adjusted to soil type, as recommended on the product label.

The pH of a soil can strongly influence the persistence of herbicides. Many labels have warnings about high pH (≥8.0) and reduced rates to avoid crop damage.

The movement of herbicides down the soil profile after rain can affect crop safety. Movement is greater on sandy soils (and those with less organic matter), and so the application rate must be lower than on heavier soils (loams, silt plus clay 40–60%).

Heavy, intense rainfall following application may cause crop damage. This will be worse if the crop has been sown shallow (<3–5 cm), where there is light soil and where the soil surface is ridged. The soil surface should not be ridged, as this can lead to herbicides being washed down and concentrated in the crop row.

6.10.4 Pre-sowing (IBS, incorporation by sowing) herbicides

The resistance status of the weeds present, particularly ryegrass, must be known in order to determine which products and mixtures are used pre-sowing. IBS is generally considered safer for the crop than post-sowing pre-emergence with most herbicides used in modern, no-till sowing systems. There is, however, little protection within the sowing row, or else there is potential for crop damage if soil is thrown into the seeding furrow.

Outlook® (dimethenamid) has been registered to control herbicide-resistant ryegrass in some pulses. BUT it is NOT REGISTERED for use in faba beans because it is deemed too damaging.

Trifluralin (i.e. TriflurX®), pendimethalin (i.e. Stomp®), tri-allate (i.e. Avadex®), cyanazine (i.e. Bladex®), simazine, terbuthylazine (Terbyne®) and some diuron brands (e.g. Diurex ®) are registered for use on faba bean. Most require mechanical incorporation by sowing, and are often used in mixtures.

Both trifluralin and pendimethalin are used on annual ryegrass and provide partial control of wild oats, barley grass and brome grass. They are also effective on a range of broadleaf weeds including red and white fumitory and wireweed. Incorporation should occur within 4–12 h of application. Stubble can also tie up these two products. Best results have been achieved when stubble is at ≤50% ground cover, preferably left standing, and when higher water volumes (>80 L/ha) and coarse droplets are used.

Triallate provides control of wild oats and assists in the control of resistant ryegrass when used in a mixture. It can be applied immediately prior to or up 3 weeks before sowing. In a mixture, it does help to control ryegrass that has some resistance to trifluralin.

Cyanazine may be applied from 14 days before sowing to the time of sowing and is often recommended in combination with trifluralin or pendimethalin.

Simazine is often mixed with trifluralin or other products to provide a broader spectrum of both broadleaf and grass weed control, including annual ryegrass and wild oats as well as capeweed, fumitory, mustards, turnips and geranium. Incorporation should be made within 4 h of application.

Some brands of diuron (e.g. Diurex®, some proprietary diurons) are currently registered for IBS or PSPE use in faba beans in all states. If IBS is used, diuron should be applied to bare soil prior to or at sowing and incorporated by the sowing operation. Note that diuron use is currently under review by APVMA.

Most of these products work best if thoroughly mixed with soil either mechanically or by irrigation or rainfall. The aim of incorporation is to produce an even band of herbicide to intercept germinating weed seeds. There is some herbicide incorporation when sowing with knife-points, provided the sowing speed will throw soil into the inter-row only and not into the adjacent seed furrow. There may be insufficient soil throw with some low disturbance, disc seeding systems.

Typically, a follow-up, post-emergent grass-weed herbicide is still required to provide the level of grass-weed control desired by growers, particularly for the seed furrow. Faba beans are not a highly competitive crop, and early post-emergent grass control is often necessary.

With the continued development of populations of annual ryegrass and/or wild oats resistant to Group A, Group B and Group D herbicides, growers are again using older products as part of their resistance strategy for the opportunity they provide to rotate chemical groups.

If using trifluralin on faba bean, avoid shallow planting (below 2.5 cm). Similar comments apply to Stomp®. Very deep planting (below 5 cm) is usually safe. Be aware, though, that deep planting may also cause problems if the emerging shoots absorb greater quantities of the chemical. Affected shoots tend to swell and deform, and can result in a weak, patchy plant stand. [10]

10 Southern/Western Faba & Broad Bean—Best Management Practices Training Course. Module 5—Weed Management. 2013. GRDC/Pulse Australia.

6.10.5 Post-sowing pre-emergent (PSPE) herbicides

Simazine

Simazine is the most widely used herbicide for broadleaf weed control, and can provide relatively cheap control of cruciferous weeds. Efficacy is highly dependent on rainfall (20–30 mm) within 2–3 weeks of application, and consequently weed control efficacy varies under drier conditions.

Simazine has an adequate level of crop safety provided the following guidelines are adhered to.

- Simazine needs to be applied to moist soil as close to planting as possible. Moist soil helps to fix the chemical onto the clay particles and minimises simazine degradation.
- Weed control will be more reliable if the seedbed is level and free of clods. When clods break down after rainfall they expose untreated soil and disrupt the herbicide 'blanket'. Heavily ridged seedbeds often exhibit 'striping' and poor weed control on the 'hills'.
- Stubble does not present major problems, other than in heavy header trails or heavily 'bunched' from tillage operations.
- Avoid shallow planting if simazine is to be used, because crop tolerance is based on physical separation of the chemical from the faba bean roots. A planting depth of 7 cm is normally adequate on clay soils.
- Crop damage is often evident in compacted wheel tracks as a result of shallower planting depth and/or the concentration of chemically treated soil in the wheel-track depressions after rain.
- The planting furrow or trench needs to be closed and levelled at planting. This will minimise the risk of simazine-treated soil being washed in and concentrated near the seedling.
- Good subsoil moisture at planting will also help to minimise the risk of crop damage. Roots will develop down into moisture, rather than developing a shallow root system in the topsoil (where simazine activity is greatest).
- If grass weeds are present at application, consider tank-mixing glyphosate or Spray.Seed®.
- Avoid using simazine on coarse-textured, sandy loam soils; even low rates can leach down to the roots and cause significant crop damage.
- Avoid overlapping when applying simazine, and double spraying on headlands.

Terbyne® (terbuthylazine, 750 g/kg)

Terbuthylazine is the newest triazine herbicide to be introduced in Australia and is registered for pre-emergent weed control in faba beans, chickpeas, lupins, field peas, lentils and triazine-tolerant canola. Terbyne® is recommended for pre-emergent use (pre or post sowing).

Terbuthylazine controls a wide range of broadleaf weeds, with some suppression of grasses, particularly if there is good soil moisture. Sufficient rainfall (20–30 mm) to wet the soil through the weed root-zone is necessary within 2–3 weeks of application. Best weed control is achieved from post-sowing application because rainfall gives the best incorporation of Terbyne®. Mechanical incorporation pre-sowing is less uniform and so weed control may be less effective.

Although terbuthylazine is similar to the old triazine herbicides atrazine and simazine, it controls more weeds, lasts longer and is different in a number of ways that make it more effective and safer to crops.

Water solubility

The higher solubility of atrazine means greater movement through the soil, potentially causing crop damage and leaching into groundwater. The lower solubility of simazine results in less movement down the soil profile but can also make it less effective than terbuthylazine, which is slightly more soluble.

Soil binding

Terbuthylazine has significantly higher soil binding than atrazine or simazine, meaning greater crop safety and better weed control.

In a field test using soil columns containing a sandy loam or sandy clay loam, 75–80% of the applied Terbyne® remained in the top 5 cm of soil after 2.5 days of watering (Mountacer *et al*. 1997).

Sencor® (metribuzin, 480 g/L)

Depending on soil type, heavy rain (>10–20 mm) after spraying can leach metribuzin into the root-zone, causing crop damage. Risk of leaching of metribuzin is greatest on sandy soils, followed by friable, well-structured soils. Very heavy rain (>80–100 mm) after spraying on these soils may cause crop damage and leach metribuzin beyond the root-zone, thus reducing residual effect.

Chemical application rate used must match the soil type (see label). Apply to crops that were sown at depths greater than 4 cm to minimise damage through root uptake.

Cautions:

- DO NOT apply until soil is well wetted by the first good soil-settling rain after sowing. Apply to moist soil for best efficacy.
- DO NOT spray plants under stress from drought, waterlogging, frost or disease.
- DO NOT allow spray mix to stand overnight.

With no-till planting systems that use knife-points and press-wheels, the risk of crop damage is increased, especially on light soil types and if heavy rain occurs after spraying. Herbicide can wash into the furrows. Use of cover-harrows after planting and before either pre- or post-emergent metribuzin application improves crop safety.

Spinnaker® (imazethapyr, 700 g/kg)

Imazethapyr is registered for the pre-emergence control of certain weeds in faba beans and may be mixed with simazine. It is a Group B herbicide. Black bindweed (*Fallopia convolvulus*) is the main weed that is controlled with this herbicide in the northern region. Other listed weeds are deadnettle (*Lamium amplexicaule*), Indian hedge mustard (*Sisymbrium orientale*), white ironweed (*Buglossoides arvensis*), wild radish (*Raphanus raphanistrum*), and wireweed (*Polygonum aviculare*).

Cautions:

- DO NOT apply to very wet soils if rain is imminent, or to soils prone to waterlogging.
- DO NOT apply to soils of very high organic matter content.
- DO NOT apply to crops or weeds under stress caused by factors such as root or foliar diseases, nutrient deficiencies, or extremes of temperature or moisture.

Apply to moist, well-prepared, clod- and weed-free soil after planting and before crop emergence. Sufficient rainfall is required after application and prior to weed emergence to wet soil to a depth of 5 cm. Use the higher rate of simazine on heavier soils, or where higher weed pressure is expected, or where wireweed is a problem. Under adverse conditions, weeds may not be totally controlled but populations will be significantly reduced and surviving plants will generally be severely retarded. Good crop growth will aid weed control.

Transient yellowing or blackening of the crop may occur. The risk of crop injury may be increased under adverse growing conditions.

Do not use this mixture on soils or in areas ill-suited to growing faba beans, as crop injury will be increased.

MORE INFORMATION

NSW DPI 'Using pre-emergent herbicides in conservation farming systems': http://www.dpi.nsw.gov.au/agriculture/farm/conservation/information/pre-emergent-herbicides

Diuron

Not all diuron brands are registered for use in faba beans. As well, the APVMA is currently reviewing use of diuron with the intent of removing it from use. Some brands are currently registered for IBS or PSPE use in faba beans in all states. If applied by IBS, it should be applied to bare soil prior to or at sowing and incorporated by the sowing operation. For PSPE, apply as a post-plant application to moist soil before weed and crop emergence. Use the lower rate on light, sandy soils and do not apply to excessively ridged or waterlogged soils. Sow the crop at least 5 cm deep. Trifluralin or imazethapyr can be tank-mixed at the recommended rates.

Weeds controlled include capeweed, *Crassula*, doublegee, *Erodium*, wild radish, wild turnip, and toad rush.

6.10.6 Post-emergent herbicides

Only one broadleaf herbicide is currently registered under permit for post-emergence use, and it is used only to a very limited extent. Imazamox (e.g. Raptor® WG) can be used post-emergent for broadleaf weed control, but can cause transient yellowing, height reduction and delayed flowering, any of which can potentially reduce yield. It is effective on cruciferous weeds (turnip, etc.).

Imazamox can result in significant crop damage in our environment, particularly where dry conditions are experienced after applivcation. As stated on the product label, Raptor® usually causes some transient crop yellowing and can cause reddish discoloration and height suppression. Flowering may be delayed resulting in yield suppression.

It is used mainly in salvage situations (as a last resort), and even then, should be applied only under good growing conditions.

With the shift into row-crop faba beans, some growers are successfully using glyphosate and other products as a directed spray into the inter-row area. This keeps a large proportion of the herbicide off the faba bean foliage, and minimises problems associated with crop damage. [11]

6.11 Post-emergent grass-weed control

Control of grass weeds post-emergence is often inconsistent, with variable levels of control depending on the rate used and the level of resistance to the fop or dim herbicide being used. This particularly applies where marginal rates of the Group A herbicides are being used because of cost constraints.

More reliable and cost-effective control is considered achievable through the adoption of a management package that addresses all of the following key issues:

- Correct weed identification.
    - Match the product used to the weeds present.
- Weeds should be small, preferably at the 2–5 leaf stage.
    - Larger weeds will require heavier rates of Group A herbicides.
- Spray when weeds are actively growing and free from temperature, water, and nutritional stress.
    - Weeds enter into moisture stress quickly, especially if secondary roots have not established.
    - The leaves can also become water-repellent under dry, dusty conditions.
    - Seedling grasses stress very quickly, and there is usually only a narrow window of ideal conditions for applying Group A herbicides.
- Application techniques and boom-spray set-up are critical in achieving coverage of seedling grasses:

11 Southern/Western Faba & Broad Bean—Best Management Practices Training Course. Module 5—Weed Management. 2013. GRDC/Pulse Australia.

MORE INFORMATION

GRDC Update Paper: Herbicide resistance management, a local, in-field perspective

- » nozzle selection to achieve a medium spray quality
  - » operating pressures >3 bar
  - » water volumes >60 L/ha.
- Use the preferred adjuvant listed on the product label.

6.11.1 Mode of action

All the grass herbicides are systemic and rely on absorption through the leaves and then translocation to the growing points (meristematic tissue) of the plant.

Treated grasses usually stop growing within 1–2 days of spraying.

Visible symptoms first occur 7–10 days after treatment, usually as a yellowing of the youngest leaves and a browning of the growing points at the base of the youngest leaves. Unfurled leaves are easily pulled out, revealing brown rotting buds at the leaf base.

The young leaves turn pale and chlorotic and then brown off. The older leaves eventually collapse, with complete plant death occurring 4–6 weeks after spraying. Some weed species may also exhibit reddening of lower leaves and leaf sheaths.

6.11.2 Avoidance of stress conditions

All grass herbicide labels emphasise the importance of spraying only when the weeds are actively growing under mild, favourable conditions. Any of the following stress conditions can significantly impair both uptake and translocation of the herbicide within the plant.

The following conditions may result in incomplete kill or suppression only of weeds:

- moisture stress (and drought)
- waterlogging
- high temperature–low humidity conditions
- extreme cold or frost periods
- nutrient deficiency, especially low nitrogen
- use of pre-emergent herbicides (e.g. simazine, trifluralin and Stomp®) that can effect growth and root development (ensure that grass weeds have fully recovered from previous herbicide applications before applying grass herbicides)
- excessively heavy dews resulting in poor spray retention on grass leaves

Research overseas has verified that translocation rates of fluazifop are 2–3 times higher in oats grown under high nitrogen status than in low-fertility situations (Table 5).

Table 5: *Impact of low nitrogen fertility on translocation of fluazifop.*

	Uptake (% applied dose)	Translocation (% applied dose)	Fluazifop translocated to youngest leaf (dpm/mg)
Low nitrogen status	69%	9%	8
High nitrogen status	63%	26%	24

Source: Dickson et al. 1990.

6.11.3 Grass-herbicide damage in faba beans

Group A herbicides can occasionally cause leaf spotting in faba beans. This is usually associated with either frost or high temperatures occurring soon after spray application. It is not the Group A but the oil mixed with it that causes the damage. It acts as a magnifying glass on the leaf and burns the leaf surface (Figure 22).

Figure 22: *Herbicide-mix injury from a Group A grass selective herbicide.*

Photo: R. Kimber, SARDI

6.11.4 Sulfonylurea residues in boom sprays

Traces of sulfonylurea herbicides in boom sprays can cause significant damage to faba bean crops and other crops (Figure 23).

The risk of residue damage is greater in the presence of grass-selective herbicides.

Decontaminate the boom if you have previously used a sulfonylurea herbicide. See product labels for specific product recommendations on decontamination.

As a guide, use fresh chlorine bleach (household grade containing 4% chlorine) at a rate of 300 mL/100 L water. Allow to stand for 15 min with agitation engaged, then drain. [12]

Figure 23: *Damage to field peas from failing to de-contaminate the spray tank after use of Eclipse®.*

Photos W. Hawthorne, Pulse Australia

MORE INFORMATION

GRDC Fact Sheet: Pre-harvest Herbicide Use

6.12 Other weed-control strategies

6.12.1 Directed sprays in-crop

With the shift to cropping faba beans on wide rows, there is greater scope for the use of 'directed sprays' of glyphosate and other chemicals, either alone or in tank-mixes with simazine. This largely avoids the problem of crop damage, and improves weed control through the ability to safely add wetters or mineral oils to the spray mix.

12 Southern/Western Faba & Broad Bean—Best Management Practices Training Course. Module 5—Weed Management. 2013. GRDC/ Pulse Australia.

Shielded sprayers

These are becoming increasingly more common in or around the cotton-growing areas, as they provide very cheap control of grass and broadleaf weeds with glyphosate.

Although faba beans do have a degree of tolerance to glyphosate during the vegetative stage, caution is still required, as the branches arising from the base and main stem contribute a large proportion of the total faba bean yield. Issues that need to be considered include:

- selection and operation of spray shields (speed, nozzle type, etc.)
- height of the crop (small faba bean plants are more susceptible)
- variety (upright types such as Amethyst or Jimbour are more suited to this technique than the more prostrate types)

6.12.2 Crop-topping

Growers should consider choosing paraquat rather than glyphosate for crop-topping pulse crops where possible to minimise resistance development. Both glyphosate and paraquat are registered for use in pulses, however only glyphosate is registered for crop-topping canola or wheat. A key tactic of integrated weed management (IWM) is to rotate modes of action as much as possible and glyphosate is a chemical that is really heavily relied on in grain growing. There is no alternative in wheat or canola, but when it comes to crop-topping in pulses, paraquat can be a sensible choice to avoid the overuse of glyphosate. Along with herbicide selection, the timing of crop-topping is key to its success. It can be difficult to align the growth stage of the weed to prevent seed-set with the maturity of the crop to prevent damage, particularly in a good season when the crop will stay green longer. This is where the second advantage of paraquat comes to the fore: it can be applied a little later.

Paraquat can be applied up until the soft dough stage of ryegrass, whereas effective control with glyphosate needs to be at the milky dough stage. This means growers using paraquat can wait a little longer to allow the crop to mature and minimise yield losses. Growers should decide in advance what yield loss they are willing to risk in order to control weed seed-set. While crop-topping might be more difficult in a good year, a wet spring also means an increase in weed seed-set so doing nothing is not an option.

Some growers will accept a loss of five to 10 per cent yield in their pulse crop in order to target the weeds at the ideal growth stage. This loss is generally recovered through improved performance in the following year's cereal crop. However, if that risk is too high, or if the crop matures too late, growers can still receive some benefits in reducing late weed seed-set by crop-topping even if some of the weeds have set seed.

Where a late crop-top is performed with a significant weed problem, growers should consider a harvest weed-seed control option in addition to improve control of seed-set. [13]

Minimising glyphosate resistance

Glyphosate resistance has been found in about five per cent of annual ryegrass populations in random surveys in SA and Victoria. There have not yet been any cases of paraquat resistance in broadacre applications in Australia. This is in contrast to selective herbicides, to all of which, including clethodim, there is extensive resistance in annual ryegrass. It will take at least 10 years for any new mode of action to be available for growers even if it were discovered tomorrow. This means it is critical for growers to preserve the effectiveness of glyphosate through integrated weed management. [14]

13 GRDC (2016), Paraquat preferred for crop-topping pulses, Ground Cover Issue 124, https://grdc.com.au/Media-Centre/Ground-Cover/Ground-Cover-Issue-124-SeptemberOctober-2016/Paraquat-preferred-for-croptopping-pulses

14 GRDC (2016), Paraquat preferred for crop-topping pulses, Ground Cover Issue 124, https://grdc.com.au/Media-Centre/Ground-Cover/Ground-Cover-Issue-124-SeptemberOctober-2016/Paraquat-preferred-for-croptopping-pulses

MORE INFORMATION

Australian Pulse Bulletin: Desiccation and croptopping in pulses

6.12.3 Desiccation

With correct timing, desiccation can improve overall weed control as well as increase profitability in pulse crops.

The major differences between crop-topping and desiccation are:

- Herbicides used for crop-topping and desiccation are not always the same.
- Timing is not the same; desiccation occurs after crop maturity. Crop-topping is earlier, aimed to reduce seed-set of weeds before crop maturity.
- Herbicides are registered for desiccation as ‘harvest aids’, and rates used are higher than those used for crop-topping.
- Both desiccation and crop-topping will cause reduced grain quality and yield if applied at the wrong maturity stage of the crop.

6.13 References and further reading

Australian Herbicide Resistance Initiative, www.ahri.uwa.edu.au

Australian Glyphosate Sustainability Working Group, http://glyphosateresistance.org.au

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DAWA. Growing Pulses in WA. Department of Agriculture and Fisheries WA, https://www.agric.wa.gov.au/pulses/western-australian-pulse-industry

Field Crop Herbicide Injury: the Ute Guide. GRDC Ground Cover Direct.

Faba bean: The Ute Guide. GRDC Ground Cover Direct.

GRDC (2008) Grain Legume Handbook for the Pulse Industry. Grain Legume Hand Book Committee/GRDC, https://grdc.com.au/uploads/documents/Index.pdf

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P White *et al* (2005) Producing pulses in the southern agricultural region. Bulletin # 4656, http://www.web.uwa.edu.au/__data/assets/pdf_file/0007/920473/Pulse_Manual_Flyer.pdf

Summer Weeds: the Ute Guide. GRDC Groundcover Direct.

Weeds: the Ute Guide—Southern & Western edition (Version 2). GRDC Ground Cover Direct.

Weeds: the Ute Guide. Weeds app available for weed identification, www.grdc.com.au/apps

WeedSmart, www.weedsmart.org.au

Insect control

Insect pest management in pulses is more than just chemical control. Correct identification of the pest or beneficial is critical. An integrated approach rather than a prophylactic approach is required. Insect pest management in faba beans lends itself to an integrated pest management (IPM) program because the crop hosts a wide range of beneficial insects throughout the growing season.

There are two key insect pests of faba beans in the northern grains region: *Helicoverpa* spp. (Figure 1), which cause yield loss and damage grain quality; and aphids (Figure 2), which are a pest chiefly because they spread viruses. Other pests occur in faba beans, but they are sporadic, minor of uncertain pest status. These include the green mirid, loopers, beet armyworm and podsucking bugs.

Figure 1: Helicoverpa *larva damaging a maturing pod.*

Photo: Melina Miles, QDAF

Figure 2: *Faba bean plant heavily infested with cowpea aphid.*

Photo: Melina Miles, QDAF

7.1 Key insect pests of faba bean

This section covers the incidence of insect pests in faba beans, and the period of crop susceptibility to damage from these pests (Table 1).

Table 1: *The incidence of insect pests in faba beans, and the period of crop susceptibility to damage from these pests. Present—present in crop but generally not damaging. Damaging—crop susceptible to damage and loss.*

Pest	Crop stage				
	Emergence/ seedling	Vegetative	Flowering	Podding	Grainfill
Blue oat mites	Damaging	Present	Present		
Cutworms	Damaging				
Slugs	Damaging	Damaging			
Aphids (virus vectors)	Transmission of virus	Damaging Transmission of virus	Present	Present	
Helicoverpa spp. Native budworm Cotton bollworm		Present	Damaging?	Damaging	Damaging
Loopers		Present	Present		
Beet armyworm	Damaging	Damaging			
Green mirid		Present	Present	Damaging?	Damaging?
Podsucking bugs			Present	Damaging?	Damaging?
Thrips	Present Damaging?	Present	Present	Damaging?	

Source: IPM guidelines, http://ipmguidelinesforgrains.com.au/crops/winter-pulses/faba-bean/

7.1.1 *Helicoverpa*

Helicoverpa armigera (cotton bollworm)

Helicoverpa punctigera (native budworm)

To manage *Helicoverpa* well, it is important to be able to sample and identify the different larval instars (very small, small, medium–large, large). Familiarity with these different life stages is critical to determining the likelihood of damage occurring and optimising timing of control.

There are two species of *Helicoverpa*, *Helicoverpa armigera* and *H. punctigera* that may occur in faba beans in the northern region. *H. armigera* is resistant to some insecticide groups (particularly the synthetic pyrethroids), whilst *H. punctigera* is susceptible to all products. While it is not always possible to do so, identifying which species is present, or knowing which predominate in your area, may help you avoid products that may not give good control. It will also help you plan to minimise selection pressure from overuse of key products, and avoid the rapid development of insecticide resistance. There are some tools that can help you make this determination.

CASE STUDY

Managing Helicoverpa in faba beans—an interim management strategy

To avoid incurring excessive damage caused by a failure to detect *Helicoverpa* in the crop before they cause damage (a sampling issue), or because the threshold is too high and more damage is done than is currently expected the following management strategy is suggested.

Start sampling for *Helicoverpa* when the crop starts flowering. Be aware of the limitations of both the beat sheet and sweep net in detecting low densities, and smaller larvae.

Use a visual sample to detect small larvae in the terminal leaves, buds and flowers before they reach medium size.

Aim to treat the crop before larvae reach medium larval size and are capable of damaging pods

Consider including a low rate of NPV (*Helicoverpa* virus) with fungicide applications to assist with the control of early instar larvae. Repeated applications of low rate NPV are likely to be more effective than single higher rate applications. (see Section 7.5.7 Control options for Helicoverpa in faba beans for discussion on NPV use in winter–spring). The use of NPV to suppress potentially damaging populations during flowering will have considerable benefits over the use of broad-spectrum insecticides (e.g. synthetic pyrethroids) by not disrupting bees (pollination) and natural enemies.

Identifying Helicoverpa

Determining which species of *Helicoverpa* are present in the crop is essential, principally because of the differing susceptibility of the two species to synthetic pyrethroids and carbamates.

Visual identification of the different species is sometimes possible from examination of larvae, however, it can be difficult and unreliable for small larvae about the size when control decisions have to be made. A hand lens, microscope or USB microscope is critical for examining small larvae.

Small *H. armigera* larvae (3rd instar) have a saddle on the fourth segment and *H. punctigera* do not (Figure 3). This is often difficult to see in the field and this method is not 100% accurate, but may be used as a guide.

In larger (5th and 6th instar) larvae, hair colour on the segment immediately behind the head is a good species indicator (Figure 4). These hairs are white for *H. armigera* and black for *H. punctigera*.

H. punctigera and *H. armigera* moths are distinguished by the presence of a pale patch in the hindwing of *H. armigera* (Figure 5).

Figure 3: *Medium* Helicoverpa armigera *(12 mm) showing the distinctive 'saddle' on fourth and fifth body segments (top), and* H. punctigera *without saddle (bottom).*

Figure 4: *Large* Helicoverpa punctigera *(left) and* H. armigera *(right) larvae showing the distinguishing dark and pale hairs behind their heads.*

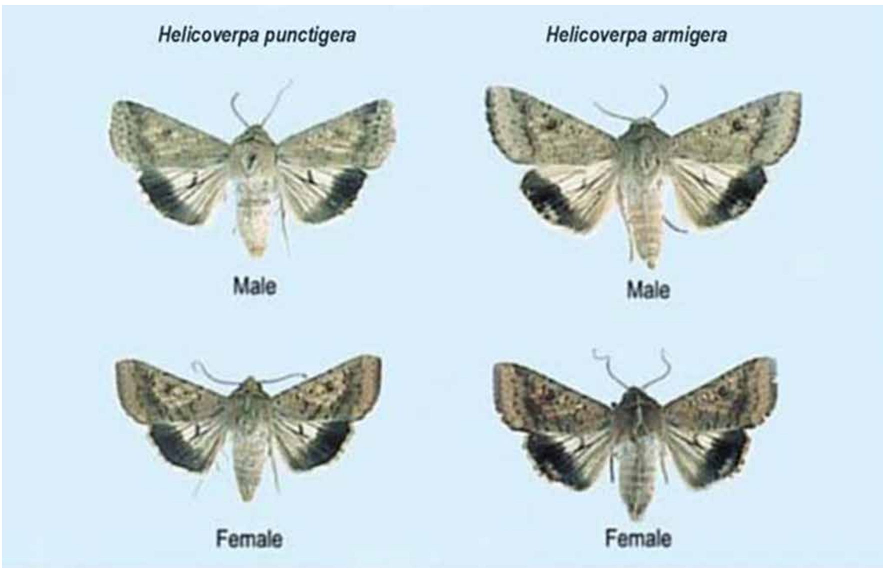


Figure 5: H. punctigera *and* H. armigera *moths are distinguished by the presence of a pale patch in the hindwing of* H. armigera.

Source: QDAF

Helicoverpa species composition can vary between seasons and regions

Species composition in the crop will be influenced by a number of factors:

- Winter rainfall in inland Australia that drives populations of *H. punctigera*; and the occurrence and timing of wind systems that carry *H. punctigera* from inland Australia to eastern cropping regions,
- Winter rainfall in eastern cropping regions which drives the abundance of local populations of *H. armigera* through the generation of spring hosts. In regions where chickpea is grown, chickpea may serve as a significant spring host for *H. armigera* emerging from diapause, if these populations are not controlled (e.g. subthreshold populations across large areas of poorly managed summer crops).
- Relative timing of flowering—podding (attractive and susceptible) stages and the immigration of *H. punctigera* and emergence of *H. armigera* from overwintering diapause. Note: in Central Queensland, *H. armigera* does not enter winter diapause and will be the predominant species in faba beans.
- Geographic location. In temperate regions (southern Queensland and further south) the majority of the *H. armigera* population over-winter from mid-March onwards and emerge during September/October. *Helicoverpa punctigera* is usually the dominant species through September when moths are migrating into eastern cropping regions. Seasonal variation can lead to *H. armigera*-dominant early infestations in some years, particularly in more northern districts. Pheromone trap catches can be used as an indication of the species present in a region. Note that pheromone traps are cannot be used to predict the size of an egg lay within a crop.

Life-cycle and development of Helicoverpa

Adult moths are active at night, but may be disturbed when sampling or walking through the crop during the day. Moths vary in colour from grey–green to pale cream and have a wing span of 3–4.5 cm (Figure 6).

Figure 6: *Native budworm (*Helicoverpa*) moths, showing male (right) and female (left). Note the buff colouring.*

Photo: SARDI

The female moths lay round eggs (0.5 mm in diameter) singly on the host plant. The eggs are white but turn brown just before hatching (Figure 7). In the spring, eggs hatch within 7–10 days (depending on temperature) and larva feed for 4–6 weeks.

The larvae can grow to 5 cm in length and vary in colour from green, yellow pink and reddish brown to almost black (Figure 8).

Figure 7: *Left to right: fresh white eggs, brown ring and black larval head visible in the eggs close to hatching.*

Source: QDAF

Larvae develop through 5–6 instars. Categorising larval size can be done in terms of instar, or more commonly, a size category (see Figure 8). Very small (1st instar), small (2nd instar), medium (3rd–4th instar) and large (5–6th instar).

Actual larval size	Larval length (mm)	Size category
	1-3	very small
	4-7	small
	8-23	medium
	24-30+	large

Figure 8: Helicoverpa *laval size categories and actual sizes.*

Once fully developed, larvae leave the plant and tunnel down up to 10 cm into the soil and form a chamber in which they pupate (Figure 9).

Pupae will normally develop to produce a moth in 2–3 weeks. The moth emerges, feeds, mates and is then ready to begin the cycle of egg laying and larval development. As with all insect development, the duration of pupation is determined by temperature, taking around 2 weeks in summer and up to 6 weeks in spring and autumn.

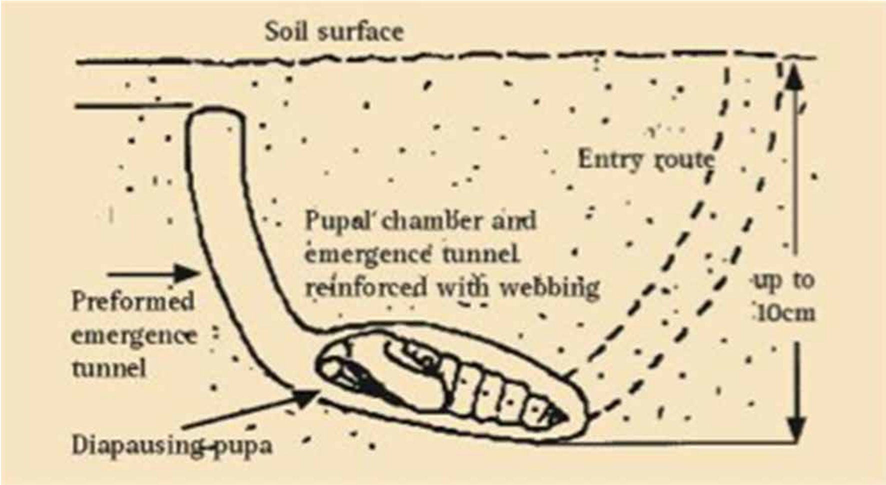


Figure 9: Helicoverpa *pupa in pupal channel, with the entry and exit tunnels that are excavated before the larva pupates.*

Source: http://www.daff.qld.gov.au/__data/assets/pdf_file/0005/72689/Insects-Helicoverpa-ecology-biology.pdf

Ninety per cent of all feeding (and therefore damage) by *Helicoverpa* is done by larva from the third instar (small–medium larva that are 8–13 mm long) onwards. Large *Helicoverpa* larvae (>24 mm) are the most damaging stage, since larvae consume about 80% of their overall diet in the fifth and sixth instars. This highlights the importance of controlling the larvae while they are still very small to small (<7 mm).

Full-grown, sixth instar larvae are up to 40 mm long with considerable variation in colours and markings (Figure 10).

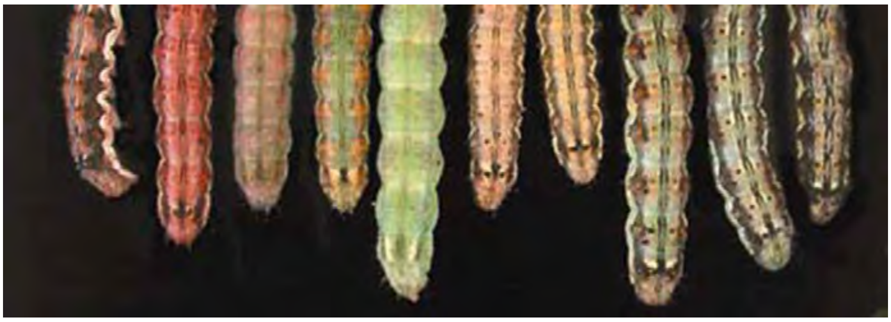


Figure 10: Helicoverpa *larval colour is very variable.*

Source: QDAF

7.1.2 Aphids

Identification

Although several aphid species may infest faba beans, the cowpea aphid (*Aphis craccivora*) is the most commonly observed because it forms very visible dark colonies. Other species are known to infest faba beans in other growing regions (pea aphid, blue green aphid; Figure 11), but a survey of which other species occur in faba beans in the north has not been conducted.

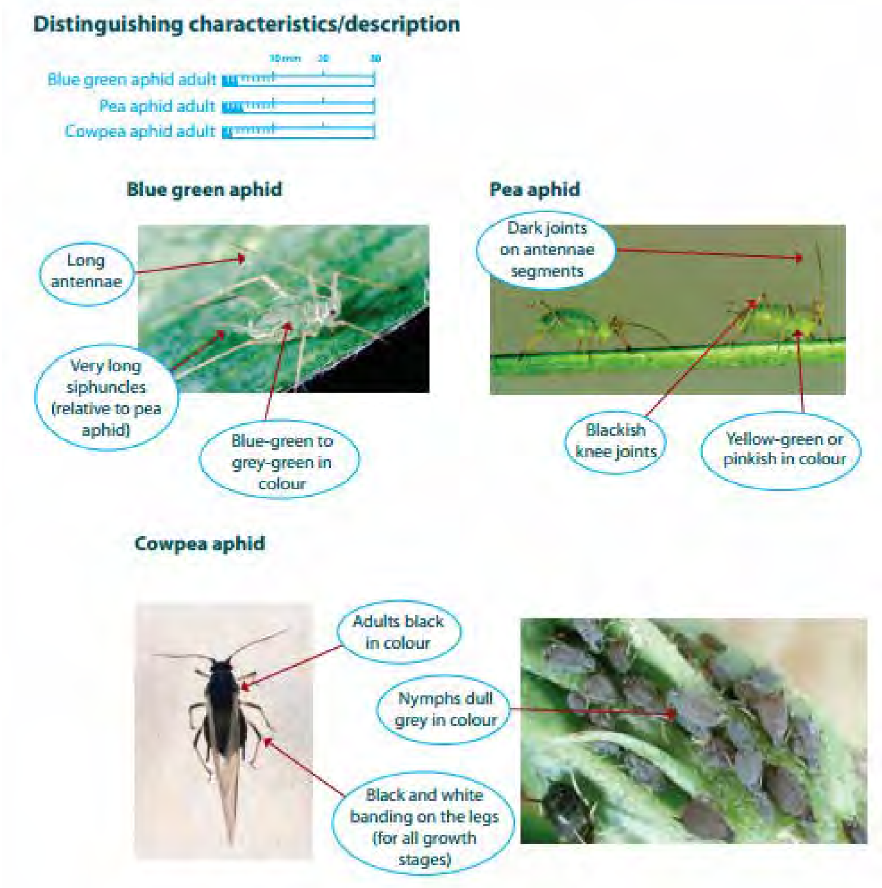


Figure 11: *Distinguishing characteristics of aphids of faba bean.*

Source: I SPY manual https://grdc.com.au/i-spy-manual

Cowpea aphid (Aphis craccivora)

Cowpea aphid is the only black-coloured aphid (Figure 12). Brown smudge bug nymphs superficially look like cowpea aphid nymphs, but cowpea aphid is unlikely to be confused with other aphids of pulses, as it is the only black aphid numerous on these crops. Adults are small (up to 2.5 mm long) and are shiny black, whereas the nymphs are slate grey (Figure 13).

The cowpea aphid is the major BLRV vector, as well as the most efficient SCSV vector and a vector of CMV.

Figure 12: *Cowpea aphid (*Aphis craccivora*). Note the different aphid ages—young to old. The older aphids are shiny black. All life stages have black and white banded legs. The white cast is a skin, shed as the aphid grows.*

Photo: Grain Legume Handbook

Figure 13: *Shiny black cowpea aphids and grey nymphs.*

Photo: Z. Ludgate, http://www.daff.qld.gov.au/plants/field-crops-and-pastures/broadacre-field-crops/integrated-pest-management/a-z-insect-pest-list/aphid-overview/cowpea-aphid

Cowpea aphid may be confused with the brown sowthistle aphid (*Uroleucon sonchi*) which may also be present in winter pulse crops on sowthistle (Figure 14). The brown sowthistle aphid does not colonise winter pulses.

Figure 14: *Brown sowthistle aphid (*Uroleucon sonchi*) can be confused with cowpea aphid. Its primary host is sowthistle, which can be common in winter pulses. Brown sowthistle aphid does not colonise winter pulses, but is able to transmit CMV.*

Photos: G. Cumming, Pulse Australia (left); Melina Miles, QDAF (right)

Life-cycle

In Australia, most pest aphid species only produce females, which may be winged (alates) or wingless (apterae), and these give birth to live young. In other countries some aphid species have different (or altered) life-cycle phases (e.g. sexual/asexual) that are initiated by host-insect interactions and/or environmental conditions. Many aphids are plant host (crop) specific. Aphids require specific host plants for their survival. Aphid populations usually decline over summer, as most species are adapted to cooler environments (introduced from the northern hemisphere). The availability of suitable host plants (e.g. specific weed families on roadsides and verges) allows populations to survive and increase. It is also possible that aphids breed up outside cropping regions, perhaps in the cooler, moister areas east of the Great Divide, and migrate into cropping regions in autumn and/or spring. This was the likely scenario for the widespread and sudden influx of cowpea aphid in the northern region in the autumn of 2014. Winged aphids move into crops in autumn and aphid numbers will usually start to build up along crop edges. Where mild autumn conditions persist, aphid populations can build quickly, but generally decline as temperatures drop in winter. The formation of winged aphids and aphid movement generally increases when host plants are dying or when overcrowding occurs with high populations. Nymphs go through several growth stages, moulting at each stage into a larger individual. Sometimes the delicate pale aphid skins or casts (the exoskeleton they have shed) can be seen. Nymphs do not have wings. Spring often triggers a rapid increase in aphid numbers as increasing temperatures and flowering crops provide favourable breeding conditions. Most aphids form dense colonies before winged aphids are produced. These move onto surrounding plants further into the crop creating hot spots. Rain, and the activity of natural enemies can impact significantly on aphid survival and population growth.

In some seasons, aphids form large colonies and heavy infestations may produce large amounts of a sticky secretion (honeydew). Faba bean leaf reaction to the honeydew and/or the fungi that grow on the honeydew can be seen on leaves below heavy aphid infestations (Figure 15).

Figure 15: *Spotting on lower leaves associated with dense aphid infestations and the production of honeydew and associated fungi.*

Photo: Melina Miles, QDAF

Direct feeding damage

Aphids damage plants by direct feeding, although generally causing minimal damage unless they are in extremely high numbers. Direct feeding damage is typically seen in hot spots, often along the margins of a paddock where the aphids have colonised the crop first. Cowpea aphid will colonise the plant terminal and gradually spread lower on the plant if densities are high.

Figure 16: *A moderate infestation of cowpea aphid in the terminal of a vegetative faba bean plant. Some distortion of the leaves is evident as a result of aphid feeding.*

Photo: Melina Miles, QDAF

The impact of direct aphid feeding is not well understood, although in most instances the crop grows out of the symptoms. The main concern with aphids is their capacity to act as vectors, carrying and transferring virus diseases (Figure 16) during feeding/sucking.

Aphids as vectors of viruses

Viruses have become a major concern to faba bean producers in the northern grain region since the mid-1990s (Table 2). Two virus disease symptoms are seen: virus mosaic (dark and light green areas on leaves), usually accompanied by leaf roughness or distortion; and virus yellowing accompanied usually by leaf stiffness or rolling, stunting, and root blackening.

Table 2: *Aphids known to transmit viruses in pulse crops.*

Aphid Species	Common name	Cucumber mosaic virus (CMV)	Pea Seed-borne mo-saic virus (PSbMV)	Beet western yellows virus (BWYV)
Acyrthosiphon pisum	Pea ahid	✓	✓ 50%	
Aphis craccivora	Cowpea aphid	✓ 9 .4%	✓	✓
Acyrthosiphon kondoi	Blue green aphid	✓ 6 .1%		
Myzus persicae	Green peach aphid	✓ 10 .8%	✓	✓ 96%
Lipaphis erysimi	turnip aphid	✓ 3 .9%		
Macrosiphum euphorbiae	Potato aphid		✓	✓ 14%
Aphis gossypii	Melon or cotton aphid	✓	✓	
Aulacorthum solani	Foxglove aphid	✓	✓	✓
Brachycaudus helichrysi	leafcurl plum aphid			✓
Brevicoryne brassicae	Cabbage aphid	✓	✓	✓
Hypermyzus lactucae	Sowthistle aphid	✓		
Myzus ascalonicus	Shallot aphid			✓
Myzus ornatus	Ornate aphid	✓		✓
Rhopalosiphum maidis	Corn aphid	✓ (in glasshouse)		
Rhopalosiphum padi	Oat aphid	✓ (in glasshouse)	✓	
Therioaphis trifolii	Spotted alfalfa aphid	✓		
Uroleucon sonchi	Brown sowthistle aphid	✓		

Note that many more vectors are listed for PsbMV and/or CMV.

% is the virus transmission rate for various species

Source: I SPY manual https://grdc.com.au/i-spy-manual

Both types of viruses are carried into crops by aphids during autumn or late winter. Both reduce yields, but virus yellowing is more severe (sometimes lethal) and widespread. Virus species causing mosaic symptoms include Bean yellow mosaic virus (BYMV) and Broad bean wilt virus (BBWV) (Figure 17). Virus species that cause yellowing (also referred to as luteoviruses or luteo-type viruses) include Alfalfa mosaic virus (AMV), Bean leaf roll virus (BLRV), Beet western yellows virus (BWYV), Subterranean clover red leaf virus (SCRLV), and subterranean clover stunt virus (SCSV), of which BLRV (often in mixed infection with SCRLV) has been most severe and widespread.

Two of the major viruses in the northern grains region are BLRV and BYMV. Both viruses survive summer on green legume plants (such as lucerne), and can infect only through aphid vectors. Chemical control may prevent infection of BLRV, as the aphid needs a relatively long period to feed on the plant and transmit the virus. Chemical control will not have any effect on the rapidly transmitted BYMV. There are no current guidelines for the application of aphicides on faba bean to control virus. Early sowing (while maximising yield) will increase the exposure of crops to aphid flights, potentially resulting in more virus infection.

Cultural controls are the first options to be implemented. These include:

- Sow even plant stands into standing stubble.
- Control weeds that host aphids, including around perimeter and in neighbouring paddocks. Although keep in mind that aphids may migrate long distances into crops, and local weed control may not always prevent aphid infestation. However, local weed control will contribute to minimizing the persistence of virus resevoirs.
- Avoid sowing faba beans in paddocks adjacent to legume pastures/forages.
- Avoid stresses that reduce crop vigour (e.g. late sowing into cold soils, excessive herbicide application, poor nutrition).
- Block faba bean paddocks together and limit aphid entry points into paddocks.

The faba bean breeding program has several lines that have higher resistance to viruses than Doza⁽ᵇ and Cairo⁽ᵇ. These breeding lines are classified as 'resistant' to viruses rather than 'immune', so cultural control will still be important.

Figure 17: *Bean seed showing Pea seed-borne mosaic virus (PSbMV) markings (SARDI).*

Source: http://www.pulseaus.com.au/pdf/Faba%20bean%20disease%20management%20strategy%20Southern%20region.pdf p. 5

How aphids transmit viruses

Aphids can spread viruses persistently or non-persistently. Once an aphid has picked up a persistently transmitted virus—for example, Beet western yellows virus (BWYV)—it carries the virus for life, infecting every plant where it feeds on phloem. Aphids carrying non-persistently transmitted viruses, such as Cucumber mosaic virus (CMV), carry the virus temporarily and only infect new plants in the first one or two probes (Figure 18). [1]

1 GRDC (2010), Aphids and viruses in pulse crops, GRDC Fact Sheet, http://www.grdc.com.au/GRDC-FS-AphidsandVirusesinPulses

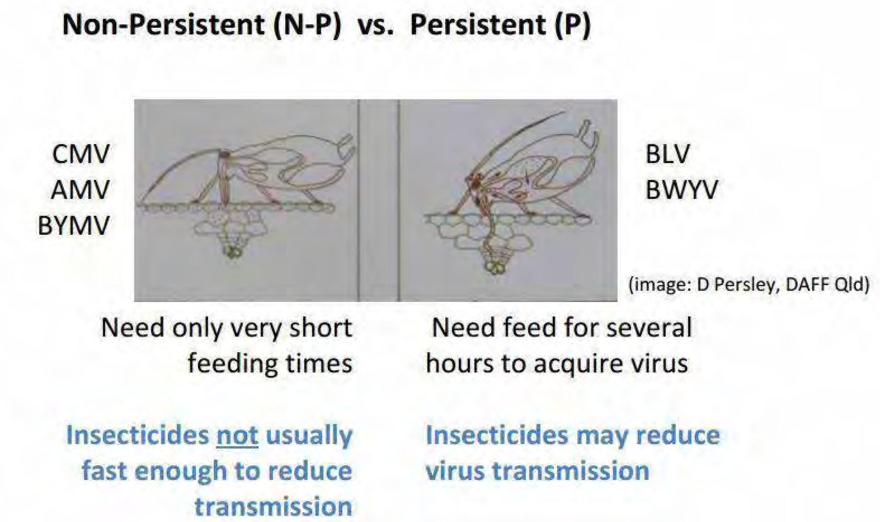
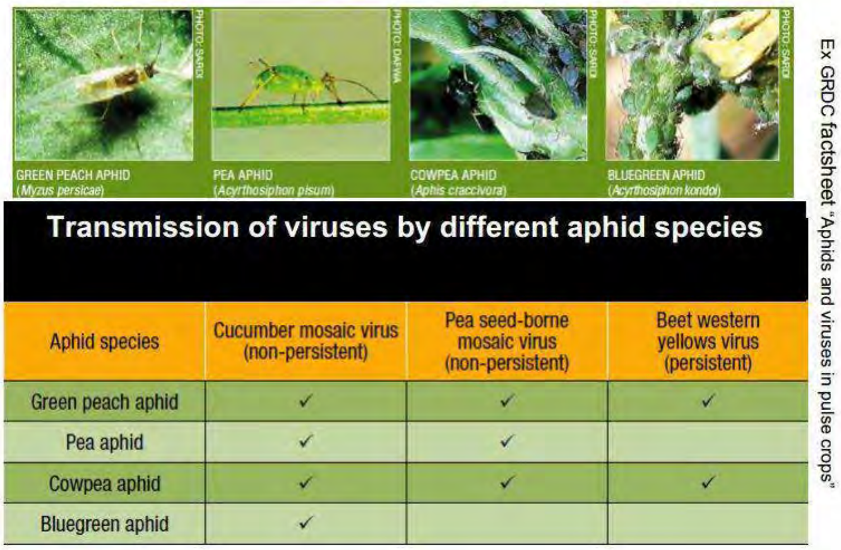


Figure 18: *Transmission of viruses by aphids.*

Source: D. Persley, QDAF

Persistent transmission

Persistent transmission means that when an insect vector feeds on an infected plant, the virus has to pass through the body of its vector and lodge in its salivary glands before it can be transmitted to a healthy plant, a process that takes >1 day. Once the insect is infectious, it remains so for the rest of its life. Very few aphid species are vectors of this kind of virus in pulses. These species of aphids tend to colonise their hosts. The pea and green peach aphids are important as vectors of luteoviruses in pulses. Because acquisition of the virus is slow, insecticides that kill aphids work well (except in the case of insecticide-resistant green peach aphid) in suppressing spread of these viruses (Figure 19), including Bean leaf roll virus (BLRV), Bean yellow mosaic virus (BYMV), Subterranean clover red leaf virus (SCRLV) and subterranean clover stunt virus (SCSV).



Transmission of viruses by different aphid species

Aphid species	Cucumber mosaic virus (non-persistent)	Pea seed-borne mosaic virus (non-persistent)	Beet western yellows virus (persistent)
Green peach aphid	✓	✓	✓
Pea aphid	✓	✓	
Cowpea aphid	✓	✓	✓
Bluegreen aphid	✓		

Figure 19: *Transmission of viruses by different aphid species.*

Source: GRDC Fact Sheet https://grdc.com.au/GRDC-FS-AphidsandVirusesinPulses

Non-persistent transmission

Non-persistent transmission means that the insect vector can land on a virus-infected plant, make a brief probe, acquire the virus on its mouthparts within seconds, and then transmit it immediately when probing on a healthy plant. The aphid loses the virus after it probes a healthy plant one or two times. After this, the insect does not infect further plants. The whole process is so fast that insecticides do not act quickly enough to prevent transmission, and can exacerbate the situation by making the aphids hyperactive, flitting from plant to plant (Figure 20). Many aphid species are vectors of this type of virus, including ones that do not colonise legumes but just land and probe pulse crops while searching for their preferred hosts, such as oat and turnip aphids. Such viruses include: Alfalfa mosaic virus (AMV), Bean yellow mosaic virus (BYMV), Cucumber mosaic virus (CMV) and Pea seed-borne mosaic virus (PSbMV).

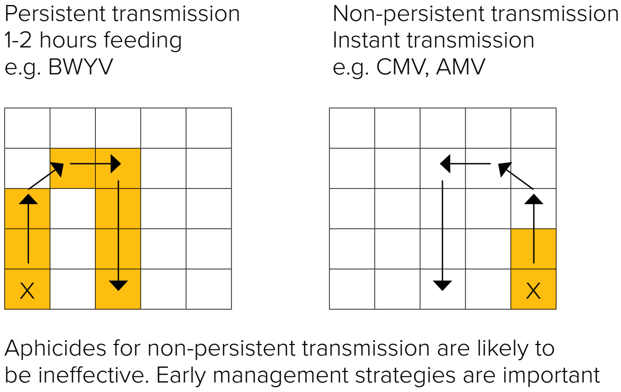


Figure 20: *Differences in the progression of infection within a field of persistent and non-persistent viruses vectored by aphids.*

Source: I SPY manual https://grdc.com.au/i-spy-manual

7.2 Other insect pests

There is a suite of other insect pests that may occur in faba beans in the northern grains region. Significant impact is either poorly understood, or sporadic. Nevertheless, it is worthwhile to be aware of their damage potential, and be able to identify them in the event of an outbreak.

MORE INFORMATION

Spotting green mirid damage on faba beans

7.2.1 Green mirid (*Creontiades dilutus*)

Green mirid adults are 7 mm long, pale green, with antennae nearly as long as the body; and often with red markings on legs (Figure 21). Wings are clear and folded flat over the back. Green mirid nymphs have a pear-shaped body and the tips of the antennae are reddish brown. Newly hatched nymphs are 1–2 mm in length. Late instar nymphs (4–5th instar) are up to 7 mm long and have dark wingbuds. All nymphs have red-tipped antennae.

Figure 21: *Green mirid adult (left) and nymph (right).*

Photo: QDAF

Green mirid adults may be confused with the Broken-backed bug (*Taylorilygus pallidulus*) and the Crop mirid (*Sidnia kinbergi*) (Figure 22). Both these other species are smaller than the green mirid.

Figure 22: *Broken-back bug adult (left) and late instar nymph (second from left). Wingbuds clearly visible on the nymph indicating it is 4–5th instar. Crop mirid nymph (far right) and adult (second from right).*

Photos: J Wessels, QDAF

For images and descriptions of mirids and mirid-like species see the *Good Bug, Bad Bug* book (http://thebeatsheet.com.au/resources/).

Life-cycle

Green mirid adults move into crops, typically in spring, from local weed hosts and/or migrate into cropping areas from inland Australia. Females insert the 1.5 mm, banana-shaped eggs into the plant stems. Females can live for 3+ weeks and lay up to 80 eggs over this period. Eggs cannot be scouted in the field. Eggs hatch in 4–5 days in summer, longer under cooler temperatures, possibly up to 10 days. There are 5 nymphal stages (instars). Development from egg to adult takes around 2 weeks in summer, longer under cooler conditions.

Damage

Adults and nymphs pierce plant tissue and release a chemical (pectinase) that destroys cells in the feeding zone. Medium and large nymphs (3rd–5th instar) are as damaging as adults. In summer pulse crops (mungbeans, adzuki beans), mirids feed on buds, flowers, and developing pods causing them to shed. When mirids feed on maturing pods, they can damage the seed without causing the pods to shed. It is this type of damage that is thought to have been caused by mirids in faba bean crops in 2014. Further research is required to validate the preliminary trial work, and to understand the impact of mirids on buds, flowers and pods/seed at different stages of development.

In preliminary trial work (M. Miles, QDAF 2014), maturing pods were caged with mirid adults for seven days (Figure 23). Control pods were caged without mirids. After seven days, half the pods were harvested, still green, and examined for damage. The remaining pods were left on the plants until maturity and then harvested. Examination of green pods and seeds showed no sign of damage (no necrosis, no spotting). The seed from the late harvested pods showed clear evidence of spotting, consistent with feeding damage caused by mirids in other crops. The impact of mirid feeding, whilst requiring further validation, is a seed quality/appearance issue.

Figure 23: *Cage used to confine green mirid adults on maturing faba bean pods to assess damage potential (left). Seed from pods not exposed to green mirids (centre). Seed from pods exposed to adult mirids for 7 days (right).*

Photos: Melina Miles, QDAF

Monitoring and thresholds

Mirids can be monitored in faba beans using a sweep net or beat sheet—in conjunction with *Helicoverpa* sampling perhaps.

There are no thresholds yet established for mirids in faba beans. It is also unclear what stages of budding—grain development and maturity are susceptible to mirids. We know from experience in summer pulses and cotton that crops are able to compensate for loss of buds and flowers. However, damage to seed quality during pod filling is more problematic.

Management

No definite management strategy has yet been devised for mirids in faba beans. However, the disruptiveness of insecticide options that will control mirids means that a considered approach is required. Some suppression of mirids may be achieved if indoxacarb is used to control *Helicoverpa*.

7.2.2 Cutworms (*Agrotis* spp.)

Several species of cutworms, including *Agrostis munda* (brown cutworm), *A. infusa* (Bogong moth; Figure 24), *A. ipsilon* (black cutworm) and *A. prophyricollis* (variable cutworm) attack a wide range of crops in the northern cropping zone. The common name cutworm is derived from the larval habit of severing the stems of young seedlings at or near ground level, causing the collapse of the plant.

Identification

Larvae are up to 50 mm long, hairless with dark heads and usually darkish coloured bodies, often with longitudinal lines and/or dark spots (Figure 25). Larvae curl up into a C-shape and remain still if picked up. Moths are a dull brown-black colour. Cutworms may be confused with armyworms and *Helicoverpa* larvae. Moths are a dull brown-black colour.

Visit the QDAF website for identification information (https://www.daf.qld.gov.au/plants/field-crops-and-pastures/broadacre-field-crops/integrated-pest-management/a-z-insect-pest-list/soil-insects/cutworm).

Damage

Cutworm larvae can sever stems of young seedlings at or near ground level, thereby causing collapse of the plant. Sometimes the young plant is partially dragged into the soil where the larvae feed on it. Larvae may also climb plants and browse on or cut off leaves. Crop areas attacked by cutworms tend to be patchy and the destruction of seedlings in one area may cause cutworms to migrate to adjacent fields. Risk period is summer and spring—one generation per crop.

Monitoring and thresholds

Inspect emerging seedlings twice per week and plants up to budding stage once per week. Check 1 m of row at a number of locations. Check along the plant row, at the base of seedlings under the soil surface and stubble. Placement of a hessian bag on the soil surface may draw cutworms to the surface. Check for their presence in the morning. Treat seedlings when there is a rapidly increasing area or proportion of crop damage. Treat older plants if 90% (9 out of 10) checks have cutworm present, or if defoliation exceeds 75%.

Management

- Controlling weeds prior to planting will reduce the risk of cutworm infestations. Moths will lay on weeds, and large larvae move from the weeds to establishing crops when weeds are sprayed, cultivated or senesce.
- A late-afternoon spray, close to the time when feeding commences, gives best results.
- Spot spraying of infested patches may suffice.
- Cutworms are killed by a number of natural enemies such as parasitoids, predators and diseases.

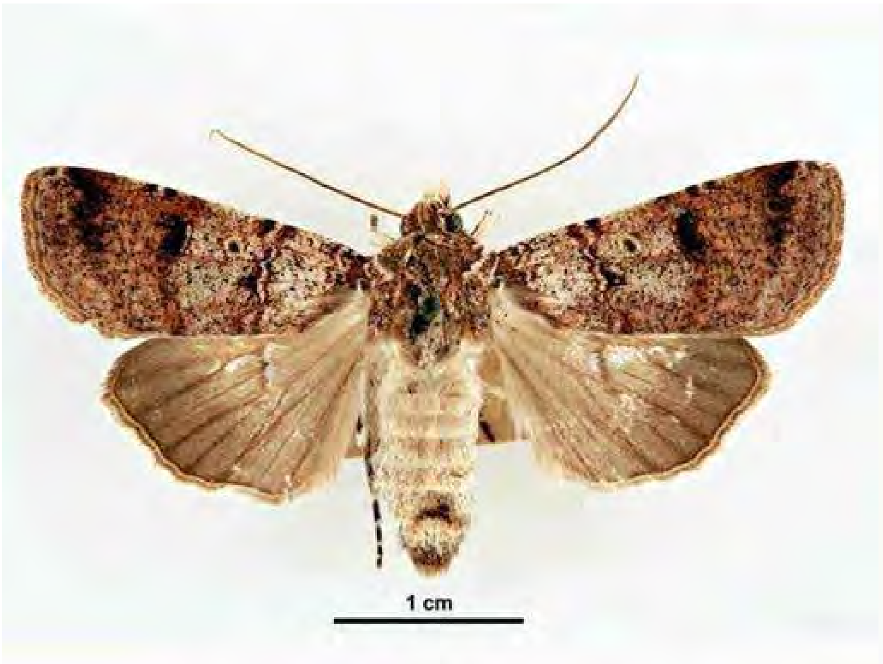


Figure 24: *Bogong moth.*

Source: Lucinda Gibson and Ken Walker Museum Victoria; http://wwwpadil.gov.au/pests-and-diseases/pest/main/136308/5837

Figure 25: *Cutworm. The common name is derived from the larval habit of severing the stems of young seedlings at or near ground level. 40 mm.*

Photo: P. Room, http://www.cottoncrc.org.au/industry/Publications/Pests_and_Beneficials/Cotton_Insect_Pest_and_Beneficial_Guide/Pests_by_common_name/Cutworms

7.2.3 Thrips

Several species of thrips can damage faba bean crops, but little is known of their economic impact. Leaf feeding damage to seedlings can occur. In seedlings, thrips cause distortion of the emerging and expanding leaves. Unless the thrip pressure is extreme, and the crop emergence compromised by limited moisture or cold, plants will grow out of the damage and it is considered cosmetic rather than damaging.

More commonly, thrips are observed in flowers. Thrips feed on the pollen in flowers and it is speculated that they affect the development of small pods. However, the link between thrips and pod damage is not well established. Thrip numbers almost always exceed the nominal threshold of 4–6 per flower. [2]

Onion thrips (*Thrips tabaci*), plague thrips (*T. imaginis*), tomato thrips (*Frankliniella schultzei*; Figure 26) and Western flower thrip (*Frankliniella occidentalis*) are all likely to be present in faba beans.

Damage

Damaged leaves and older pods are marked with silvery brown blotches. Unless excessive, (for example, on seedlings where growth has slowed because of cool, wet or dry conditions) plants will grow through this damage. Thrips can transmit Tomato spotted wilt virus (TSWV), which is often mistaken for chocolate spot (Figure 27).

Monitoring and thresholds

Seedling thrip infestation can be monitored by gently pulling up seedlings to examine for the presence of thrips (using a hand lens if necessary). In budding and flowering plants, beat the growing points and flowers onto your hand (or white paper) to dislodge the thrips.

2 NSW DPI (2013) Insect and mite control in field crops 2013. NSW DPI management guide, http://www.dpi.nsw.gov.au/__data/assets/pdf_file/0005/284576/Insect-and-mite-control-in-field-crops-2013.pdf

Figure 26: *Adult tomato thrips (*Frankliniella schultzei*).*

Photo: L. Wilson, http://www.daff.qld.gov.au/plants/field-crops-and-pastures/broadacre-field-crops/integrated-pest-management/a-z-insect-pest-list/thrips-overview/tomato-thrips,-plague-thrips

Figure 27: *Tomato spotted wilt virus (TSWV), which can be transmitted by thrips and is often mistaken for chocolate spot.*

Photo: Drew Penberthy, Penagcon

Figure 28: *Oedema on faba bean pods are not a result of insect feeding.*

Photo: Melina Miles, QDAF

Oedema on the surface of faba bean pods are not caused by insect feeding (Figure 28). This damage is often assumed to be caused by thrips; this is incorrect. Oedema is a physiological condition that causes surface 'blisters' on leaves and pods. Oedema occurs typically when the soil is warm and moist, and the night air is cool and humid, and a thick crop canopy further reduces air movement. As a result, plant transpiration is lower than water uptake. When the blisters rupture, the oedema dry leaving a warty or scaly 'scab'.

7.2.4 Loopers

Tobacco looper Chrysodeixis argentifera

Vegetable looper Chrysodeixis eriosome

Soybean looper Thysanoplusia orichalcea

Loopers are occasional seen in faba beans, and it is possible that any of the three species above could be present. Loopers can be distinguished from *Helicoverpa* by their 'looping' action when walking—visit the Beat Sheet on YouTube to see looper and *Helicoverpa* larvae movements (http://www.youtube.com/user/TheBeatsheet).

Other distinguishing features of loopers:

- their body tapers to the head; and

- they have only two pairs of hind legs, as opposed to four for *Helicoverpa*.

Identification

Eggs are pale yellow-green, ribbed and are flatter than *Helicoverpa* eggs. Looper eggs hatch in 3–6 days. There are six larval stages. Larvae take 2–3 weeks to develop. Larval colour can vary considerably. Large larvae are usually green with white stripes. Larvae can reach 50 mm in length. Looper larvae usually pupate under leaves in a thin silken cocoon. Pupae are dark above and pale underneath.

Figure 29: *Soybean looper showing characteristic irregular feeding damage (left) and looping action (right).*

Photos: Melina Miles, QDAF

Damage

Larvae feed on leaves. Eighty per cent of defoliation is done by medium–large larvae. Looper damage is characterized by large irregular shaped holes in the leaves, usually coinciding with the appearance of large larvae (Figure 29). In contrast, *Helicoverpa* leaf feeding results in rounded holes.

Loopers have the potential to cause significant defoliation in crops, but this level of damage has not been recorded in faba beans.

Monitoring and thresholds

Be alert to the presence of small looper larvae, and the likelihood that the visible level of defoliation will accelerate as larvae reach late instar stage (40–50 mm in length).

Larvae will be dislodged with beat sheet and sweep net sampling. The presence of plants with evident leaf feeding should trigger sampling specifically for loopers.

There is no threshold established for loopers in faba beans.

Management

Looper eggs and larvae are attacked by the same predators and parasitoids as other lepidopteran pests e.g. predatory beetles, predatory bugs and parasitoid wasps. Should control be warranted, *Bacillus thuringiensis* var. *kurstaki* (Bt), a naturally occurring bacteria, is effective against small larvae, and most products applied for *Helicoverpa* control will incidentally control loopers.

7.2.5 Beet armyworm

Lesser (or beet) armyworm (*Spodoptera exigua*) has been recorded causing minor defoliation in vegetative faba beans in the northern region in the autumn of 2014.

Identification

Eggs are laid in ‘rafts’ of 10 to 30 and are covered by creamy brown scales by the female moth. Newly hatched larvae aggregate around the egg raft. Late instar larvae are 30–40 mm long. Mature larvae may be confused with *Helicoverpa* larvae but are green to brown, about half the length of a mature *Helicoverpa* larva, with a white stripe along each side of the back. The moth is about 10 mm in length with grey/brown, mottled forewings. The hindwing is of a pearly white.

For images of egg rafts, and moths see Pests and Beneficials in Australian Cotton Landscapes (http://www.cottoninfo.com.au/sites/default/files/documents/pandbsguideweb%20%281%29.pdf).

Life-cycle

In summer, the egg stage lasts for 3 days. The larval stage lasts for about 9–14 days and usually has six instars. Pupation occurs in the soil and lasts for about 10 days. In autumn and winter, these stages may take somewhat longer to progress through.

Damage

The young larvae remain near the egg raft and skeletonise the leaf (Figure 30). Larger larvae may infest seedling and cause defoliation.

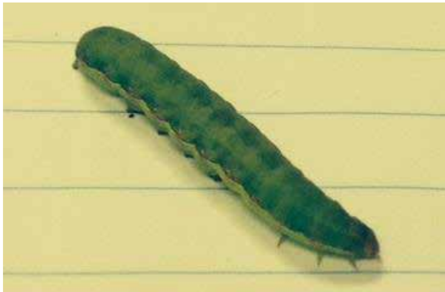


Figure 30: *Beet armyworm (*Spodoptera exigua*) larva (left) and feeding damage to vegetative faba bean (right).*

Photos: Chris Teague, Landmark, Goondiwindi, 2014

7.2.6 Slugs

Slugs are not a widespread issue in the northern region, although there are some areas that have an ongoing problem with slugs. Faba beans are probably one of the more tolerant winter crops, generally growing out of slug damage without any adverse impact. Field slug (*Deroceras reticulatum*), Black keeled slug (*Milax gagates*) and the Marsh slug (*D. larvae*) have been recorded from the northern region (M. Nash, pers. comm.).

For a full description, see Identification and control of pest slugs and snails for broadacre crops in Western Australia (Micic et al. 2007).

Identification

The most common species in southern Australia is thought to be the reticulated or field slug, *Deroceras reticulatum* (Figure 31). Usually grey in colour the adult slugs range from about two to four centimetres long.

The black keeled slug, *Milax gagates* has also been found in canola and wheat paddocks. This slug is uniform black to grey and four to five centimetres long.

Figure 31: *Top: Field slug (*Deroceras reticulatum*). Bottom: Black keeled slug (*Milax gagates*).*

Photo: Peter Mangano, DAFWA

Life-cycle

Slugs are hermaphrodites (individuals are both male and female). Each individual can lay about 100 eggs.

Moisture is essential for slug survival and some species may move down the soil to depths of 20 cm or more in dry periods and reappear when conditions improve.

Damage

Slugs have caused major damage in emerging canola, pulse and wheat crops especially in high rainfall areas but have also caused damage in lower rainfall areas in wetter years (Figure 32). The black-keeled slug will feed both above and below ground on germinating seedlings. Damage is usually greater in cracking clay soils which provide better habitat for slugs, because of the higher water-holding capacity of the soils.

Figure 32: *Slug damage in a faba bean seedling. Beans tolerate slug damage better than many other crops, particularly compared with lupin or canola.*

Photo: W. Hawthorne, Pulse Australia

Monitoring and thresholds

Monitoring has recently been shown to be an unreliable way to assess slug densities, and the need for control (Michael Nash, pers. comm.). This is principally because slug distribution across a field is highly variable, and they are only active under a narrow range of conditions.

Management

The effective management of slugs requires an integrated approach. Figure 33 shows a timeline for implementing a range of management strategies that will impact on a slug population.

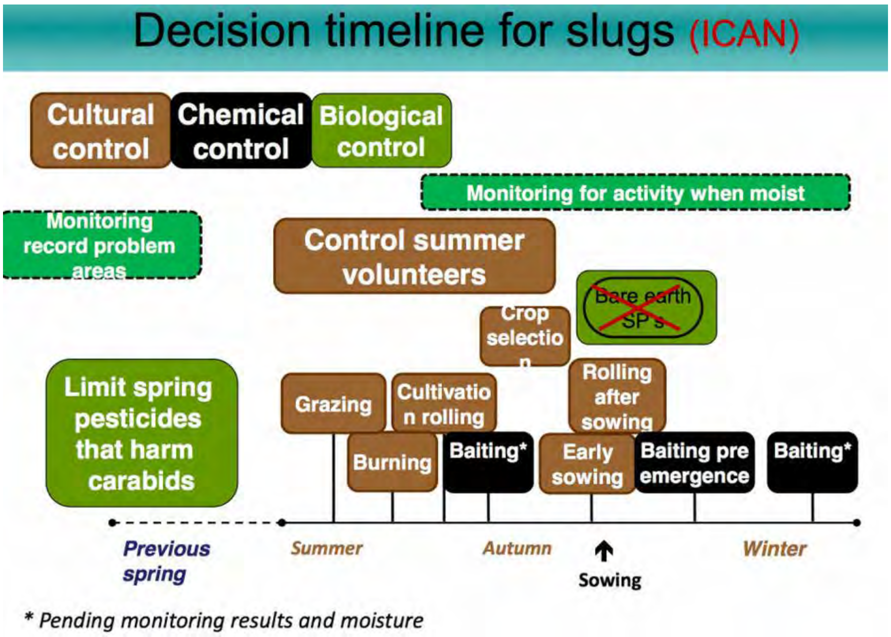


Figure 33: *Timeline for implementing slug management strategies.*

Source: Michael Nash, SARDI http://ipmguidelinesforgrains.com.au/wp-content/uploads/Apr2014-Snugs_SAVic.pdf

- Cultivation and rolling, and burning stubble after weeds are controlled will reduce slug populations.
- Rolling the soil after seeding can also reduce slug damage.
- Bait at sowing to protect seedlings as they emerge. Buried bait is less effective than bait on the soil surface.
- The most effective baits are metaldehyde and iron chelates. Metaldehyde damages the mucus producing cells and is therefore less affected by cold and wet conditions. Rates of up to 10 kg/ha may be necessary.
- Baiting will generally only kill 50% of the slug population at any one time, hence the need for a multi-pronged approach.
- Minimise the prophylactic use of synthetic pyrethroids ('just a bit in because we're going over the paddock anyway). SPs kill predatory beetles (carabids) that feed on slugs.

Further information on slug management and current research visit the Snug Blog maintained by slug researcher Michael Nash, SARDI (https://www.facebook.com/ASnugBlog or at https://asnugblog.wordpress.com).

7.3 Identification resources are useful for checking whether insects are friend or foe

7.3.1 Insect ID: The Ute Guide

The primary insect identification resource for grain growers is 'Insect ID: The Ute Guide'—a digital guide for smartphones and tablets that is progressively updated as new information becomes available (Figure 34).

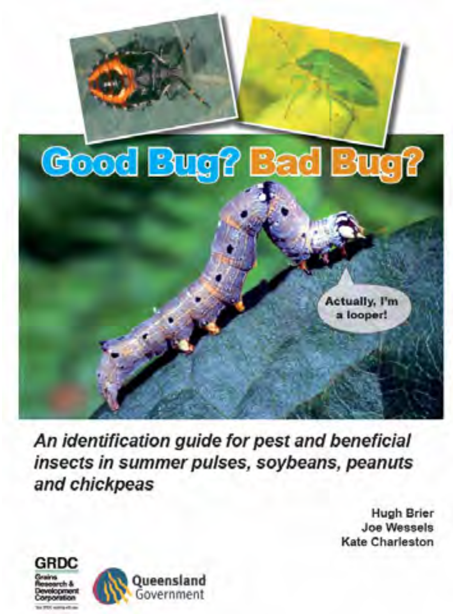
Insect ID is a comprehensive reference guide to insect pests commonly affecting broadacre crops and growers across Australia, and includes the beneficial insects that may help to control the pests. Photos have been provided for multiple life-cycle stages, and each insect is described in detail, with information on the crops they attack, how they can be monitored and other pests that they may be confused with. Use of this app should result in more confident identification of key pests and beneficial insects.

Not all insects found in field crops are listed in this app, so further advice may be required before making control or management decisions. Talk to your agronomist or state department of agriculture/primary industries for more complete information on identification, management and thresholds.

Figure 34: *Screenshots from the iOS edition of Insect ID: The Ute Guide.*

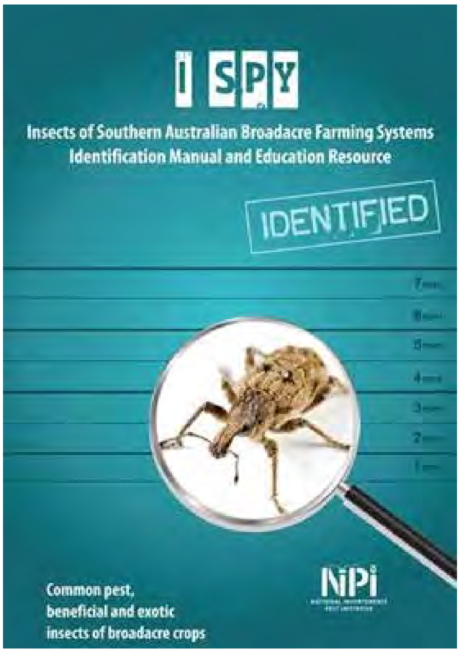
7.3.2 The Good Bug, Bad Bug book

The Good Bug, Bad Bug book (downloadable pdf from http://thebeatsheet.com.au/resources/)



7.3.3 I SPY manual

I SPY manual (downloadable pdf from http://www.grdc.com.au/i-spy-manual)



MORE INFORMATION

Insect pest management in faba beans

7.4 The pest management process

Figure 35 depicts the process of pest management. The components are considered below.

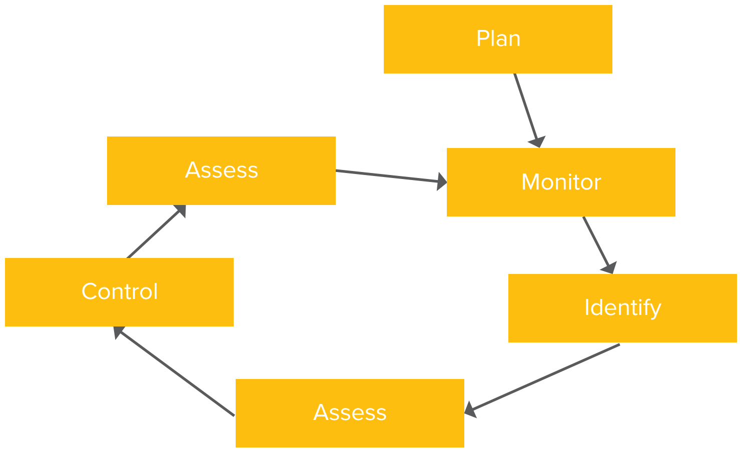


Figure 35: *Pest management process.*

Source: Southern/Western Faba and Broad Bean—Best Management Practices Training Course. Module 3—Varieties. 2013. Pulse Australia

7.4.1 Planning

- Be familiar with which pests are likely to attack the crop in your region, their damage symptoms, and when they may occur and cause crop loss.
- Discuss sampling protocols with your local agronomist and plan how you will cope with the logistics of sampling. Will the agronomist do all the sampling? Will the grower and agronomist share the responsibility?
- Have the appropriate sampling equipment available (sweep net and/or beat sheet)
- Discuss what general approach you will be taking to managing the pests. For example:
- Will you act early, or follow current recommended thresholds? Will you use softer options, or cheaper broad spectrum options?
- What is the likely mix of *Helicoverpa* species in your district, and how might this affect your choices?
- How will you handle an outbreak of minor pests, or species that we don't know much about?

Be aware of the latest management options, pesticide permits and registrations in faba beans, and any use and withholding period restrictions.

7.4.2 Monitoring

- Scout crops regularly during 'at risk' periods (see Table 1), at least once per fortnight.
- Distinguish between the pest being present during a susceptible stage of crop development, and stages where they will cause no significant impact on the crop.
- Be familiar with which sampling method is appropriate for the pests that are likely at each stage of crop development. For example:
- Visual and ground searches for cutworm and aphids during the seedling stage.
- Baited shelter traps for slugs prior to sowing and at establishment
- Beat sheet for loopers, mirids, *Helicoverpa* from vegetative stages to maturity.

Record insect counts and other relevant information using a consistent method to allow comparisons over time. For example:

- For visual inspections do a set number of plants, or metres of row, or square metres (use a stick or quadrat for consistency
- For beat sheet sampling, use a standardized beat sheet (1.2 m wide) and stick (1.0 m in length), and a consistent number of beats/shakes per sample (10)
- Record crop stage, level of damage to leaves, buds, flowers and pods which will help determine the overall impact of some species (particularly relevant where there are no existing numerical thresholds to guide decisions)

Provide this information in a written form to the grower—or demand it from your agronomist.

7.4.3 Correct identification of insect species

It is not important to identify every insect present in your crop, but to be familiar enough with the key pest and beneficial species to recognize the different life stages before you start monitoring.

7.4.4 Assessing management options

Use the crop monitoring information to decide what control action (if any) is required.

Take into consideration other factors that may influence the approach you take. For example:

- Likely level of insecticide resistance in *Helicoverpa* (dependant on the abundance of *H. armigera* in the population)
- Rate of pest population growth over a series of visits. Rapidly increasing populations may need a different approach to a population that is static, or increasing slowly. The damage potential of the pest is also important in this context.
- The crop potential to compensate for insect damage
- Stage of development (greater potential to compensate for damage during vegetative–flowering). The later the damage (e.g. to pods) the less opportunity there is to compensate for loss.
- Available soil moisture, potential for adequate rainfall
- Temperatures that may limit flowering and pod set in late spring.

7.4.5 Control

Ensure that aerial operators and ground-rig spray equipment are calibrated and set up for best practice guidelines.

If a control operation is required, ensure application occurs at the appropriate time of day.

Record all spray details including rates, spray volume, pressure, nozzles, meteorological data (relative humidity, temperature, wind speed and direction, inversions and thermals) and time of day.

7.4.6 Re-assess and document results

Re-assess pest populations in the crop within 3–7 days of spraying, depending on the product used and expectations of time to control the population. Be aware that some newer products act more slowly than older, broadspectrum knockdown products like synthetic pyrethroids (SPs) and organophosphates (OPs).

It is important to re-assess the field within the window of product efficacy, rather than waiting up to 2 weeks to re-assess. Delaying the post-treatment assessment beyond a week runs the risk of having re-infestation, or hatching of eggs post spray. These post-spray reinfestation events can be difficult to distinguish from a control failure if the post-treatment assessment is not made in the appropriate timeframe.

When making a post-treatment assessment look for and record:

- pest density
- life stages in the population may be important to record for some species, and will provide information on whether the treatment has performed as expected, or there is an issue with contact, resistance or re-infestation/emergence of juveniles
- if crop damage is ongoing, or has ceased.

Record the post-treatment data with the pre-treatment data.

7.5 Monitoring faba bean for insect pests

There are a number of sampling methods that can be used in faba beans, and the use of one or more of these methods when crop checking depends on the crop stage, which pests are likely.

It is likely that more than one method may be necessary to effectively estimate pest density. For example, when sampling for *Helicoverpa* a beat sheet or sweep net will not dislodge small larvae in terminals and flowers. A visual inspection of a number of plants is required in addition to sweep net or beat sheet sampling. Table 3 shows the recommended methods for each of the pest species at different stages of crop development.

Table 3: *Sampling methods recommended for specific pests at different stages of faba bean crop development.*

Pest	Sampling method			
	Emergence–seedling	**Vegetative**	**Flowering–pod set**	**Pod fill–maturity**
Blue oat mites	Visual			
Cutworms	Visual in crop or neighbouring weeds Quadrat	Visual in crop or neighbouring weeds Quadrat		
Slugs	Baited shelter trap Visual	Baited shelter trap Visual		
Aphids (virus vectors)	Visual (% plants infested, density)	Visual (% plants infested, density)		
Helicoverpa spp.			Beat sheet Sweep net Visual in terminals and flowers for small larvae	Beat sheet Sweep net Visual in terminals and flowers for small larvae
Loopers		Visual (look for feeding damage) Beat sheet to estimate density		

Pest	Sampling method			
	Emergence–seedling	Vegetative	Flowering–pod set	Pod fill–maturity
Beet armyworm		Visual (look for feeding damage) Beat sheet to estimate density		
Green mirid			Beat sheet	Beat sheet
Podsucking bugs			Beat sheet	Beat sheet
Thrips	Visual; look for typical damage symptoms on leaves and terminals			

MORE INFORMATION

Insect management in fababeans and canola recent research

Recent insect pest management research findings

7.5.1 Sampling strategy and technique

Usually economic thresholds are developed using a specific sampling technique, and it is important to use that technique in order to relate your density data to the threshold recommendations. At this point, the majority of threshold recommendations for faba beans are thought to be 'best bets' and they have not been derived experimentally using a specific sampling method. Refer to the sampling information for each specific pest (Table 3) to determine the most appropriate technique for detecting the species.

The sweep net is widely used in the south for sampling faba beans where the primary pest is *Helicoverpa punctigera*.

Preliminary research results on effective sampling methods for *Helicoverpa* (QDAF 2014; Figure 36), has shown that neither the sweep net and beat sheet are effective in sampling smaller larvae. Sampling small larvae is important in terms of identifying a potentially damaging population before larvae are too large to control, and before the larvae start causing damage to grain. In response to this finding, a visual inspection of terminals (leaves, flowers and buds) is recommended in conjunction with either sweep net or beat sheet sampling.

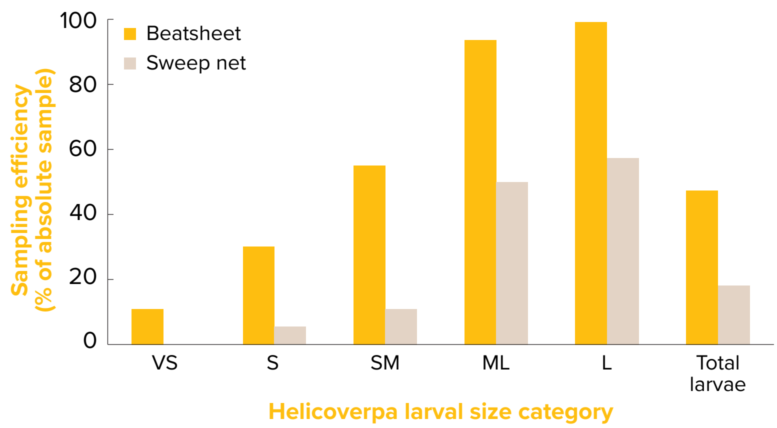


Figure 36: *The relative efficacy of sweep net and beat sheet sampling in detecting different sizes of* Helicoverpa *larvae in a flowering faba bean crop. Data is presented as a percentage of the known total (absolute) larval population in the section of crop sampled with each method*

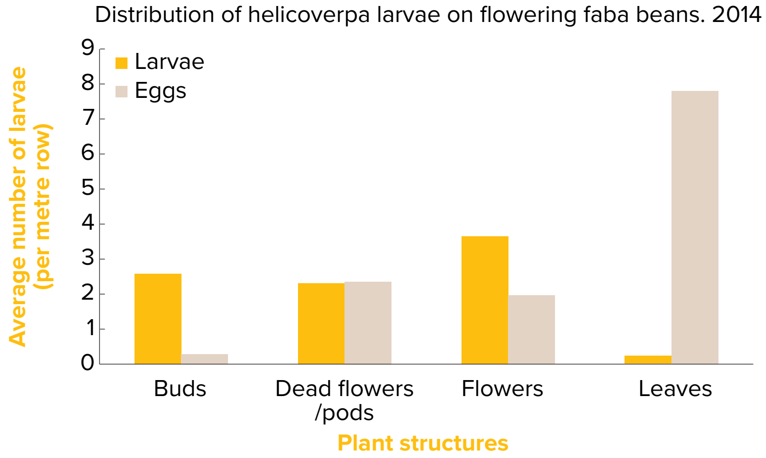
Source: QDAF, 2014

Larger larvae are easily dislodged from the crop, but the smaller larvae are not, suggesting that they are feeding is protected, or more complex structures on the plant. Dissection of flowering plants to determine the distribution of larvae showed that larvae are in the buds and flowers, rather than on leaves. It also revealed that small larvae are predominantly located at the top of the plant in the terminal (Figures 37 and 38).

This data set has only been collected for flowering faba beans at this point. It is possible that the efficacy of the sampling methods may improve as the crop develops further, and particularly as there are fewer complex structures in which larvae can shelter. Research is ongoing to determine if the distribution of larvae changes during the development of the crop, and to finalise monitoring recommendations for *Helicoverpa*.

Figure 37: *Small larva feeding on a bud in the terminal of a faba bean plant. The larva was only visible after pulling open the terminal during a visual inspection of the plant.*

Photo: Melina Miles, QDAF



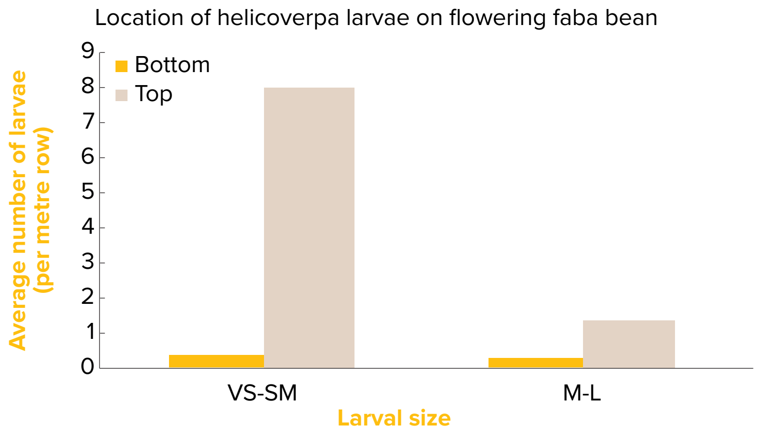


Figure 38: *Location of larvae, and specifically of small larvae, in the canopy of a flowering faba bean crop.*

Source: QDAF, 2014

How to use a beat sheet

The beat sheet is a useful method for sampling a number of pest species in faba beans. It is usually associated with *Helicoverpa* monitoring, but is equally useful for making an estimate of the density of loopers, armyworm, mirids, and podsucking bugs.

Place the beat sheet with one edge at the base of a row. On 1-m row spacing, spread the sheet out across the inter-row space and up against the base of the next row (Figure 39). Draping over the adjacent row may be useful for row spacing <1 m, or where there is canopy closure. It also minimises insects being thrown off the far side of the sheet.

Figure 39: *The beat sheet can be used between the rows as is done in chickpeas (left) or in larger crops, draped over the adjacent row to maximize capture of insects dislodged when sampling (right).*

Photos: GRDC, QDAF

Using a 1-m-long stick (dowel, heavy conduit), shake the row vigorously 10 times to dislodge larvae from the plants. Size and count larvae on the sheet.

A standard beat sheet is made from plastic or tarpaulin material with heavy dowel on each end to weigh the sheet down. The beat sheet is typically 1.3 m wide by 1.5 m long. The extra 0.15 m on each side catches insects thrown out sideways.

Watch a video on using a beat sheet in canola or chickpea at the Beat sheet YouTube channel (http://www.youtube.com/user/TheBeatsheet).

How to use the beat sheet to sample faba beans

Check crops regularly (at least once a week) with a beat sheet, from flowering through to harvest.

To avoid possible edge effects, start sampling at least 50 m into the field.

Each time you inspect, take 5–10 samples across the field. The number of samples should be influenced by what you find. Consistently high, or low, numbers of insects will require fewer samples be taken because the overall picture is clear. Where pests are patchy, and numbers are variable, more samples will be needed to be confident in averaging the counts to get an estimate of pest numbers.

An estimate of pest density is usually the average of all individual samples taken (e.g. 5+1+4+3+2+5+5=25, 25/7=3.6 per sampling unit).

In addition to larval counts, visual observation of crop growth stage, progress of flowering/podding, and the presence of natural enemies (beneficials) all provide useful information for making decisions.

When using a beat sheet, it is worth converting pest density estimates into standard units, generally the number per m^2. This conversion adjusts for the amount of crop (linear metres of row) at different row configurations.

To convert pest density to m^2, use the following formula:

Number per m^2 = average number of pests ÷ row spacing (in metres)

How to use a sweep net to sample faba beans

Where crops are sown on narrow row spacings and it is not possible to get a beat sheet between the rows, or you want to make a quick assessment of whether there are pests in the crop, a sweep net can be used to sample faba beans.

Watch a video on how to use a sweep net to sample for insects at The Beat Sheet YouTube channel (http://www.youtube.com/user/TheBeatsheet).

Hold the sweep net handle in both hands and sweep it across in front of your body in a 180° arc. Take a step with each sweep. Keep the head of the net upright so the bottom of the hoop travels through the canopy. Use sufficient force in the sweep to pass the hoop through the canopy and dislodge larvae.

To avoid possible edge effects, start sampling at least 50 m into the field.

Take 10 sweeps and then stop and check the net for insects. Taking too many sweeps in a sample will result in damage to the insects and make identification more difficult.

Each time you inspect, take 5–10 samples across the field. The number of samples should be influenced by what you find. Consistently high, or low, numbers of insects will require fewer samples be taken because the overall picture is clear. Where pests are patchy, and numbers are variable, more samples will be needed to be confident in averaging the counts to get an estimate of pest numbers. If the patchiness seems to be associated with different parts of the field, take samples at a range of locations around the field.

There may be opportunities to treat just a portion of the field, rather than the whole field, where pests infestations are restricted within a field. Cutworm, earth mites, aphids and *Helicoverpa* can all have limited distribution in a field, most commonly around edges, or on an edge closest to the source of infestation.

An estimate of pest density is usually the average of all individual samples taken (e.g. 5+1+4+3+2+5+5=25, 25/7=3.6 per sampling unit).

Because sweep nets penetrate only a proportion of the crop (the top section), understanding the distribution of the pests in the canopy will provide information on the relative usefulness of the sweep net and beat sheet for sampling a range of insect pests.

Recording monitoring data for decision-making

Keeping records is a routine part of crop checking. Successive records of crop inspections will show you whether pest numbers are increasing or decreasing, the progression towards damaging stages and densities, and provide evidence of pest mortality/beneficial impact. In conjunction with pest information, basic information on the crop stage, damage, crop growth and environmental conditions are relevant. This information is critical in deciding whether a control is necessary, and the appropriate timing.

Insect checking records should include as a minimum:

- date and time of day
- crop growth stage
- average number of pests detected, and their stage of development
- checking method used and number of samples taken
- management recommendation (economic threshold calculation)
- post-treatment counts.

7.5.2 What to be aware of when sampling for *Helicoverpa*

Eggs and very small larvae

Egg counts are an unreliable indicator of *Helicoverpa* larval densities, and potential crop damage. Eggs are difficult to find and count, and egg survival through to larvae is generally very low because eggs fall off plants in the wind/rain, and are eaten by predators. Counting eggs is not recommended, or required in estimating *Helicoverpa* larval densities.

MORE INFORMATION

Aphids – to spray or not to spray

Similarly, very small larvae (<3 mm) are difficult to find in the crop, and mortality in other crops is known to be high. Given the high level of beneficial insect activity in faba beans, we can assume that many eggs and very small larvae will be eaten by predators (predatory bugs, ladybeetles, red and blue beetles, lacewings).

Visible egg lays and moth activity in the crop are indicative of *Helicoverpa* pressure in the crop, and should be a sign that *Helicoverpa* needs to be monitored for in coming days/weeks.

Small, medium and large larvae

Exactly which larval stages have the capacity to cause damage in faba beans has not been researched. At this point we are assuming that *Helicoverpa* behaves similarly in faba beans to how it behaves in other pulses.

It is typically the medium–large larvae that cause the majority of crop loss in pulses. These larvae (>8 mm) will feed on buds, flowers, and penetrate pods to feed on developing seed. In general, *Helicoverpa* larvae consume 80% of their total lifetime consumption in the final two instars (large larvae). This is why it is important to implement control, if required, before larvae reach this stage.

The natural mortality of larger larvae is lower than for earlier stages, although there are a number of natural enemies that will attack medium–large larvae (e.g. *Microplitis* parasitoid, predatory bugs, *Netelia*, *Heteropelma*) (Figure 40).

Figure 40: *Microplitis cocoon beside a parasitized* Helicoverpa larva *(left). (right) Collection of predators caught in a sweep net (lady beetles, brown lacewing, damsel bug, green mirid visible).*

Photos: Melina Miles, QDAF

7.5.3 *Helicoverpa* damage in faba beans

Helicoverpa larvae will feed on leaves, buds, flowers and the developing grain in pods. It is not known if they have a preference for particular structures, but preliminary examination of in-plant distribution in flowering/podding faba beans has shown few larvae on leaves compared with the number on the reproductive structures.

Flowers and buds

Whilst the poor rate of conversion of flowers to pods in faba beans is acknowledged, there seems to be a general acceptance that the plant produces an excess of flowers and protecting these is not necessary. Observations during trial work (QDAF) have shown significant levels of damage to flowers can occur, resulting in non-viable flowers. The larvae feed directly on the pollen sacs or on the ovary of the flower (Figure 41). Whilst no threshold is currently proposed for *Helicoverpa* in flowering crops, it is suggested that monitoring for *Helicoverpa* commence prior to the first pods setting.

Figure 41: Helicoverpa *damage to flowers, damaging the pollen sacs (left) and the ovary (right).*

Photos: Melina Miles, QDAF

Pods and grain damage

Helicoverpa are very damaging to faba bean pods, making many more exploratory holes and partially consuming more grain than seen in other pulses.

The holes make the pods vulnerable to infection by fungi and bacteria, which may in turn increase the likelihood of weathered and discoloured grain (Figure 42). Investigation is required into how *Helicoverpa* feeding contributes to defective grain alone (insect damage) or in combination with 'weathering' impacts.

Figure 42: Helicoverpa *damage to faba bean pods. Multiple entry points in a pod and partially consumed grain are typical, allowing entry by fungi and bacteria that may contribute to increased levels of defective grain.*

Photos: Melina Miles, QDAF

7.5.4 Defective grain and the contribution of *Helicoverpa*

One of the concerns been raised repeatedly in terms of *Helicoverpa* management in faba beans is the issue of defective grain. To determine whether insect damage was the main cause of defective grain QDAF analysed the data from 80+ receival notes from faba bean deliveries in NSW between 2010 and 2012. The top ten contributing categories of defective grain are presented in Table 4. Whilst insect damage is not making the highest contribution to overall defective grain (1.3% on average), the overall impact of insect damage may be higher if weathering and poor colour are a result of insect damage. These quality aspects require further investigation.

Table 4: *Top ten contributing defective grain categories for NSW-delivered faba bean samples (2010–12), n=83 samples.*

Ranking	Defective grain category	Average of all seed (%)
1	Broken/damaged	2.0
2	Insect damage	1.3
3	Weathered	1.2
4	Shrivelled	1.1
5	Poor colour	0.8
6	Sprouted	0.53
7	<3.75 mm	0.41
8	Caked	0.32
9	Seed coat broken/split	0.31
10	Green/immature	0.13

Source: QDAF data

7.5.5 Thresholds

Insect pest thresholds provide a guide to what number of the pest is likely to cause significant economic loss if not controlled. Thresholds are a critical component of pest management, ensuring that treatments are only applied when the value of the crop loss is greater than the cost of controlling the pest.

Some economic thresholds are derived from extensive trial work that establishes a relationship between pest density and crop loss—accounting for crop compensation.

However, the majority of the thresholds available to guide decisions in faba beans are what is known as 'nominal or 'best bet' thresholds. These thresholds are not developed from trial work, but based on educated guesses and experience.

Helicoverpa thresholds for faba beans are nominal thresholds, and there is some variation in the recommendations made in the different growing regions/ states (Table 5).

Table 5: *Published thresholds for* Helicoverpa *in faba beans.*

Pest	Faba bean threshold
WA	Yield loss (/ha) estimated for every larva per 10 sweeps 90 kg (Mangano et al. 2006)
VIC/SA	4–8 larvae per m^2 (beating) 2–3 larvae per 10 sweeps (Insectopedia 2000)
NSW	2–4 larvae per m^2 (less than 10 mm) Human consumption 1 per m^2

It is not possible to extrapolate threshold data from chickpea, or summer pulses, to faba beans because the relationship between *Helicoverpa* and the crop may be very different. For example, the WA yield loss estimate for chickpea is 30 kg/ha; very different from the 90 kg/ha estimated for faba beans.

Yield and quality thresholds

The published thresholds for *Helicoverpa* in faba beans appear to be based on the economics of yield loss (loss of grain weight). However, given the low tolerance for defective grain in faba beans, it is probable that a loss in quality (and consequently downgrading) will occur before economically significant grain loss occurs.

Research is necessary to determine the impact of *Helicoverpa* feeding damage on yield loss, and quality.

When the DAFWA figure of 90 kg/ha is used to calculate the economic threshold (Table 6), the threshold is considerably lower than the nominal thresholds recommended.

Conversion of beat sheet samples and sweep net samples to a common unit (e.g. per metre squared) has is not yet possible. The equivalence has not been tested.

Table 6: *Faba bean yield loss-based ready reckoner for* Helicoverpa.

Cost of control ($/ha)	Grain price ($/t)		
	300	400	500
15	0.6	0.4	0.3
20	0.7	0.6	0.4
25	0.9	0.7	0.6
30	1.1	0.8	0.7
35	1.3	1.0	0.8
40	1.5	1.1	0.9

Base on DAFWA yield loss estimate of 90 kg/ha per larva per 10 sweeps.

7.5.6 Other considerations when making control decisions based on *Helicoverpa* larval densities are:

- environmental conditions and the health of the crop
- how quickly the crop is finishing, and how long it will be susceptible to damage
- how likely is wet weather than may exacerbate the *Helicoverpa* damage through weathering

- prevalence of natural control agents such as parasitic wasps, predatory shield bugs, ladybirds and diseases
- type and location of pest damage and whether it affects yield indirectly or directly
- stage in the life-cycle of the pest and the potential for damage—how long until the larvae are damaging, or pupated?
- crop stage and ability of the crop to compensate for damage
- value of the crop (high-value crops cannot sustain too much damage as a small loss in yield or quality could mean a large financial loss) versus the cost of the spraying and the likely yield or quality benefit gained from control. [3]

7.5.7 Control options for *Helicoverpa* in faba beans

Within the range of options available for pest control in faba beans, there is considerable variability in the impact they will have on beneficial insects (predators, parasitoids, bees) in the crop. It is worth being familiar with the relative impact of the softer, moderate and highly disruptive options (Table 7).

Table 7: *Relative selectivity (impact on beneficial insects) of a range of insecticides/ biopesticides registered for use in faba beans.*

Product	Overall ranking	Predatory beetles - Total	Predatory bugs - Total	Apple Dimplling bug	Lacewing adults	Spiders	Total (wasps)	Ants	Thrips
Bt	Very low	VL	VL	VL	VL	VL	VL	VL	VL
NPV (Vivus Max)	Very low	VL	VL	VL	VL	VL	VL	VL	VL
Pirimicarb (Pirimor)	Very low	VL	L	VL	VL	VL	VL	VL	L
Petroleum spray oil	Very low	VL	VL	VL	VL	L	VL	H	VL
Indoxacarb (Steward)	Low	L	VL	H	M	VL	VL	H	VL
Emamectin (Affirm)	Mod	L	H	H	L	M	M	VL	M
Dimethoate (200 mL/ha)	Mod	M	M	M	M	L	M	H	M
Dimethoate (500 mL/ha)	High	M	M	H	VH	M	H	VH	M
OP's	High	H	H	VH	L	M	H	VH	H
Pyrethroids	Very high	VH	VH	VH	VH	VH	VH	VH	VH

Source: www.ipmworkshops.com.au; Cotton pest management guide 2012–13 for more detailed information

Resistance management strategies

The capacity for *H. armigera* to develop resistance to widely used insecticides is well documented. One of the key factors leading to this has been prolonged exposure to certain chemical groups, both within and across seasons.

3 Southern/Western Faba & Broad Bean—Best Management Practices Training Course 2013. Pulse Australia.

Minimising the risk of poor control, and exacerbating resistance, can be achieved through the following strategies:

- Determine the likelihood of *H. armigera* being present in the crop before attempting to control a population of *Helicoverpa* with OPs, SPs. The use of pheromone traps for *H. armigera* and *H. punctigera* in the spring will provide useful information on the level of activity of the two species.
- Consider the impact of sprays on *Helicoverpa*, even if *Helicoverpa* is not the target. Every exposure contributes to selection for resistance to those products.
- Do not use the same chemical group in consecutive sprays. With the efficacy of some of the newer chemistry, it may be tempting to continue using it rather than rotating with another group. The more exposures *Helicoverpa* populations have to the same active ingredient, the more likely it is that resistance will develop.

The cotton and grains industries monitor levels of *Helicoverpa* resistance to key insecticide groups and the two Bt toxins deployed in genetically modified (GM) cotton and key grain crops (information available on the Cotton CRC website).

Spray smart

Timing and coverage are both critical to achieving good control of *Helicoverpa* larvae, whether using a chemical insecticide or a biopesticide (such as NPV or Bt).

A poor level of control from inappropriate timing risks crop loss and the costs of re-treating the field. Poor timing also increases the likelihood of insecticide resistance by exposing larvae to sub-lethal doses of insecticide. Regular crop scouting enables assessment of both the number of *Helicoverpa* larvae in the crop and the age structure of the population.

Ensure crops are being checked when they are susceptible to *Helicoverpa* damage. Early detection is critical to ensure effective timing of sprays.
Larvae that are feeding or moving in the open are more easily contacted by spray droplets. Target larvae before they move into protected feeding locations (e.g. flowers, pods).

Ensure larvae are at an appropriate size to control effectively with the intended product (Figure 43).
Very small (1–3 mm) to small (4–7 mm) larvae are the most susceptible stages and require a lower dose to kill. Larvae grow rapidly; if a spray application is delayed more than 2 days, the crop should be rechecked and reassessed

Assess if the larvae are doing economic damage. Only spray if the value of the crop saved is more than the cost of spraying. Vegetative feeding generally does not equate to significant yield loss.

Good coverage is increasingly important with the introduction of ingestion-active products because the larvae must actually feed on plant material covered with an adequate dose of the insecticide or biopesticide.

Attract-and-kill products such as Magnet® consist of a liquid moth lure based on floral volatiles mixed with an insecticide. Only a relatively small area needs to be treated (<2% of the total crop), minimising impact on natural enemies. Reducing the pest moth population decreases the number of eggs laid into a crop, which can lower subsequent pest pressure and delay the need for foliar insecticides.

Figure 43: Helicoverpa *larva killed by NPV.*

Photo: Melina Miles, QDAF

7.6 Legal considerations for pesticide use

Information on the registration status, rates of application and warnings related to withholding periods, occupational health and safety (OH&S), residues and off-target effects should be obtained before making decisions on which pesticide to use. This information is available from State Department Chemical Standards Branches, chemical resellers, Australian Pesticide and Veterinary Medicine Authority (APVMA) and the pesticide manufacturer.

Background to some of the legal issues surrounding insecticide usage is provided here, but it is by no means exhaustive. Specific questions should be followed up with the relevant staff from your local State Department.

7.7 Registration

Users should be aware that all pesticides go through a process called registration, where they are formally authorised (registered) by APVMA for use:

- against specific pests
- at specific rates of product
- in prescribed crops and situations
- where risk assessments have evaluated that these uses are:
- effective (against the pest, at that rate, in that crop or situation)
- safe (in terms of residues not exceeding the prescribed MRL (maximum residue level)
- not a trade risk.

Labels

A major outcome of the registration process is the approved product label—a legal document—that prescribes the pest and crop situation where a product can be legally used, and how.

MSDS

Material Safety Data Sheets are also essential reading. These document the hazards posed by the product, and the necessary and legally enforceable handling and storage safety protocols.

Permits

In some cases a product may not be fully registered but is available under a permit with conditions attached, which often require the generation of further data for eventual registration.

APVMA

The national body in charge of administering these processes is called the APVMA (the Australian Pesticides and Veterinary Medicines Authority) and is based in Canberra.

Always read the label

Apart from questions about the legality of such an action, the use of products for purposes or in manners not on the label involves risks. These risks include reduced efficacy, exceeded MRLs and litigation.

Be aware that pesticide-use guidelines on the label are there to protect product quality and Australian trade by keeping pesticide residues below specified MRLs. Residue limits in any crop are at risk of being exceeded or breached where pesticides:

- are applied at rates higher than the maximum specified
- are applied more frequently than the maximum number of times specified per crop
- are applied within the specified withholding period (i.e. within the shortest time before harvest that a product can be applied)
- are not registered for the crop in question.

PestGenie

Pest Genie® (http://www.pestgenie.com.au) is an easy-to-use, web-based system, which provides a full suite of tools to aid compliance with legal, OH&S and industry requirements related to the storage and use of chemicals, including pesticides and animal health products.

7.8 References and further reading

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Helicoverpa management in chickpeas

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Parasitoids: Natural enemies of helicoverpa

Understanding helicoverpa ecology and biology: Know the enemy to manage it better (PDF, 1.0MB)

Using NPV to manage helicoverpa in field crops (PDF, 446.1KB)

Nematode management

8.1 Background

Root-lesion nematodes (*Pratylenchus thornei* and *P. neglectus*) are worm-like organisms, less than 1 mm in length, which feed inside plant roots. RLN use their head and a syringe-like stylet in their mouthpart to break open cell walls and feed on the contents of root cells (Figure 1). [1]

Root-lesion nematodes can complete several generations during growth in a susceptible crop. RLN develop from an egg and pass through four juvenile stages to become an egg-laying female. The females are self-fertile and males are rarely found of *P. thornei* and *P. neglectus*. Under ideal conditions, the life cycle takes about 6 weeks for *P. thornei*, depending on the temperature. Populations of RLN increase with each generation; therefore, more plant roots are damaged, which in turns restricts the uptake of water and nutrients from the soil (see Figure 2).

Intensive cropping of susceptible crops—particularly wheat—will lead to an increase in RLN levels in the soil, meaning that crop rotation is the key to reducing RLN and the damage caused by this pest.

Studies have shown that the extent of yield loss caused by *P. thornei* and *P. neglectus* is related to the populations present at planting. In the northern grain region, *P. thornei* at two nematodes per gram of soil anywhere in the soil profile is considered a damaging population, causing yield loss of up to 70% in wheat and 20% in chickpeas.

Faba bean is resistant to *P. neglectus*. There are variable reports about the response of faba beans to *P. thornei* (Pt), but in terms of usefulness as a break-crop for Pt, the crop is generally rated as 'susceptible'.

1 GRDC Tips and tactics, Root-lesion nematodes. Northern region, https://grdc.com.au/Resources/Factsheets/2015/03/Root-Lesion-Nematodes

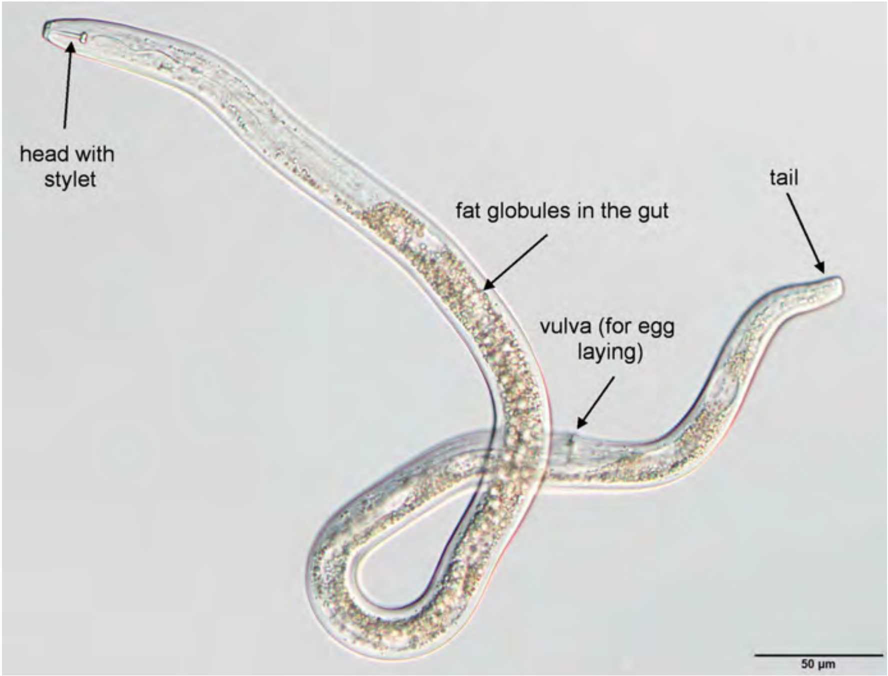

Figure 1: *A* Pratylenchus thornei *adult female viewed under the microscope. The nematode is approximately 0.65 mm long.*

Photo: GRDC Tips and tactics, Root-lesion nematodes. Northern region, https://grdc.com.au/Resources/Factsheets/2015/03/Root-Lesion-Nematodes

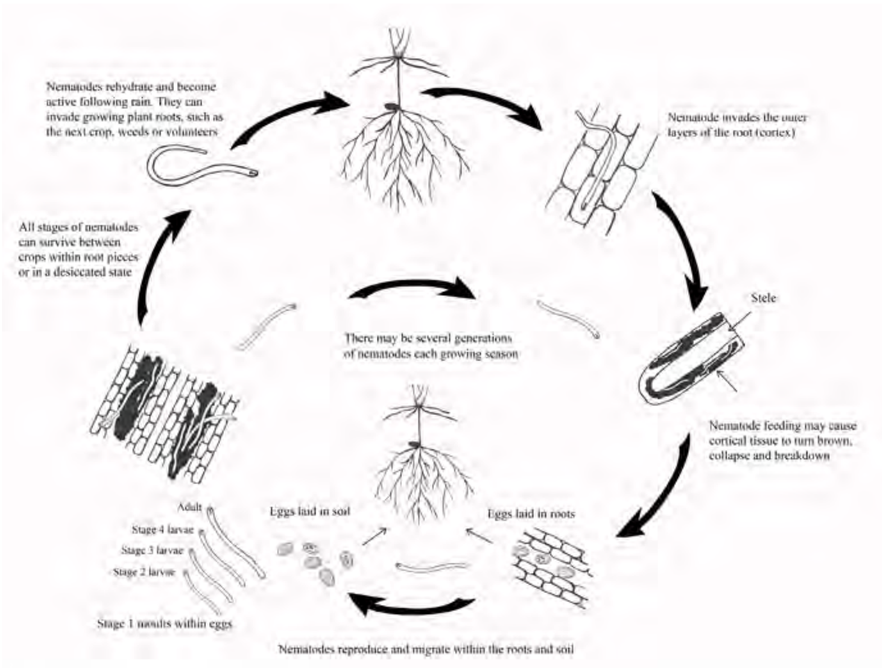

Figure 2: *Life cycle of root-lesion nematode.*

GRDC Tips and tactics, Root-lesion nematodes. Northern region, https://grdc.com.au/Resources/Factsheets/2015/03/Root-Lesion-Nematodes

MORE INFORMATION

Ground Cover Supplement: Northern researchers dig deep to understand root lesion nematode life span

8.1.1 *Pratylenchus thornei*

In the northern grain region, RLN are found throughout northern New South Wales and Queensland. Pt is more widespread and generally occurs in higher populations than *P. neglectus* (see Figure 3).

Results from 600 samples tested in 2010–13 showed that 50% of paddocks had populations above 2 nemotodes/g soil. A recent survey in Central Queensland found that 28% of paddocks had RLN, with 26% of those paddocks containing Pt. Populations were generally low, but in the Dawson–Callide region of Central Queensland, 5% of samples had populations above 2 nematodes/g soil. [2]

At planting, damaging populations of RLN can be found deep in the soil. In some soils, peak numbers are as deep as 60 cm. This happens because the hot, dry conditions of the surface soil can cause nematode death, and RLN can migrate down the soil profile where cooler, moist conditions favour survival. Therefore, be aware that RLN populations in surface soil may not give a full picture of the population density at depth threatening crops, particularly after a long fallow. However, if RLN are detected in the surface soil, start actively managing for RLN.

MORE INFORMATION

GRDC Update Paper: Impact from Pratylenchus thornei, Macalister 2015

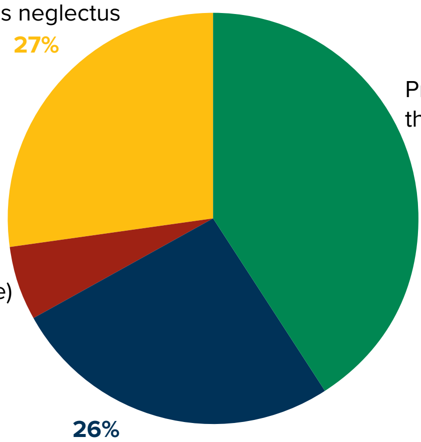

Figure 3: *Occurrence of* Pratylenchus thornei *and* P. neglectus *from 2010 to 2013 in the northern grain region (604 paddocks); 50% of samples had root-lesion nematode populations above the wheat damage threshold of 2,000 nematodes/kg soil (or 2/g soil).*

GRDC Tips and tactics, Root-lesion nematodes. Northern region, https://grdc.com.au/Resources/Factsheets/2015/03/Root-Lesion-Nematodes

MORE INFORMATION

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https://www.grdc.com.au/Research-and-Development/GRDC-Update-Papers/2013/07/Managing-root-lesion-nematodes-how-important-are-crop-and-variety-choice

Journal article: JP Thompson (2010) Occurrence of root-lesion nematodes (*Pratylenchus thornei* and *P. neglectus*) and stunt nematode (*Merlinius brevidens*) in the northern grain region of Australia. *Australasian Plant Pathology* (vol. 39, 254–264), http://link.springer.com/article/10.1071/AP09094

8.1.2 Other nematodes in the northern grain region

The stunt nematode (*Merlinius brevidens*) is widely distributed in the northern region (found in about three-quarters of fields). It feeds on the outside of plant roots (an ectoparasite) and it is thought to be less damaging than RLN. In 2007, large populations were identified in winter cereals in northern NSW, and research is under way into the interaction of these nematodes with fungi in causing root disease.

In lighter textured soils, stubby-root nematode (*Paratrichodorus* sp.) and root-knot nematodes (*Meloidogyne* spp.) have been found on cereals and grain legumes. Other RLN species occurring away from traditional wheat areas are *Pratylenchus zeae* on maize and sugarcane, and *Pratylenchus brachyurus* on peanuts.

There have been isolated reports of cereal cyst nematode (*Heterodera avenae*) from near Tamworth and Dubbo in NSW, on lighter textured soils and friable clay soils. [3]

2 GRDC Tips and tactics, Root-lesion nematodes. Northern region, https://grdc.com.au/Resources/Factsheets/2015/03/Root-Lesion-Nematodes

3 J Thompson, K Owen, T Clewett, J Sheedy, R Reen (2009) Management of root-lesion nematodes in the northern grain region. Department of Agriculture, Forestry and Fisheries Queensland, http://www.daff.qld.gov.au/plants/field-crops-and-pastures/broadacre-field-crops/crop-diseases/root-lesion-nematode

8.2 Symptoms and detection

Root-lesion nematodes are microscopic and cannot be seen with the naked eye in the soil or in plants. The most reliable way to confirm the presence of RLN is to test farm soil. Nematodes are extracted from the soil for identification and determination of their population size. Look out for tell-tale signs of nematode infection in the roots and symptoms in the plant shoots, and if seen, submit soil and root samples for nematode assessment.

Aboveground symptoms of RLN attack in wheat can include:

- stunting
- yellowing of lower leaves
- poor tillering and reduced biomass
- wilting, particularly when the season turns dry.

If crown rot is also present, then RLN attack can increase the expression of whiteheads. Many susceptible crops, other than wheat, do not show aboveground symptoms of RLN attack.

Figure 4: *Symptoms of severe root-lesion nematode damage in an intolerant wheat variety.*

Source: Management of root-lesion nematodes in the northern grain region: http://www.daff.qld.gov.au/plants/field-crops-and-pastures/broadacre-field-crops/crop-diseases/root-lesion-nematode

Symptoms can be confused with nutrient deficiency and may be exacerbated by a lack of nutrients. Infected plants may wilt prematurely in dry periods and at the end of the season.

When roots are damaged by RLN, the plants become less efficient at taking up water and nutrients and tolerating stresses such as drought or nutrient deficiencies. Affected plants may partly recover if the rate of new root growth exceeds the rate at which RLN damage the roots. However, recovery will depend on the extent of root damage, the growing conditions, and whether sufficient fertiliser is applied.

An examination of washed plant roots may provide some information, but symptoms can be difficult to see and roots may be difficult to remove from heavy clay soils. Primary and secondary roots may show a general browning and discoloration.

The root cortex (or outer root layer) is damaged and may disintegrate. Diagnosis is best confirmed with laboratory testing of soil and/or plants for the presence and population densities of the two species. [4]

4 GRDC (2009) Root lesion nematode dominates in the north. Northern Region. Plant Parasitic Nematodes Fact Sheet, GRDC, http://www.grdc.com.au/uploads/documents/GRDC_NematodesFS_North_4pp.pdf

MORE INFORMATION

GRDC Update Paper: Root lesion nematodes importance impact and management

MORE INFORMATION

Single test improves stubble-borne disease management

MORE INFORMATION

Predicta B an identity kit for soil borne pathogens

8.3 Management

No nematicides are currently registered for use in cereal crops in the northern grain region. Nematicides are expensive and offer only partial control of RLN in the northern grain region, because of poor penetration into the soil (RLN are often found deep in the soil profile). [5]

Rotations and variety choice are key to the successful reduction of RLN populations in the soil. Only non-host crops or resistant varieties will minimise the build-up of RLN. Tolerant crops will suffer less damage, but if these varieties are susceptible, RLN numbers can still increase.

As different species of RLN can be hosted on different crops, it is important to identify which species is/are present. Testing services are available around Australia and growers are advised to contact their local department of agriculture.

Regular testing has shown that there are crop varieties with tolerance to Pt. It is recommended that varieties be chosen to minimise crop loss. In cases of heavy infestation with Pt, non-affected crops such as sorghum (grain and forage), cotton, millets (but not white french millet), panicum, sunflowers, lablab, pigeon peas, canary seed, durum wheat and linseed can be grown in rotation.

For *P. neglectus*, faba beans, mungbeans, black gram, soybeans, cowpeas, lablab, triticale, and linseed can be grown.

Testing for RLN

1. *Test your farm.* A microscope-based identification and counting service for nematodes found on grain farms in the northern region provided by QDAF Qld. Contact QDAF Customer Service Centre on 13 25 23.
2. PreDicta B. A DNA-based soil analysis service that is delivered by accredited agronomists and can detect *P. neglectus*, *P. thornei* and cereal cyst nematode. Contact your local agronomist, or to locate your nearest supplier, email your contact details and location to predictab@saugov.sa.gov.au. Crown Analytical Services in Moree are the agents for the northern region (phone 0437 996 678 or email: crownanalytical@bigpond.com).

CASE STUDY

Impact of summer crops or a weed-free fallow on the yield of the next wheat crop and on Pratylenchus thornei populations in Queensland

The experiments were set up at a *P. thornei*-infested site, in adjacent fields with differing cropping histories: (i) a low *P. thornei* site with a cropping history of five successive, resistant crops (cotton, sunflowers and maize) where *P. thornei* populations were 0.15 nematodes/g soil at 0–90 cm soil depth; and (ii) a damaging *P. thornei* site with a cropping history of only one resistant sorghum crop (wheat, sorghum, wheat) where *P. thornei* populations were 2.5/g soil at 0–90 cm soil depth.

A weed-free fallow and several varieties each of sorghum, maize, sunflowers, mungbeans and soybeans were planted; then after a 13-month fallow, tolerant and intolerant wheat varieties were planted.

Low *P. thornei* site. This experiment showed no differences in *P. thornei* populations after growing the summer crops. Populations remained very low 0.25 nematodes/g soil at 0–90 cm soil depth. The following tolerant wheat (cv. EGA Wylie) yielded 3.7 t/ha and the intolerant wheat (cv. Strzelecki) 3.6 t/ha (see Figure 5).

5 J Thompson, K Owen, T Clewett, J Sheedy, R Reen (2009) Management of root-lesion nematodes in the northern grain region. Department of Agriculture, Forestry and Fisheries Queensland, http://www.daff.qld.gov.au/plants/field-crops-and-pastures/broadacre-field-crops/crop-diseases/root-lesion-nematode

Damaging *P. thornei* site. Populations increased after growing most soybean and mungbean varieties. Mungbean cv. Emerald and soybean cv. Soya791 were moderately resistant compared with the other varieties. After growing sorghum, maize and sunflowers, populations of

P. thornei were similar to those in the fallow and there were no significant differences between hybrids (see Figure 5). The following tolerant wheat (cv. EGA Wylie) yielded 3.7 t/ha and the intolerant wheat (cv. Strzelecki) 1.9 t/ha (see Figure 5).

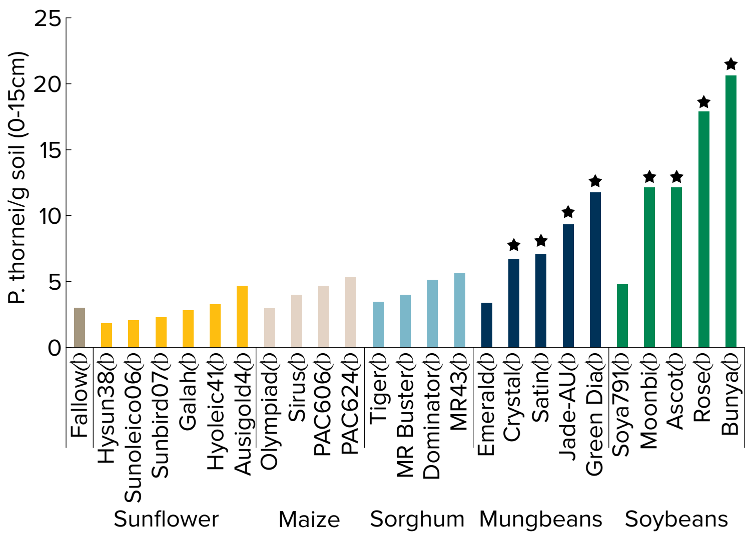

Figure 5: *Populations of* Pratylenchus thornei *per g soil (0–15 cm depth) at harvest of summer crops. The star indicates populations significantly (P < 0.05) higher than the fallow treatment.*

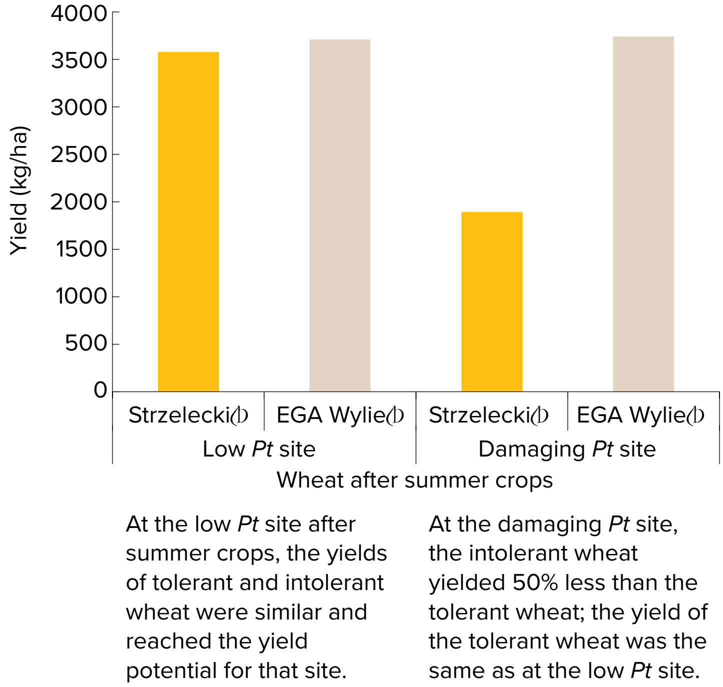

Figure 6: *Yields of tolerant wheat (cv. EGA Wylie⊕), and intolerant wheat (cv. Strzelecki), at the sites that began with low or damaging populations of P. thornei (Pt). Wheat yields are averaged across the summer crops planted before the wheat.*

8.3.1 Resistance *versus* tolerance

Resistance: nematode multiplication

- Resistant crops do not allow RLN to reproduce and increase in number in their roots.
- Susceptible crops allow RLN to reproduce so that their numbers increase. Moderately susceptible crops allow increases in nematode populations but at a slower rate.

Tolerance: crop response

- Tolerant varieties or crops yield well when sown in fields containing large populations of nematodes.
- Intolerant varieties or crops yield poorly when sown in fields containing large populations of nematodes (Figure 7 and Table 1).

Variety ratings for nematodes

Varieties are rated according to their tolerance or intolerance and their susceptibility or resistance to nematodes. The mechanisms of resistance and tolerance are different and need to be treated as such.

Intolerance means the crop yields poorly when attacked.

Susceptibility means nematode numbers increase during the cropping season.

Tolerance and intolerance ratings indicate the effect nematodes will have on the yield of the current crop.

Resistance/susceptibility ratings indicate the effect the crop variety will have on reproduction of the nematodes, and hence the possible effect on the next crop via the nematode population remaining in the soil to infect the next crop.

Pictured are four combinations of ratings for nematodes. Tolerance/intolerance = the effect on the yield of the current crop, Resistance/susceptibility = the effect on building nematode numbers and the carryover to next year's crop.

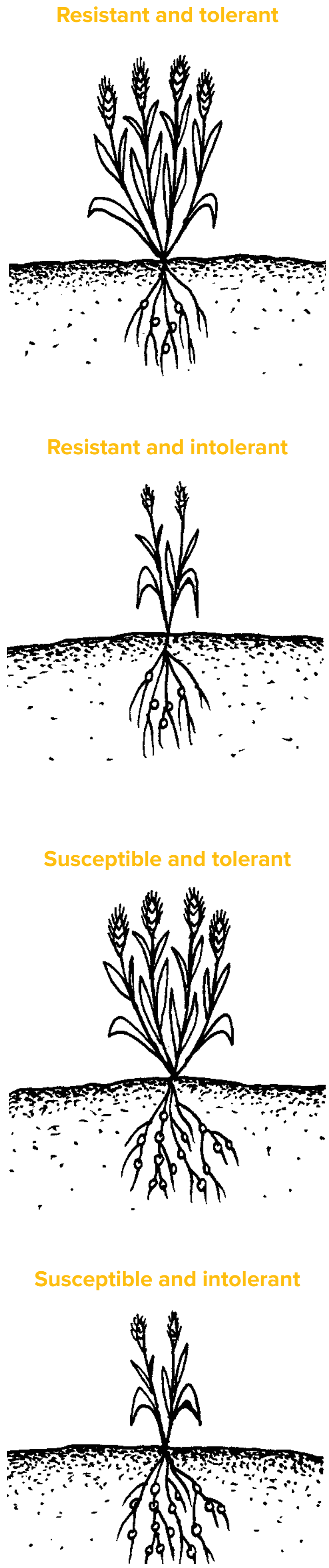

Figure 7: *Variety ratings for nematodes.*

Source: Southern and Western Plant Parasitic Nematodes Fact Sheet 2009, GRDC, http://www.grdc.com.au/uploads/documents/GRDC_NematodesFS_SthWst_6pp.pdf

Table 1: *Resistance and tolerance of pulses to* Pratylenchus *spp.*

	Pratylenchus neglectus		***Pratylenchus thornei***	
	Resistance	**Tolerance**	**Resistance**	**Tolerance**
Chickpeas	S–MR	MI–T	VS–R	MI–T
Faba beans	R	-	MR	MI
Field peas	R	-	R	T
Lentils	R	T	R	MT
Vetch:				
Blanchefleur	MR	T	S	I–MI
Languedoc	MR	T	MS	I–MI
Morava	MR	T	MS	I–MI

S, Susceptible; R, resistant; I, intolerant; T, tolerant; M, moderately; V, very. Chickpea varieties have a range of resistances and tolerances to Pratylenchus species

Paddock hygiene

A paddock that is free of parasitic nematodes is a valuable asset. RLN appears to be spread in soil moved by surface water, vehicles and farm machinery. Good hygiene, by removing adherent soil from farm machinery, should be adopted to avoid infesting clean paddocks. Avoid contamination of fields by ensuring that farm machinery entering this paddock is free of soil from other paddocks. It is essential to clean machinery with a pressure hose away from uninfested paddocks.

8.4 Damage caused by pest

Numbers of RLN build up steadily under susceptible crops (Figure 8), causing a decrease in yields over several years. Yield losses >50% can occur in some wheat varieties and up to 20% in some chickpea varieties. The amount of damage caused will depend on:

- the numbers of nematodes in the soil at sowing
- the tolerance of the variety of the crop being grown
- the environmental conditions

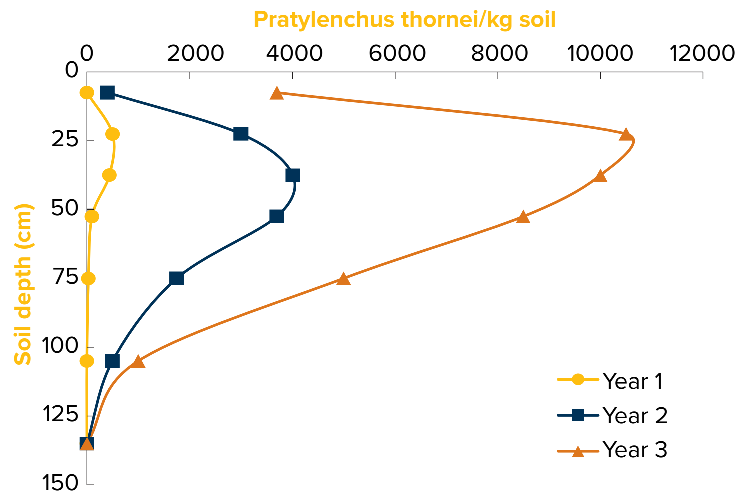

Figure 8: *Numbers of root-lesion nematode (*Pratylenchus thornei*) during 3 years of continuous wheat at Wellcamp, Queensland. Populations increased from low levels to levels that would reduce yields of intolerant crops. The graphs show numbers in the soil sampled before sowing wheat each year.*

Source: Management of root-lesion nematodes in the northern grain region: http://www.daff.qld.gov.au/plants/field-crops-and-pastures/broadacre-field-crops/crop-diseases/root-lesion-nematode

8.4.1 How do faba beans compare with other crops for build-up of *Pratylenchus thornei*?

The Northern Grower Alliance has conducted trials on the response of faba beans to Pt. Comparisons were made with other crops, and between varieties of faba beans.

Key findings:

- The faba bean varieties tested resulted in similar Pt build-up to the bread wheat and chickpea varieties. Canola (two sites), linseed and field peas left lower populations of Pt.
- The differences between faba bean varieties for Pt build-up appear smaller than for chickpea or wheat. PBA Warda⍉ tended to show lower Pt build-up than Doza⍉ and Cairo⍉.
- There is no evidence to date of yield losses to Pt in faba beans.

MORE INFORMATION

GRDC Update Paper: Impact from Pratylenchus thornei, Macalister 2015

Table 2: *Comparison of crops for Pt build-up risk and frequency of significant variety differences.*

Crop	Pt build-up risk	Variety differences
Sorghum	Low	None observed
Cotton	Low	None observed
Sunflower*	Low	None observed
Linseed*	Low	-
Canola*	Low** to Medium	None observed
Field peas*	Low to Medium	Low
Durum-wheat	Low to Medium	Moderate
Barley	Low to Medium**	Moderate
Bread-wheat	Low, Medium to High**	Large
Chickpea	Medium to High	Moderate to Large
Faba beans	Medium to High	Low
Mung beans*	Medium to High ?	Moderate to Large ?

Source: GRDC 2015

For crops with a range of build-up risk but a dominant category, the dominant category is in bold e.g. barley where the majority of varieties in the medium risk category but some low risk

* data only from 1–2 field trial locations for these crops; ** crops with a range of build-up risk but a dominant category, the dominant category is identified by (**), e.g. barley, where the majority of varieties are in the medium risk category but some low risk; bread-wheat, varieties in all categories but most varieties are in the medium to high risk categories.

Comparisons between species

Yallaroi 2012 (Figure 9)

Samples were taken on 2 January 2013.

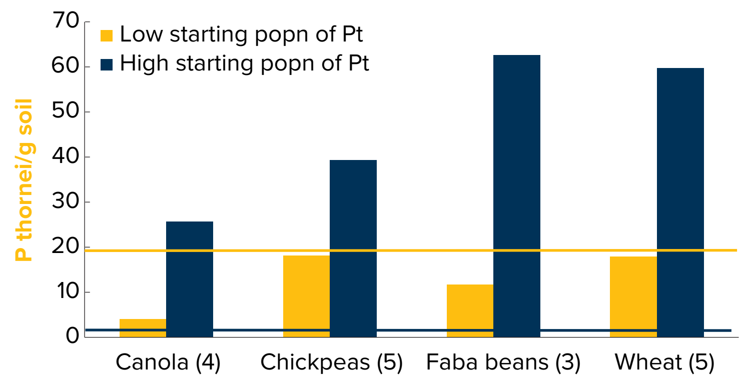

Figure 9: Pratylenchus thornei *populations remaining after a range of winter crop species at Yallaroi 2012 (numbers in parentheses are the number of varieties for each crop—for wheat, this is five common bread wheat varieties). The two horizontal lines indicate the starting population levels when sampled 24 February 2012.*

Weemelah 2011 (Figure 10)

Samples of all crops except faba beans and wheat were taken on 21 March 2012. Samples of faba beans and wheat were taken on 30 April 2012.

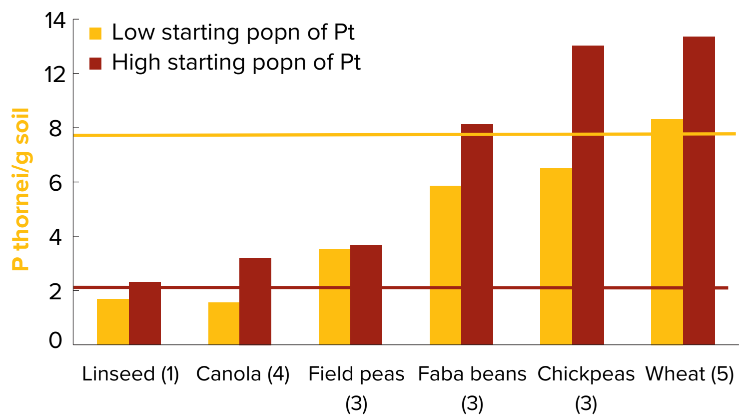

Figure 10: Pratylenchus thornei *populations remaining after a range of winter crop species at Weemelah 2011 (numbers in parentheses are the number of varieties for each crop—for wheat, this is five common bread wheat varieties). The two horizontal lines indicate the starting population levels when sampled 31 March 2011.*

Comparisons between faba bean varieties

Yallaroi 2012 (Figure 11)

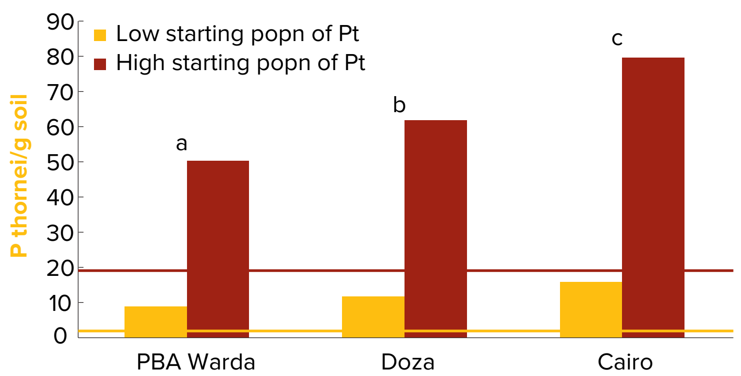

Figure 11: Pratylenchus thornei *populations remaining after growing faba bean varieties at Yallaroi 2012. The two horizontal lines indicate the starting population levels when sampled 24 February 2012. Varieties that do not share the same letter are significantly different at P = 0.05.*

Tulloona (NVT) 2012 (Figure 12)

Samples were taken on 19 February 2013.

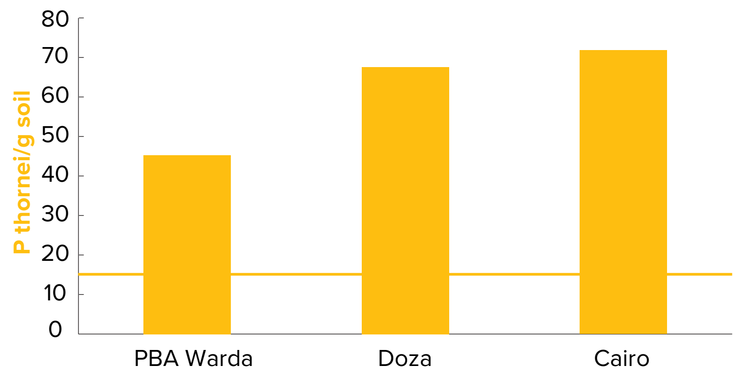

Figure 12: Pratylenchus thornei *populations remaining after a range of faba bean varieties at Tulloona 2012. Horizontal line indicates the starting population level at planting. There was no significant difference between varieties.*

Weemelah 2011 (Figure 13)

Samples were taken on 30 April 2012.

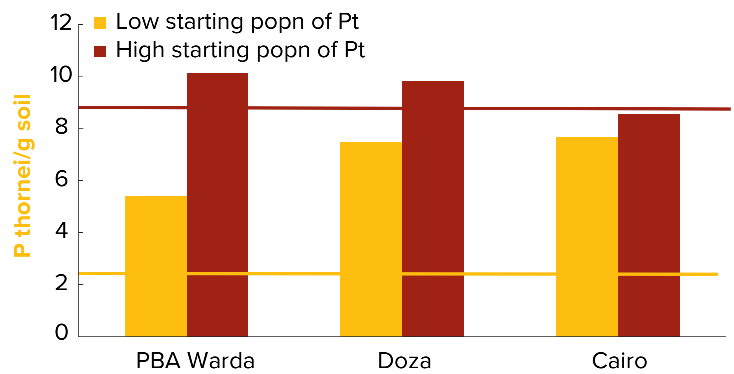

Figure 13: *Comparison of Pt populations remaining after a range of faba bean varieties at Weemelah 2011. The horizontal line indicates the starting population level when sampled 31 March 2011. There was no significant difference between varieties.*

For more information on nematodes in pulse crops, see GRDC GrowNotes—Chickpeas Section 8.

8.5 References

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Diseases

MORE INFORMATION

Pulse Australia: Visual quality charts

9.1 Fungal disease management strategies

Disease management in pulses is critical, and relies on an integrated management approach involving variety choice, crop hygiene and strategic use of fungicides. The initial source of the disease can be from the seed, the soil, the pulse stubble and self-sown seedlings, or in some cases, other plant species. Once the disease is present, the source is then from within the crop itself.

Note that the impact of disease on grain quality in pulses can be far greater than yield loss. This must be accounted for in thresholds because in pulses, visual quality has a significant impact on market price. Examples are Ascochyta blight in most pulses, and *Pea seed-borne mosaic virus* (PSbMV) in field peas.

A plant disease may be devastating at certain times and yet, under other conditions, it may have little impact. The interaction of host, pathogen and environment are all critical points in disease development, and all can be represented by the classical disease triangle (Figures 1 and 2). Diseases such as Ascochyta blight and Phytophthora root rot can cause total crop failures very quickly, whereas Botrytis grey mould and root lesion nematodes may 'tick' away over the season and mask their true effects on crop performance and yield.

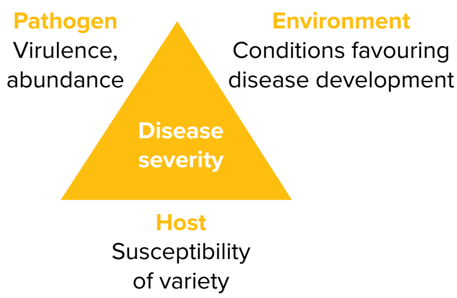

Figure 1: *The fungal disease triangle (Agrios 1988).*

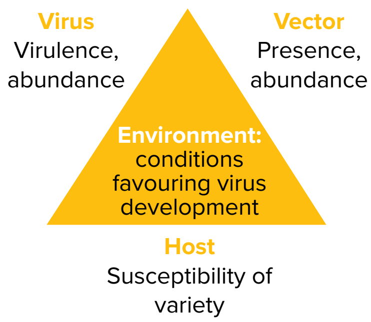

Figure 2: *The virus (and some bacterial) disease triangle (Jones 2012).*

Disease management should be a consideration when planning any rotation, particularly at the beginning of the season. This is especially important for faba beans where the first action of defence against diseases begins with paddock selection. Other criteria such as seed quality and treatment are also vitally important.

Determine which diseases are the highest priorities to control in the pulse crop being grown, and sow a variety that is resistant to those diseases if possible. Strategic fungicide application combined with paddock selection is also part of an overall program to minimise disease impact. Fungicide disease control strategies alone may not be economic in high-risk situations, particularly if susceptible varieties are grown.

Variety selection

Growing a resistant variety reduces the risk and reliance on foliar fungicides.

Distance

Proximity to stubble of the same pulse from the previous year will affect the amount of infection for some diseases. Aim for a separation distance of at least 500 m.

Paddock history and rotation

Aim for a break of at least 4 years between planting the same pulse crop. A high frequency of crops such as lentils, faba beans, vetch, field peas, chickpeas, *Lathyrus* or clover pasture puts pulses at greater risk to multi-host disease pathogens such as *Phoma*, *Sclerotinia* and *Botrytis*. Ascochyta blight species are more specific to each pulse crop but 3–4 year rotations are still important. Canola can also increase the risk of Sclerotinia rot.

Hygiene

Take all necessary precautions to prevent the spread of disease. Reduce last year's pulse stubble if erosion is not a risk and remove self-sown pulses before the new crop emerges.

Seed source

Use seed from crops where there were low levels of disease, or preferably no disease, especially at podding. Avoid sowing seed that is known to have disease infection, particularly the susceptible varieties. Have seed tested for disease status where recommended.

Fungicide seed dressings

Seed dressings are partially effective early in high disease-risk situations, particularly for diseases such as seed-borne Botrytis grey mould, Phoma blight and Ascochyta blight. They are not effective on viruses and bacterial diseases.

Sowing date

To minimise foliar disease risk, do not sow too early to avoid excessive vegetative growth and early canopy closure. Early crop emergence may coincide with greater inoculum pressure from old crop residues nearby. Aim for the optimum sowing window for the pulse species and your district.

Sowing rate

Aim for the optimum plant population (depending on region, sowing time, crop type, variety), as denser canopies can lead to greater disease incidence. Adjust the seeding rate according to seed size and germination.

Sowing depth

Sowing deeper than is usual practice will help reduce the emergence of infected seedlings. The seeding rate must be adjusted upwards to account for the potential of a lower emergence and establishment percentage.

Foliar fungicide applications

Disease-resistant varieties do not require the intense regular foliar fungicide program that susceptible varieties need to control foliar diseases. Some pulses may require fungicide treatment for Botrytis grey mould if a dense canopy exists. Successful disease control with fungicides is dependent on timeliness of spraying, the weather conditions that follow, and the susceptibility of the variety grown. Monitoring for early detection and correct disease identification is essential. Correct fungicide choice is also critical.

Mechanical damage

Any physical damage due to excessive traffic, wind erosion, frost, hail, post-emergent rolling or herbicide damage can lead to the increased spread of foliar disease in pulses, particularly bacterial blight in peas.

Controlling aphids

This may reduce the spread of viruses, but not eliminate them. Protective insecticide treatments are unlikely to be successful if applied strategically, or economic if applied regularly. Usually the virus spread has occurred by the time the aphids are detected.

Harvest management

Early harvest will help reduce disease infection of seed, and is also important for grain quality and to minimise harvest losses. Crop desiccation enables an earlier harvest, reduces moisture risk and adverse weather risks. Moisture contents of up to 14% are allowable at delivery. Do not desiccate prior to physiological maturity as this can affect grain quality. [1]

9.2 Integrated pest management

Integrated pest management (IPM) is a multi-layered approach of crop management to reduce chemical inputs and solve ecological problems. Although originally developed for insect pest management, IPM programs now encompass diseases, weeds and other pests.

Integrated pest management is performed in three stages: prevention, observation, and intervention. It is aimed at significantly reducing or eliminating use of pesticides while managing pest populations at an acceptable level.

An IPM system is designed around six basic components.

1. Acceptable disease levels

- Emphasis is on economical control, not eradication.
- Elimination of the disease is often impossible, and can be economically expensive and environmentally unsafe.
- Integrated pest management programs work to establish acceptable disease levels (action thresholds) and then apply controls if those thresholds are likely to be exceeded. Thresholds are disease- and site-specific. What is acceptable at one site may not be acceptable at another site or crop. By allowing some disease to be present at a reasonable threshold means that selection pressure against resistance is reduced.

2. Preventive cultural practices

- Use varieties best suited to local growing conditions and with adequate disease resistance.
- Maintaining healthy crops is the first line of defence, together with plant hygiene and crop sanitation (e.g. removal of diseased plants to prevent spread of infection). Crop canopy management is also very important in pulses, hence time of sowing, row spacing and plant density and variety attributes become important.

3. Monitoring

- Regular observation is the key to IPM.

1 Southern/Western Faba and Broad Bean—Best Management Practices Training Course. Module 3—Varieties. 2013. Pulse Breeding Australia.

- Observation is broken into inspection and then identification. Visual inspection, spore traps, and other measuring tools are used to monitor disease levels. Accurate disease identification is critical to a successful IPM program. Record-keeping is essential, as is a thorough knowledge of the behaviour and reproductive cycles of target pests.
- Diseases are dependent on both specific temperature and moisture regimes to develop (e.g. rust requires warm temperatures, Ascochyta blight often requires colder temperatures). Monitor the climatic conditions and rain likelihood to determine when a specific disease outbreak is likely.

4. Mechanical controls

- Burn or plough in pulse stubble, removing hay, cultivating self-sown seedlings.
- Should a disease reach unacceptable levels, or high inoculum loads are anticipated, then mechanical methods may be needed for crop hygiene.

5. Biological controls

- Crop rotation and paddock selection is a form of biological control.
- Also using crops and varieties with resistance to the specific disease is important. Other biological products are not necessarily available for disease control.

6. Responsible use of fungicides

- Synthetic pesticides are generally only used as required and often only at specific times in a disease life cycle.
- Fungicides that are applied as protection ahead of conditions that are conducive to disease (e.g. sustained rainfall) may reduce total fungicide usage. Timing is critical with foliar fungicides, and may be more important than the rate used. Protection is better than cure, because once the disease is established in the canopy there is an internal source of infection that is hard, or even impossible, to control with later fungicide applications. [2]

9.3 Key criteria and considerations

9.3.1 Risk assessment

Risk assessment is the prediction of likely damage from a faba bean disease. It can be used at the paddock, whole farm, regional, state or national level. The choice of variety, disease management options and fungicide availability are some of the factors determining risk. Seasonal conditions and sowing times have a huge impact on risk as well.

The distribution and dispersal (large-scale spatial patterns) of a pathogen contribute to the regional occurrence of a disease. This regional pattern has been evident in the chocolate spot epidemics in the different states in the early years of faba bean production using the variety Fiord. Even in 2010, early sowing in some areas exposed crops to early and sustained infection. In these intensive faba bean production areas, the build-up of fungal inoculum prior to the growing season, coupled with conducive weather conditions early and into the spring, were major factors leading to the rapid onset of disease across large geographic areas. However, in other areas where the early season conditions were also favourable for chocolate spot, crops did not suffer too badly. Why was this so? Increased distance of new crop from inoculum on infested stubble and old crop volunteers meant that the limited distribution of the fungus in these areas had less impact than in the more intensive systems.

Risk assessment relies on the actions of the grower, their confidence in forecasts, and their tolerance for accepting risk. To make decisions for pre-season disease management options, such as choosing the appropriate variety, growers need information about mid- to long-term disease risk. The risk of chocolate spot can be managed by pre- and post-planting operations. On the other hand, a disease such

2 Southern/Western Faba and Broad Bea— Best Management Practices Training Course. Module 3—Varieties. 2013. Pulse Breeding Australia.

as common root rots can only be managed by pre-planting decisions, i.e. marrying together information on crop history and seed treatment needs. As well, the risk of the occurrence of waterlogging and pooling water should be understood.

The history of faba bean production in Australia is relatively short, but we do now have experience and long-term records of production in adverse years. Moreover, it is likely that diseases are cyclical in nature, rather than being a 'given' year-in year-out, which goes hand in hand with our variable climate. It is evident that the risk of severe faba bean diseases is intimately linked with weather conditions (rainfall, humidity and temperatures).

Modelling can provide some predictive ability on both rainfall probability and on how a crop will perform under those conditions (in the absence of disease). If epidemiological data for specific diseases are included into the algorithms, powerful models can be constructed. However, modelling pulse disease in Australia, including faba bean, is in its infancy. However, we do have a good understanding of the epidemiology of the predominant diseases and their close association with weather conditions. Hence, fungicide protection applied before rainfall events is an integral part of an overall disease management strategy.

Significant pressure from a particular disease in the southern region is maybe 1-in-3-year event or maybe 1-in-5, based on current varieties, but varies with the location, disease and management strategies in place. Rust emerged as a significant factor in 2011, yet chocolate spot was relatively minor. In 2010, the opposite occurred. Fungicide product choice and timing had some influence on this though. Severe rust has likely been a 1-in-10-year occurrence, but protection is often applied when Ascochyta blight is being controlled. The experiences with the northern varieties Doza⍉ and Cairo⍉ demonstrate how vulnerable we are to Ascochyta blight if we do not have varietal resistance. Cercospora leaf spot is virtually an annual occurrence in southern bean crops where there has been a paddock history of beans.

Chocolate spot is a more regularly occurring disease, but it is manageable. Its risk cannot be predicted because of variable rainfall.

Ideally, chemical options should be seen as a last resort, rather than the primary strategy; they are often a crude substitute for intelligent planning. Fungicides are but one weapon in the arsenal and we need to be prudent in the way they are used. Our farming systems should prioritise disease prevention and protection over disease cures.

Knowing your paddock history, its layout (topography) and soil parameters will help you assess your level of risk.

9.3.2 Steps in risk assessment

Identify factors that determine risk:

- **Pathogen:** exotic *v*. endemic, biotypes, pathogenicity, survival and transmission, amenable to chemical management.
- **Host:** host range, varietal reactions, vulnerability, does susceptibility change with growth stage?
- **Environment:** weather dependency, interactions with nutrition, herbicides, other diseases, agronomic factors, e.g. planting depth, row spacing, no-tillage, soil conditions.
- **Risk management:** access to components of management plan; ease of implementing plan; how many options; cost of implementation.

Assess level of factors:

- **Pathogen:** level of inoculum, dirty seed, aggressiveness of isolate, weed hosts prevalent in paddock or nearby, paddock history.
- **Host:** how susceptible, nutritional status, frost susceptibility, herbicide susceptibility.

- **Environment:** length of season, likelihood of rain, drought, waterlogging, irrigation, availability of spray gear, paddock characteristics, herbicide history.
- **Risk management:** has it not yet been considered, a plan is being developed, or is a plan in place?

What risk level is acceptable?

- **High:** grower is prepared to accept substantial yield loss as potential returns are high and financial situation sound; crop failure will not affect rotation or other components of the farming system.
- **Low:** grower needs cash flow and cannot afford to spend much or lose the crop; failure seriously impacts on farming system.

9.3.3 Paddock selection

The selection of the most appropriate paddock for growing faba beans requires consideration of a number of important factors, many of which are related to the modes of survival and transmission of pathogens such as *Ascochyta fabae* or *Phoma medicaginis*.

- Rotation
  - Develop a rotation of no more than 1 year of beans in 4 years.
  - Plant beans into standing stubble of previous cereal stubble to protect against rain-splash of soil-borne spores, protect against erosion and reduce attractiveness of the crop to aphids (aphids may vector viruses).
  - Consideration also needs to be given to previous crops that may host pathogens such as *Sclerotinia, Rhizoctonia* and *Phoma medicaginis*.
  - *Ascochyta fabae* and *Botrytis fabae* are faba bean specific, whereas *Botrytis cinerea* has a wide host range including lentil and weeds such as *Euphorbia* spp., groundsel and emu-foot.
  - *Phoma medicaginis* var. *pinodella* can be hosted by lucerne, clover, field pea, lupin and chickpea as well as *Phaseolus* spp.
- History of bean diseases
  - Previous occurrence of soil-borne diseases (Sclerotinia stem rot, Stem nematode or perhaps even *Pratylenchus* nematodes) constitutes a risk for subsequent faba bean crops for up to 10 years.
  - At least 500 m (preferably more) distance from previous year's bean crop.
- Weeds
  - Realise that nearly all weeds host *Sclerotinia* spp.
  - Some of the viruses affecting faba and broad bean also have wide host ranges. Weeds, particularly perennial legumes, host viruses and their aphid and leafhopper vectors (e.g. *Cucumber mosaic virus,* CMV).
- Herbicide history
  - Have triazine, 'imi' or sulfonylurea herbicides been applied in the last 12 months?
  - The development of some diseases is favoured in herbicide-weakened plants.

The presence of these herbicide residues in soil may cause crop damage and thus confusion over in-field disease diagnosis.

9.3.4 Variety selection

A component of risk assessment is to understand what different varietal ratings mean with respect to a given disease and its management. The National Variety Trial (NVT) Disease Rating System was introduced in 2007 to provide growers, agronomists, industry and researchers with a better understanding of varietal differences in field crops including faba beans in response to different disease interactions, and to deliver uniformity in disease descriptions between crops. It provides one tool to

MORE INFORMATION

Ground Cover Supplement: Nationally coordinated effort to tackle ascochyta blight of pulses growers and agronomists to determine the most appropriate variety by matching disease risk in a given location and situation to the available varieties (Table 1).

In practical terms, under average conditions for disease development, no economic yield loss is expected in resistant varieties, and control measures are unlikely to be profitable. Resistance does not mean immunity though:

- Varieties with a disease description of moderately resistant are expected to sustain low to moderate yield loss and control measures are likely to be cost-effective.
- Varieties with a disease description of moderately resistant to moderately susceptible are expected to sustain moderate to high losses and control measures are necessary to ensure a profitable crop.
- Varieties with disease description of moderately susceptible or worse will sustain very high to total yield loss and control measures are essential to produce a harvestable crop.

Note also that pulse varieties are now rated for Ascochyta blight on both foliage and pods/seed because there are differences. This may influence control strategies and timings during podding to preserve seed quality, hence marketability. Table 1 provides a standard method of rating varieties for disease based on one used by faba bean breeders and pathologists worldwide. We encourage growers and agronomists to use this method and its terminology to help reduce confusion. The table only deals with genetic reactions—management does not change the reactions, just the consequences. [3]

Table 1: *Faba bean variety ratings for the common bean diseases in Australia.*

Variety	Ascochyta blight		Chocolate spot	Rust	Cercospora spot	PSbMV Seed staining
	Foliage	Seed				
Ascot VF	R	R	VS	S	S	–
Aquadulce	MS	MS	MS	MS	S	MS
Cairo⌀	VS	VS	VS	MS	–	–
Doza⌀	VS	VS	MS	MR-R	S	–
Farah⌀	MR-R	MR-R	S	S	S	S
Fiesta VF	MS-MR	MS	S	S	S	S
Fiord	MS	MS	VS	S	S	S
Icarus	VS	VS	MR	MR	–	–
Manafest	VS	VS	MS	MS	–	–
Nura⌀	MR-R	MR-R	S	MS	S	VS
PBA Kareema⌀	MR-R	MR-R	MS	MS-MR	S	
PBA Rana⌀	R	R	MS	MS-MR	S	MR-R
PBA Warda⌀	S	S	MS	MR-R	S	–

VS, Very susceptible; S, susceptible; MS, moderately susceptible; MR, moderately resistant; R, resistant
Source: Pulse Australia.

Note revised status of variety PBA Rana⌀, PBA Kareema⌀ and other northern varieties for rust foliar infection after 2011 incidence; also Nura⌀ for chocolate spot susceptibility under early sown and higher disease pressure situations.

In a season such as 2010, when repeated cycles of infection occurred, even MR varieties can experience yield-reducing levels of disease.

3 Southern/Western Faba and Broad Bean—Best Management Practices Training Course. Module 3—Varieties. 2013. Pulse Breeding Australia.

9.3.5 Seed quality and treatment

Use only seed of high quality (purity, germination and vigour). Source seed from a paddock where diseases, particularly those that affect pods, were not detected. In particular, seed from a crop known to have been heavily affected by Ascochyta blight should not be used.

Treatment of seed with a fungicide dressing is an option, but not essential; it controls seed-borne Ascochyta blight and Botrytis grey mould, and several soil-borne fungal diseases (Table 2).

Do not mix rhizobial inoculant with fungicide seed dressings. Apply the fungicide seed dressing first and then apply the inoculants as a second operation sometime later after the fungicide has dried and immediately prior to seeding.

Table 2: *Seed dressings registered for use with faba beans (but not often used).*

Active ingredient:	**Thiram**	**thiram + thiabendazole**
Example trade name:	**Thiram®**	**P-Pickel® T**
Ascochyta blight	NR	NR
Botrytis grey mould	NR	NR
Damping off	–	R
Fusarium	–	R
Phoma root rot	–	–
Phytopthora root rot	–	–
Pythium diseases	–	R
Jurisdiction	**All states**	**All states**

R, Registered product label claim. NR, not registered for use in this crop. Refer to the current product label for complete 'Direction for Use' prior to application

Prior to the use of any crop protection product, ensure that it is currently registered or that a current permit exists for its use in faba beans.

Registered labels and current permits can be found on the APVMA website www.apvma.gov.au.

9.3.6 On-farm and off-farm hygiene

Control of volunteer faba or broad beans during summer–-autumn and in fallows is vital to avoid carryover of inoculum of chocolate spot, rust and Ascochyta blight pathogens. Some broadleaf weeds are alternative hosts of one or more of the viruses that affect beans, and of *Sclerotinia* species, and should be killed prior to planting and during crop growth.

Pathogens such as *Ascochyta fabae* can be transmitted via infected stubble and soil. Soil and stubble movement may occur by machinery, during windy and/or wet weather, and flooding. Therefore, it is essential that all headers and sowing equipment be thoroughly cleaned to remove grain, soil and stubble before moving from property to property, and if possible in particularly high-risk disease situations, between individual paddocks. The logistics of actually doing this may be difficult when it comes time to harvest; however, growers need to be aware that decisions that they or their contractor make may increase the risk of certain diseases in the future.

Spray rigs, should also be cleaned to reduce the risk of disease transmission particularly if contractors are used.

Floodwaters may transport disease agents. Floods during January 2011 would have moved faba bean stubble infected with *A. fabae,* as well as soil and weeds harbouring the pathogen.

Paddock inspections should be carried out using clothing suitable to the task and footwear should ideally be disinfected prior to entering a crop. This is an important point for agronomists who may move through several crops in one day.

MORE INFORMATION

GRDC Update Paper: Pulse diseases the watch outs for 2016

9.3.7 Regular crop monitoring

The four main diseases where monitoring is necessary are rust (*Uromyces fabae*), chocolate spot (*Botrytis fabae*), cercospora (*Cercospora zonata*) and Ascochyta blight (*Ascochyta fabae)*. By following the monitoring process recommended for these diseases, there is the opportunity to assess the impact or presence of other diseases, weeds or plant disorders. To be effective, crop monitoring needs to include a range of locations in the paddock, preferably following a 'V' or 'W' pattern.

Rust

The time to start monitoring for rust in faba beans depends on sowing time and presence of infection on bean stubble from the previous year.

With early sown beans, infection can occur at early emergence when temperature and rainfall conditions are suitable for its spread. Later sown beans may not get infected until spring when temperatures, moisture conditions and humidity are high. [4] The disease can develop very quickly, requiring only six hours of leaf wetness for infection. Rust is not usually a problem every year in southern regions, and often occurs in years with good spring rainfall and mild temperatures. [5]

In early sown beans, monitor for rust from 2–3 weeks after emergence (4–5 weeks from sowing) and protect against early infection when *Cercospora* is also being controlled with foliar fungicide.

Similarly, for beans sown at more regular times, monitoring for rust can start to occur when the beans are being monitored for infection by *Cercospora* and/or *Ascochyta* early (4–5 weeks from sowing).

In all beans, monitoring for rust needs to occur when monitoring for chocolate spot and late Ascochyta blight.

Chocolate spot

Chocolate spot is more likely to occur in bulky crops where there is canopy closure. The critical stage for the first inspection will be just before the commencement of flowering, as temperatures begin to increase, and then regularly through the flowering and seed-filling period. Lesions occur on leaves and flowers first, but can occur on stems and pods. Flower abortion and drop can occur.

Symptoms first appear as small brown spots on leaves and flowers, which then rapidly develop into large, irregular-shaped lesions on leaves and decay of flowers when conditions remain favourable for the disease.

Chocolate spot (caused by *Botrytis fabae*) requires high leaf moisture or humidity (>70%) within the crop canopy and optimal temperatures are 15–28°C. When humidity levels decrease or maximum daily temperature exceed ~28°C, the infection levels decline sharply. In conditions conducive to chocolate spot, follow the recommendations outlined later in this chapter.

4 Pulse Australia (2016) Faba bean fungicide guide: 2016 season. Australian Pulse Bulletin, http://pulseaus.com.au/growing-pulses/bmp/faba-and-broad-bean/2016-season-fungicide-guide

5 K Lindbeck (2015) Pulse diseases the watch outs for 2016.GRDC Update Paper, https://grdc.com.au/Research-and-Development/GRDC-Update-Papers/2016/02/Pulse-diseases-the-watch-outs-for-2016

More regular crop monitoring and protection may also be required in high-risk situations such as:

- cropping immediately adjacent to last year's crop
- non-optimal paddock selection (e.g. waterlogging)
- high disease pressure experienced last year
- susceptible variety planted
- shortened rotation. [6]

Cercospora

Cercospora monitoring must start 2–3 weeks after emergence, or within 4–6 weeks of sowing. This is particularly important where faba beans have been grown in the paddock in recent years or there have been quite a few beans grown in that paddock over time.

Protective fungicide needs to be applied before or at first signs of cercospora lesions, or within the monitoring timeline, irrespective of symptoms when disease risk is high.

Subsequent monitoring should occur when checking for chocolate spot prior to and during flowering and podding. [7]

Ascochyta blight

The initial symptoms will be lesions on the leaves and stems of young plants. A distinguishing feature is fungal fruiting structures (small black dots) visible within the centre of lesions.

Monitoring should commence 2–3 weeks after emergence, or 10–14 days after a rain event. This is to allow time for disease expression after an infection event, such as transmission from infected seed or rain-splashed inoculum. Infected seedlings may deteriorate quickly and plant-parts above the lesion may break off, making symptoms difficult to detect.

Timing is critical. After the initial inspection, subsequent inspections should occur every 10–14 days after a rain or heavy dew event. During dry periods, inspections can be less frequent. When monitoring, look for signs of lesions on leaves, or if severe, wilting in upper foliage or small areas of dead or dying plants, and if present examine individual affected plants for symptoms of infection. This method will allow more of the crop to be inspected than a plant-by-plant check. [8]

9.3.8 Foliar fungicides

Foliar fungicides (Table 3) are essential for the management of Ascochyta blight in all varieties, and are an important tool for the management of BGM. Varieties with higher levels of Ascochyta blight resistance do not require as many sprays as susceptible varieties. The success of foliar fungicides depends on timeliness of spraying (hence the importance of regular crop monitoring), appropriate fungicide selection, and correct application. Early detection and fungicide application is vital.

6 Pulse Australia (2016) Faba bean fungicide guide: 2016 season. Australian Pulse Bulletin, http://pulseaus.com.au/growing-pulses/bmp/faba-and-broad-bean/2016-season-fungicide-guide

7 Pulse Australia (2016) Faba bean fungicide guide: 2016 season. Australian Pulse Bulletin, http://pulseaus.com.au/growing-pulses/bmp/faba-and-broad-bean/2016-season-fungicide-guide

8 Pulse Australia (2016) Faba bean fungicide guide: 2016 season. Australian Pulse Bulletin, http://pulseaus.com.au/growing-pulses/bmp/faba-and-broad-bean/2016-season-fungicide-guide

Table 3: *Fungicides registered for use.* [9]

Faba Bean Foliar Fungicide	Trade Name example	Chocolate Spot	Rust	Ascochyta	Cercospora	WHP Harvest
Chlorothalonil 720	CC Barrack 720	1.4-2.3 l/ha	1.4-2.3 l/ha	NR	NR	7 days
Mancozeb 750	Dithane SC	1.7–2.2 l/ha	1.7–2.2 l/ha	1.7–2.2 l/ha	1.7–2.2 l/ha	7 days
Carbendazim	Spin Flo	500 ml/ha	NR	NR	NR	28 days
Procymidone 500	Sumislex 500	500 ml/ha	NR	NR	NR	9 days
Copper	Champ 500DF	1.2 kg/ha	1.2 kg/ha	NR	NR	1 day
Metiram	Polyram DF	1.0–2.2 kg/ha	1.0–2.2 kg/ha	1.0–2.2 kg/ha	1.0–2.2 kg/ha	42 days
Tebuconazole	Folicur SC	NR	145 ml/ha Permit	NR	145 ml/ha Permit	21 days
Prothio + Teb	Prosaro	NR	NR	600-750 ml/ha Permit	NR	21 days
Propiconazole	Tilt, Throttle, FMC Prop	NR	NR	Tilt 500 ml/ha Throttle 250 ml/ ha FMC Prop 227 ml/ha Permit	NR	14 days

Many Emergency Use Permits have short term expiry dates (e.g. 30/11/2016)

NR = Not Registered (not effective for this disease)

CHECK CURRENT REGISTRATIONS AT: www.apvma.gov.au

Prior to the use of any crop protection product, ensure that it is currently registered or that a current permit exists for its use in faba beans.

Registered labels and current permits can be found on the APVMA website www.apvma.gov.au.

9.4 Fungal disease control

In many regions seasonal conditions in 2016 have been extremely wet, with continuing rain events and waterlogged soils. Decisions about the viability of crops need to be made early rather than later if disease has taken hold in the crop. It may be a better option to abandon crops and prepare for a following crop if diseases are apparent and environmental conditions favour the disease (saturated soils, average daily temperatures >15°C and high humidity). Faba bean crops will shut down as temperatures rise >28°C and the yield potential will be limited if pods aren't filled in the next few weeks.

The crop needs continuing fungicide protection for good pod fill and many paddocks are not accessible by ground sprayers to give adequate spray coverage required.

If an early decision about crop viability is made, extra costs for crop protection are avoided and nutrients will be available for following crops. In northern areas a summer crop may be an option, if herbicide residues are not a problem. [10]

9.4.1 Principles of fungicide use

A fungicide program needs to account for disease risk categories, based on:

- varietal susceptibility or resistance
- source of seed and treatment of seed
- planting proximity to faba and broad bean stubbles from the previous season
- level of inoculum present from crop residue or volunteer plants

9 Pulse Australia (2016) Faba bean fungicide guide: 2016 season. Australian Pulse Bulletin, http://pulseaus.com.au/growing-pulses/bmp/faba-and-broad-bean/2016-season-fungicide-guide

10 Pulse Australia (2016) Faba bean fungicide guide: 2016 season. Australian Pulse Bulletin, http://pulseaus.com.au/growing-pulses/bmp/faba-and-broad-bean/2016-season-fungicide-guide

MORE INFORMATION

Pulse Australia: Faba bean fungicide guide 2016 season

- climatic conditions in relation to disease infection

Registration status

The product must be registered or have a permit for the disease and use.

Withholding Period: All products and timings used in the fungicide program must meet Australian withholding periods and export slaughter intervals to satisfy overseas markets.

Fungicide resistance management

The maximum number of sprays of a product must be adhered to, so as to minimise the risk of fungicide resistance developing.

Mode of action

Using products with a range of mode of actions for control of diseases further reduces the chance of fungicide resistance development and improves efficacy. Fungicides are also recommended at times of the disease life cycle where they will be most effective according to their mode of action.

Early harvest

Harvest at maturity to minimise seed infection and potential down grading. Seed damage from Ascochyta blight is usually more severe when crops are harvested late. The moisture content allowable on delivery is 14%. Harvest losses, seed splitting and downgrading in quality can be substantial if faba beans are harvested at <12% moisture.

9.4.2 When to spray

Fungicide sprays will control fungal disease, but when and how often to spray will depend on the varietal resistance, amount of infection, the impending weather conditions and the potential yield of the pulse crop.

Fungal disease control is geared around protection rather than curing. The first fungicide spray must be applied as early as necessary to minimise the spread of the disease. Additional sprays are required if the weather conditions favour the disease.

9.4.3 Principles of spraying

A fungicide spray at the commencement of flowering protects early pod set. Additional protection may be needed in longer growing seasons until the end of flowering. Fungicides last around 2–3 weeks.

Remember all new growth after spraying is unprotected.

In periods of rapid growth and intense rain (50 mm over several days), the protection period will reduce to ~10 days.

The timing of fungicide sprays is critical (Table 4). A spray in advance of a rainy period is most desirable. Despite some fungicide washing off, the disease will be controlled. Delaying until after a rainy period will decrease the effectiveness of the fungicide as the disease will have started to spread. [11]

The need and timing of repeat fungicide sprays depends on:

- the amount of unprotected growth
- rainfall after spraying
- the likelihood of a further extended rainy period

Unprotected crops can lose >50% in yield. In severe cases the crop may drop all its leaves

11 Southern/Western Faba and Broad Bean—Best Management Practices Training Course. Module 3—Varieties. 2013. Pulse Breeding Australia.

Table 4: *Principles of when to spray for fungal disease control in faba bean.*

Disease	Occurrence	When to spray
Ascochyta blight	First appears in cool and wet conditions before flowering	At 6–8 weeks after sowing, during seedling stage. Again during flowering if Ascochyta blight is detected and rain is likely. Again at end of flowering when pods are filling, if Ascochyta blight is detected and rain is likely. Disease is spread by rainfall
Chocolate spot	Develops late winter (15–20°C) in humid (>70% RH) conditions, usually at flowering	During early to mid-flowering as a protective spray. Additional sprays may be necessary through flowering and pod filling if disease progresses
Cercospora leaf spot	On lowest leaves soon after emergence	Shortly after emergence prior to establishment of disease. Approximately 5–7 weeks after sowing
Rust	Later in the season, during warm (20–30°C) humid conditions.	At first sign of disease during flowering or pod filling.

9.5 Registered fungicides

Registered fungicides to use as seed dressings are listed in Table 2. Note that they are not often used in faba bean.

Registered fungicides to use as foliar fungicides are listed in Table 3.

Refer to the current product labels for complete 'Direction for Use' prior to application.

Prior to the use of any crop protection product, ensure that is currently registered or that a current permit exists for its use in faba beans.

Registered labels and current permits can be found on the APVMA (www.apvma.gov.au).

9.6 Summary of a foliar fungicide strategy

Time-lines and fungicide strategies based on the variety and disease being targeted are summarised in Figure 3 and Table 4. See also Figure 4. The strategy used for each disease is based on the resistance or susceptibility status of the variety. Use Table 1 to determine this. Choose a fungicide or a fungicide mixture to handle the targeted diseases (see Tables 3 and 5).

Consider also the disease carryover (Table 6) and cross-infection (Table 7) potential.

Faba beans
Example fungicide regimes
(R=resistant; MR=moderately resistant; MS=moderately susceptible; S=susceptible

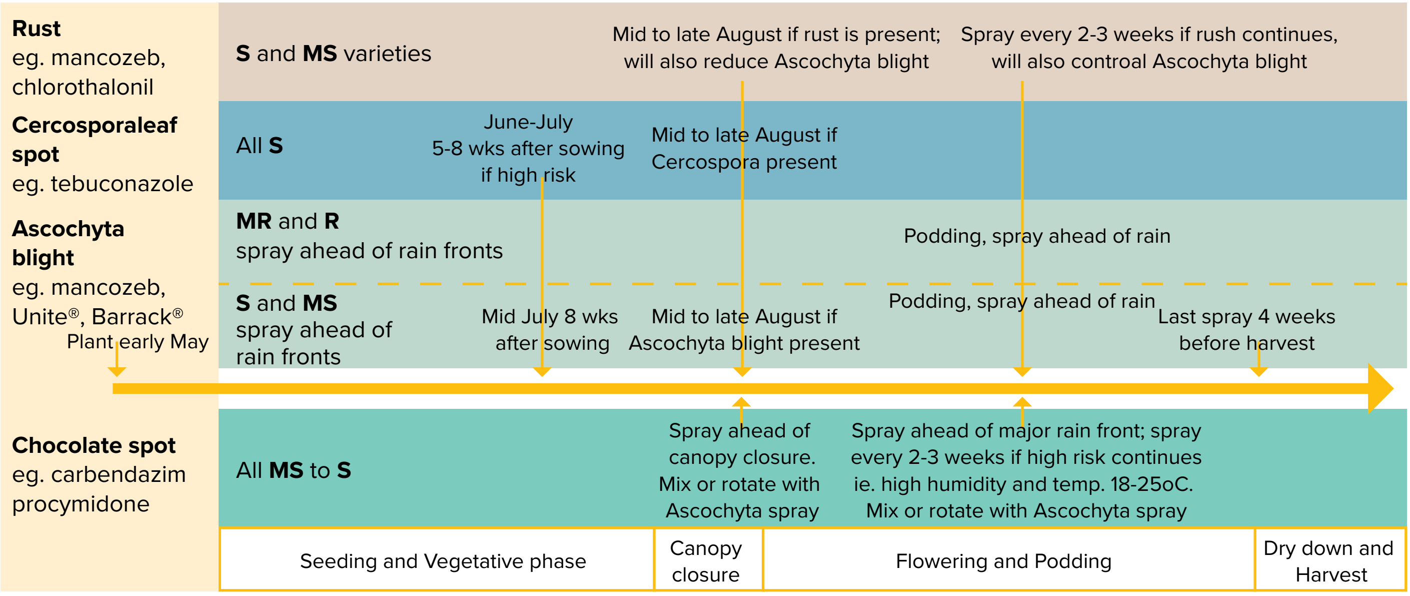

Figure 3: *Fungicide timing for faba bean disease control with specific variety choices. Foliar fungicide application times based on variety resistance (R) or susceptibility (S) to that specific disease (SARDI).*

Source: Jenny Davidson, SARDI

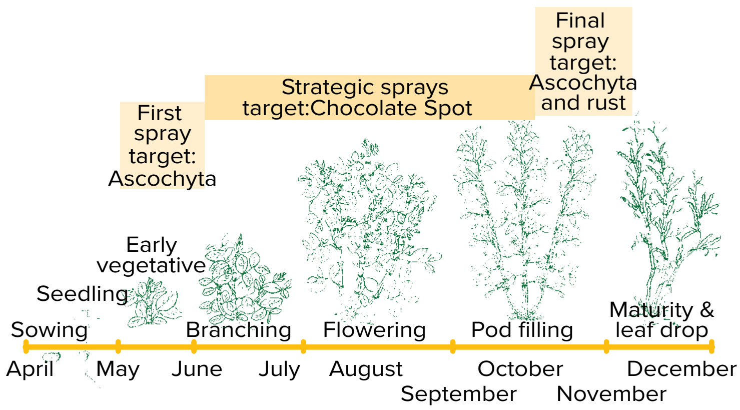

Figure 4: *Crop growth stages and strategic fungicide spray program.*

Source: PulsePoint 16, NSW DPI, 2002

MORE INFORMATION

GRDC Update Paper: Pulse diseases the watch outs for 2016

Table 5: *Fungicide choices.*

Critical period	Disease		Fungicide*	Comments
	Target	Secondary		
First critical period. Early vegetative (5–8 weeks after emergence)	Ascochyta blight	–	Mancozeb or chlorothalonil	Early fungicide application is critical to restrict early development and spread of disease.
	Cercospora leaf spot	–	Tebuconazole or carbendazim	Cercospora spot is often first disease to appear.
	Cercospora leaf spot plus	Chocolate spot	Tebuconazole + mancozeb or use carbendazim	Early chocolate spot control can be important in early sown crops. Rust could be an early target in early sown crops as well. Use the lower rate on crops <20 cm in height.
	Ascochyta blight plus	Cercospora spot	Tebuconazole + Mancozeb or carbendazim + Mancozeb, or chlorothalonil by itself.	Use the higher rate for dense crops or if disease pressure is severe.
	Cercospora leaf spot plus	Ascochyta blight	Either tebuconazole or carbendazim + either Mancozeb or chlorothalonil.	
	Rust plus	Chocolate spot	Mancozeb or chlorothalonil	
Second critical period. Pre canopy closure, during flowering (13–16 weeks after emergence through flowering)	Ascochyta blight plus	Chocolate spot	Mancozeb or chlorothalonil	Early-mid-flowering protection before the disease establishes is recommended: before canopy closure.
	Chocolate spot plus	Ascochyta blight	Either carbendazim or procymidone + either Mancozeb or chlorothalonil	Protection of flowers to assist pod set is important. If Ascochyta blight is detected, and/or chocolate spot appears in the upper third of the crop canopy, and rain or high humidity are likely, then apply fungicide if crop has sufficient yield potential.
	Chocolate spot plus	Cercospora	Carbendazim or chlorothalonil or procymidone + tebuconazole	
	Severe chocolate spot	–	Procymidone	
Third critical period. Late flowering to end of flowering when pods are filling (15–20 weeks after emergence)	Ascochyta blight &/or rust plus	Chocolate spot	Mancozeb or chlorothalonil	If Ascochyta is detected, rain is likely or new spots of chocolate spot appear or are likely to appear on unprotected leaves on the upper third of the plant, then apply or re-apply fungicide if the crop has sufficient yield potential.
	Chocolate spot plus	Ascochyta blight &/or rust	Either carbendazim or procymidone + either Mancozeb or chlorothalonil	Observe all withholding periods.
	Chocolate spot	–	Carbendazim or procymidone	

Note that metiram is considered comparable to mancozeb and so can be substituted for it

Table 6: *Carryover of major faba bean diseases showing their relative importance as sources of infection.*

Disease	Stubble	Seed	Soil
Ascochyta blight	★★★	★★	★
Chocolate spot (*Botrytis*)	★★★	★	★
Cercospora leaf spot	★★	–	★★★
Rust	★	–	–

MORE INFORMATION

Ground Cover Supplement: Close monitoring shows changing pathogen strains

Table 7: *Diseases occurring on pulses with potential for cross-infection.*

	Chickpea	Faba beans	Lentils	Lupins	Peas	Vetch
Botrytis grey mould						
Botrytis cinerea	★★	★★	★★	★	★★	★★
Chocolate spot						
Botrytis fabae	★	★★	★★			★★
Cercospora leaf spot						
Cercospora zonta		★★				
Sclerotinia disease						
Sclerotinia sclerotiorium	★★		★★	★★	★★	
Sclerotinia trifoliorium	★★	★★		★★		
Bacterial blight						
Pseudomonas andropogonis	★					
Pseudomonas syringae pvv. *syringae*		★★	★		★★	
Pseudomonas syringae pvv. *pisi*					★★	
Ascochyta blight						
Ascochyta fabae		★★				★
Ascochyta lentis			★★			
Ascochyta pisi	★				★	★
Ascochyta rabiei	★★					
Phoma blight						
Phoma medicaginis var. *pinodella*	★★	★★	★★	★	★★	★★
Black spot (see also *Phoma* and *Ascochyta*)						
Mycosphaerella pinodes	★★	★	★		★★	★
Anthracnose						
Colletotrichum gloeosporioides				★★		
Brown leaf spot						
Pleiochaeta setosa				★★		
Grey leaf spot						
Stemphylium botryosum	★		★★	★★		

	Chickpea	Faba beans	Lentils	Lupins	Peas	Vetch
Downy mildew						
Peronospora viciae					★★	★
Powdery mildew						
Erysiphe polygoni					★★	
Septoria leaf spot						
Septoria pisi					★★	
Phomopsis disease						
Phomopsis leptostromiformis				★★		
Rust						
Uromyces viciae-fabae[A]		★★			★	★★
Root-lesion nematode						
Pratylenchus neglectus	★					
Pratylenchus thornei	★★	★★				★★
Stem nematode						
Ditylenchus dipsaci	★	★★			★★	★
Viruses						
Bean yellow mosaic virus		★		★★		
Cucumber mosaic virus	★	★	★★	★★		
Luteoviruses complex (e.g. Bean leaf roll virus and Bean western yellows virus)	★★	★★	★		★★	★★
Tomato spotted wilt virus hosted by lupins can cause cross infection in faba beans				★		
Pea seedborne mosaic virus					★★	
Alfalfa mosaic virus	★★	★	★★			★
Wilt						
Fusarium oxysporum[A]				★★	★★	
Root rots						
Fusarium	★	★	★	★	★	★
Macrophomina	★				★★	
Phytophthora medicaginis	★★					
Pleiochaeta setosa			★★			
Pythium [B]	★		★	★	★	
Rhizoctonia	★	★★	★★	★★	★★	★★
Sclerotinia [C]	★		★	★	★	

★ Disease occurs in this crop but does not caused major damage; ★★ Disease has caused major damage to this crop

A Strain differences between crops.

B Pythium and Botrytis grey mould is worse (★★★) in white peas than dun peas (★★)

C Sclerotinia (root rot) is worse (★★) in Kabuli than Desi (★).

9.7 Legal considerations of pesticide use

Before deciding which pesticide to use information should be obtained on the pesticide's registration status, rate of application, withholding period, Occupational health and safety (OH&S) issues, residues and off-target effects. This information is available from the State Department Chemical Standards Branches, chemical resellers, Australian Pesticides and Veterinary Medicines Authority (APVMA) and the pesticide manufacturer.

Background information is provided here to some of the legal issues surrounding fungicide usage, but it by no means exhaustive. Specific questions should be followed up with the relevant staff from your local State Department.

Registration

Users should be aware that all pesticides go through a process called registration, where they are formally authorised (registered) by the Australian Pesticide and Veterinary Medicine Authority (APVMA) for use:

- against specific pests
- at specific rates of product
- in prescribed crops and situations
- where risk assessments have been evaluated and that these uses are:
  - » effective against the pest, at that rate, in that crop or situation
  - » safe in terms of residues not exceeding the prescribed maximum residue level (MRL)
  - » not a trade risk

Labels

A major outcome of the registration process is the approved product label, a legal document, that prescribes the pest and crop situation where a product can be legally used, and how.

Material Safety Data Sheets

Material Safety Data Sheets (MSDS) are also essential reading. These document the hazards posed by the product, and the necessary and legally enforceable handling and storage safety protocols.

Permits

In some cases a product may not be fully registered, but is available under a permit with conditions attached, which often require the generation of further data for eventual registration.

APVMA

The national body in charge of administering these processes is called the Australian Pesticides and Veterinary Medicines Authority (APVMA) and is based in Canberra.

Details of product registrations and permits are available via the APVMA's website www.apvma.gov.au.

Always read the label

Apart from questions about the legality of such an action, the use of products for purposes or in manners not on the label involves potential risks. These risks include reduced efficacy, exceeding MRLs and litigation.

Be aware that pesticide-use guidelines on the label are there to protect product quality and Australian trade by keeping pesticide residues below specified MRLs. Residue limits in any crop are at risk of being exceeded or breached where pesticides:

- are applied at rates higher than the maximum specified

- are applied more frequently than the maximum number of times specified per crop
- are applied within the specified withholding period (i.e. within the shortest time before harvest that a product can be applied)
- are not registered for the crop in question.

9.8 Symptom sorter

Tables 8 and 9 can be used to help diagnose diseases from other crop-damaging causes in faba beans, starting from the symptom description in Table 8.

Table 8: *Faba bean symptom sorter.*

Description	Crop effect	Plant symptoms	Disorder
Scattered plants	Wilting	Premature death	Sclerotinia rot
	Yellow/pale green	Leaves distorted	Mosaic viruses
	Stunted	Premature death	Yellowing viruses
Patches	Poor emergence	Plants chewed	Mouse damage, snails
	Brown/grey	Stem and leaf spotting	Red-legged earth mite, chocolate spot
	Yellow/red	Stunted	Root rots, dodder
		Premature death	Root and crown rot
	Pale green	Leaf and pod spotting	Thrips
	Stunted	Leaves/stem distorted	Stem nematode, mites (seedlings)
	Wilting	Leaves distorted	Cow pea aphids
	Physically damaged	Stems, leaves & pods	Mouse damage, bird/hare damage
Highly alkaline soil	Yellowing	Young leaves yellow	Iron deficiency
		Tip death	Manganese deficiency
	Patches	Plants chewed	Snails
	Stunted	Black leaf edges	Group B herbicide damage
Acidic soil	Yellow/red	Stunted	Nodulation failure
Low lying areas	Grey	Black leaf edges	Frost
	Yellow/red	Premature death	Waterlogging
General	Poor emergence	Stunted	Seed sown too deep
		Tip death	Triazine herbicide
	Stunted	Young leaves yellow	Group F herbicide damage
		Leaf spotting	Zinc deficiency
		Leaves distorted	Clopyralid herbicide damage
	Pale green	Leaves distorted	Group M damage
			Group I herbicide damage
		Leaf spotting	Downy mildew
	Yellow/red	Tip death	Boron toxicity
	Grey/brown	Leaf spotting	Ascochyta blight, chocolate spot, rust, Cercospora leaf spot, Alternaria leaf spot, hail
	Physically damaged	Leaf, stem & pods damaged	Triazine herbicide
	None obvious	Pods chewed	Native budworm
		Pod spotting	Oedema

Source: Faba beans –The Ute Guide (GRDC).

Table 9: *Key features of the main faba bean diseases and disorders.*

Disorder and cause	Seed-borne?	Symptoms	Distribution and occurrence	Survival and spread	Management
Waterlogging or root rotting (root anoxia—not a disease)	No	Slow death; little defoliation; roots not rotted but may be dark; plants hard to pull up	Patches; poorly drained areas; heavy rainfall; higher temperatures, i.e. later in season	Caused by insufficient supply of oxygen to roots	Avoid low lying or poorly drained paddocks or areas within paddocks. Sow in raised beds
Seed-borne root rot *Botrytis cinerea*, *Botrytis fabae* *Ascochyta fabae* (very rare)	Yes	Seedlings wilt and die, epicotyl rots	Rare, as seedling wilting and death is not common to either *Botrytis* or *Ascochyta* in beans. Occurs in random individual plants (not patches)	Seed	Quality seed; seed treatment, variety choice
Chocolate spot *Botrytis fabae* Including: Botrytis grey mould *Botrytis cinerea*	Yes/no	Leaf, flower, stem and pod lesions and rapid tissue death. Possibly lesions covered in mould	Occurs from late winter–early spring when canopy closes and warm humid conditions persist; individual plants but spread quickly to patches	Can be seed-borne, but mostly pathogen has airborne spores which can blow in	Sow a variety with best resistance available. Avoid highly susceptible varieties; use a foliar spray program; plant on wider rows; follow faba bean chocolate spot management package
Sclerotinia root and stem rot *Sclerotinia* spp.	Only as sclerotia in seed	Wilting and death; bleached root, collar and stem tissue; white cottony mould at site of lesion; sclerotia at lesions or inside stems	Root and collar lesions result from direct infection from sclerotia; stem lesions result from air-borne ascospores released from sclerotial apothecia, scattered or patches; favoured by denser canopies, wet events	Sclerotia persist in soil for many years; wide host range including pulses, canola, sunflowers and broadleaf weeds but not cereals or grasses	Sow seed that is clean of sclerotia. Avoid paddocks with history of *Sclerotinia* of its hosts; rotate with cereals; some varieties more susceptible
Rhizoctonia rot *Rhizoctonia solani*	No	Death of seedlings, stunting of survivors due to root damage, re-shooting after damping off of epicotyl	Can be a problem in irrigated crops grown immediately after cotton. Often occurs in 1–5-m stretches of row	Survives in soil and on decomposing trash. Probably present in most soils	Allow time for decomposition of (preceding) crop debris. Tillage should help
Ascochyta blight *Ascochyta fabae*	Yes	Necrotic spotting on all plant parts; lesions with visible fruiting structures (pycnidia); stem lesions; plant death	Individual plants which can spread to small patches, which enlarge rapidly in after rain events to severely damage leaf, stem and pods, possibly killing areas of susceptible crops	Faba bean residue very important in spread especially header dust and surface water flow; infected seed; volunteers	Follow faba bean *Ascochyta* management package, which includes variety choice and foliar fungicides

Disorder and cause	Seed-borne?	Symptoms	Distribution and occurrence	Survival and spread	Management
Cercospora leaf spot *Cercospora zonata*	No	Small dark grey–black lesions on lower leaves early in the season. Change to brown/red as expand and can merge to large lesions. Defoliation in lower canopy at flowering	Scattered plants on infested soil, linked to faba bean history in paddock	Survives in soil and infested faba bean residue	Follow faba bean cercospora leaf spot management package published annually; includes foliar fungicides
Rust *Uromyces viciae-fabae*	No	Leaf, stem and pod pustules develop leading to tissue death	Occurs very early in early sown crops, but normally late in season when warm humid conditions persist; Most plants affected, but possibly in patches. Often in association with chocolate spot	Faba bean residue and self-sown seedlings very important in spread. Airborne spores can blow around	Avoid highly susceptible varieties; use foliar fungicide program; follow faba bean rust–*Ascochyta* management package
Root-lesion nematodes *Pratylenchus* spp	No	Often showing no symptoms. If severe, possibly poor growth; small black lesions on lateral roots sometimes visible	Can affect large areas of crop. *P. thornei* more prevalent on high clay content soils	Wide host range; survives & spreads in soil; anhydrobiosis allows nematodes to persist for prolonged dry periods	Farm hygiene; rotate with resistant species (faba bean is one); grow tolerant varieties
Stem nematode *Ditylenchus dipsaci*	Yes/no	Poor emergence and establishment, stunting and distortion of seedlings, swollen stem bases	Symptoms usually occur in patches, but the large sections of a crop can be affected in severe cases	Wide host range; survives and spreads in soil and plant residue	Farm hygiene; rotate with resistant species
Alfalfa mosaic virus Cucumber mosaic virus	Not in faba beans, but is in other pulses	Not necessarily an issue in faba beans. In other crops is initially bunching, reddening or yellowing, wilting or death of shoot tips; later discoloration	Initially scattered plants or patches, often at edges of crop; more common in thin stands and areas	Viruses persist and multiply in weeds and pasture legumes; aphid-borne	Establish uniform stand by using recommended sowing rates and times; sowing into standing stubble
Phloem-limited viruses (luteoviruses): Bean leaf roll virus Subterranean clover redleaf virus Beet western yellows virus Subterranean clover stunt virus	No	Death of entire plant; luteovirus-infected plants often have discoloured phloem	Close to lucerne, irrigated perennial clovers; seasons or districts with major aphid flights		Cereal stubble deters aphids; avoid sowing too early; grow resistant varieties

9.9 Rust

(*Uromyces viciae-fabae*)

9.9.1 Symptoms

Numerous small, orange–brown pustules, surrounded by a light yellow halo appear on the leaves of plants affected by rust (see Figures 5 and 6). As the disease develops severely infected leaves wither and drop off (Figure 7). The rust pustules on the stems are similar to, but often larger than, those on these leaves. Late in the season, stem lesions darken as resting spores of the fungus are produced in pustules (Figure 8).

Isolated rust pustules may also appear on the pods. A severe rust infection may cause premature defoliation, resulting in smaller seeds.

Figure 5: *Young rust infections have a pale green ring, compared with no ring around chocolate spot infection (at pencil tip).*

Photo: Grain Legume Handbook

Figure 6: *Bean rust shows as orange 'bumps' on leaves.*

Photo: SARDI .

Figure 7: *Leaves can be heavily infected with rust.*

Photo: Grain Legume Handbook

Figure 8: *Rust on faba bean stem.*

Photo: Grain Legume Handbook

9.9.2 Economic impact

Rust is most prevalent in all warmer bean-growing areas, i.e. the northern grains region, and may significantly reduce yields. The disease has caused losses of up to 30% on its own, and in combination with chocolate spot has reduced yields by up to 50%.

9.9.3 Disease cycle

The fungus survives on stubble trash and infects self-sown bean plants directly without the need for alternate hosts. Rust spores are blown long distances onto new crops by the wind.

Rust pustules form on the first few plants to be infected and the disease spreads from these to other plants. Rainfall or dew is necessary for infection.

Rust can occur from early to mid-spring onwards and is favoured by warm temperatures (>20oC). Rust infection can occur following 6 hours of leaf wetness, so does not require extended wet periods.

9.9.4 Control

Growing resistant varieties will reduce the risk of disease infections (see Table 1). Prevention is difficult because the fungus spores can be carried long distances by wind to infect crops far from the initial source of infection.

Risk of the disease can be reduced by burning or burial of old bean stubbles and crop rotation.

MORE INFORMATION

http://www.grdc.com.au/Media-Centre/Ground-Cover/Ground-Cover-Issue-106-Sept-Oct-2013/New-faba-bean-rust-option

Fungicides may be used to control the disease and prevent a rust epidemic (see Table 3 and Table 5) in areas where the disease is most prevalent. Several sprays will be necessary for adequate disease control.

Fungicides for rust: Rust can become an important disease in beans during late flowering and podding. A foliar spray of mancozeb, chlorothalonil or a copper product will control rust.

Mancozeb or chlorothalonil provides the added key benefit of suppressing chocolate spot and Ascochyta blight.

A permit for tebuconazole use in faba beans and broad beans was approved in September 2013.

The permit for tebuconazole has been issued as PER13752 and applies from 31 May 2013 until 30 June 2016. A copy is available from the APVMA website (http://permits.apvma.gov.au/PER13752.PDF). The old permit (PER12657) and the three-day withholding period are no longer current. Significant changes to observe with the new permit include:

- where it is the only active in products containing 430 g/L of tebuconazole;
- long withholding periods (WHPs): 21 days for harvest and 14 days for grazing (adherence to these new WHPs should not be difficult for bean growers);
- approved use for rust and *Cercospora*; and
- a maximum of three applications at 145 mL/ha still applies. [12]

9.10 Chocolate spot

(*Botrytis fabae*)

9.10.1 Symptoms

Spots, ranging from small leaf spots to complete blackening of the entire plant are symptoms of chocolate spot. Leaves are the main areas affected, but under favourable conditions, the disease may also affect stems, flowers and pods (Figures 9–19).

The disease usually occurs in two phases: first a 'passive' (non-aggressive) phase where reddish-brown spots are 'peppered' over the leaves and stem and then an 'aggressive' phase, where tissue around the spots is rapidly killed leaving large, black or grey blighted sections on plant parts.

Small, black sclerotia can sometimes be found inside the stems of badly diseased plants. In moist conditions, the fruiting structures of this fungus may be visible, protruding as grey hair-like formations from the surface of infected plant parts e.g. on the underside of diseased leaves.

12 Southern/Western Faba & Broad Bean—Best Management Practices Training Course. Module 6—Disease Management. 2013. GRDC/ Pulse Australia.

Figure 9: *Poor pod set and leaf loss from failing to protect against chocolate spot early.*

Photo: Pulse Australia

Figure 10: *Chocolate spot can cause thick parts of crop (e.g. headlands) to lodge.*

Photo: Grain Legume Handbook

Figure 11: *Infections of chocolate spot in beans start as small brown spots.*

Photo: Grain Legume Handbook

Figure 12: *Two examples of chocolate spot leaf lesions. (Photos: SARDI).*

Figure 13: *Chocolate spot (*Botrytis fabae*) lesion in the field, showing some expansion across the leaf.*

Photo: Joop Van Leur, NSWDPI

Figure 14: *Chocolate spot (*Botrytis fabae*) lesion from Figure 13 showing lesion expansion and sporulation after a few days in humid chamber.*

Photo: Joop Van Leur, NSWDPI

Figure 15: *Chocolate spot on flowers will prevent pod set.*

Photo: SARDI

Figure 16: *Grey, dead areas of chocolate spot spread and flowers are also blighted, stopping any pod set.*

Photo: Grain Legume Handbook

Figure 17: *Chocolate spot on stems.*

Photo: Grain Legume Handbook

Figure 18: *Chocolate spot on leaves.*

Photo: Grain Legume Handbook

Figure 19: *Chocolate spot lesion on pod leading to infection and staining on seed.*

Photo: SARDI

Figure 20: *Stained faba beans.*

Photo: SARDI

9.10.2 Economic importance

Chocolate spot occurs in all areas where faba beans are grown. It is the major disease of faba beans in southern Australia. Losses range from minor to complete crop failure depending on the seriousness of infection, the time at which infection occurs and the amount of spring rainfall.

In unprotected crops, the disease commonly reduces yields by 30–50% in a bad year, mainly by preventing podset (see Figures 15 and 16)

Seed from badly affected plants may have a reddish-brown stain, which lowers its market value (Figure 20).

Symptoms of chocolate spot can be confused with symptoms of Cercospora leaf spot or damage on leaves from herbicides or physical events, which then allow minor diseases such as *Alternaria* (*Alternaria alternata*) to infect. Correct disease identification is necessary to avoid unnecessary spraying or incorrect fungicide use.

9.10.3 Disease cycle

The fungus can survive in crop debris, in infected seed, or on self-sown plants. Infection usually begins when spores originating from infested bean trash are carried onto new crops by wind. These spores can be carried over long distances. Chocolate spot may also be introduced into new bean-growing districts by sowing infected seed.

Once the disease becomes established it rapidly spreads within the crop. It spreads most aggressively in warm, humid conditions particularly at flowering time.

Chocolate spot is favoured by warm (15–25°C), humid conditions (>70% RH) that extend for 4–5 days and can spread rapidly within a crop. It typically develops later in the season during flowering and after canopy closure. Yield loss due to chocolate spot results from pod abortion and plant damage.

9.10.4 Control

Varieties with resistance to the disease should be grown in areas where the likelihood of chocolate spot is high.

Disease risk can be reduced by destroying all bean trash and self-sown plants before sowing, by sowing disease-free seed and by crop rotation. Delaying sowing also reduces disease risk.

Fungicides can be used to control the disease (see Tables 3 and 5).

Fungicides available for chocolate spot include those containing mancozeb, chlorothalonil, carbendazim or procymidone. Copper products may have some efficacy. Chocolate spot is targeted in critical period 2, as well as critical period 3 (see Table 5).

If chocolate spot incidence is high or the disease is spreading in the crop, then carbendazim or procymidone are more effective than chlorothalonil, mancozeb or copper.

Label regulations limit carbendazim to a maximum of two consecutive sprays at 14-day intervals. Carbendazim is a systemic fungicide with single-site specificity so the probability of resistance developing increases with regular use. It is best to alternate carbendazim with either chlorothalonil or mancozeb. Observe the withholding period for grain prior to harvest for carbendazim (30 days).To ensure that chocolate spot is controlled before it has a significant impact on the yield of the crop, the crop should be checked for disease every seven days while the temperature remains below 15°C. If the weather is mild with day temperatures between 15°C and 20°C and humidity >70%, crop inspections should be made every three days.

Spraying to control chocolate spot could begin at early flowering as a protective spray that is able to penetrate the canopy.Follow up sprays will be necessary where:

- chocolate spot lesions are visible within the upper canopy, or
- relative humidity in the crop is likely to remain high for at least a week, or
- disease is increasing.

9.10.5 Chocolate spot management options

Follow the principles of integrated disease management (IDM) which include:

- crop rotation and paddock selection
- growing resistant varieties (Table 1)
- clean seed and fungicide seed dressings
- canopy management through time of sowing, seeding rate and row spacing
- regular crop monitoring
- strict hygiene on and off farm
- strategic use of foliar fungicides.

Note: Seed dressings (Table 2) are not usually required, and only protect the emerging seedling from seed-borne *Botrytis* and common root rots. Seed dressings will not protect the emerged seedling from raindrop splashed *Ascochyta* or wind-borne botrytis.

Differing spray programs have been developed based on each variety's chocolate spot rating (Figure 3 and Table 6).

Fungicides used in faba beans are predominantly used as protectants only—unlike wheat stripe rust fungicides, most have little or no systemic action, and they will not eradicate an existing infection. Procymidone has some systemic activity, and carbendazim has some limited systemic activity that should not be relied upon. To be effective, all these fungicides must be applied before infection and before it spreads, i.e. before rain. The key to a successful chocolate spot spray program is regular monitoring combined with strategic, timely application of registered fungicides ahead of rainfall events (Figures 3 and 4, Table 3).

Moderately resistant (MR)

(No varieties currently available)

Varieties with some resistance to chocolate spot may require fewer and later fungicide applications for chocolate spot (*Botrytis*) control. The disease simply moves slower in these varieties, but will be devastating if left unprotected in high disease pressure situations.

Moderately susceptible (MS)

(PBA Rana⍉, PBA Kareema⍉, PBA Warda⍉, Aquadulce, Doza⍉)

If the disease is present or the risk is deemed high, apply an early foliar fungicide for chocolate spot, either just before canopy closure or before flowering. Repeat foliar fungicide will likely need to be applied during flowering and podding to ensure leaves are retained clean of lesions. Application at late podding may be required to protect grain quality in high-risk situations or if the disease is present. Note that these varieties will have minimal botrytis in the pods and seeds if the leaf canopy is kept clean of the disease.

Varieties with moderate susceptibility to chocolate spot may require no fewer and just as many fungicide applications for botrytis control as a susceptible variety. The disease does move slower in these varieties, but will be devastating if left unprotected in medium to high disease pressure situations.

Susceptible (S)

(Nura⍉, Farah⍉, Fiesta)

Apply an early foliar fungicide for chocolate spot just before canopy closure or before flowering if the disease is present or the risk is deemed high. Repeat foliar fungicide likely will be required during flowering and podding, until flowering is completed and no more new growth occurs. Ensure leaves are retained clean of lesions so that grain can be filled and to protect grain quality in high risk or disease pressure situations. Note that these varieties will have minimal botrytis in the pods if the leaf canopy is kept clean of the disease.

Very susceptible (VS)

(Fiord, Cairo⍉)

Regular foliar fungicide applications for chocolate spot control will be necessary in most areas, commencing early and applying it before a prolonged rainfall event. Apply a fungicide before the disease is detected, from the commencement of flowering until 4 weeks before maturity. Starting early with protective applications applied ahead of a rainfall event is critical, as control is often ineffective if fungicides are applied after the disease has taken hold. [13]

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9.11 Ascochyta blight

(*Ascochyta fabae*)

9.11.1 Symptoms

Ascochyta blight starts as grey spots. These show through both sides of leaves whereas young chocolate spot lesions do not show through at first (Figure 21). *Ascochyta* spots become irregularly shaped, and they may merge to cover most of the leaf surface (Figure 22).

Leaf tissue next to the affected patches may become black and die off. Many tiny black fruiting bodies develop within the patches as the disease progresses. The pale centres may fall out, leaving holes in leaves (Figures 23 and 24).

Patches on the stem tend to be elongated, sunken and darker than leaf lesions and usually covered with scattered fruiting bodies (Figure 25). The stems may split and break at the point of infection causing plants to lodge (Figure 26).

On pods, the infected patches are black and sunken (Figures 27 and 28). Well-developed patches can penetrate the pod and infect the developing seeds. Infected seeds may be smaller than normal and discoloured (Figure 29). Badly infected pods may split open and seeds can have brown or black stains (Figure 30).

Symptoms of Ascochyta blight may be confused with symptoms of Cercospora leaf spot or damage on leaves from herbicides or physical events, which then allow minor diseases such as *Alternaria* (*Alternaria alternata*) to infect. Correct disease identification is necessary to avoid unnecessary spraying or incorrect fungicide use.

Figure 21: *Infections start as small grey spots and may spread to the leaf edge following moisture run. Inset; Ascochyta lesion.*

Photo: Grain Legume Handbook

Figure 22: *Typical* Ascochyta *blight lesion.*

Photo: SARDI

Figure 23: *Older infections turn pale with black specks.*

Photo: Grain Legume Handbook

Figure 24: *Spotting from herbicide application can look like Ascochyta blight or Cercospora leaf spot, but note absence of pycnidia.*

Photo: SARDI

Figure 25: *Stem infections are sunken with pale centres.*

Photo: Grain Legume Handbook

Figure 26: *Severe stem infections can cause complete blight of stems (on left).*

Photo: Grain Legume Handbook

Figure 27: *Pod infections are black and sunken. They range from small isolated spots to the large multiple infection shown here.*

Photo: Grain Legume Handbook

Figure 28: *Ascochyta blight pod lesions affect seed quality. Protection is required as it is all too late when it gets to this stage.*

Photo: DPI Vic

Figure 29: *Left: Ascochyta blight on bean stems cause stem breakage and lodging. Right: Staining resulting from Ascochyta infection. The disease is transferred by seed to new crop.*

Photo: Grain Legume Handbook

Figure 30: *Bean grain with Ascochyta blight damage.*

Photo: SARDI

9.11.2 Economic importance

The disease is widespread in southern Australia, where yield losses of up to 80% may occur.

Ascochyta blight first caused widespread damage to chickpeas in northern New South Wales (NSW) and southern Queensland in 1998, when extremely wet conditions favoured disease development and spread. The fungus is now considered endemic in chickpeas in all growing regions except central Queensland, but is not yet regarded as a significant threat to faba bean north of central NSW. [14]

Beans discoloured by *Ascochyta* infection may be rejected or discounted.

9.11.3 Disease cycle

The *Ascochyta* fungus can survive on crop debris, self-sown plants and on infected seed. The disease spreads short distances from infected to healthy plants by rain splash spores, during the growing season, or over longer distances via wind early in the season.

Infection can occur at any stage of plant growth following either rain or heavy dew. *Ascochyta* infection is likely to occur in environments with prolonged wet, cool (5–15°C) conditions and usually develops early in the growing season. Damage from stem infection often results in serious crop lodging in susceptible varieties. However, development of this disease can also be important late in the season. Pod infection with Ascochyta blight can cause seed staining and the subsequent downgrading of faba bean grain.

9.11.4 Control

Growing resistant varieties (Table 1) will reduce the risk of severe disease infestations and the staining of seed. Ascochyta blight can be controlled by sowing disease-free seed, by crop rotation, by controlling self-sown beans in rotations and by sowing crops away from infected bean trash.

Chemical seed treatments reduce the risk of introducing disease from infected seed (Table 2).

Fungicide use: If risk of *Ascochyta* blight is high, or it persists and continues to spread in the bean crop, then chlorothalonil is considered more effective than mancozeb. Beware of the grazing withholding period and the export slaughter interval (ESI) restriction with chlorothalonil (63 days). Take note of the withholding period for grain prior to harvest for mancozeb (30 days) and chlorothalonil (14 days).

Ascochyta blight is targeted in all critical periods, particularly in susceptible varieties, when conditions favour disease spread.

Foliar sprays with fungicide (Table 3) are likely to be economic for susceptible varieties. Fungicides should be applied at about 6 weeks to reduce lodging losses from stem infections. Late sprays can reduce seed infection.

9.11.5 *Ascochyta* management options

Follow the principles of IDM, which include:

- crop rotation and paddock selection
- growing resistant varieties (Table 1)
- clean seed and fungicide seed dressings
- regular crop monitoring
- strict hygiene on and off farm
- strategic use of foliar fungicides

14 K Moore, M Ryley, G Cumming, L Jenkins (2013) Northern Pulse Bulletin. Chickpea: Ascochyta Blight Management. Pulse Australia, Northern Pulse Bulletin. Chickpea: Ascochyta Blight Management. 2013, Pulse Australia

Note: Seed dressings (Table 2) only protect the emerging seedling from seed-borne *Ascochyta* and seed-borne *Botrytis*. Seed dressings will not protect the emerged seedling from rain-drop splashed *Ascochyta* or wind-borne *Botrytis*.

Differing spray programs have been developed based on each variety's Ascochyta blight rating (Figure 3 and Table 1).

Fungicides used in faba beans are protectants only—unlike wheat stripe rust fungicides, they have no systemic action, and they will not eradicate an existing infection. To be effective they must be applied before infection, i.e. before rain. The key to a successful *Ascochyta* spray program is regular monitoring combined with timely application of registered fungicides (Table 3).

Resistant (R)

(PBA Rana⚓, PBA Kareema⚓, Nura⚓, Farah⚓)

Only consider applying an early foliar fungicide for Ascochyta blight if the disease is present and the risk is high.

A foliar fungicide applied during podding is unlikely to be required to protect grain quality in most situations. Note that these varieties have resistance to Ascochyta blight in the pods.

Varieties with resistance to Ascochyta blight require fewer and later fungicide applications for control, if at all. This may result in the early development of chocolate spot infection, which would have normally been controlled as a result of fungicide application for early Ascochyta blight management in less resistant varieties. Early monitoring and control of Chocolate spot is still critical in *Ascochyta*-resistant varieties.

Susceptible (S)

(Fiesta VF, Aquadulce, PBA Warda⚓, Doza⚓, Cairo⚓)

Foliar fungicide applications for Ascochyta blight control will be necessary in most areas, commencing early. Apply a fungicide before the disease is detected, from early emergence (6–8 weeks) through flowering until 4 weeks before maturity. Starting early with protective applications is critical, as control is often ineffective if fungicides are applied after the disease has taken hold. [15]

9.12 *Sclerotinia* stem rot

(*Sclerotinia trifoliorum* var. *fabae, S. sclerotiorum, S. Minor)*

9.12.1 Symptoms

Plants can be attacked at any stage of growth. In young plants the infection usually begins close to ground level and a slimy-wet rot extends into the stem and down into the roots.

Affected plants are easily pulled from the soil. They usually have a blackened base that is covered with cottony, white fungus growth.

Usually isolated plants rather than patches of plants are affected in crops. Older plants can get the infection on any part of their stems, leaves or pods. Infected plants suddenly wilt and collapse.

Sclerotia (2–5 mm in diameter) form on the surface of infected plants and in the central cavity of the stem. These sclerotia are usually white at first then turn black.

9.12.2 Economic importance

Crop losses in Australia have been small so far. However, the disease poses a potential threat.

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9.12.3 Disease cycle

The fungus can survive in the soil for several years. It has a wide host range (including oilseed crops) and may survive on other plants even if beans are not grown.

Sclerotinia may act as either a leaf or a root disease. The foliar form of the disease may be spread by airborne spores. Infection begins when these spores settle on the crop. If conditions are cool and wet, the disease develops rapidly and affected plants soon wilt and die.

While damage to the foliage encourages infection, the fungus can infect uninjured tissue.

Root disease occurs when soil-borne spores directly invade the root tissue. A slimy wet root rot develops and the infected plants suddenly wilt and die.

9.12.4 Control

Crop rotation prevents rapid disease build up, but once established in a crop it is difficult to control. Rotations with other legumes and oilseed crops will not break the disease cycle. Cereal crops are not hosts and so can be used in the rotation.

Lower seeding rates, wider row spacing and good weed control allow a more open crop, which remains drier and is less prone to disease.

9.13 Aphanomyces root rot

(Aphanomyces euteiches)

9.13.1 Symptoms

Chlorosis and wilting of the plant, associated with necrosis in the roots.

9.13.2 Economic importance

This root rot has been observed in recent years in parts of northern NSW. It is unlikely to be a major pathogen of faba beans at the present. However, the expansion of this crop in regions with heavy soils and high rainfall, or irrigated fields, increases the risk of losses.

9.13.3 Disease cycle

The fungus survives in soil and is exacerbated by waterlogging. It can spread from crop to crop in the soil, either via infected plant debris or as resting spores.

In wet soils, this fungus can invade plant roots and cause root rot. Wet conditions also encourage the spread of disease within a field. The reduced root development causes the plants to die when they are stressed.

9.13.4 Control

The disease can be reduced by crop rotation.

It is not known if this strain of the disease can also affect other pulses. A pea-infecting strain is known to occur in Europe.

9.14 Botrytis grey mould (BGM)

(Botrytis cinerea)

9.14.1 Background

Botrytis grey mould (BGM) in faba beans is a minor problem compared with chocolate spot (*Botrytis fabae*).

The control of BGM in faba beans is the same as for chocolate spot.

9.14.2 Economic importance

Botrytis grey mould is a less serious disease of faba and broad beans than is chocolate spot in beans in southern Australia, but the two are sometimes found together in association.

Discoloured seed may be rejected or heavily discounted when offered for sale. If seed infection levels are >5% then it may be worth grading the seed.

Occurrence is worst in wet seasons, particularly when crops develop very dense canopies.

9.14.3 Biology and epidemiology

The life cycle of BGM in faba and broad bean is similar to, but only slightly different than that of chocolate spot.

BGM is a significant pathogen of other pulse crops particularly lentil, chickpea and ornamental plants grown under glasshouse conditions, and fruit including grapes, strawberries and apples. Like with chocolate spot, flowers are especially vulnerable to BGM infection. *B. cinerea* does not infect cereals or grasses.

Botrytis cinerea has been recorded on over 138 genera of plants in 70 families. Legumes and asteraceous plants comprise approximately 20% of these records. As well as being a serious pathogen, *B. cinerea* can infect and invade dying and dead plant tissue. This wide host range and saprophytic capacity means inoculum of *B. cinerea* is rarely limiting. If conditions favour infection and disease development, BGM will occur.

This makes management of BGM different from Ascochyta blight, which is more dependent on inoculum, at least in the early phases of an epidemic.

9.15 Root rots, including Phoma blight and damping off

(Fusarium, Rhizoctonia, Pythium spp. and *Phoma medicaginis* var. *pinodella)*

9.15.1 Symptoms

Root rot is the most common symptom of Phoma blight as plants can be infected on the stem below ground level. Lesions on the stems below soil level are black. Infected plants are stressed.

Seedlings affected by root rot gradually turn black and leaves droop. The plants usually do not collapse completely. The taproot may become quite brittle, except in Pythium root rot when they become soft. When plants are pulled from the ground the lower portion of the root snaps off and remains in the soil. The upper portion of the taproot is dark, shows signs of rotting and may lack lateral roots. Distinct dark brown to black lesions may be visible on the taproot.

The leaves and stems of affected plants usually start turning black.

Older plants dry-off prematurely and are often seen scattered across a field.

In some cases, seeds may rot before they emerge.

9.15.2 Economic importance

Root rot can occasionally be a serious disease especially when soils are wet for prolonged periods.

9.15.3 Disease cycle

All the fungi responsible for root rot are soil dwellers, the most important medium of transmission. They can survive from crop to crop in the soil, either on infected plant debris or as resting spores.

In wet soils these fungi can invade plant roots and cause root rot. Wet conditions also encourage the spread of disease within a field. The reduced root development causes the plants to die when they are stressed.

Spores of the fungus produced on crop residue can be carried onto the new crop by wind. Infection can occur at any stage of plant growth, provided conditions are favourable. Moisture is essential for infection to occur.

During wet weather, the disease may spread further, when spores of the fungus are carried onto neighbouring plants by wind and rain-splash.

Severe pod infection can result in reduced seed set and infected seed.

9.15.4 Management options

The disease can be reduced by crop rotation. As this disease may also affect other pulses, faba beans should be sown in rotation with another non-legume crop. Although faba beans are deemed reasonably tolerant of waterlogging, they should not be grown in areas subject to severe waterlogging.

Damping off can be controlled using fungicide seed treatment, but this is not common practice with faba beans.

Disease risk can be reduced by planting clean seed to prevent disease build up. Fungicidal seed dressing should control seed-borne infection (Table 2). Their use on faba beans is however not a common practice.

9.16 Viruses

Faba and broad beans are naturally infected by around 50 viruses worldwide, and the number continues to increase. Fortunately only few are of major economic importance in Australia.

Major viruses known to infect faba beans in Australia include:

- Bean leaf roll virus (BLRV)
- Beet western yellow virus (BWYV)
- Soybean dwarf virus (SBDV), syn. Subterranean clover red leaf virus (SCRLV)
- Subterranean clover stunt virus (SCSV)
- Clover yellow vein virus (ClYVV)
- Bean yellow mosaic virus (BYMV)

Less common viruses that occur in Australia are:

- Clover yellow vein virus (ClYVV)
- Alfalfa mosaic virus (AMV)
- Tomato spotted wilt virus (TSWV)
- Broad bean wilt virus (BBWV)
- Cucumber mosaic virus (CMV)

Except for TSWV, which is transmitted by specific thrips species, these viruses need aphid vectors to spread from infected to healthy plants.

Note that we need keep other viruses of faba beans out of Australia. Other viruses of economic importance on faba beans globally but not in Australia include Faba bean necrotic yellows virus and Broad bean mottle virus. Also there are viruses that are important in specific locations within specific countries. These include Broad bean true mosaic virus, Broad bean stain virus, Chickpea chlorotic dwarf virus, Milk vetch dwarf virus, Pea early browning virus and Pea enation mosaic virus.

9.16.1 Virus types

Viruses can be classified by the manner in which they are transmitted by insect vectors.

Persistent transmission means that when an insect vector feeds on an infected plant, the virus has to pass through the body of its vector and lodge in its salivary glands before it can be transmitted to a healthy plant, a process that takes >1 day. Once the insect is infectious, it remains so for the rest of its life. Very few aphid species are vectors of this kind of virus in pulses and they tend to colonise the hosts they transmit the virus to (e.g. faba bean). The pea, cowpea and green peach aphids are important as vectors of persistently transmitted viruses in pulses. Because acquisition and transmission of the virus is relatively slow, insecticides that kill aphids can work in suppressing virus spread. Aphids do not often colonise legumes; however, but they will remain for long enough to transmit luteoviruses.

Non-persistent transmission means that the insect vector can land on a virus infected plant, make a brief probe, acquire the virus on its mouth-parts within seconds and then transmit it immediately when probing on a healthy plant. The aphid loses the virus after it probes a healthy plant one or two times. After this, the insect does not infect further plants until it probes another infected plant. The whole process is so quick that insecticides do not act fast enough to prevent transmission, and can exacerbate the situation by making the aphids hyperactive, flitting from plant to plant. Many aphid species are vectors of this type of virus including ones that do not colonise legumes but just land and probe pulse crops while searching for their preferred hosts (e.g. oat and turnip aphids).

The category luteovirus arises from the Latin luteus (yellow), because of the symptomatic yellowing of the plant that occurs as a result of infection. [16]

Table 10: *Virus categories and general symptoms.*

Virus	Aphid transmission	Seed transmission*	Visual symptom type	Visual symptoms	Virus type (genus)
AMV, Alfalfa mosaic virus	Non-persistent	Yes	Shoot tip	Necrotic or chlorotic local lesions, sometimes mosaics that do not necessarily persist	Alfamovirus
BBWV, Broad bean wilt virus	Non-persistent	No	Mosaic, shoot tip	Vein clearing, mottling and necrosis of shoot apex, plant wilts, mottled, malformed and stunted	Fabavirus
BLRV, Bean leaf roll virus	Persistent	No	Top yellowing	Upward leaf-rolling accompanied by interveinal yellowing of older leaves and flowers abscised	Luteovirus
BWYV, Beet western yellows virus	Persistent	No	Top yellowing	Interveinal yellowing of the older or intermediate leaves. Mild chlorotic spotting, yellowing, thickening and brittleness of older leaves	Luteovirus
BYMV, Bean yellow mosaic virus	Non-persistent	Yes	Mosaic	Transient vein chlorosis followed by obvious green or yellow mosaic. Usually no leaf distortion	Potyvirus
CMV, Cucumber mosaic virus	Non-persistent	Yes	Shoot tip	Mosaics, stunting and possibly some chlorosis	Cucumovirus
ClYVV, Clover yellow vein virus	Non-persistent	No	Shoot tip, mosaic	Mosaics, mottles or streaks, vein yellowing or netting	Potyvirus

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Virus	Aphid transmission	Seed transmission*	Visual symptom type	Visual symptoms	Virus type (genus)
PSbMV, Pea seed-borne mosaic	Non-persistent	Yes	Mosaic	Systemic dark and light-green zonal leaf mottle, slight to moderate downward rolling of leaf margins. Distortions of leaf shape associated with mottle patterns. Seed markings	Potyvirus
SCRLV, Subterranean clover red leaf virus	Persistent	No	Top yellowing	Mild yellowing, stunting and reddening	Luteovirus
SCSV, Subterranean clover stunt virus	Persistent	No	Top yellowing	Top yellows, tip yellows or leaf roll. Leaf size reduced, petioles and internodes shortened	Nanavirus
TSWV, Tomato spotted wilt virus	Persistent	No	Shoot tip, mosaic	Necrotic and chlorotic local lesions, mosaic, mottling, leaf shape malformation, vein yellowing, ringspots, line patterns, yellow netting and flower colour-breaking	Tospovirus

Seed transmission in faba beans is minimal for all viruses, and of no epidemiological significance. It is, however, significant in terms of quarantine and keeping foreign virus strains out of Australia

In some seasons, viruses can become a problem in bean crops. Viruses such as Bean leaf roll virus (BLRV), Beet western yellows virus (BWYV) and to some extent Pea seed-borne mosaic (PSbMV) are not seed transmitted, but these become established after aphid-vector activity.

The most important factors that predispose pulse crops to severe virus infection are:

- Infected seed or close proximity to a substantial virus reservoir (e.g. lucerne, summer weeds, field peas for PSbMV).
- High summer–autumn rainfall and the subsequent uncontrolled multiplication of aphids on host plants. Early aphid flights to newly emerged crops can cause early infection and economic loss as infected plants act as a reservoir for further spread of infection within the crop.

9.16.2 Symptoms

Initially diseased plants are scattered, but by the time the crop matures, luteoviruses may have infected nearly the entire crop (Figures 31–49).

Luteoviruses cause yellowing and stiffening of the leaves, and sometimes an upwards rolling of the leaf margins (see Figures 31 to 33 for BLRV) If infection occurs at the seedling stage, the whole plant shows symptoms. If infection occurs later, only the tops of shoots show symptoms ('top yellows'). Infected plants become stunted and die prematurely unless infection occurs after podding.

Tomato spotted wilt virus (TSWV) causes tip necrosis and plant death (see Figures 35 to 39). Economically significant incidences have been found in the northern region, since the introduction of the Western flower thrips, a highly efficient TSWV vector in that region. However, it does not yet appear to be a major problem in the southern region. Note that symptoms of thrips feeding can be confused with TSWV (Figures 40 and 41).

Infections by BYMV causes leaves to turn pale green (Figure 45). Usually, there is a mosaic of dark green patches over the pale green leaves. The leaves develop an uneven surface texture and outline compared with healthy leaves. There is little or no stunting.

Figure 31: *Bean leaf roll virus.*

Photo: Grain Legume Handbook

Figure 32: Bean leaf roll virus.

Photo: Joop Van Leur,NSW DPI

Figure 33: *Bean leaf roll virus. Note bare ground around the plants.*

Photo: Pulse Australia

Figure 34: *Clover yellow vein virus (ClYVV) leaf symptoms and tip necrosis prior to eventual plant death. Symptoms in beans can resemble those of Tomato spotted wilt virus (TSWV) with death of the growing point.*

Photo: SARDI

Figure 35: *Tomato spotted wilt virus (TSWV) stem necrosis and ring spot lesions.*

Photo: Joop Van Leur, NSW DPI

Figure 36: *Close up of Tomato spotted wilt virus (TSWV) ring spot lesions.*

Photo: Joop Van Leur, NSW DPI

Figure 37: *Tomato spotted wilt virus (TSWV) stem and tip necrosis.*

Photo: Joop Van Leur, NSW DPI

Figure 38: *Tomato spotted wilt virus (TSWV) pod necrosis.*

Photo: Joop Van Leur, NSW DPI

Figure 39: Tomato spotted wilt virus (TSWV) stem necrosis and black lesions.

Photo: Joop Van Leur, NSW DPI

Figure 40: *Necrosis of the growing tip can caused by thrips feeding only, not by TSWV.*

Photo: Joop Van Leur, NSW DPI

Figure 41: *Necrosis of the growing tip can caused by thrips feeding only, not by TSWV.*

Photo: Joop Van Leur, NSW DPI

Figure 42: *Stem necrosis can be caused by other causes than TSWV, in this case chocolate spot.*

Photo: Joop Van Leur, NSW DPI

Figure 43: *Stem necrosis can be caused by other causes than TSWV, in this case frost.*

Photo: Joop Van Leur, NSW DPI

Figure 44: *Leaf symptoms of Bean yellow mosaic virus.*

Photo: Grain Legume Handbook

Figure 45: *Bean yellow mosaic virus (BYMV) in faba bean.*

Photo: SARDI

Figure 46: *Pea seed-borne mosaic virus (PSbMV) symptoms in faba bean.*

Photo: Roger Jones, DAFWA

Figure 47: *Bean seed showing Pea seed-borne mosaic virus (PSbMV) marking that can affect marketability.*

Photo: R. Kimber, SARDI

Figure 48: *Subterranean clover stunt virus (SCSV) in very early sown beans.*

Photo: Wayne Hawthorne, Pulse Australia

Figure 49: *Soybean dwarf virus (SBDV) is also known as subterranean clover red leaf virus (SCRLV).*

Photo: Joop Van Leur, NSW DPI

9.16.3 Economic importance

Viruses are a significant problem of faba beans in the northern grain region.

Damage caused by viruses varies greatly from season to season and depends on the prevalence of aphids.

The luteovirus BLRV was detected for the first time in 1993 in northern NSW (in faba beans, narbon beans and a forage legume *Lathyrus ochrus*). By 1995, BLRV had caused major yield losses in faba beans in northern NSW. It had a major impact in parts of South Australia in the drought of 2007.

Another luteovirus, SBDV (also known as SCRLV), has been infecting faba beans crops in Australia since the 1970s and does not appear to be a serious problem.

Bean yellow mosaic virus occurs commonly at a low frequency in faba bean crops and has not caused any serious losses.

Clover yellow vein virus caused plant death in spring-sown beans grown adjacent to irrigated white clover in South Australia in the late1990s. Similar symptoms are seen in faba bean crops on occasions, but can be confused with other causes.

9.16.4 Disease cycle

Aphids bring the viruses into faba bean crops from surrounding plants, usually legumes (e.g. lucerne or clovers). Some viruses, such as BWYV, AMV, CMV, BYMV and TSWV, have a host range that includes non-legume species. Hence other plant species (e.g. sow thistle, turnip weed) can act as a virus source at the start of the season.

9.16.5 Control

There are no totally proven control measures for viruses. Virus management in pulses aims at prevention through integrated management practice that involves controlling the virus source, aphid populations and minimising virus transmission into and within the pulse crop.

Application of seed and foliar insecticides aimed at preventing feeding by aphids can help, but needs further confirmation that they can prevent infection by viruses.

Rotate pulse crops with cereals to reduce virus and vector sources and where possible avoid close proximity to perennial pastures (e.g. lucerne) or other crops that host viruses and aphid vectors. Eliminate summer weeds and self-sown pulses that are a 'green bridge' host for viruses and a refuge for aphids and their multiplication.

Aphids are the major means by which viruses enter faba bean crops. TSWV is, however, spread by thrips. Winged aphids acquire virus by feeding on alternative hosts (particularly lucerne and irrigated perennial clovers) and then land on faba bean plants on which they feed thus transmitting viruses. Probing and feeding needs to be prolonged for transmission of persistently transmitted viruses (0.1–4.0 h for luteoviruses), but brief probing can transmit non-persistently transmitted viruses. Eventually aphids colonise the bean plant and become very visible in the crop.

Cucumber mosaic virus and AMV are non-persistently transmitted by a range of aphid species. *Acyrthosiphon gossypii* is one of many possible vectors of both. The luteoviruses are persistently aphid-transmitted, but are more vector-specific.

Aphids move between adjacent plants to feed before colonising faba beans plants. The result is that faba bean crops show a characteristic scattered distribution of patches of virus-infected plants. This contrasts with crops such as chickpeas, in which aphids do not colonise, where only individual plants are infected.

Aphid activity is influenced by seasonal conditions and will require early monitoring in nearby crops and pastures.

Virus risk can be managed by combining a number of different control measures:

- Suppress the virus source within the crop. Sow seed with <0.1% seed infection.
- Distancing crops from lucerne, weeds or other species that act as a reservoir for viruses, diseasesand aphids.
- Control volunteer weeds during summer and autumn.
- Use a seed treatment of Gaucho 350SD® (imidacloprid), which is registered for early aphid protection to control persistently transmitted viruses.
- Retention of cereal stubble to deter aphids and decrease aphid landing rates.
- Sowing at recommended plant densities to achieve early closure of the crop canopy (closed canopies deter aphids).
- Sowing at recommended times to avoid autumn aphid flights.
- Note that high seeding rates and narrow row spacing to provide early canopy closure assists in aphid control, but conflicts with management of fungal diseases.Ensure faba bean plants are less attractive to aphids by minimising seedling disease, herbicide damage and poor nutrition.

Growers should only consider applying insecticide for virus control if they consider their crops to be at high risk. Insecticides aimed at controlling damage from aphid feeding are normally too late to control virus spread and damage.

Virus testing resources

Several options for diagnostic testing are available. Only some tests can be performed with relative ease in the field.

Note: at least 14 virus species occur in Australian pulse crops (i.e. AMV, BYMV, CMV, BWYV, SCRLV, LNYV, BLRV, TSWV, TSV, TuMV, four mastreviruses).

MORE INFORMATION

http://www.grdc.com.au/Media-Centre/Ground-Cover/Ground-Cover-Issue-86-May-June-2010/Smarter-pest-management

Current testing options may not detect the less common viruses. Detection of virus in one or two plants is not proof that the virus is causing the problem. It is important to check for a range of viruses, as the one being tested for may not be the one or ones causing symptoms.

Detection of a seed-borne virus does not mean there will be virus present in progeny seed. Seed samples from the crop would require testing to determine if seed infection has occurred.

9.17 Root-lesion nematodes (RLN)

(Pratylenchus neglectus, P. Thornei and other *Pratylenchus* spp.*)*

Root-lesion nematodes are discussed at greater length in *GrowNotes Faba Beans 8: Nematode Control.*

Worldwide, the genus *Pratylenchus* is the second most important group of plant-parasitic nematodes. More than 90 species of root lesion nematode (RLN) are known worldwide. The two main species of RLN, *Pratylenchus neglectus* and *P. thornei,* occur in the cropping regions of southern and eastern Australia.

Pratylenchus thornei and *P. neglectus* have been detected at potentially damaging levels in nearly 30% of fields in the northern grain region.

Intolerant wheat varieties can lose >50% yield and some chickpea varieties up to 20% yield when nematode populations are high. [17]

All RLN species cause root damage and yield losses, particularly in cereals. Root lesion nematodes have a wide host range, including cereals and grassy weeds, pulses, pasture and forage legumes and oilseeds.

With the exception of chickpeas, pulses tend to have good resistance to either *P. neglectus* or *P. thornei*, so can reduce nematode populations in cropping rotations.

MORE INFORMATION

Single test improves stubble-borne disease management

Table 11: *Resistence and tolerance of pulses to the major* Pratylenchus *species.*

Crop	*Pratylenchus neglectus*		*Pratylenchus thornei*	
	Resistance	Tolerance	Resistance	Tolerance
Chickpea	S to MR*	MI to T*	VS to R*	MI to T*
Faba bean	MR	–	VS	–
Field pea	R	–	R	T
Lentil	R	T	R	MT
Vetch - Blanchefleur	MR	T	S	I-MI
- Languedoc	MR	T	MS	I-MI
- Morava	MR	T	MS	I-MI

VS, Very susceptible; S, susceptible; MS, moderately susceptible; MR, moderately resistant; R, resistant; I, intolerant; MI, moderately intolerant; T, tolerant; MT, moderately tolerant.

* Chickpea varieties have a range of resistances and tolerances to Pratylenchus species

MORE INFORMATION

http://soilquality.org.au/factsheets/root-lesion-nematode-in-queensland/

http://www.daff.qld.gov.au/__data/assets/pdf_file/0010/58870/Root-Lesion-Nematode-Brochure.pdf

Repeated glasshouse and field experiments carried out by Department of Agriculture, Fisheries and Forestry Queensland (QDAF) have shown that faba beans are very susceptible to *P. thornei* and moderately resistant to *P. neglectus*. Further trials on the tolerance of faba beans to RLN will be run in 2015–16.

17 QDAF (2009) Management of root-lesion nematodes in the northern grain region. GRDC/QDAF. http://www.daff.qld.gov.au/__data/assets/pdf_file/0010/58870/Root-Lesion-Nematode-Brochure.pdf

What is resistance and tolerance?

Resistance: nematode multiplication

Resistant crops do not allow RLNs to reproduce and increase in number in their roots.

Susceptible crops allow RLN to reproduce so that their numbers increase. Moderately susceptible crops allow increases in nematode populations, but at a slower rate.

Tolerance: crop response

Tolerant varieties/crops yield well when sown in fields containing high populations of nematodes.

Intolerant varieties/crops yield poorly when sown in fields containing high populations of nematodes.

9.17.1 Symptoms

Pratylenchus may impair root function, limiting water and nutrient uptake by the plant. Affected plants may show general un-thriftiness or symptoms of nitrogen deficiency. Symptoms are increased when plants are subjected to water and nutrient stress, or when combined with root damage caused by fungi.

Symptoms of infection on root systems include:

- disintegration of outer layers of root tissue
- reduction in root hairs and/or nodules
- lack of/or stunting of side (lateral) roots
- brown lesions and discoloration of roots.

Root symptoms are often difficult to diagnose in the field and are usually not seen until plants are older than 8 weeks. Root symptoms are generally more obvious in plants grown in sandier soils.

9.17.2 Yield losses

Yield losses to *Pratylenchus* species is an indication of susceptibility. Minimal yield loss however indicates crop tolerance, even though nematode numbers might have multiplied whilst the crop is growing. Resistance is when the nematode population does not multiply during that crop's growth, irrespective of the impact on crop yield.

In trials in 1996, the most tolerant pulse crop varieties, with the least yield losses were Dooen chickpeas, Icarus faba beans and Popany vetch. Amethyst chickpea yield loss due to *Pratylenchus neglectus* was 43%. For *Pratylenchus thornei*, the vetch varieties Blanchefleur and Languedoc appeared intolerant with losses of 27% and 30%.

9.17.3 Symptoms

Severely affected plants are stunted and may have some yellowing of their foliage, but often have no obvious foliar symptoms of disease. Diseased plants usually have shorter lateral roots and fewer root hairs. Microscopic examination of the root system is required to confirm the presence of the nematode.

9.17.4 Economic importance

There is likely to be minimal yield loss in faba beans to *Pratylenchus* nematodes. In susceptible crops like chickpea, yield losses have been up to 50% under heavy nematode numbers. Yield losses in the following wheat crop or pasture may also occur. Nematode numbers appear to increase where susceptible crops like chickpea are grown in rotation with wheat.

9.17.5 Disease cycle

Nematodes are small worm-like organisms <1 mm in length and are able to move freely through moist soils and young root tissues. As the females move through plants they feed on the plant roots, causing lesions, and deposit eggs.

There may be several generations of nematodes within a growing season. Nematodes are likely to multiply under a range of host crops such as wheat and chickpeas. Barley is only moderately susceptible. Many grass weeds and legumes can also host nematodes.

Nematodes survive over the summer months in dry soil and root residues to become active again when the winter rains start.

MORE INFORMATION

Predicta B an identity kit for soil borne pathogens

9.17.6 Management options

Resistant varieties will reduce the impact of nematode infection. *Pratylenchus* can be controlled by using resistant crops such as faba beans, peas or lupins in the rotation. Chickpea–wheat rotations should be avoided where root lesion nematodes numbers are high. Soil-borne disease risk can be assessed through the DNA based Predicta B™ Root Disease Test. [18]

9.18 Improving diagnostic skills

Accurate diagnosis is the first step in successfully managing a problem. The following principles and practical tips will help you reach an accurate answer.

9.18.1 Key diagnostic principles

- Diagnosis draws on several disciplines including plant nutrition, meteorology, soil science, agronomy, entomology, weed science and plant pathology.
- An incorrect diagnosis and inappropriate recommendation will usually be ineffective and possibly more costly than inaction.
- Not all plant disorders are cause by plant pathogens; consider genetic, insect, animal, environmental and agronomic causes.
- Some problems involve more than one cause, although usually there will be only one major cause.
- In some cases, correct diagnosis is impossible without a paddock inspection.
- Take notes (and photographs). As well as recording historical information (e.g. sowing date, variety, previous crop etc.), describing the distribution and symptoms in writing hones observational skill.
- Know what a healthy crop should look like at the major growth stages.

9.18.2 Practical tips

Keep an open mind, and start on a broad scale to establish spatial and temporal patterns.

What is the distribution of the disorder across the district?

Regional distribution of a problem can eliminate many causes and may identify likely ones. If only one crop or one grower in the district has the problem, the cause is unlikely to be environmental, or an air-borne disease, e.g. faba bean rust. Isolated problems often reflect some agronomic problem, e.g. wrong type or rate of herbicide, poor quality seed, inadequate nutrition, nodulation failure, deep seeding or a soil-borne pest or disease.

What is the distribution of the disorder across the paddock?

Is the pattern linked with a farming operation (past and present?), for example:

18 Southern/Western Faba and Broad Bean—Best Management Practices Training Course. Module 3—Varieties 2013. Pulse Breeding Australia.

- Is it linked to cultivation, old fence line, sheep camp, sowing, varieties, spraying, harvesting?
- Does it follow drainage lines or is it confined to low or high parts of the paddock?
- Does it affect individual plants throughout the paddock, individual plants at the edge of the crop or in thin areas, or does it occur in patches?

Walk through the crop with your eyes shut sensing changes in soil compaction to establish links between hard zones and symptoms. Run your hands across the plants. Do they feel stiff and leathery; cool or hot?

What has the weather been like? Could it be frost, heat stress, drought, waterlogging?

What has the insect activity been like? Are there aphids on the windscreen or moths in the crop?

Determine the progression of symptoms. Look at plants showing the range of symptoms from apparently healthy, to just starting to show the problem, to just about the die:

- Are plants easy to pull up?
- Do they break off at ground level?
- Look for evidence of feeding by insects, birds or rodents.

Dig up plants:

- Is soil clinging loosely to their roots (evidence of fungal hyphae)?
- Wash soil from roots in bucket and examine against a light-coloured background.
- Make progressive tangential slices into the root, collar and stem looking for vascular discoloration.

Finally, if you suspect a plant disease, remember the Disease Triangle.

A crop can only have a serious disease problem if three conditions are met:

- susceptible host
- prevalent causal agent
- favourable environment

9.19 Sample preparation for diseased plant specimens

(Compiled information from QDAF Farmnote 115, Don Hutton)

For accurate diagnoses it is imperative that specimens are carefully selected, well presented and submitted with adequate information.

9.19.1 Selection of specimens

Select plants that show the range of symptoms, i.e. slightly to severely affected. Include several healthy plants for comparison. Collect whole plants if practicable, including the roots. For root diseases, include roots and some soil from the root zone (i.e. roots contained in a soil plug).

9.19.2 Preservation

Fresh plant specimens should normally be presented. If delays are likely to occur in transit and plant material is likely to break down and/or become mouldy, dry specimens only should be prepared.

DO NOT FREEZE samples.

Fresh specimens are best stored in aerated conditions at high humidity and cool temperatures (preferably not in the car or ute). Use an Esky with fridge bricks to keep samples cool. Diagnosis of viruses requires very fresh specimens. Plants should be wrapped in dry paper and placed in a plastic bag. The paper should not be wet. If dead tissue is present on the sample, damp paper should be avoided as moulds may develop.

Dried specimens are best when dried rapidly. Place plant parts between sheets of newspaper (with some pressure), and change paper daily for 1 week.

9.19.3 Packaging

Fresh specimens likely to decompose e.g. pods should be wrapped in paper and placed in a suitable container. Other plant parts can be placed in partially inflated plastic bags and tied-off (fairly loosely to allow aeration but not desiccation). Soil samples should be packed in a sealed plastic bag or airtight container.

Dry specimens should be supported between two firm surfaces, e.g. cardboard, before dispatch.

N.B. Diagnoses for suspect virus diseases can only be made with fresh specimens.

9.19.4 Labelling

Use waterproof ink. All containers should be clearly marked. If labels inside bags are used, make sure they are plastic otherwise paper can become mush.

9.19.5 Dispatch

Specimens should be sent ASAP after collection to the relevant authority. If possible, collection and dispatch should be timed to avoid weekend delays in transit and examination. Label the item 'Plant Specimens—Perishable' or 'Soil Samples'.

9.20 References

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Virus management in pulses. Pulse Australia Bulletin, http://www.pulseaus.com.au/growing-pulses/publications/manage-viruses

Plant growth regulators and canopy management

Not applicable for this crop.

MORE INFORMATION

http://www.pulseaus.com.au/growing-pulses/publications/desiccation-and-croptopping

www.apvma.gov.au

http://www.dpi.nsw.gov.au/__data/assets/pdf_file/0018/157203/pulse-point-09.pdf

Crop desiccation/spray out

11.1 Desiccation

Pulses can be desiccated pre-harvest to enable earlier harvest and to dry out green weeds. This is becoming common practice, particularly for chickpeas, field peas, lentils, and faba beans. Timing is based on crop physiological maturity.

Desiccation prepares the pulse crop for harvesting by removing moisture from plants and late-maturing areas of the paddock.

Premature desiccation may cause staining of the seed coat, excessive green cotyledons in the sample or small or wrinkled seed, all of which can create marketability problems.

In faba bean, desiccation can occur when seed from the top of the plant has a black scar (hilum) and the lower 25% of pods are black. At this stage, the upper pods are still bright green but the lowest pods are starting to turn black and have seeds with a completely black hilum.

If the seed is to be retained for sowing, do not use glyphosate to desiccate beans.

Windrowing may be considered as an alternative to desiccation. The timing of windrowing is similar to that of desiccation. [1]

Desiccation is an aid to a timely harvest, particularly where uneven ripening occurs across a paddock, and is now a common practice in chickpea and mungbean. Desiccation enables a timely harvest, to avoid weather damage. Timing of application is when the grain is 75–90% mature, to avoid reducing the quality of the harvested grain.

Desiccation is a valuable management tool especially under conditions where:

- There is a problem with green weeds at harvest.
- Improved harvest efficiency is needed.
    - Desiccation eliminates many of the problems associated with green stems and gum build-up, which cause uneven flow of material through the header, and 'jamming' problems.
    - Minimising jamming enables drum speeds to be reduced in many cases, with a reduction in cracked or damaged grain.
- 'Early' summer rain causes reshooting and re-flowering of faba beans.
- There are problems with patchy or delayed crop maturity on heavy clay soils.
- 'Early harvest management' is being adopted.

Benefits from crop desiccation are similar to those from windrowing and include more uniform maturity, reduced problems associated with late weed growth, and advanced harvest date. Unlike windrowing, the crop is not placed on the ground so there is less risk of wet weather causing problems.

Timing is critical, and early desiccation should be avoided because it will result in yield and quality losses. Crop damage from ground rigs can also be an issue, particularly in tall crops. Tramlining may help and they should be considered at sowing if crop desiccation is likely to be used.

1 Southern/Western Faba and Broad Bean—Best Management Practices Training Course, 2012. Pulse Australia.

Note that desiccation does not necessarily allow earlier harvest, whereas windrowing does. [2]

11.2 Crop-topping

Crop-topping is part of an integrated weed management strategy; it should not be considered a sole strategy.

Crop-topping aims to stop the seed-set in surviving weeds without substantially affecting crop yield and grain quality. It is timed to control weed seed-set from survivors of normal in-crop weed control. Crop-topping cannot be used in all pulses.

Timing is aimed at the soft dough stage of the target grass-weed species, typically annual ryegrass, to stop seed-set. If wild radish is the target, the herbicide should be applied at the pre-embryo stage. In most crops, targeting wild radish exposes the crop to a heightened risk of crop damage.

When used correctly in the appropriate pulse species, the crop will be almost mature or fully mature, and grain quality will be unaffected.

Crop-topping faba beans can result in discoloured seed coat or cotyledons (kernel) and either rejection or severe downgrading at delivery. Even in other pulses, growers need to be aware of grain-quality defects if crop-topping is done earlier than the crop desiccation or windrowing stage.

Timing of crop-topping can be marginal in faba beans. Fiord is the earliest maturing faba bean variety, but in many cases, even Fiord will not mature early enough to enable efficient crop-topping without affecting grain quality and yield. [3]

11.3 Seed and pod development

Maturation of pods and seed is staggered up each podded branch and between branches. The effects of higher temperatures and varying degrees of moisture stress on the plant mean that maturity time is generally more compressed and of shorter duration than flowering.

A problem often confronting agronomists and farmers is how to optimise the timing of the desiccant spray when there are various stages of seed maturity present on individual plants, as well as variation across the paddock.

This can be further compounded by soil-type variation or paddock micro-relief.

Inspection of commercial crops nearing desiccation often reveals that while the lower 30% of pods have dried to <15% seed moisture (seeds detached from pod), the upper 25% of pods on each fruiting branch are still at 30–40% moisture content and at varying stages approaching physiological maturity (as indicated by black hilum appearance).

11.4 Timing of desiccation

The optimal stage to desiccate the crop is when the vast majority of seeds have reached physiological maturity, i.e. 90–95% of the crop. Our best guide presently is to base this on a visual inspection of the seeds within the top 25% of uppermost pods on each main fruiting branch (Figure 1).

Seeds are considered physiologically mature when the distinctive black hilum seed starts to show.

2 Southern/Western Faba and Broad Bean—Best Management Practices Training Course, 2012. Pulse Australia.

3 Southern/Western Faba and Broad Bean—Best Management Practices Training Course, 2012. Pulse Australia.

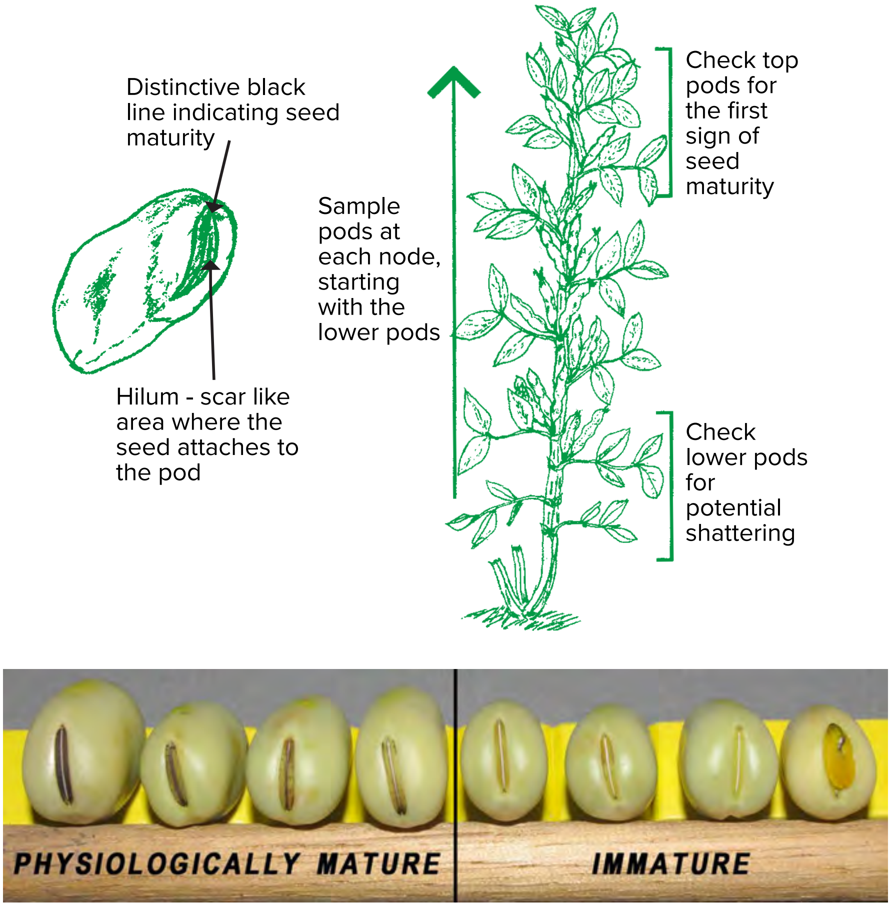

Figure 1: *Assessing correct timing of desiccation.*

Sources: diagram, Gordon Cumming, photo, Grain Legume Handbook 2008

11.4.1 Effect of desiccants on green immature seeds

Application of desiccants to seed that is still green and actively filling will result in:

- a reduction in grain size (and yield)
- an increase in a greenish discoloration of the seed coat
- a reduction in seed viability (dead or abnormal seed)

In faba bean crops intended for use as seed or for sprouting markets, glyphosate should not be used because it will affect seed germination (Table 1), even when applied after physiological maturity.

Table 1: *Effects of desiccation timing on seed viability.*

Treatment	Crop stage	% Normal seed	% Abnormal seed	% Total germinated
Nil pre-harvest treatment		92	2	94
Desiccated, glyphosate	Seed physiological maturity	27	63	90
	Seed physiological maturity plus 6 days	64	29	93
Windrowed	Seed physiological maturity	89	2	91
	Seed physiological maturity plus 6 days	85	7	92

Source: Matthews and Holding 2004.

11.4.2 Products registered for the desiccation of faba bean

Extracts from the product labels of Reglone® and Roundup PowerMax® are presented in Table 2.

Table 2: *Products registered for desiccation of faba bean (note: always read the label supplied with the product before each use).*

Active ingredient	Example trade name	Rate	Critical comments
Diquat	Reglone (200 g/L)	2–3 L/ha	Spray as soon as the crop has reached full maturity. Helps overcome slow and uneven ripening and weed problems at harvest. DO NOT harvest for 2 days after application
Glyphosate	Roundup Attack (570 g/L)	0.645–1.7 L/ha	Apply when physiologically mature and <15% green pods. Use higher rates where crops or weeds are dense and where faster desiccation is required. DO NOT harvest within 7 days of application

Warning: do not use Glyphosate to desiccate beans that are to be used for seed or sprouting as germination is affected (see Table 1)

11.5 Windrowing

Windrowing of faba bean has become common in some areas as growers try to reduce problems associated with direct-heading, uneven crop maturity or weed-seed management. It is primarily used to bring harvest date forward, uniformly ripen the crop, and protect the crop from shattering where harvest is to be delayed, or it can be a part of general management to reduce seed-set of weeds present.

Windrowing faba bean crops provides a number of benefits:

- It aids uniform maturity of the crop in paddocks that are ripening unevenly.
- Problems caused by late-maturing weeds are avoided. These include delayed harvest, which increases the risk of staining caused by the weather and disease, and storage problems from green weed contamination.
- It can advance harvest date when done as soon as the crop is mature, avoiding clashes with other crops, such as cereals.
- Weed seed is moved into a windrow that can be burnt after harvest.
- Low pods are harvested rather than being left behind, because of the lower cutting height possible with a windrower.
- Excessively tall crops can be better handled at harvest. When tall crops are direct-headed, the reel can be in the way pushing plants forward, causing problems with feeding material into the header and losses on the cutter bar. Direct-heading of very tall and lodged crops is also very slow. Windrowing can dramatically increase header efficiency.
- Windrowing reduces damage to headers. Sticks and stones can damage knife fingers and sections, retractable fingers and other components on headers working in rougher country. Pick-up fronts leave most of these on the ground.

Windrowing should only be used if direct-heading of the faba bean crop is likely to be cause problems, and should not be considered necessary every year.

There are several risks to windrowing crops:

- Windrowing too early (prior to crop maturity) can cause significant yield and quality losses. Small and shriveled seed will result from drying down of immature seed.

MORE INFORMATION

http://www.dpi.nsw.gov.au/__data/assets/pdf_file/0018/157203/pulse-point-09.pdf

http://www.grdc.com.au/uploads/documents/GRDC_LateSeasonHerbicideUse_FS.pdf

http://www.dpi.nsw.gov.au/archive/agriculture-today-stories/ag-today-archives/march-2009/benefits,-risks-of-sowing-pulses-early

- Windrowing too late can cause shatter losses as the cutter bar hits the crop.
- The seed coat can discolour if left too long in the windrow, especially in wet conditions when mould growth and seed staining can occur.
- Summer storms after windrowing can cause moisture to be retained in the windrows, making it difficult to pick up the windrow without mud and potentially leading to quality deterioration.

Timing of windrowing is critical and should be based on seed maturity rather than measurements such as leaf colour and drop, or pod colour, as these can be misleading. Leaves can be prematurely lost and pods blemished by disease. Faba bean seed is considered physiologically mature a black line is visible on the hilum (a scar-like area on the seed where it attaches to the pod (see Figure 1).

The cutting height for windrowing should be just below the bottom pods, with the reel following the top of the crop. The reel speed should be quite slow. The delivery opening in the windrower should be large enough to prevent blockages or there will be lumps in the windrow. Windrows should be dense and tightly knit for best results (Figures 2 and 3).

Curing should take about 10–12 hot days. However, heavy infestations of wild radish and other weeds could delay drying.

Pick-up fronts are the most common type used for harvesting windrows. However, crop lifters placed close together on open fronts have been used with some success.

Figure 2: *Faba bean windrows.*

Photo: W. Hawthorne, Pulse Australia

Figure 3: *Inside an opened windrow of faba bean.*

Photo: W. Hawthorne, Pulse Australia

Harvest

Well before harvest, marketing plans need to have been developed and practices implemented to ensure that a marketable quality product is grown, harvested, delivered, stored and then marketed.

12.1 Impact of delayed harvest on profitability

Early harvest of pulses is critical, because delays can result in significant yield losses due to lodging, shattering and pod loss. Grain quality, and hence price, can also suffer through mechanical damage or weathering and seed staining. Moisture levels at harvest affect the quality of the grain in storage.

If harvesting grain for seed, germination rates are improved if grain is harvested at 12–14% moisture and then stored in aerated silos or immediately graded and bagged. Crop desiccation with herbicides prior to crop maturity may reduce grain quality and seed germination.

Harvest delays in faba beans cost growers and the pulse industry a lot of money. In any production area, it is not unusual to see a spread of up to 4–6 weeks in the harvesting of faba bean crops planted on the same sowing rain. Many late-harvested crops reduced moisture content of ~8%, whereas the maximum moisture content for receival is 14%.

A grower's decision to delay faba bean harvest is usually influenced by the following factors:

- Faba bean harvest can clash with cereal harvest. Faba beans are still largely considered a 'secondary' crop, with wheat or barley taking precedence at harvest time.
- The possibility of achieving premiums for Prime Hard/Australian Hard wheat or malting for barley is also a major incentive for prioritising the cereal harvest, although in reality, the premiums for early harvested faba beans are often greater.
- The perception that faba beans 'weather' reasonably well is a fallacy (see later discussion).
- Uneven ripening of faba bean crops can occur if not desiccated or windrowed, especially when grown on heavy clay soils or variable soil types. Having a good even plant stand helps to keep the crop even as dry-down occurs prior to harvest.
- Faba beans are considered slower or more difficult to harvest. This does not have to be the case if desiccation is used, and the header is modified to suit them.

Faba beans are the most profitable winter crop for more growers, because they take a more professional approach to production and marketing, rather than treating it as a minor, secondary crop where it is 'planted last, harvested last, and sold to the nearest buyer'. [1]

12.1.1 Yield losses

Yield losses increase significantly the longer harvest is delayed.

1 Southern/Western Faba and Broad Bean—Best Management Practices Training Course 2012. Pulse Australia.

Although they are not normally prone to pod splitting and shelling out in all but extreme wet-weather conditions, faba beans are very prone to pod splitting and pod drop after weather events once the plant has dried down. Weathering of the grain can also occur in split pods.

Yield losses of up to 30% have been recorded in the field:

- It is estimated that grain losses due to a 2–4-week delay in harvest ranged from A$93/ha to A$238/ha, depending on seasonal conditions.
- Most of the losses were due to pod loss at the header front, or unthreshed pods lost out the back of the machine.

Lodging can increase the longer faba beans are left standing, and the risk is higher if the crop is high-yielding and has been planted on wide rows.

Loss of moisture below the National Pulse Receival Standard of 14% moisture content maximum:

- 500 t of faba bean at 14% grain moisture, valued at $450/t, is worth $225,000.
- The same grain harvested at 8% moisture delivers 470 t, so at $450/t is worth $210,600.
- This is a loss to the grower of $14,400. [2]

12.1.2 Deterioration in grain quality

Grain quality deteriorates the longer mature faba beans are left exposed to weathering in the field.

The seed coat of faba bean is very prone to cracking if it has been exposed to wetting and drying events due to rain or heavy dew. Expansion of the seed as it absorbs moisture, and then contraction as it dries, weakens the seed coat. This renders it much more susceptible to mechanical damage during harvest and handling operations.

Levels of cracked and damaged grain can be as high as 50% in extreme cases of field weathering and prolonged rainfall.

Faba beans that do not meet the Number 1 Receival Standard of 6% maximum defective beans will need to be graded.

This incurs a cost to the grower of:

- $15–25/t grading costs; and
- downgrading of the seconds into the stockfeed market at a value of $120–140/t.

Early harvested faba bean seed is much more resilient against breakage during harvesting and subsequent handling, even at low moisture contents.

Some faba beans are ultimately processed into dhal or flour by removing the seed coat (hull) and splitting the cotyledons. Visual appearance is still critical for marketing though. Older seed that is darkened with age splits better than new-season grain. The milling process uses abrasive-type mills to gradually abrade the seed coat from the cotyledons, and is reliant on the seed coat being firmly attached to the cotyledons.

Cracking and weakening of the seed coat prior to processing substantially reduces the recovery percentage of splits, as well as reducing the quality of the final product.

Field-weathered faba beans after rain are also more difficult to thresh out at harvest, and often contain much higher levels of unthreshed pods and pod material.

Faba bean seeds discolour and darken when exposed to field weathering. Darkening of the seed coat is caused by oxidation of polyphenol compounds (tannins).

The following conditions play a major role in accelerating seed coat darkening:

- rainfall

2 Southern/Western Faba and Broad Bean—Best Management Practices Training Course 2012. Pulse Australia.

- cool–mild temperatures
- high humidity
- sunlight

Usually, there is no direct penalty or discount for a moderate degree of seed coat darkening; however, it does have a significant impact on the marketability of the product and the reputation of the Australian industry as a supplier of quality product. Quality is becoming increasingly more important as Australian traders attempt to establish market share against other bean-exporting countries (France and the UK).

We are highly likely to see much greater segregation and premiums paid for lighter coloured, large-seeded faba bean types as new varieties with these traits are developed and the Australian industry becomes more quality-conscious.

- Weathering of seed due to delays in harvesting can substantially increase mould infection levels. High levels of mould infection will also cause darkening of the seed coat. Humid (>70% relative humidity), wet conditions favour the development of a range of fungi in late-harvested bean crops. Although *Alternaria* spp. usually predominate, *Asperguillus*, *Gladosporium* and *Penicillium* species may also be present.
- Increased risk of late Ascochyta infection can develop on dry senescing pods under wet conditions, and can penetrate through to the seed in susceptible varieties. The current Export Receival Standard for visible ascochyta lesions is a maximum of 1% on the seed cotyledon (kernel).
- For the current Australian Pulse Standards go to: http://www.pulseaus.com.au/marketing/receival-trading-standards.
- Native budworm (*Helicoverpa punctigera*) can occasionally attack senescing faba beans, particularly where rainfall has softened the pod. Insect-damaged seeds are classified as defective beans, and they cannot exceed the tolerance level of 3%. [3]

12.1.3 Missed marketing opportunities

Delayed harvest often means that growers miss out on premiums paid for early-harvested crops of good quality. This is the case in most years, with the possible exception where major production problems have been encountered and there is a 'shorts' market place. Weathering and mechanical damage is also more likely in late-harvested crops.

Early harvest gives the grower some degree of control over how and when the crop is marketed, whereas late-harvested faba beans can often be 'price-takers' in a falling market or encounter delivery delays. [4] If the market starts to slide, many farmers will put the faba beans into storage and market them away from the harvest period, often content to leave them in storage until they get the price that they want.

In the northern region, ease of storage has meant that greater marketing has occurred throughout the season, more so than during harvest. Insect storage pests are not much of a concern or risk with faba beans.

12.2 Implementing early harvest management

A range of management components contribute to an early-matured crop, and all can be important at different times and for different reasons. It is important to understand the potential and limitations of each component. Optimal results in terms of yield, profit and earliness will come from these components being applied in the most appropriate and balanced way, and as dictated by seasonal conditions.

These components include:

1. Sowing

3 Southern/Western Faba and Broad Bean—Best Management Practices Training Course 2012. Pulse Australia.

4 Southern/Western Faba and Broad Bean—Best Management Practices Training Course 2012. Pulse Australia.

- Sow at the earliest opportunity but within the preferred planting window for your area. Dry-sowing in the northern region is not a preferred option to try to get timeliness.
- Moisture-seeking equipment and/or press-wheels can significantly enhance seeding opportunities under marginal soil moisture conditions. The success of moisture seeking, particularly in marginal conditions, is increased greatly by running a set of Kelly discs (or something similar) over the paddock immediately after planting and prior to applying the residual herbicides. This seems to prevent drying out down into the disturbed soil and helps to achieve a more uniform establishment of the crop.
- Use adapted varieties that meet your target for early harvesting.
- Precision planters or machines with automatic depth control will often achieve more uniform plant establishment and crop development, and consequently more even crop maturity. This is particularly so when sowing into marginal soil moisture and drying conditions.

2. In-crop management

- Control Botrytis grey mould if present during flowering.
- Control native budworm during flowering to maximise early podset.
- Avoid using herbicides that delay crop maturity, e.g. flumetsulam (i.e. Broadstrike®).

3. Harvest management

- Consider windrowing to enable earlier maturity and harvest date.
- Consider using a desiccant to dry late plants and any weeds.
- If using glyphosate (or equivalent registered products) to terminate crop growth at the 80–90% black–brown pod stage, be aware of potential impacts on seed quality.
- Set up the header to operate efficiently at 14–15% grain moisture content.
- A major advantage of high-moisture harvesting is that harvest can commence earlier in the season and earlier each day.
- Harvesting at 14% moisture content rather than 12% can effectively double the harvest period available on any one day in hot environments.
- Blend, aerate and/or dry the sample to the required receival standard of 14% moisture. [5]

12.3 Harvesting and header settings

Pulses are easily threshed, so concave clearances should be opened and the drum speed reduced.

If there are many summer weeds, the drum speed may need to be increased to ensure that weeds do not block the machine. Pulses are larger than wheat, so a concave with many wires or blanked-off sections can stop grain separation. To get the best performance, alternate wires and blanking-off plates will have to be removed. Maximum wind settings and barley sieve settings should ensure a good sample (Table 1).

If there are summer weeds, the rake at the back of the sieves should be blanked-off to stop them entering the returns. Summer weeds may cause walkers and sieves to block completely, causing high grain losses. If there are many weeds in the crop, then desiccation is advisable, to have all plants in the paddock dry for harvest.

When harvesting pulses for seed, take extra care to reduce grain cracking, even if this means making a poor sample. Gentle harvesting will give the best seed quality. Rotary harvesters are gentler on the crop and generally cause less grain damage than conventional harvesters.

5 Southern/Western Faba and Broad Bean—Best Management Practices Training Course 2012. Pulse Australia.

Faba beans can be harvested with minor adjustments and modifications. Open-front or pick-up fronts are best suited to the job.

Faba beans should be harvested as soon as they mature, because pods will fall if harvest is delayed.

The crop varies in height from 15 to 80 cm, with pods held up in the canopy. This means that direct heading without crop lifters is possible with open-front and closed-front machines. Some fingers may have to be removed when using closed-front machines. Faba beans thresh easily but are prone to cracking, so adjust thresher speed (400–600 rpm) and concave (10–30 mm) to suit. Removing alternate wires and blank-off plates from the concave will help to reduce cracking. If possible, cover the rasp bars with plate.

Harvesting grain at high moisture levels up to 14% should minimise cracking.

Harvest early, before summer weeds become a problem, to reduce clogging, staining and sample contamination. Desiccating the crop will kill summer weeds and ensure even crop-ripening.

As faba beans are destined for human consumption, a good sample off the header is usually required. [6]

Table 1: *Harvester settings for pulses.*

	Chickpeas	Faba beans	Green lentils	Red lentils	Lupins	Field peas	Vetch
Reel speed	Medium	Slow	Slow	Slow	Slow	Medium	Slow
Spiral clearance	High	High	Low	Low	High	Standard	Low
Thresher speed (rpm)	400–600	400–600	350–450	350–450	400–600	400–600	400–600
Concave clearance (mm)	10–30	15–35	20–30	10–20	10–30	10–30	10–30
Fan speed	High	High	High	High	High	High	Medium
Top sieve (mm)	32	32–38	32	16	32	25	25
Bottom sieve	16	16–19	8–16	3–10	16	16	10–16
Rotor speed[A] (rpm)	700–900	700–900	350–450	350–450	700–900	700–900	Slow

[A]Rotary machines only.
Source: Grain Legume Handbook.

12.4 Modifications and harvest aids

Early harvesting can solve many problems, and losses are reduced because the pods are less prone to shatter or drop. The crop is also easier to gather because it stands more erect, allowing the harvester front to operate at a greater height, reducing the amount of dirt, rock and sticks entering the harvester.

Early harvesting also means fewer summer weeds to clog the harvester.

Early harvesting also plays a role in disease control and crop establishment in the following crop. Early harvested grain is of better quality in terms of colour, weathering and disease.

A straw chopper may be of value to chop up the stubble and spread it uniformly. Crop lifters are not required unless the crop is badly lodged or late-sown and drought-affected.

Set the finger tine reel to force the material down onto the front. Moving the broad elevator auger forward can improve the feeding of light material.

Vibration due to cutter-bar action, plant-on-plant or reel-on-crop impact and poor removal of cut material by the auger all cause shattering and grain loss.

6 Southern/Western Faba and Broad Bean—Best Management Practices Training Course 2012. Pulse Australia.

Grain loss can be reduced by harvesting in high humidity or at night to minimise pod shattering, and avoid harvesting in extreme heat.

Finger reels are less aggressive than bat reels and cause fewer pod losses.

Double-acting cutter-bars reduce cutter-bar vibration losses. Four-finger guards with open second fingers also reduce vibrations (Figure 1).

A lupin breaker is a cheap and simple device that can increase harvesting capacity to reduce grain loss. It is a small, serrated plate that attaches to the front spiral and creates an aggressive, positive feed action to clear-cut material from the front of the knife.

Figure 1: *Four-finger guards to reduce vibration.*

Other options are available to improve pulse harvesting (Figures 2–5). [7]

Aussie-Air

Directs an air blast through reel fingers, and are suitable for both heavy and light crops.

The manufacturer claims an extra 15 horsepower is required to drive an Aussie-Air, but there is also a lesser horsepower requirement because of wider concave clearances. The actual horsepower required should be no more than for a heavy cereal crop.

Harvestaire

Replaces a reel with a manifold that directs a blast of air into the front:

- The manifold causes some interference with the incoming crop.
- Correct orientation of air blast is very important.
- An optional secondary fan to increase the air blast is worthwhile.
- The device is more effective in light crops.

Vibra-mat

A vinyl mat that vibrates with the knife, stops bunching at the knife of open front headers and helps the table-auger to clear-cut materials; its chief advantage is that this device is very cheap. It is more effective in light crops.

It is important to match groundspeed to table-auger capacity and crop density; too slow and the plants will not have enough momentum to carry to the front, too fast and the cut crop will not be cleared from behind the knife.

7 Southern/Western Faba and Broad Bean – Best Management Practices Training Course 2012. Pulse Australia.

Extension fingers

Plastic extension fingers, ~30 cm long that fit over existing fingers, can save significant losses for little financial outlay at the knife. Pods that would have fallen in front of the knife are caught on the fingers and pushed into the comb by the incoming crop.

Extended fronts

Extended fronts are now available for some headers and reduce losses at the knife by increasing the distance between the knife and auger to a maximum of 760 mm. This helps to stop losses from material bunching in front of the auger, where pods can fall over the knife and be lost.

Platform sweeps

Platform sweeps are used in conjunction with extended fronts and they consist of fingers that rake material towards the auger to help eliminate bunching. They can also be used on conventional fronts.

Draper fronts

Draper fronts such as MacDon® and Honeybee® have large clearances behind the knife and carry the crop to the elevator. The front can also be used for cereals without modification.

NB: Cost–benefits must be assessed, because a small area of pulses may not justify the cost of some of the above modifications. [8]

Figure 2: *Belt-front fitted with cross-auger.*

Photo: W. Hawthorne, Pulse Australia

8 Southern/Western Faba and Broad Bean—Best Management Practices Training Course 2012. Pulse Australia.

Figure 3: *Short fingers on a flex-front.*

Photo: Grain Legume Handbook

Figure 4: *Plastic extension fingers fitted to a draper front.*

Photo: G. Cumming, Pulse Australia

Figure 5: *Harvestaire front combined with extension fingers and a blue vibra-mat.*

Photo: G. Cumming, Pulse Australia

12.5 Achieving a clean sample

Harvesting faba beans can be costly if debris such as stones, sticks or too much dirt is picked up with the beans. Machinery damage can be reduced by a variety of practices.

12.5.1 Rolling for harvest efficiency

Harvester damage may be reduced by rolling paddocks after sowing to flatten and firm soil and depress obstacles such as stumps and stones.

12.5.2 Perforated screens

Perforated screens fitted on the bottom of the broad elevator, cross-augers, and grain and seconds elevators reduce the amount of dirt in the sample.

The perforated screen at the broad elevator is large and removes the dirt before it enters the main working mechanism of the harvester.

12.5.3 Harvester speed

Excessive harvester speeds will cause large losses of grain and force more dirt into the harvester. Generally, speeds >8 km/h are not recommended, irrespective of the type of harvester front used.

12.5.4 Harvesting in high humidity

Harvesting in humid conditions, when pods are less prone to shatter, can reduce grain losses. However, more unthreshed pods may appear in the grain sample. It is unwise to harvest faba bean at night unless using a pick-up front or some positive height control, which will stop the front from digging into the dirt. Some farmers have fitted wheels on the outer end of their fronts, as a depth-stop. Others have bought ultrasonic automatic depth controls to control header height.

12.5.5 Pick-up fronts

Pick-up fronts the same as or similar to those used for picking up windrows can be used to harvest windrowed faba beans. The pick-up fronts greatly reduce the amount of dirt entering the harvester and make harvesting easier, because harvesting height is not as critical as with a front fitted with lifters. This allows harvesting at night. The fingers on the pick-ups are closely spaced and they will gather the entire crop, so crop losses are reduced.

There are different types of pick-ups. Some have fingers attached to rotating belts (draper pick-ups) and others have fingers attached to rotating drums (peg-roller pick-ups). The peg-roller types are similar and cheap but tend to shatter pods and cause slightly higher grain losses than the draper type. The draper types are more expensive but will reduce losses if harvesting late.

12.5.6 Flexible cutter-bar fronts (flexi-fronts)

The cutter-bars of these fronts are hinged in short sections, allowing the whole front to flex and closely follow the ground contour. They use skid plates and are particularly good for short crops such as lentil and field pea, but can also be used on cereals by locking the hinged sections together. [9]

12.6 Lodged crops

If the crop has lodged, it is usually best to harvest in the opposite direction, or at right angles, to the direction the crop has fallen. Crop lifters may help.

If sown on wide rows, use crop lifters and harvest up and back in the rows. The crop usually feeds in better over the knife section, and also provides the header operator with a better view of any rocks or sticks in the paddock. [10]

An even plant stand and the correct population density will minimise the impact of lodging at harvest time, because the plants lean on each other as they start to lodge and the header can usually still get under the lowest pods.

12.7 Assessing grain harvest losses

Grain can be lost at a number of points during harvest, and each loss needs to be assessed so that corrective action can be taken. Grain can be lost before harvest (due to pod shedding), at the harvester front (due to the front type or setup), and in the thrashing system of the machine (due to drum, concave and sieve settings) (Figure 6).

To determine harvest losses:

- Harvest a typical area without stopping the machine, then stop and allow the machine to clear itself of material.
- Back the harvester about 10 m and shut down the machine.
- Sample grain losses in each of the following three areas:
  - pre-harvest (i.e. in the standing crop in front of the harvester, 'A' in Figure 6).
  - front (in the cut crop in front of the harvester, 'B' in Figure 6).
  - machine (in the cut crop behind the harvester including trash, 'C' in Figure 6)
- Sampling is best done using a quadrat with an area of 0.1 m^2.
- Count the number of seeds lying within each of 10 quadrats in each of the three locations.
  - Average the 10 samples in each area. [11]

9 Southern/Western Faba and Broad Bean—Best Management Practices Training Course 2012. Pulse Australia.

10 Southern/Western Faba and Broad Bean—Best Management Practices Training Course 2012. Pulse Australia.

11 Southern/Western Faba and Broad Bean—Best Management Practices Training Course 2012. Pulse Australia.

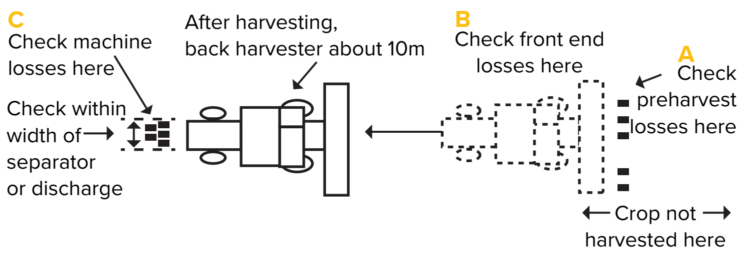

Figure 6: *Sampling places for estimating pre-harvest (A), front (B) and machine (C) losses.*

Source: The Chickpea Book

Example:

Grain losses on the ground can then be calculated, using 100-seed weights.

Faba bean: 100-seed weight = 60 g

Seed on the ground = 8 per quadrat

Seed loss = (no. of seeds/m^2) × (100-seed wt)
= (80 × 60)/10
= 480 kg/ha

12.8 Handling faba beans

Faba beans are a large, plump grain and are very prone to mechanical damage during handling. This especially applies to:

- overly dry grain (<10% moisture content)
- crops that have been exposed to weather damage prior to harvest

The use of tubulators or belt conveyors can reduce damage compared with conventional spiral augers.

Grain may be handled up to six times before delivery to receival points, so it is important to:

- minimise the number of handling stages where possible
- use efficient handling techniques that minimise damage

If using augers:

- Operate slow and full.
- Use large-diameter augers.
- The flight pitch should be greater than the auger diameter.
- Length of the auger should be no longer than necessary; the shorter the better.
- Keep auger incline as low as practical.
- Check flight-casing clearance. Optimal clearance is typically 50% of grain size to minimise occurrence of grain wedging between the auger spiral and the casing, and then cracking.
- Auger drives should be at the discharge end, and not on the intake.
- Putting a fine spray of water onto the stream of faba beans at the bottom of the auger is also used to reduce damage to the seed.

Approximate weight of grain stored in 1 m^3 of silo is shown in Table 2. The actual value can vary as much as 6–7% in wheat and barley and 15% in oats. In pulses, the variation is likely to be less (3–4%), and it will vary with the grain size, variety and season. [12]

Table 2: *Calculating silo capacities.*

Grain	Cubic metres	Weight (kg)	3-bushel bags
Broad beans	1	645	9.2
Chickpeas	1	750	9.2
Faba beans	1	750	9.2
Field peas	1	750	9.2
Lentils	1	800	9.2
Lupins	1	750	9.2
Vetch	1	750	9.2
Wheat	1	750	9.2
Barley	1	625	9.2
Oat	1	500	9.2
Example: silo of faba beans	67.4	50,550	620

Source: Grain legume Handbook.

Calculating the volume of a cylinder

Volume = area of base (diameter squared × 0.7854) × height

Calculating the volume of a cone

Volume = 1/3 (area of base × height)

12.9 Grain cleaning

Re-cleaning of samples after harvest is sometimes necessary. Cereals can be cleaned from most pulses (not lentil) with a 3- or 4-mm rotary screen. The 3.75-mm slotted screen is popular and will help screen out split grain. The paddles or agitators in rotary screens should be either new or sufficiently worn that the grain being harvested cannot jam between the outside of the paddle and the rotary screen.

Screens or paddles can be damaged beyond repair if the grain jams. Fitting the screens with a spacer will provide additional clearance and so avoid the problem.

Milk thistle buds can be difficult to separate if they contaminate the sample because they are similar in size and weight to peas. However, if desiccated or given time to dry, the buds disintegrate when put through an auger and can be easily separated.

Dirt and most small weed seeds can be separated in rotary screens; however, the dirt will increase component wear. [13]

12.10 Grain quality

It is extremely important to monitor the quality of grain before and during harvest. Seed coat and kernel (cotyledon) can be discoloured by crop-topping or premature desiccation in parts of the paddock if ripening is uneven. Staining of seed caused by green plants in the crop or admixture of splits, weeds, stones, etc., will reduce the value of your grain and can lead to rejection or dockages.

12 Southern/Western Faba and Broad Bean—Best Management Practices Training Course 2012. Pulse Australia.

13 Southern/Western Faba and Broad Bean—Best Management Practices Training Course 2012. Pulse Australia.

Visual appearance is vital. Human food markets demand a quality sample without cracking, staining, de-hulled seeds or insect damage. Pulse samples showing no header damage will always be more acceptable to a buyer. The large seed-size of faba beans makes them prone to mechanical damage. Minimising the number of times augers shift grain around helps to reduce mechanical seed damage.

Grain quality is at its highest when first loaded into storage but can steadily deteriorate if the storage environment is not well managed. A combination of good farm hygiene, storage choice and aeration cooling are important keys for maintaining grain quality and overcoming many problems with pests associated with storage.

Critical/key points to remember with regard to storing pulses are:

- Pulses stored at >12% moisture content require aeration cooling to maintain quality.
- Meticulous hygiene and aeration cooling are the first lines of defence against pest incursions.
- Fumigation is the only option available to control pests in stored pulses; it requires gas-tight, sealable storage.
- Avoiding mechanical damage to pulse seeds will maintain market quality and seed viability, and be less attractive to insect pests.

Growers contemplating medium–long-term storage (6–12 months) need to be aware that faba beans continue to age, and quality will deteriorate in sunlight and over time.

All faba beans will darken considerably in storage, and the rate of seed-coat darkening (deterioration in grain colour) will be accelerated by:

- high seed moisture content
- high temperatures
- high relative humidity
- condition of the seed at harvest
- sunlight.

To maintain lighter seed coat colour and minimise darkening of seed, any pulses stored at >12% moisture content will require aeration cooling to maintain quality.

Mature seed subjected to field weathering prior to harvest will deteriorate quickly in storage, even if stored under 'acceptable' conditions of temperature and relative humidity.

Growers should avoid even short–medium storage of weather-damaged grain.

Pulse grain with high germination and vigour when placed in storage can remain viable for at least 3 years, providing the moisture content of the grain does not exceed 11% and cool grain temperatures are maintained.

Storage life of pulses is determined by temperature, moisture content, insects and diseases. Careful management of these factors is critical to avoid deterioration during storage.

After grain enters storage, it needs regular monitoring, which allows early action and intervention if insect or grain quality issues arise. Monitoring grain at least monthly for insects, moulds, grain temperature and moisture should be standard practice.

MORE INFORMATION

GRDC Fact Sheet, 'Storing pulses': https://grdc.com.au/Resources/Factsheets/2014/07/Grain-Storage-Fact-Sheet-Storing-Pulses

Moisture

Pulses harvested at ≥14% moisture must be dried before going into storage to preserve seed germination and viability. As a rule, every 1-percentage point rise in moisture content above 11% per cent will reduce the storage life of pulse seed by one-third. Any pulse stored above 12% moisture content will require aeration cooling to maintain quality.

Temperature

High temperatures in storage will cause a decrease in grain viability. Temperatures of stored pulse grain should not exceed an average of 25°C, and preferably the average temperature should be <20°C. In general, each 4°C rise in average stored temperature will halve the storage life of the grain.

A practical way of reducing temperatures is to paint the silo white; dark-coloured silos will absorb more heat.

Painting a silo white is practical way of reducing the temperature of stored grain next to the silo walls and in the silo headspace area. Dark-grey walls on silos will absorb more of the sun's heat. Grain is a good insulator against heat transfer, so the sun's heat on the north and west walls of the silo plus the roof does not penetrate much further than 30 cm beyond the silo wall.

Grain in large silos (>75 t) will remain cooler because grain is a poor conductor of heat, and day–night temperature fluctuations rarely reach 15 cm beyond the silo wall. Small silos (<20 t) and field bins will have larger temperature fluctuations and this can cause deterioration in grain quality.

Therefore, combining aeration cooling plus white paint or bright, reflective surfaces on small silos storing planting seed or other grains has benefits.

12.11 References and further reading

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Stored Grain Website – Information Hub: http://www.storedgrain.com.au

Storage

13.1 Handling faba and broad bean

Faba beans are a very large, plump grain and are prone to mechanical damage during handling. This especially applies to:

- over-dry grain (<10% moisture content)
- crops that have been exposed to weather damage prior to harvest

The use of belt conveyors can reduce damage compared with conventional spiral augers.

Grain can be handled up to six times before delivery to receival points, so it is important to:

- minimise the number of handling stages wherever possible; and
- use efficient handling techniques that minimise damage.

If using augers:

- Operate slow and full.
- Use large diameter augers.
- The flight pitch should be greater than the auger diameter.
- Length of the auger should be no longer than is necessary; the shorter the better.
- Keep auger incline as low as practical.
- Check flight casing clearance; optimal clearance is typically 50% of grain size to minimise grain becoming wedged between the auger spiral and the casing and cracking.
- Auger drives should be at the discharge end, and not on the intake.

Approximate weight of grain stored in a cubic metre of silo is shown in Table 1. The actual figures can vary as much as 6–7% in wheat and barley and 15% in oats. In pulses, the variation is likely to be less (3–4%), and will vary with grain size, variety and season.

MORE INFORMATION

Faba bean foray into the north takes hold

Table 1: *Calculating silo capacities.*

Grain	Volume (m^3)	Weight (kg)
Broad beans	1	645
Chickpeas	1	750
Faba beans	1	750
Field peas	1	750
Lentils	1	800
Lupins	1	750
Vetch	1	750
Wheat	1	750
Barley	1	625
Oat	1	500
Example silo of faba beans	67.4	50,550

Source: Grain legume Handbook.

Calculating the volume of a cylinder

Volume = area of base (diameter squared × 0.7854) × height

Calculating the volume of a cone

Volume = 1/3 (area of base × height)

13.2 Grain cleaning

Re-cleaning of samples after harvest is sometimes necessary. Cereals can be cleaned from most pulses (not lentils) with a 3- or 4-mm rotary screen. The 3.75-mm slotted screen is popular and will help screen out split grain. The paddles or agitators in rotary screens should be new or sufficiently worn so that the grain being harvested cannot jam between the outside of the paddle and the rotary screen.

Screens or paddles can be damaged beyond repair if the grain jams. Fitting the screens with a spacer will provide additional clearance and so avoid the problem.

Milk thistle buds can be difficult to separate if they contaminate the sample, because they are similar in size and weight to peas. However, if desiccated or given time to dry, the buds disintegrate when put through an auger and can be easily separated.

Dirt and most small weed seeds can be separated in rotary screens; however, the dirt will increase component wear.

13.3 Grain quality

For information on grain quality see Section 12.10 Grain quality.

13.4 Grain storage principles

Store grain dry and clean. Take multiple samples during harvest, checking the moisture content of grain entering storage with a moisture meter that has been checked for accuracy. Moisture content of grain during harvest changes during the day and evening. Aerate grain while filling storages and during the storage period to maintain low grain temperatures. Monitor grain at regular intervals, checking on quality and pests. Keep a record for each silo, recording pests and any treatment details.

MORE INFORMATION

GRDC Fact Sheet 'Storing pulses': https://grdc.com.au/Resources/Factsheets/2014/07/Grain-Storage-Fact-Sheet-Storing-Pulses

Cooling grain and aeration cooling

Cooler grain temperatures have several advantages:

- Seed viability (germination and vigour) is maintained longer.
- Moist grain can be safely held for a short time before blending or drying.
- Moisture migration and condensation inside the silo is reduced.
- Insect-breeding life cycles are slowed (or cease in some instances) and hot spots are prevented.
- Mould growth is reduced.
- Darkening of the seed coat is slower.

Aeration cooling is a vital tool when storing pulses in a silo. It allows for longer term storage of low-moisture grain by creating cool, uniform conditions that maintain seed quality, protect seed viability, and reduce mould and insect development. Its use also allows grain to be harvested earlier and at higher moisture levels, capturing grain quality and reducing mechanical seed damage.

Aerated silos are fitted with fans that push air through the grain to cool the grain and equalise the moisture and temperature throughout the silo. An aeration system requires a waterproofed vent on the top of the silo to allow air to escape freely. This vent needs to be sealable if fumigation is required in a gas-tight, sealable silo.

An aeration system should provide the appropriate airflow rates. Aeration cooling can be achieved with airflow rates of 2–4 L/s.t. For example, a small, single-phase aeration fan driven by a 0.37 kW (0.5 horsepower) electric motor for silos ~70–100 t capacity should deliver this airflow rate.

Controlled aeration should reduce grain temperature to ≤23°C. Controlling aeration cooling is a three-stage process: continual, rapid, and maintenance. Cooling achieved during storage depends on the moisture content of the grain and the humidity and temperature of the incoming air. An understanding of the effects of relative humidity and temperature when aerating stored grain is important. Automatic aeration controllers are used to turn fans on and off automatically, selecting the optimum ambient temperature and humidity conditions. This provides the most reliable results.

MORE INFORMATION

GRDC booklet 'Aerating stored grain—cooling or drying for quality control': http://www.grdc.com.au/GRDC-Booklet-AeratingStoredGrain

Grain Storage Fact Sheet 'Performance testing aeration systems': http://www.grdc.com.au/Resources/Factsheets/2012/08/Grain-Storage-Performance-testing-aeration-systems

13.4.1 Preventing moisture migration

For most storage situations, grain is best stored using aeration cooling. Generally, a silo is only left sealed for a short period of 1 or 2 weeks for fumigating an insect pest infestation. If, however, grain is sealed up in a silo, it must be of sufficiently low moisture content to prevent moisture migration.

While a silo is sealed, there is no venting and therefore no escape for warm, moist air in the headspace. Hence, moisture can migrate and condense in upper silo headspace and grain layers. This top area of the grain is at high risk from mould and insect pests if left warm and moist over time.

Moisture sources

Grains. Grain and seed are living and release moisture as they respire. Especially in silos with no aeration, this moisture moves upwards by convection currents created by the temperature difference between the grain in the center of the silo and the walls, which can be either warmer or cooler.

Grain insects. Insects or mites in the grain respire and release moisture and heat into air spaces as they respire. If grain is stored at >14% moisture content, then enough moisture may be carried into upper grain layers to place that grain at risk of mould. There is no moisture migration in an aerated silo as the entire stack is normally cooled to one temperature (≤23°C).

Condensation impact. Moisture carried into the silo headspace can condense on a cold roof and fall back as free water. This can then cause a circle of mould

MORE INFORMATION

GRDC booklet 'Aerating stored grain—cooling or drying for quality control': https://www.grdc.com.au/~/media/75BCB3243E4F490FB4B7CB8D38ADAABF.pdf

Grain Storage Fact Sheet 'Performance testing aeration systems': http://www.grdc.com.au/Resources/Factsheets/2012/08/Grain-Storage-Performance-testing-aeration-systems

GRDC Fact Sheet 'Dealing with high-moisture grain': http://www.grdc.com.au/Resources/Factsheets/2013/06/Grain-Storage-Dealing-with-highmoisture-grain

For general information on handling, drying and cooling see: Agridry Rimik Pty Ltd: http://www.agridry.com.au

or germinated grain against the silo wall. Moist grain can also contain greater numbers of insects.

Leaks. Water entering through structural damage will increase grain moisture content to a level where mould and insect growth can occur.

13.4.2 Drying grain and aeration drying

Continuous-flow or batch dryers provide reliable drying, although they can reduce quality if run at too high a temperature. Do not exceed 45°C when using heat to dry faba beans. Check the specifications or talk to the manufacturer about safe conditions for drying pulses.

High-capacity aeration drying systems can also be used to dry grain, and are ideally suited for drying grain harvested at 15–16% moisture content. Aeration drying has a lower risk of cracking and damaging pulses, which can occur with hot air dryers. Aeration drying requires much higher performance fans to move high volumes of air through the grain at a faster rate than that required for cooling only.

Airflow rates of at least 15–25 L/s.t are required for reliable aeration drying. By comparison, airflow rates as small as 2–4 L/s.t can achieve aeration cooling.

Careful selection of ambient air using an automated controller can remove moisture from the stored grain over a period of 1 or 2 weeks.

13.5 Insect pests in storage

Insects are not considered a major problem in stored faba beans. While bruchids (Bruchinae) are considered primary pests of pulse crops, very few bruchid species in Australia attack faba bean. (Note: there are exotic Bruchids (not present in Australia) that attack faba bean.)

The only exception appears to be in cases where faba beans are loaded into storages containing residues of cereal grain already infested with cereal pest insects such as flour beetles (*Tribolium* spp.) and grain borers (*Rhyzopertha* spp.). These prior infestations can develop and spread in the faba beans.

The key to control is maintaining excellent hygiene in and around storage facilities. Combined with aeration cooling, this should prevent infestations developing.

Most insect development ceases at temperatures <20°C. Freshly harvested grain usually has a temperature of ~30°C, which is an ideal breeding temperature for many storage pests. Aeration fitted to stores will rapidly reduce grain temperatures, reducing insect breeding and aiding grain quality (Table 2).

Table 2: *Effect of grain temperature on storage pest insects and mould.*

Temperature (°C)	Insect and mould development
40–55	Seed damage occurs, reducing viability
30–40	Mould and insects are prolific
25–30	Mould and insects active
20–25	Mould development is limited
18–20	Young insects stop developing
<15	Most insects stop reproducing, mould stops developing

Source: Kondinin Group via GRDC factsheet 'Aeration cooling for pest control'.

If insects in stored faba beans need treatment, the only control options are phosphine fumigation, an alternative fumigant or controlled atmospheres such as carbon dioxide (CO_2) or nitrogen (N_2).

To ensure effective fumigation and control of all insect life stages, and to reduce the risk of resistance development, fumigation must be carried out in a sealed, gas-tight silo.

No insecticide sprays are currently registered for use on faba beans. Markets are particularly sensitive to insecticide residues, so detection of any residues on faba beans could result in loss of a market, not just rejection of a contaminated delivery.

Residual sprays should not be used on storages and handling equipment that is to be used for faba beans.

Use of diatomaceous earth (DE, e.g. Dryacide®) as a structural treatment may be possible. Always check with the grain buyer for delivery standards or allowances before using any product that will come into contact with stored grain.

Not all silos can be sealed adequately to enable fumigation. However, all silos can have aeration added to them. So if the silo is not sealable to make it suitable for fumigation, fitting aeration cooling fans will assist with pest control and grain quality. Well-managed aeration cooling, coupled with excellent hygiene, can overcome insect pest infestation problems in 7 out of 10 years. However, aim to have at least two sealable silos available on your farm to enable effective fumigations when required.

MORE INFORMATION

GRDC Grain Storage Fact Sheet 'Hygiene and structural treatments for grain storages': http://www.grdc.com.au/Resources/Factsheets/2013/06/Grain-Storage-Fact-Sheet-Hygiene-and-structural-treatments-for-grain-storages

GRDC Fact Sheet 'Storing pulses': https://grdc.com.au/Resources/Factsheets/2014/07/Grain-Storage-Fact-Sheet-Storing-Pulses

13.6 Farm and grain hygiene

Maintaining good farm and grain hygiene plays a crucial role in overcoming many problems associated with storage pests leading to reduced grain quality. Prevention is better than cure.

Basic hygiene practices include:

- Remove all grain residues from empty storage facilities and all grain handling and carriage equipment before new grain is stored and equipment used.
- Clean up spillages around silos and remove or use all residues to prevent re-infestation.
- Always spread grain hygiene residues to a depth of <50 mm at a dump-site to prevent the site from becoming an infested breeding site for storage pests. Most of these insects are strong fliers, moving >1 or 2 km.
- Once storages and equipment have been cleaned, treat them with an inert dust treatment (i.e. DE).
- Ensure that insect pests or weeds are not carried onto your property on farm equipment (i.e. harvesters); equipment should be thoroughly cleaned down after use.

13.7 Fumigation

Phosphine is the only fumigant currently registered for use in pulses. It is illegal and dangerous to put phosphine into unsealed storages.

Successful fumigation requires a gas-tight, sealable silo. For a fumigation to be effective against all life-cycle stages, as well as insects with resistance, the fumigant gas must be held in the silo at a given concentration for a certain period. This is only possible in gas-tight, sealable silos.

Silos purchased as gas-tight should be checked by the silo supplier and grower once they are erected, by using a pressure test. When they are filled with grain, they should be checked again prior to fumigation. Pressure testing should be part of the annual silo maintenance routine when checking and replacing worn or damaged seals and carrying out any repairs when the silo is empty.

MORE INFORMATION

GRDC Fact Sheet 'Grain storage pressure testing sealable silos': https://grdc.com.au/~/media/ReFocus-media-library/Document/GRDC-Document-Store/Publications-Media-and-Communications/Factsheets/Grain-Storage-FS-Pressure-testing-sealable-silos.pdf

Minimum fumigation exposure times for phosphine fumigation are:

- 7 days with grain temperatures >25°C
- 10 days at 15–25°C

Grain stored <15°C should not be fumigated with phosphine, because insects are hard to kill at low temperatures.

For large, sealable storages (e.g. >150 t capacity), a fumigation recirculation system should be fitted to the storage to ensure that gas is evenly distributed throughout the grain bulk in a timely manner during the fumigation exposure period.

Controlling insects in storage

During crop growth, insect control programs aim to control field insects. For insect pests detected in stored grain, fumigation is the primary control measure.

Provided fumigation is carried out correctly, the fumigant will penetrate the grain and destroy all stages of insects: adults, eggs, larvae in the storage. This includes insects that may have developed some level of phosphine resistance.

Effective fumigation with phosphine needs a concentration of 300 ppm (a chemical to air ratio) to be maintained for 7 days (when grain is stored >25°C) or 200 ppm for 10 days (15–25°C). An unsealed silo will not hold these concentrations, even using a high dosage rate. Poor fumigations may appear to have been successful when dead adults are observed, but many of the eggs, larvae and pupae survive and will continue to infest the grain. In addition, insects that survive are more likely to carry phosphine-resistance genes. This has serious consequences for future insect control across the entire industry.

Treating stored pulses

Storages should be cleaned prior to filling with new grain. If, however, there is reason to believe there are stored-grain insect pests in a silo or in freshly harvested grain, fumigation can be carried out as soon possible to ensure that all stages are eliminated before any grain damage or weight loss occurs. If possible, prior to fumigation, aeration of freshly harvested grain to create uniform, cool conditions in the grain bulk is a valuable first step.

Phosphine fumigation

Phosphine is a highly toxic substance (Schedule 7). Always read safety advice on the label and comply with state legislative requirements.

Caution should always be used when dealing with phosphine gas; it is not only toxic but also highly explosive. Observe all post-fumigation ventilation and withholding periods for handling and grain use.

Gas respirators suitable for protection against phosphine must be worn. Always open containers of phosphine preparations in the open air. When opened, use the entire contents or dispose of excess chemical. Do not reseal leftover tablets; once they have been exposed to air, they will begin to evolve into gas and may become explosive.

For safety reasons, it is best not to work alone when applying phosphine tablets or in a structures that have been fumigated.

Warning signs must be clearly displayed when the fumigation is in process (Figure 1). These should have details of when the fumigation started and the end date, as well as ventilation details, with entry to the silo prohibited during both fumigation and ventilation. Signs should be placed at all storage access points during fumigation.

MORE INFORMATION

Grains Industry Guide 'Fumigating with phosphine, other fumigants and controlled atmospheres': http://www.grdc.com.au/uploads/documents/GRDC-Fumigating-with-Phosphine-other-fumigants-and-controlled-atmospheres.pdf?shortcut=1

Figure 1: *Warning sign that must be clearly displayed when fumigation is in process.*

This phosphine warning sign can be downloaded from www.storedgrain.com.au.

Phosphine application and dosage rates

Refer to label instructions. Use only sealable storage.

Phosphine has about the same density as air and spreads rapidly in all directions once applied in a storage.

There are two forms of phosphine available for use on-farm: bag chains and tablets. Bag chains are the safest form, and ensure that no residue is spilt onto the grain. Tablets are the more traditional form and can be purchased in tins of 100. Phosphine blankets are also available; however, these are designed for bulk storages of ≥600 t.

Phosphine application rates are based on the total silo capacity (internal volume of the structure) that is to be fumigated, whether or not the silo is full, partly filled or empty (Table 3). The rates are the same for all crops.

The application rate for fumigating with a standard bag chain is one bag chain per 75 m^3. The application rate for phosphine is 1.5 g/m^3, which is equivalent to three tablets per 2 m^3.

Always read the product label to confirm recommended application rates.

Table 3: *Recommended rates of phosphine—sealed silo.*

Cubic metres	Bushels	Tonnes	Number of tablets
18	500	14	28
37	1000	28	56
56	1500	42	84
74	2000	56	111
92	2500	70	138

Source: Grain Legume Handbook.

Bag chains may be hung in the headspace or rolled out flat in the top of a gas-tight silo so that air can pass freely around them. Tablets should be spread out evenly on trays and then hung in the headspace or placed level on the grain surface. Some silos may also be fitted with purpose-built facilities to apply phosphine

MORE INFORMATION

Grain Legume Handbook 2008: https://grdc.com.au/uploads/documents/Index.pdf

Grain Storage Fact Sheet 'Performance testing aeration systems': http://www.grdc.com.au/Resources/Factsheets/2012/08/Grain-Storage-Performance-testing-aeration-systems

Grain Storage Fact Sheet 'Hygiene and structural treatments for grain storages': http://www.grdc.com.au/Resources/Factsheets/2013/06/Grain-Storage-Fact-Sheet-Hygiene-and-structural-treatments-for-grain-storages

Grain Storage Fact Sheet 'Pressure testing sealable silos': https://grdc.com.au/~/media/ReFocus-media-library/Document/GRDC-Document-Store/Publications-Media-and-Communications/Factsheets/Grain-Storage-FS-Pressure-testing-sealable-silos.pdf

from the bottom. These must have a passive or active air circulation system to carry the phosphine gas out of the confined space as it evolves, otherwise explosion can occur.

Ventilation and withholding period after fumigation

Ensure that correct, safe ventilation of the fumigation is carried out and the withholding period is observed according to label directions.

Sealing silos

The Australian Standard (AS 2628-2010) allows growers to refer to an industry benchmark when purchasing a gas-tight, sealable silo, giving confidence that they are investing in a silo that will perform in the way it is intended when fumigation is required.

Growers may choose to retro-seal existing farm silos rather than buying new gas-tight silos. Note, however, that not all silo designs can be successfully retro-sealed and made gas-tight.

Silos that are not adequately sealed lose gas through very small holes, preventing the fumigant reaching and maintaining gas concentrations necessary for an effective insect kill (Figures 2–4).

Figure 2: *Obviously, this silo is not sealed. It is dangerous as well as ineffective with a fumigant such as phosphine.*

Photo: Grain Legume Handbook

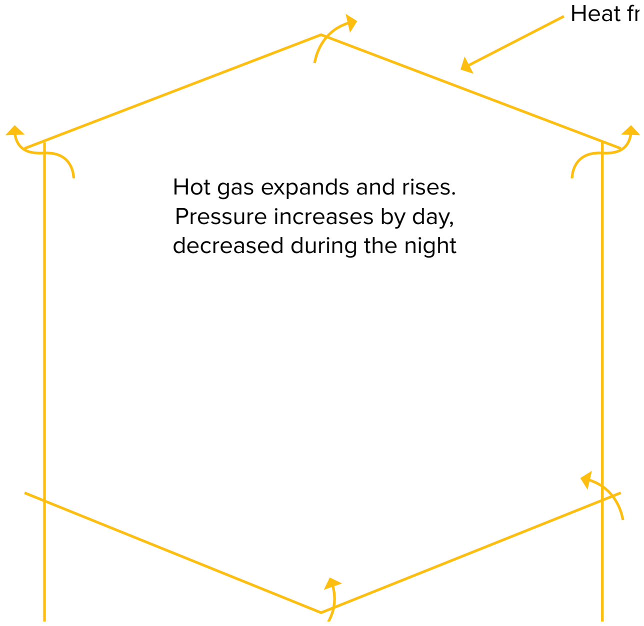

Figure 3: *Gas loss from silo through heat effects.*

Source: Grain Legume Handbook

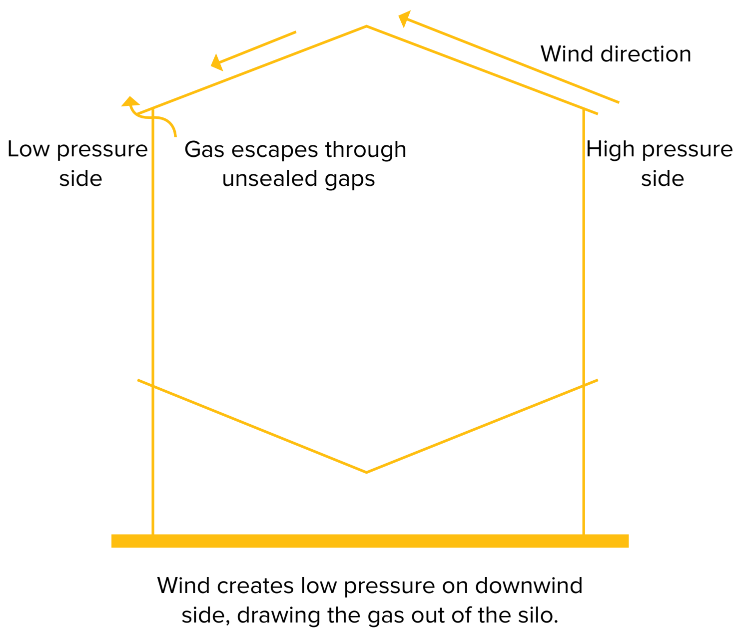

Figure 4: *Gas loss from silo through wind effects.*

Source: Grain Legume Handbook

Figure 5: *A gas lock on sealed silos gives a quick and reliable means of checking the seal of the silo. Some silos marketed as 'sealed' may not prove to be when tested.*

13.7.1 Testing silos for seal

A relief valve fitted to protect the structure of a sealable silos can also be used as a gauge for pressure testing. This allows for easy and regular seal tests. The relief valve should be filled to the second line (Figure 5) with light hydraulic oil. Do not use water, as it will evaporate. Vegetable oil is also unsuitable because it may react with the phosphine.

Test the silo for gas tightness using the pressure relief valve by applying a '5-minute half-life test' when new and a '3-minute half-life test' for all older existing sealable silos.

Key points:

- A silo sold as a 'sealable silo' needs to be pressure tested to be sure it's gas-tight.
- Check new sealable silos for Australian Standard pressure sealing compliance (AS2628).
- Pressure test sealed silos upon erection, annually and before fumigating.
- Maintenance is the key to ensuring a silo purchased as sealable can provide a reliable fumigation result.

MORE INFORMATION

Grain Storage Fact Sheet 'Pressure testing sealable silos': https://grdc.com.au/~/media/ReFocus-media-library/Document/GRDC-Document-Store/Publications-Media-and-Communications/Factsheets/Grain-Storage-FS-Pressure-testing-sealable-silos.pdf

13.8 Silo or grain bags

Grain bags (known also as silo bags, sausage bags or harvest bags) are becoming increasingly popular (Figure 6). It is important to appreciate their role and how they function, particularly when used to store pulse grain.

There are success stories with grain bags when used to store grain temporarily, including pulses. Failures have also occurred when appropriate precautions were not taken.

Pulses are riskier grains than cereals to store in grain bags. Pulse grain has been rejected by markets because of objectionable taints and odours derived during improper storage in a grain bag.

Grain bags are a sealed storage with no aeration. To maintain grain quality in storage, it is essential to bag the grain at the correct moisture content and ensure that the bag remains sealed throughout the entire storage period to prevent moisture ingress.

High-moisture grain, condensation, water aggregation under the film or leaks can cause localised mould and widespread spoilage in pulses.

Even with adequate seals, hermetic conditions (low oxygen (O_2), high CO_2) to protect against insects and mould are difficult to achieve consistently because of either high grain temperatures or low grain moisture content at the time of storage.

Figure 6: *Silo bags (or grain, harvest bags) should be considered as only temporary storage for pulse grains because of quality issues that can arise.*

Photo: W. Hawthorne, Pulse Australia

13.8.1 Pulse quality risks and grain bags

There are risks associated with storing pulses in grain bags:

- Pulse grain may not retain its quality, colour or odour, especially if the seal is breached.
- Contamination and moisture can enter bags from vermin and other pests that create holes in the bag.
- Excessive grain moisture can result in condensation within the bag, causing localised areas of mould and objectionable odours.
- Pockets of mouldy grain can develop in grain bags, along with an offensive, distinctive 'mouldy' odour throughout. There is a nil tolerance of this in receival standards
- Marketers have rejected pulse grain because of objectionable moulds, taints and odours acquired through storage in grain bags.
- Removing taints and odours in affected grain is not necessarily possible, even with further aeration.
- Grain stored in grain bags can develop an overall offensive, distinctive 'plastic' odour that requires considerable periods of aeration to remove. There is nil tolerance of odours in receival standards
- Achieving and keeping hermetic conditions under Australian conditions is difficult and it should not be relied upon as the only source of storage insect control.

MORE INFORMATION

GRDC Fact Sheet 'Successful storage in grain bags': http://storedgrain.com.au/successful-storage-in-grain-bags/

- Grain moisture content is critical. Pulses, particularly the larger seeded ones such as faba bean, have bigger airspaces between grains than do cereals, so moisture can move more freely in them.

13.9 References and further reading

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P White *et al.* (2005) Producing pulses in the southern agricultural region. Department of Agriculture Western Australia Bulletin # 4656, http://www.web.uwa.edu.au/__data/assets/pdf_file/0007/920473/Pulse_Manual_Flyer.pdf

Environmental issues

14.1 Temperature

Temperature, daylight, daylength, and drought are the major factors affecting flowering in faba beans. Temperature is generally more important than daylength. Flowering is invariably delayed under low temperatures but more branching occurs.

Progress towards flowering is rapid during long days, while under short daylength, flowering is delayed but never prevented. However, some faba bean varieties are less sensitive to daylength than others. This has enabled breeders to identify improved varieties that flower early in the short-day, winter growing season in southern Australia. [1]

High temperatures

Separating the effects of very high temperature from those of water stress is difficult, because in rainfed agriculture, they nearly always occur together. There is, however, no doubt that high temperature has deleterious effects.

In lupin, short bursts of temperature ≥~35°C can reduce the size of individual seeds and, if this occurs early in seed-filling, will cause seed abortion. Similar effects are likely in other grain legume species. In all pulses, high temperature will cause premature cessation of flowering, and shedding of flowers and young pods. Early maturity of field peas, faba beans and lentils is an effective strategy to escape high temperature. [2]

Temperature and sowing time

Timing of sowing largely determines the timing of the crop's finish and the temperature environment in which it will finish.

Sowings made prior to the recommended sowing window tend to be more vegetative and suffer from:

- poor early podset because of low light or low temperatures (10°C) at flowering commencement
- higher risk of chocolate spot at flowering and through podding
- crops being more pre-disposed to lodging
- increased frost risk at flowering and early podding
- high water use prior to effective flowering and the earlier onset of moisture stress during flowering and podding

Late-planted crops are more likely to suffer from:

- high temperatures and moisture stress during flowering and podding
- greater pressure from native budworms
- fewer branching and flowering sites, unless plant population is increased
- shorter plants and lower podset, which is more difficult to harvest [3]

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1 Southern/Western Faba and Broad Bean—Best Management Practices Training Course. Module 3—Varieties, 2013. Pulse Australia.

2 DAWA (2005) Producing pulses in the northern agricultural region. Bulletin 4656, Department of Agriculture Western Australia. http://www.web.uwa.edu.au/__data/assets/pdf_file/0007/920473/Pulse_Manual_Flyer.pdf

3 Southern/Western Faba and Broad Bean—Best Management Practices Training Course. Module 3—Varieties. 2013, Pulse Australia.

MORE INFORMATION

Australian Pulse Bulletin: Minimising frost damage in pulses

14.2 Frost

Faba beans are like many other cool-season pulses in that they are reasonably tolerant of cold conditions, even at flowering. However, sub-zero temperatures in winter can damage leaves and stems of the plant. This occurs particularly in the northern grains region, where severe frosts can cause a characteristic 'hockey-stick' bend in the stem (Figure 1). However, beans have some ability to recover from this damage by being able to regenerate new branches in these severe cases. New regrowth occurs from the base of the frost-affected plants if moisture conditions are favourable.

Some varieties of faba bean released in the northern region have been bred for their tolerance to frosts during the vegetative growth stage. This tolerance in the varieties PBA Warda⚬ and Doza⚬ means less death of stems and 'club foot', results of severe frost seen in northern Australia, but not in southern areas. Current varieties grown in southern Australia (e.g. Fiesta, Farah⚬, Nura⚬ and PBA Rana⚬) are susceptible to severe vegetative frosts when grown in northern Australia.

Figure 1: *Severe vegetative frost can cause bends like a hockey stick in faba bean stem and branches in northern Australia. (Photos: G Cumming, Pulse Australia)*

Frosts also cause flower, pod and seed abortion (Figures 2–4). Pods at a later stage of development are generally more resistant to frost than flowers and small pods, but may suffer some mottled darkening of the seed coat.

Frost will normally affect the smallest pods first, even though they are the higher pods on the plant. Similarly, pod abortion induced by moisture stress is normally also noted on the last formed pods in the upper parts of the plant. Visual symptoms of frost and moisture-stress damage to pods are, however, quite different.

Frosts during early flowering affecting early podset can be compensated for later by subsequent pods that set higher up the plant, provided the seasonal conditions are favourable to fill them.

An observation from the paddock shows that the effects of frost on flowers and pods are reduced by having good closure, which stops the frost from getting right down around the stems and pods.

Figure 2: *Frost can cause flower or pod abortion (usually smaller pods). Damage to the seed depends on the size of the pod or seed and the severity of the frost.*

Photo: W. Hawthorne, Pulse Australia

Figure 3: *Frost can cause seed staining from 'burning' the seed coat next to the pod wall.*

Photo: W. Hawthorne, Pulse Australia

Figure 4: *Frosted faba beans.*

Photo: M. Seymour (2005) Producing pulses in the northern agricultural region. DAWA, http://www.web.uwa.edu.au/__data/assets/pdf_file/0007/920473/Pulse_Manual_Flyer.pdf p. 13

14.3 Waterlogging

Too much water, as occurs in waterlogging, results in a shortage of oxygen in the soil. Oxygen is not very soluble in water, and diffuses through it very slowly, so roots in saturated soil soon become oxygen-deficient. Toxic substances produced by changes in soil chemistry may also accumulate in waterlogged soils; these further impair root function. The damage to plants from waterlogging and their tolerance to it depends on the degree and duration of saturation, the soil temperature (oxygen is depleted more quickly in warm than cool soils), the stage of the crop (germinating and seedling crops are generally more susceptible than established crops), and the crop species.

Pulses are generally not well suited to waterlogged soils. Faba beans are the pulse most tolerant to waterlogging and they exhibit some adaptation in new roots when the soil has been saturated for >2 weeks. Faba beans are able to produce good yields under waterlogged conditions that can cause failure of chickpea or lentil crops (Figure 5). The variety Fiesta appears slightly more tolerant of waterlogging than Fiord or Ascot. Importantly, however, the growth of faba beans will still be reduced when they are subjected to extended periods of waterlogging (>2 weeks), and chocolate spot disease is likely to be more severe. [4]

Irrigated faba bean grown at Kerang, Victoria, on drained soils (tile drains at 1.0 m) yielded 4.2 t/ha, whereas undrained crops yielded 2.7 t/ha when sown on raised beds and 1.9 t/ha where sown into a conventionally laser-levelled bay (Drew 1994). The water table level was maintained at about 1.0 m below the soil surface for the season on drained soils, but on undrained soils was 0.1–0.3 m from the surface until September, and then fell away to 0.8–0.9 m to the end of November.

4 DAWA (2005) Producing pulses in the northern agricultural region. Bulletin 4656, 2005, Department of Agriculture Western Australia, http://www.web.uwa.edu.au/__data/assets/pdf_file/0007/920473/Pulse_Manual_Flyer.pdf

Figure 5: *Faba beans (background) and lentils (foreground) grown in a waterlogged area. Waterlogging has killed the lentils, but faba beans appear unaffected.*

Photo: M. Seymour (2005) Producing pulses in the northern agricultural region. DAWA, http://www.web.uwa.edu.au/__data/assets/pdf_file/0007/920473/Pulse_Manual_Flyer.pdf p. 11

Iron deficiency and waterlogging

Iron deficiency may occasionally be observed on alkaline, high-pH soils following a waterlogging event after irrigation or heavy rainfall. The deficiency is due to the interference with iron absorption and translocation to the foliage.

Symptoms include a general yellowing of young leaves, which can develop in severe cases to distortion, necrosis and shedding of terminal leaflets (pinnae).

A mixture of 1 kg/ha of iron sulfate + 2.5 kg/ha of crystalline sulfate of ammonia (not prilled) + 200 mL non-ionic wetter/100 L water has been successfully used to correct a deficiency. [5]

14.4 References

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5 Southern/Western Faba and Broad Bean—Best Management Practices Training Course. Module 3—Varieties 2013. Pulse Australia.

Marketing

The final step in generating farm income is converting the tonnes produced into dollars at the farm gate. This section provides best in class marketing guidelines for managing price variability to protect income and cash-flow.

Figure 1 shows a grain selling flow chart that summarises:

- decisions to be made
- drivers behind the decisions
- guiding principles for each decision point.

The grower will run through a decision-making process each season, because growing and harvesting conditions, and prices for grains, change all the time. For example, in the seven years to and including 2015, Port Adelaide faba bean values varied by between A$115/t and as much as A$250/t, a variability of 30–60% (Figure 2). For a property producing 200 tonnes of faba beans this means $23,000–$50,000 difference in income, depending on the timing of sales.

The reference column refers to the section of the GrowNote where you will find the details to help in making decisions. [1]

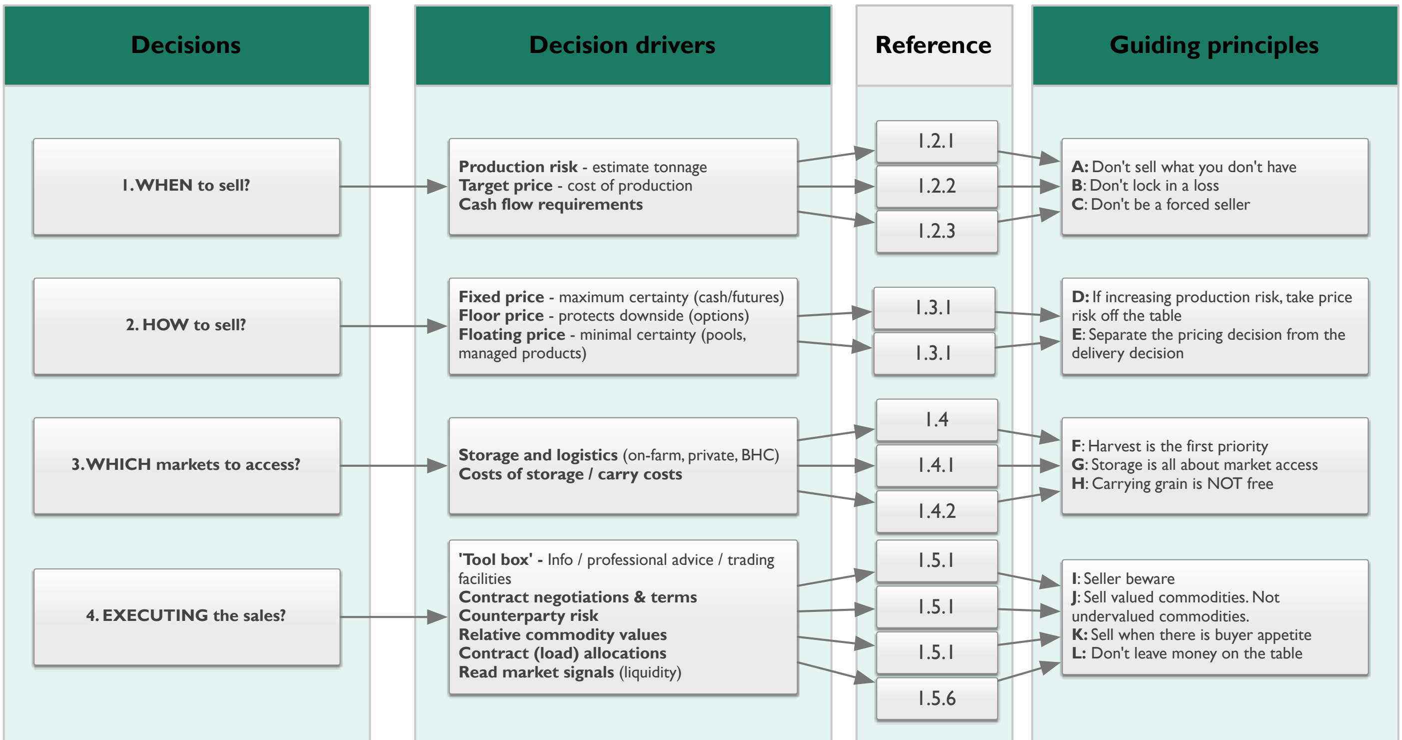


Figure 1: *Grain selling flow chart.*

1 Profarmer Australia (2016), Marketing Field Peas, GRDC Northern Field Pea GrowNote

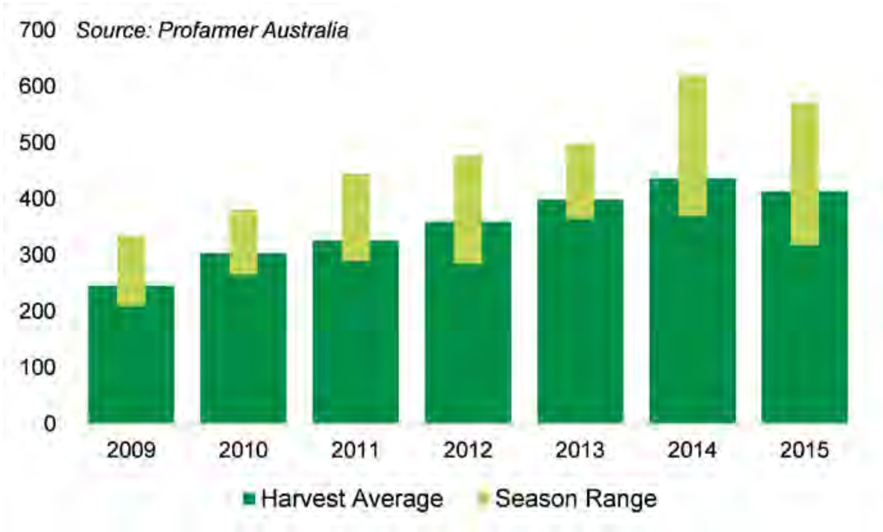


Figure 2: *Seasonal variance in Port Adelaide faba bean values.*

Source: Profarmer Australia

15.1 Selling principles

The aim of a selling program is to achieve a profitable average price (the target price) across the entire business. This requires managing several unknowns to establish a target price and then work towards achieving the target price.

Unknowns include the amount of grain available to sell (production variability), the final cost of producing the grain, and the future prices that may result. Australian farm-gate prices are subject to volatility caused by a range of global factors that are beyond our control and are difficult to predict.

The skills growers have developed to manage production unknowns can also be used to manage pricing unknowns. This guide will help growers manage and overcome price uncertainty. [2]

15.2.2 Be prepared

Being prepared by having a selling plan is essential for managing uncertainty. The steps involved are forming a selling strategy and forming a plan for effectively executing sales.

The selling strategy consists of when and how to sell.

When to sell

Knowing when to sell requires an understanding of the farm's internal business factors, including:

- production risk
- a target price based on cost of production and a desired profit margin
- business cash flow requirements

How to sell

Working out how to sell your grain is more dependent on external market factors, including:

- time of year—determines the pricing method
- market access—determines where to sell
- relative value—determines what to sell

2 Profarmer Australia (2016), Marketing Field Peas, GRDC Northern Field Pea GrowNote

The following diagram (Figure 3) lists the key principles to employ when considering sales during the growing season.

Exactly when each principle comes into play is indicated in the discussion of marketing planning and timing in the rest of section 15. [3]

Figure 3: *Timeline of grower commodity selling principles.*

Source: Profarmer Australia

15.2.2 Establish the business risk profile

Establishing your business risk profile helps you determine when to sell: it allows you to develop target price ranges for each commodity, and provides confidence to sell when the opportunity arises. Typical business circumstances and how to quantify the risks during the production cycle are described below (Figure 4).

3 Profarmer Australia (2016), Marketing Field Peas, GRDC Northern Field Pea GrowNote

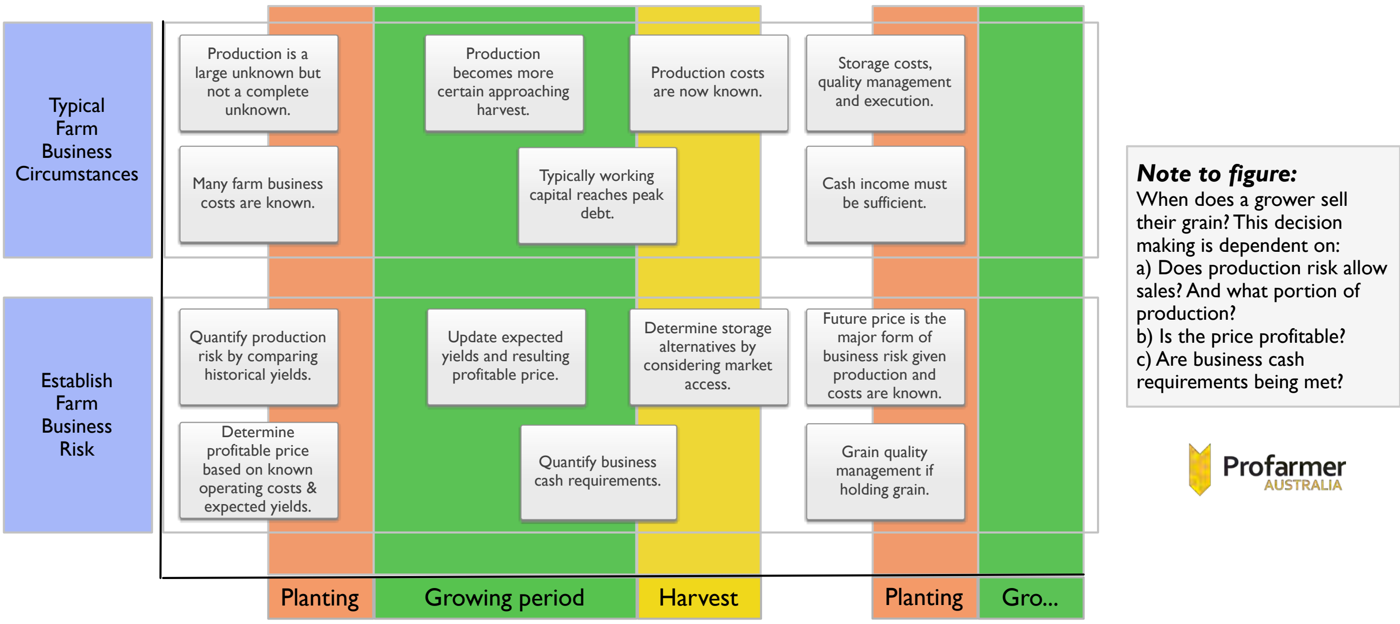


Figure 4: *Typical farm business circumstances and risk.*

Source: Profarmer Australia

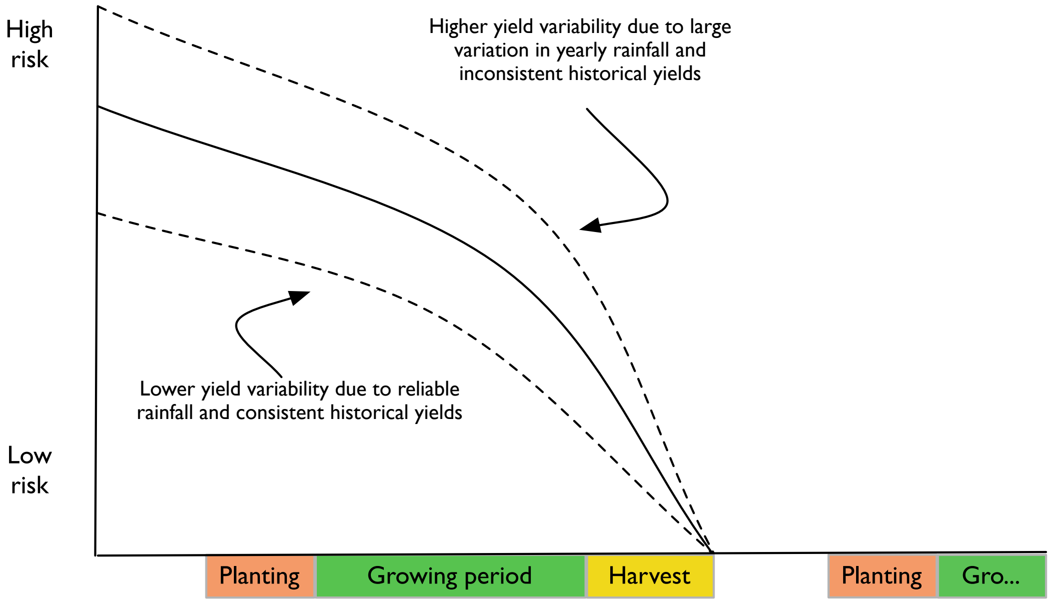
Production risk profile of the farm

Production risk is the level of certainty around producing a crop and is influenced by location (climate, season and soil type), crop type, crop management, and time of the year.

Principle: You can't sell what you don't have.

Therefore, don't increase business risk by over committing production. Establish a production risk profile (Figure 5) by:

1. Collating historical average yields for each crop type and a below-average and above-average range
2. Assess the likelihood of achieving average, based on recent seasonal conditions and seasonal outlook
3. Revising production outlooks as the season progresses.



Note to figure:
The quantity of crop grown is a large unknown early in the year however not a complete unknown. 'You can't sell what you don't have' but it is important to compare historical yields to get a true indication of production risk. This risk reduces as the season progresses and yield becomes more certain. Businesses will face varying production risk levels at any given point in time with consideration to rainfall, yield potential, soil type, commodity etc.

Profarmer AUSTRALIA

Figure 5: *Typical risk profile of a farm operation.*

Source: Profarmer Australia

Establishing a target price

A profitable commodity target price is the cost of production per tonne plus a desired profit margin. It is essential to know the cost of production per tonne for the farm business, which means knowing all farming costs, both variable and fixed.

Principle: Don't lock in a loss.

If committing production ahead of harvest, ensure the price will be profitable. The steps needed to calculate an estimated profitable price is based on the total cost of production and a range of yield scenarios, as provided below (Figure 6).

Estimating cost of production - Wheat	
Planted area	1,200 ha
Estimate yield	2.85 t/ha
Estimated production	3,420 t
Fixed costs	
Insurance and general expenses	$100,000
Finance	$80,000
Depreciation/Capital replacement	$70,000
Drawings	$60,000
Other	$30,000
Variable costs	
Seed and sowing	$48,000
Fertiliser and application	$156,000
Herbicide and application	$78,000
Insect/fungicide and application	$36,000
Harvest costs	$48,000
Crop insurance	$18,000
Total fixed and variable costs	$724,000
Per tonne equivalent (total costs + estimated production)	$212 /t
Per tonne costs	
Levies	$3 /t
Cartage	$12 /t
Receival fees	$11 /t
Freight to port	$22 /t
Total per tonne costs	$48 /t
Cost of production port FIS equiv	$259.20
Target profit (ie 20%)	$52.00
Target price (port FIS equiv)	**$311.20**

Step 1: Estimate your production potential. The more uncertain your production is, the more conservative the yield estimate should be. As yield falls, your cost of production per tonne will rise.

Step 2: Attribute your fixed farm business costs. In this instance if 1,200 ha reflects 1/3 of the farm enterprise, we have attributed 1/3 fixed costs. There are a number of methods for doing this (see M Krause 'Farming your Business') but the most important thing is that in the end all costs are accounted for.

Step 3: Calculate all the variable costs attributed to producing that crop. This can also be expressed as $ per ha x planted area.

Step 4: Add together fixed and variable costs and divide by estimated production.

Step 5: Add on the 'per tonne' costs like levies and freight.

Step 6: Add the 'per tonne' costs to the fixed and variable per tonne costs calculated at step 4.

Step 7: Add a desired profit margin to arrive at the port equivalent target profitable price.

Figure 6: *An example of how to estimate the costs of production.*

Source: Profarmer Australia

GRDC's manual Farming the Business also provides a cost-of-production template and tips on grain selling v. grain marketing.

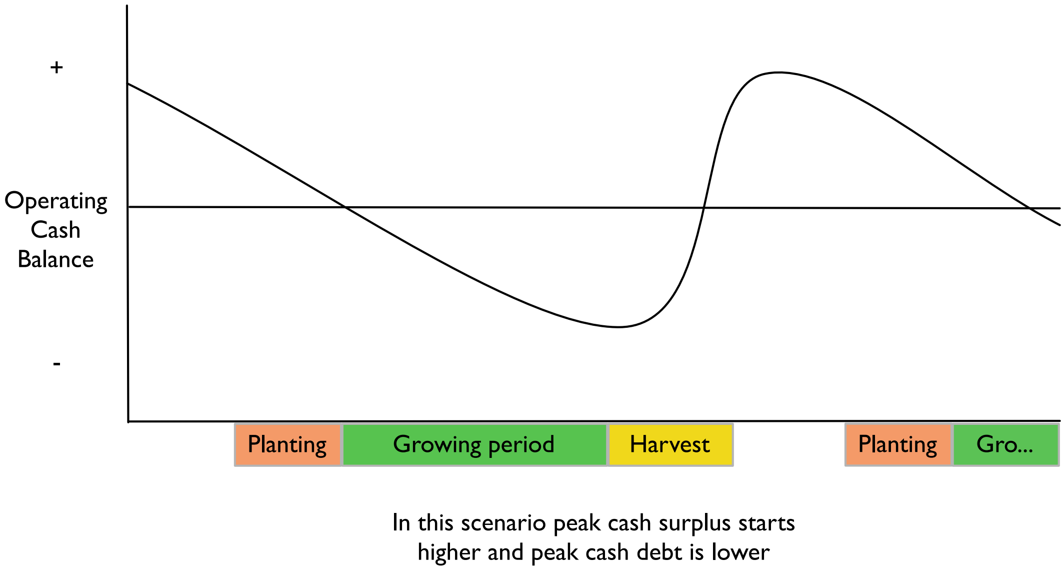
Income requirements

Understanding farm business cash flow requirements and peak cash debt enables growers to time grain sales so that cash is available when required. This prevents having to sell grain below the target price to satisfy a need for cash.

Principle: Don't be a forced seller.

Be ahead of cash requirements to avoid selling in unfavourable markets.

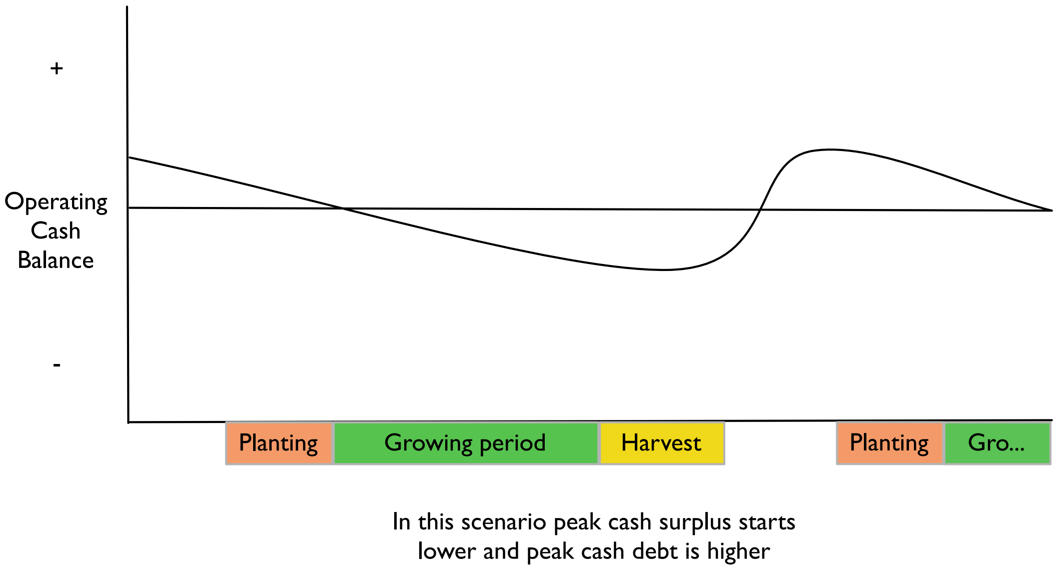
Typical cash flow to grow a crop is illustrated below (Figures 7 and 8). Costs are incurred upfront and during the growing season, with peak working capital debt incurred at or before harvest. Patterns will vary depending on circumstance and enterprise mix. Figure 8 demonstrates how managing sales can change the farm's cash balance.



Note to figure:
The chart illustrates the operating cash flow of a typical farm assuming a heavy reliance on cash sales at harvest. Costs are incurred during the season to grow the crop, resulting in peak operating debt levels at or near harvest. Hence at harvest there is often a cash injection required for the business. An effective marketing plan will ensure a grower is 'not a forced seller' in order to generate cash flow.

Figure 7: *A typical operating cash balance when relying on cash sales at harvest.*

Source: Profarmer Australia



Note to figure:
By spreading sales throughout the year a grower may not be as reliant on executing sales at harvest time in order to generate required cash flow for the business. This provides a greater ability to capture pricing opportunities in contrast to executing sales in order to fulfil cash requirements.

Figure 8: *Typical operating cash balance when crop sales are spread over the year.*

Source: Profarmer Australia

The 'when to sell' steps above result in an estimated production tonnage and the risk associated with producing that tonnage, a target price range for each commodity, and the time of year when cash is most needed. [4]

4 Profarmer Australia (2016), Marketing Field Peas, GRDC Northern Field Pea GrowNote

15.2.3 Managing your price

The first part of the selling strategy answers the question about when to sell and establishes comfort around selling a portion of the harvest.

The second part of the strategy, managing your price, addresses how to sell your crop.

Methods of price management

Pricing products provide varying levels of price risk coverage, but not all products are available for all crops (Table 1).

Table 1: *Pricing methods and how they are used for different crops.*

	Description	Wheat	Barley	Canola	Oats	Lupins	Field peas	Chick peas
Fixed price products	Provides the most price certainty	Cash, futures, bank swaps	Cash, futures, bank swaps	Cash, futures, bank swaps	Cash	Cash	Cash	Cash
Floor price products	Limits price downside but provides exposure to future price upside	Options on futures, floor price pools	Options on futures	Options on futures	none	none	none	none
Floating price products	Subject to both price upside and downside	Pools	Pools	Pools	Pools	Pools	Pools	Pools

Figure 9 summarises how the different methods of price management are suited for the majority of farm businesses.

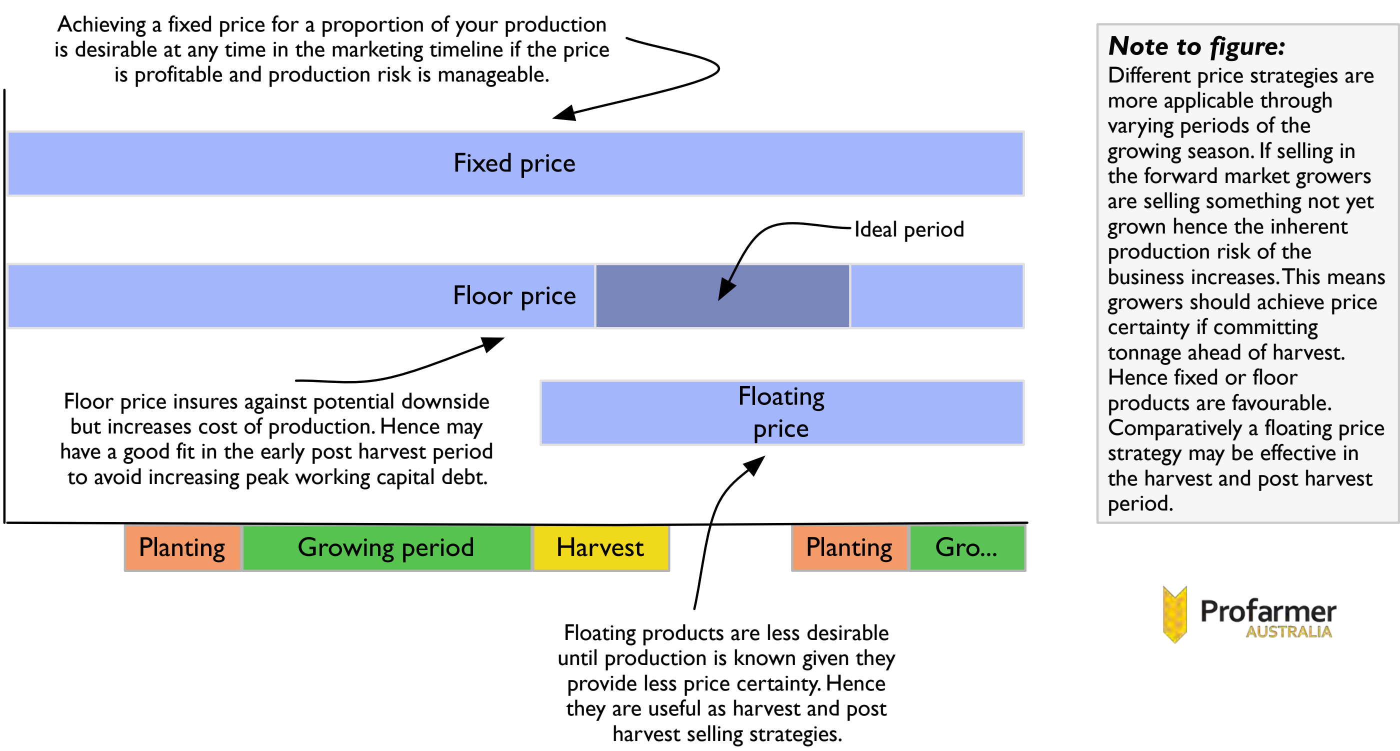


Figure 9: *Price strategy timeline, summarising the suitability for most farm businesses of different methods of price management for different phases of production.*

Source: Profarmer Australia

Principle: If increasing production risk, take price risk off the table.

When committing to unknown production, price certainty should be achieved to avoid increasing overall business risk.

Principle: Separate the pricing decision from the delivery decision.

Most commodities can be sold at any time with delivery timeframes negotiable, hence price management is not determined by delivery.

1. *Fixed price*

A fixed price is achieved via cash sales and/or selling a futures position (swaps) (Figure 10).

It provides some certainty around expected revenue from a sale as the price is largely a known except when there is a floating component in the price. For example, a multi-grade cash contract with floating spreads or a floating basis component on futures positions.

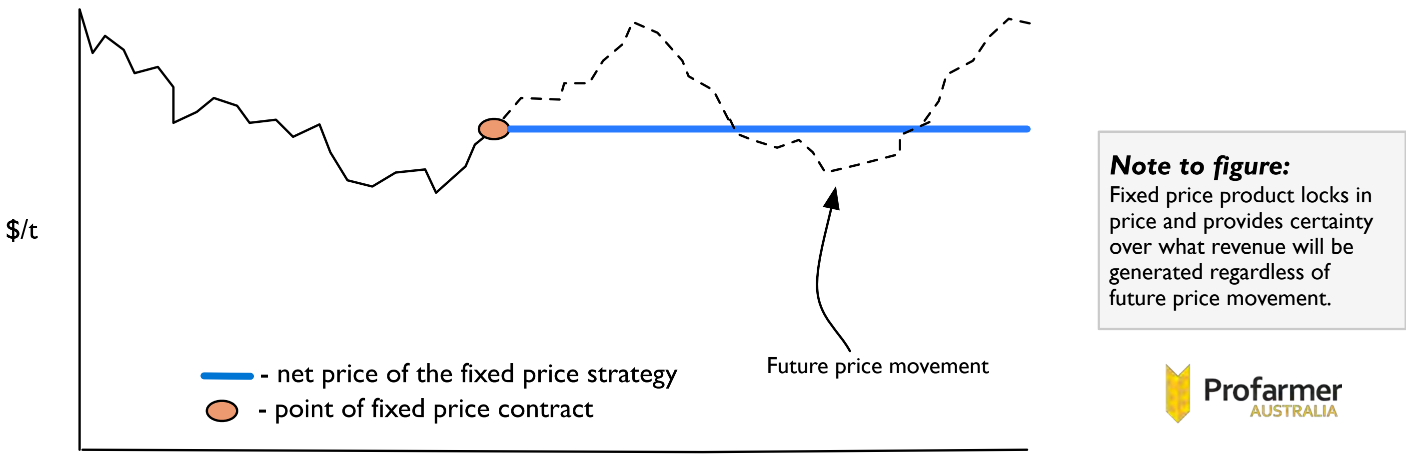
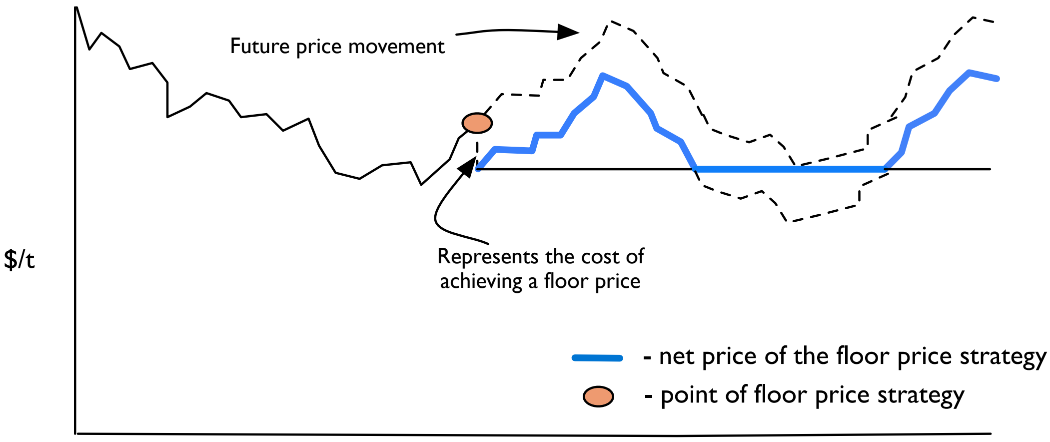


Figure 10: *Fixed price strategy.*

Source: Profarmer Australia

2. *Floor price*

Floor price strategies (Figure 11) can be achieved by utilising options on a relevant futures exchange (if one exists), or via a managed sales program (i.e. a pool with a defined floor price strategy offered by a third party). This pricing method protects against potential future price decrease whilst capturing any price increase. The disadvantage is that this kind of price 'insurance' has a cost, which adds to the farm's cost of production.



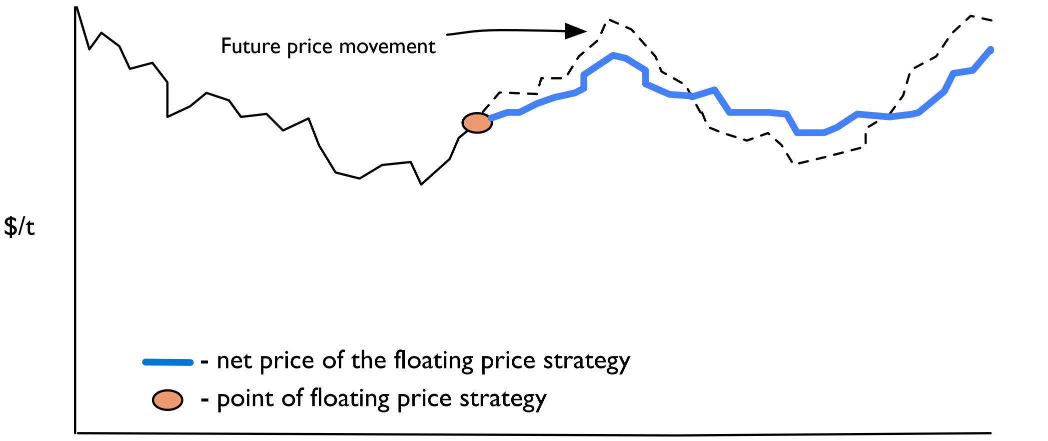
Note to figure:
A floor price strategy insures against potential future downside in price while allowing price gains in the event of future price rallies.

Figure 11: *Floor price strategy.*

Source: Profarmer Australia

3. *Floating price*

Many of the pools or managed sales programs are a floating price, where the net price received will move up and down with the future movement in price (Figure 12). Floating price products provide the least price certainty and are best suited for use at or after harvest rather than before harvest.



Note to figure:
A floating price will move to some extent with future price movements.

Figure 12: *Floating price strategy.*

Source: Profarmer Australia

Having considered the variables of production for the crop to be sold, and how these fit against the different pricing mechanisms, the farmer may revise their selling strategy, taking the risks associated with each mechanism into account. Fixed price strategies include physical cash sales or futures products and provide the most price certainty, but production risk must be considered.

Floor price strategies include options or floor price pools. They provide a minimum price with upside potential and rely less on production certainty, but cost more.

Floating price strategies provide minimal price certainty and are best used after harvest. [5]

5 Profarmer Australia (2016), Marketing Field Peas, GRDC Northern Field Pea GrowNote

15.2.4 Ensuring access to markets

Once the questions of when and how to sell are sorted out, planning moves to storage and delivery of commodities to ensure timely access to markets and execution of sales. Planning where to store the commodity is an important component of ensuring the type of access to the market that is likely to yield the highest return (Figure 13).

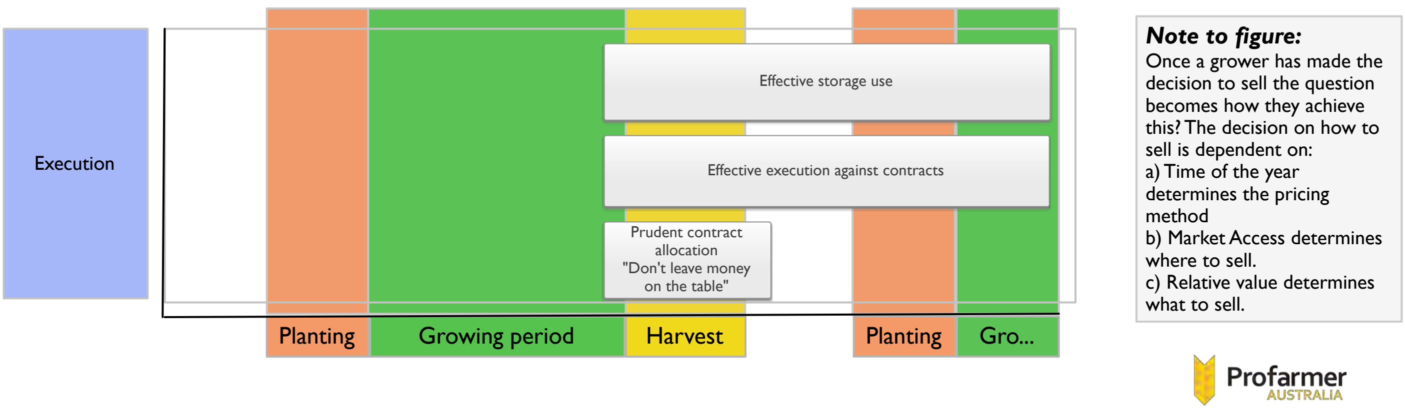


Figure 13: *Storage decisions are influenced by selling decisions and the timing of all farming activities.*

Source: Profarmer Australia

Storage and logistics

The return on investment from grain handling and storage expenses is optimised when storage is considered in light of market access to maximise returns as well as harvest logistics.

Storage alternatives include variations around the bulk handling system, private off-farm storage, and on-farm storage. Delivery and quality management are key considerations in deciding where to store your commodity (Figure 14).

Principle: Harvest is the first priority.

During harvest, getting the crop into the bin is the most critical aspect of business success; hence storage, sale and delivery of grain should be planned well ahead of harvest to allow the grower to focus on the harvest itself.

Bulk export commodities requiring significant quality management are best suited to the bulk handling system. Commodities destined for the domestic end user market, (e.g. feedlot, processor, or container packer), may be more suited to on-farm or private storage to increase delivery flexibility.

Storing commodities on-farm requires prudent quality management to ensure that the grain is delivered to the agreed specifications. If not well planned and carried out, it can expose the business to high risk. Penalties for out-of-specification grain arriving at a buyer's weighbridge can be expensive, as the buyer has no obligation to accept it. This means the grower may have to incur the cost of taking the load elsewhere and may also have to find a new buyer.

On-farm storage also requires that delivery is managed to ensure that the buyer receives the commodities on time and with appropriate weighbridge and sampling tickets.

Principle: Storage is all about market access.

Storage decisions depend on quality management and expected markets.

For more information on on-farm storage alternatives and economics, see Section 13: Grain Storage.

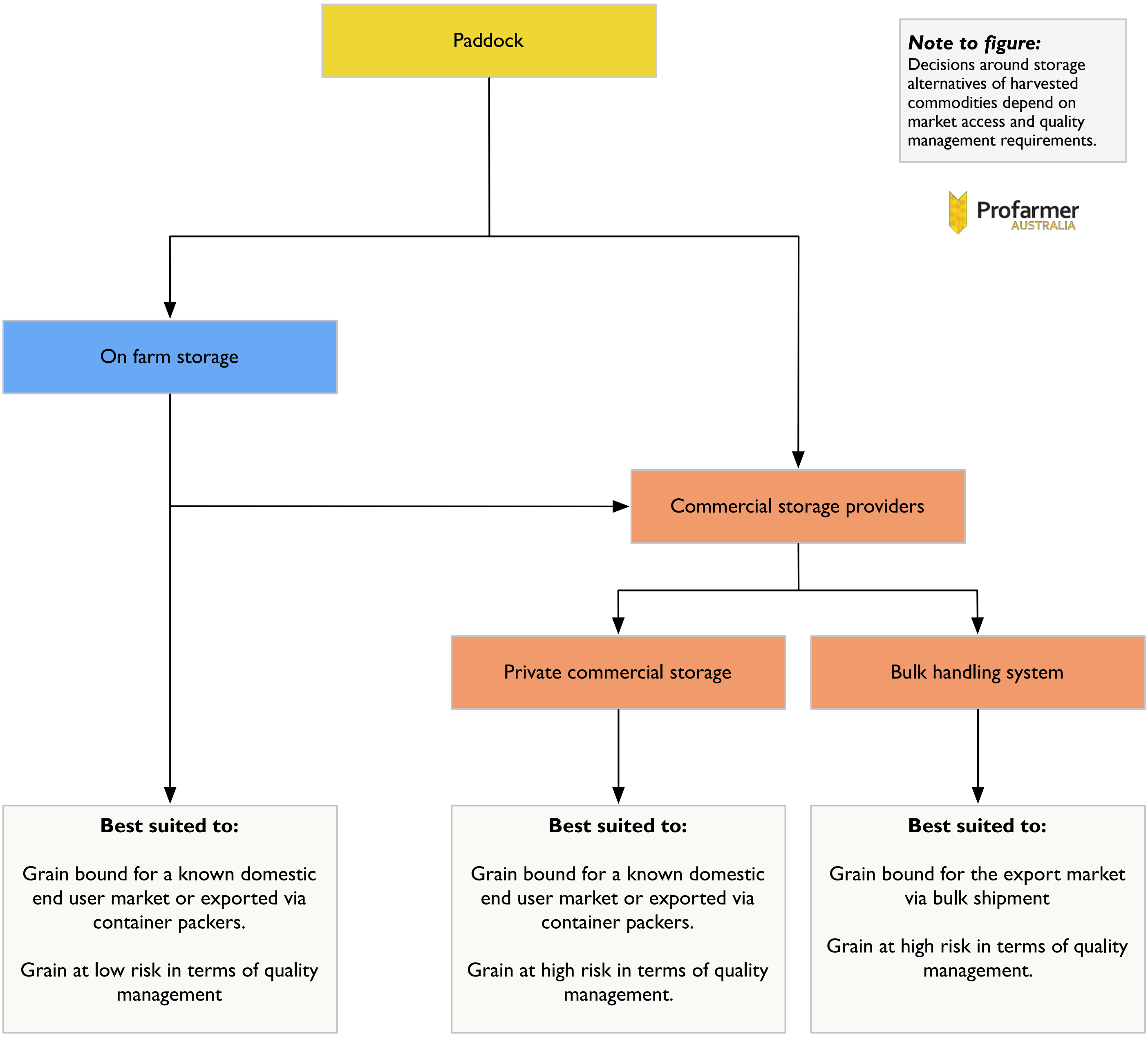


Figure 14: *Grain storage decision-making.*

Source: Profarmer Australia

Cost of holding grain

Storing grain to access sales opportunities post-harvest invokes a cost to 'carry', or hold, the grain (Figure 15). Price targets for carried grain need to account for the cost of carry.

Carry costs are typically $3–4/t per month and consist of:

- monthly storage fee charged by a commercial provider (typically ~$1.50–2.00/t)
- monthly interest associated with having wealth tied up in grain rather than available as cash or for paying off debt (~$1.50–2.00/t, depending on the price of the commodity and interest rates).

The price of carried grain therefore needs to be $3–4/t per month higher than the price offered at harvest.

The cost of carrying also applies to grain stored on the farm, as there is a cost of capital invested in the farm storage plus the interest component. A reasonable assumption is a cost of $3–4/t per month for on-farm storage.

Principle: Carrying grain is not free.

The cost of carrying grain needs to be accounted for if holding it for sale after harvest is part of the selling strategy.

If selling a cash contract with deferred delivery, a carrying charge can be negotiated into the contract. For example, a March sale of canola for March–June delivery on the buyers call at a price of $300/t + $3/t carrying per month, would generate revenue of $309/t delivered in June. [6]

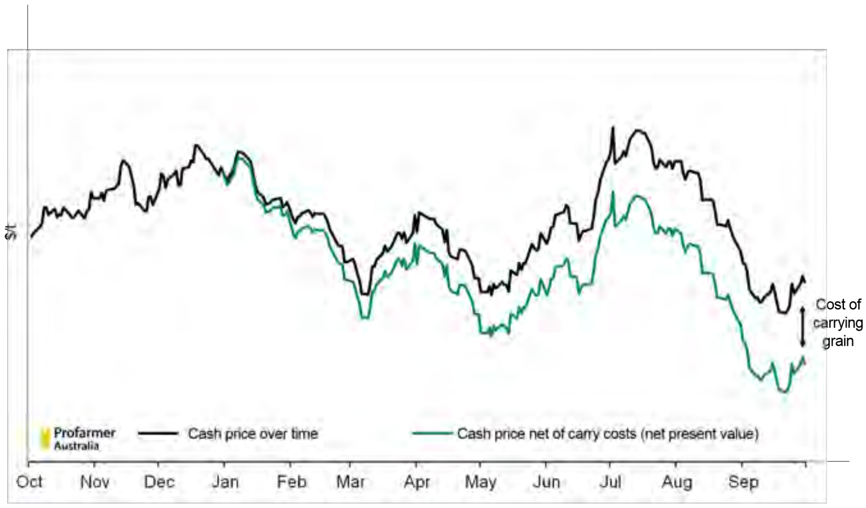


Figure 15: *Cash values v. cash values adjusted for the cost of carrying.*

Source: Profarmer Australia

Optimising farm gate returns involves planning the appropriate storage strategy for each commodity to improve market access and ensure that carrying costs are covered in the price received. [7]

15.2.5 Converting tonnes into cash

This section provides guidelines for converting the selling and storage strategy into cash by effective execution of sales.

Set up the toolbox

Selling opportunities can be captured when they arise by assembling the necessary tools in advance. The toolbox for converting tonnes of grain into cash includes the following:

1. Timely information—this is critical for awareness of selling opportunities and includes:
- market information provided by independent parties
- effective price discovery including indicative bids, firm bids, and trade prices
- other market information pertinent to the particular commodity.
2. Professional services—grain selling professional services and cost structures vary considerably. An effective grain selling professional will put their clients' best interest first by not having conflicts of interest and investing time in the

6 Profarmer Australia (2016), Marketing Field Peas, GRDC Northern Field Pea GrowNote

7 Profarmer Australia (2016), Marketing Field Peas, GRDC Northern Field Pea GrowNote

relationship. A better return on investment for the farm business is achieved through higher farm-gate prices, which are obtained by accessing timely information, and being able to exploit the seller's greater market knowledge and greater market access.

3. Futures account and bank swap facility—these accounts provide access to global futures markets. Hedging futures markets is not for everyone; however, strategies which utilise exchanges such as the Chicago Board of Trade (CBOT) can add significant value.

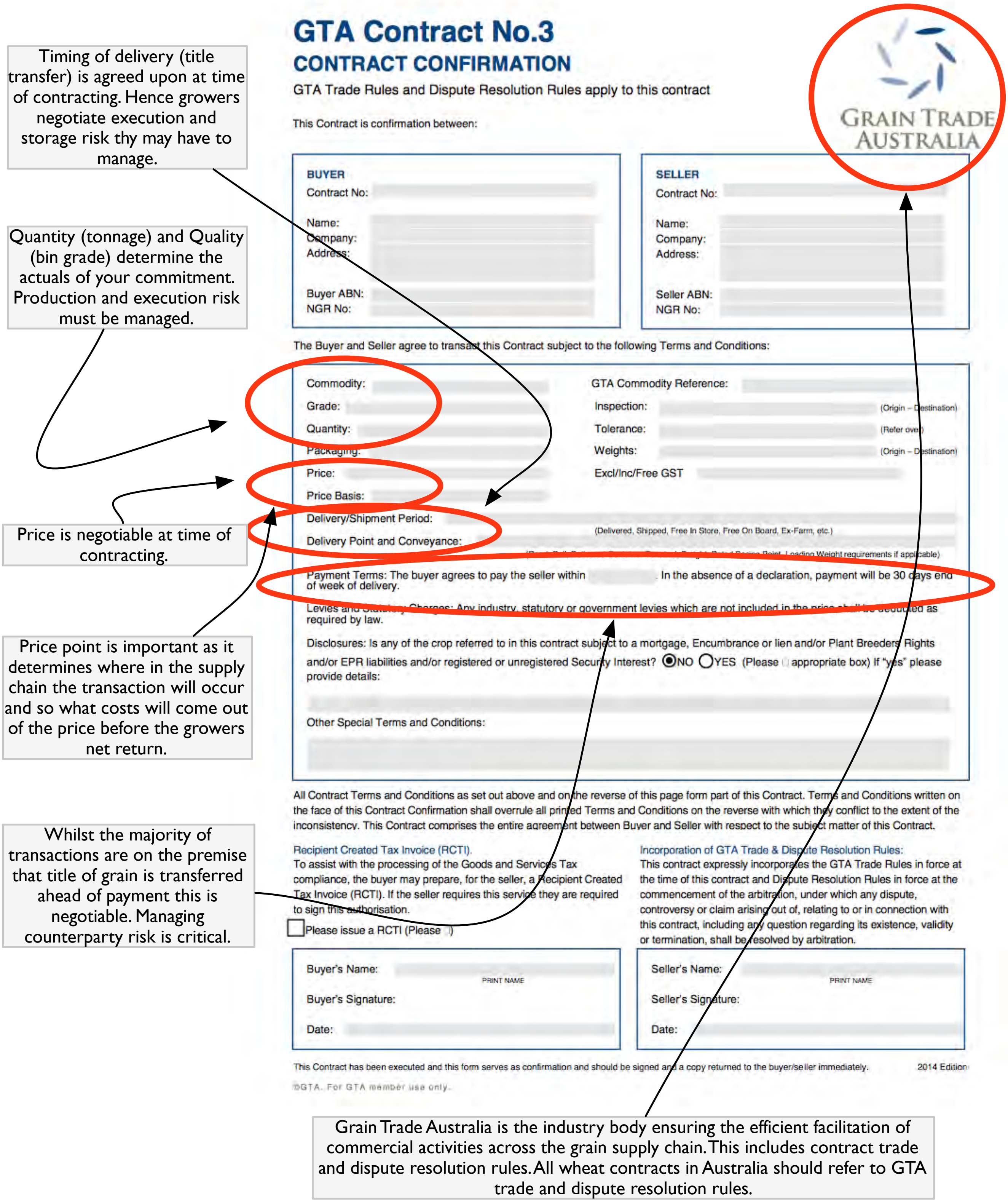
For a list of current financial members of Grain Trade Australia including buyers, independent information providers, brokers, agents, and banks providing over-the-counter grain derivative products (swaps), see http://www.graintrade.org.au/membership

For a list of commodity futures brokers, see http://www.asx.com.au/prices/find-a-futures-broker.htm

How to sell for cash

Like any market transaction, a cash–grain transaction occurs when a bid by the buyer is matched by an offer from the seller. Cash contracts are made up of the following components, with each component requiring a level of risk management (Figure 16):

- Price—future price is largely unpredictable, so devising a selling plan to put current prices into the context of the farm business is critical to managing price risk.
- Quantity and quality—when entering a cash contract you are committing to deliver the nominated amount of grain at the quality specified, so production and quality risks must be managed.
- Delivery terms—the timing of title transfer from the grower to the buyer is agreed at time of contracting. If this requires delivery direct to end users, it relies on prudent execution management to ensure delivery within the contracted period.
- Payment terms—in Australia, the traditional method of contracting requires title on the grain to be transferred ahead of payment, so counterparty risk must be managed.



GTA Contract No.3

CONTRACT CONFIRMATION

GTA Trade Rules and Dispute Resolution Rules apply to this contract

GRAIN TRADE AUSTRALIA

This Contract is confirmation between:

BUYER
Contract No:
Name:
Company:
Address:
Buyer ABN:
NGR No:

SELLER
Contract No:
Name:
Company:
Address:
Seller ABN:
NGR No:

The Buyer and Seller agree to transact this Contract subject to the following Terms and Conditions:

Commodity: | GTA Commodity Reference:
Grade: | Inspection: (Origin – Destination)
Quantity: | Tolerance: (Refer over)
Packaging: | Weights: (Origin – Destination)
Price: | Excl/Inc/Free GST
Price Basis:
Delivery/Shipment Period: (Delivered, Shipped, Free In Store, Free On Board, Ex-Farm, etc.)
Delivery Point and Conveyance:

Payment Terms: The buyer agrees to pay the seller within . In the absence of a declaration, payment will be 30 days end of week of delivery.

Levies and Statutory Charges: Any industry, statutory or government levies which are not included in the price shall be deducted as required by law.

Disclosures: Is any of the crop referred to in this contract subject to a mortgage, Encumbrance or lien and/or Plant Breeders Rights and/or EPR liabilities and/or registered or unregistered Security Interest? NO YES (Please appropriate box) If "yes" please provide details:

Other Special Terms and Conditions:

All Contract Terms and Conditions as set out above and on the reverse of this page form part of this Contract. Terms and Conditions written on the face of this Contract Confirmation shall overrule all printed Terms and Conditions on the reverse with which they conflict to the extent of the inconsistency. This Contract comprises the entire agreement between Buyer and Seller with respect to the subject matter of this Contract.

Recipient Created Tax Invoice (RCTI).
To assist with the processing of the Goods and Services Tax compliance, the buyer may prepare, for the seller, a Recipient Created Tax Invoice (RCTI). If the seller requires this service they are required to sign this authorisation.
Please issue a RCTI (Please)

Incorporation of GTA Trade & Dispute Resolution Rules:
This contract expressly incorporates the GTA Trade Rules in force at the time of this contract and Dispute Resolution Rules in force at the commencement of the arbitration, under which any dispute, controversy or claim arising out of, relating to or in connection with this contract, including any question regarding its existence, validity or termination, shall be resolved by arbitration.

Buyer's Name: PRINT NAME
Buyer's Signature:
Date:

Seller's Name: PRINT NAME
Seller's Signature:
Date:

This Contract has been executed and this form serves as confirmation and should be signed and a copy returned to the buyer/seller immediately. 2014 Edition

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Figure 16: *Typical terms of a cash contract.*

Source: Grain Trade Australia

The price point within a cash contract will depend on where the transfer of grain title will occur along the supply chain. Figure 17 shows the terminology used to describe these points and the associated costs to come out of each price before growers receive their net return.

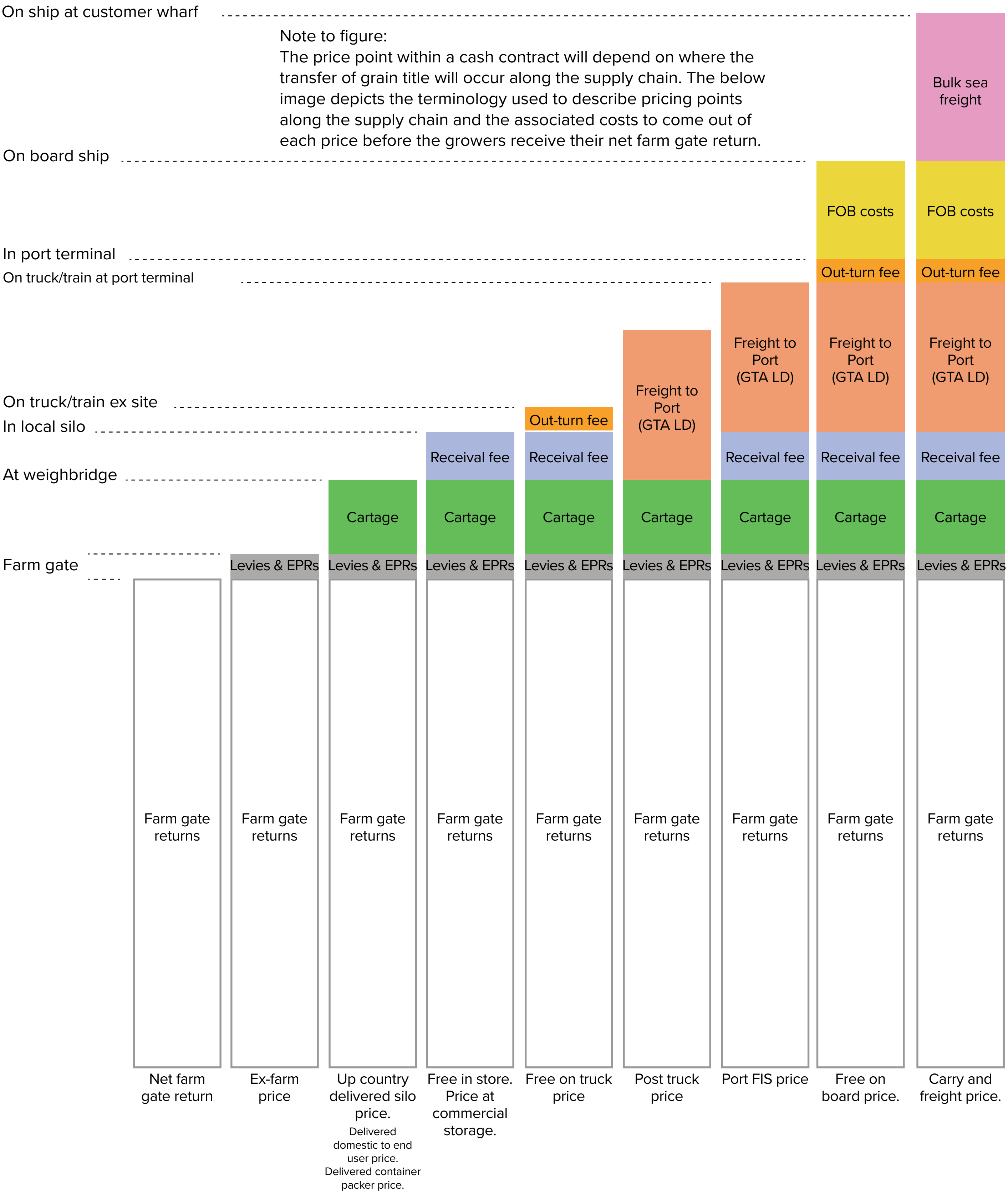


Figure 17: *Cost and pricing points throughout the supply chain.*

Source: Profarmer Australia

MORE INFORMATION

http://www.graintrade.org.au/contracts

http://www.graintrade.org.au/commodity_standards

http://www.graintransact.com.au

http://www.grainflow.com.au

http://emeraldgrain.com/grower-logins/

https://www.cleargrain.com.au/terms-and-conditions

https://www.cleargrain.com.au/get-started

MORE INFORMATION

GTA managing counterparty risk 14/7/2014

Clear Grain Exchange title transfer model

GrainGrowers guide to managing contract risk

Counterparty risk: A producer perspective, Leo Delahunty

Cash sales generally occur through three methods:

- Negotiation via personal contact—traditionally prices are posted as a 'public indicative bid'. The bid is then accepted or negotiated by a grower with the merchant or via an intermediary. This method is the most common and available for all commodities.
- Accepting a 'public firm bid'—cash prices in the form of public firm bids are posted during harvest and for warehoused grain by merchants on a site basis. Growers can sell their parcel of grain immediately by accepting the price on offer via an online facility and then transfer the grain online to the buyer. The availability of this depends on location and commodity.
- Placing an 'anonymous firm offer'—growers can place a firm offer price on a parcel of grain anonymously and expose it to the entire market of buyers, who then bid on it anonymously using the Clear Grain Exchange, which is an independent online exchange. If the firm offer and firm bid match, the particulars of the transaction are sent to a secure settlement facility, although the title on the grain does not transfer from the grower until they receive funds from the buyer. The availability of this option depends on location and commodity. Anonymous firm offers can also be placed to buyers by an intermediary acting on behalf of the grower. If the grain sells, the buyer and seller are disclosed to each counterparty.

Counterparty risk

Most sales involve transferring title of grain prior to being paid. The risk of a counterparty defaulting when selling grain is very real and must be managed. Conducting business in a commercial and professional manner minimises this risk.

Principle: Seller beware.

There is not much point selling for an extra $5/t if you don't get paid.

Counterparty risk management includes:

- Dealing only with known and trusted counterparties.
- Conducting a credit check (banks will do this) before dealing with a buyer they are unsure of.
- Selling only a small amount of grain to unknown counterparties.
- Considering credit insurance or letter of credit from the buyer.
- Never delivering a second load of grain if payment has not been received for the first.
- Not parting with the title before payment, or requesting and receiving a cash deposit of part of the value ahead of delivery. Payment terms are negotiated at time of contracting. Alternatively, the Clear Grain Exchange provides secure settlement whereby the grower maintains title on the grain until they receive payment, and then title and payment are settled simultaneously.

Above all, act commercially to ensure the time invested in implementing a selling strategy is not wasted by poor management of counterparty risk.

Relative values

Grain sales revenue is optimised when selling decisions are made in the context of the whole farming business. The aim is to sell each commodity when it is priced well and to hold commodities that are not well priced at any given time. That is, to give preference to the commodities of the highest relative value. This achieves price protection for the overall farm business revenue and enables more flexibility to a grower's selling program whilst achieving the business goal of reducing overall risk.

Principle: Sell valued commodities, not undervalued commodities.

If one commodity is priced strongly relative to another, focus sales there. Don't sell the cheaper commodity for a discount. For example, a farmer with wheat and barley to sell will sell the one that is getting good prices relative to the other, and hold the other for the meantime (see Figure 18).

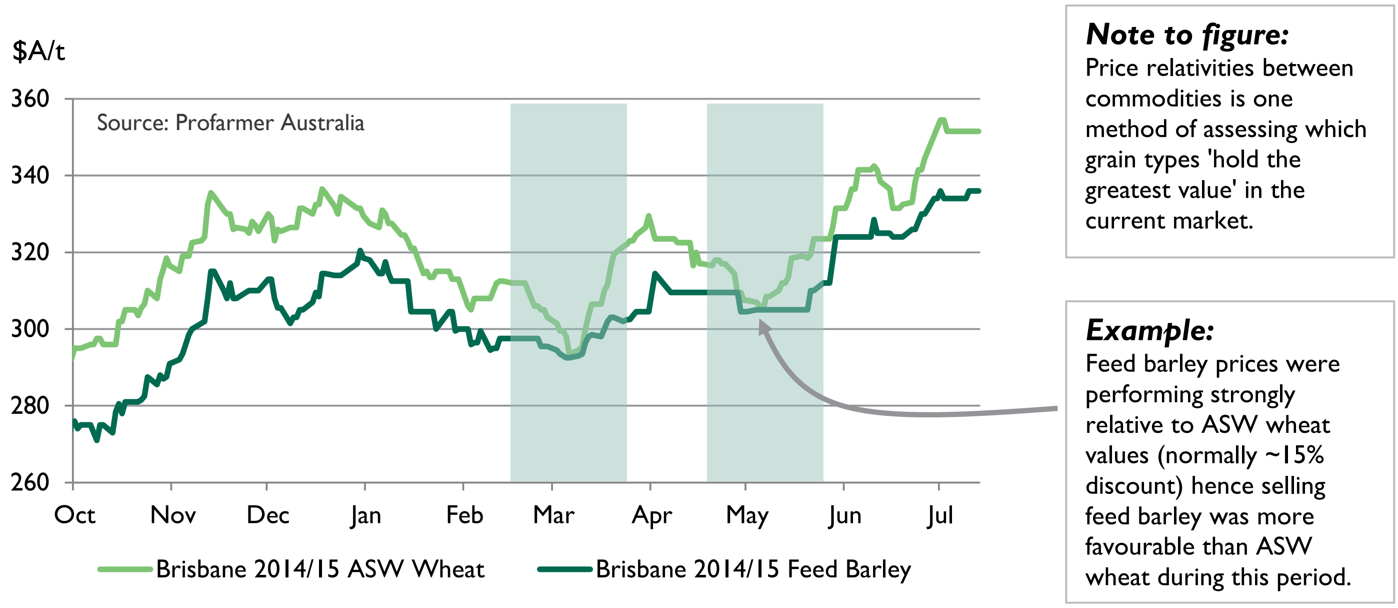


Figure 18: *Brisbane ASW wheat v. feed barley are compared, and the barley held until it is favourable to sell it.*

Source: Profarmer Australia

If the decision has been made to sell wheat, CBOT wheat may be the better alternative if the futures market is showing better value than the cash market (Figure 19).

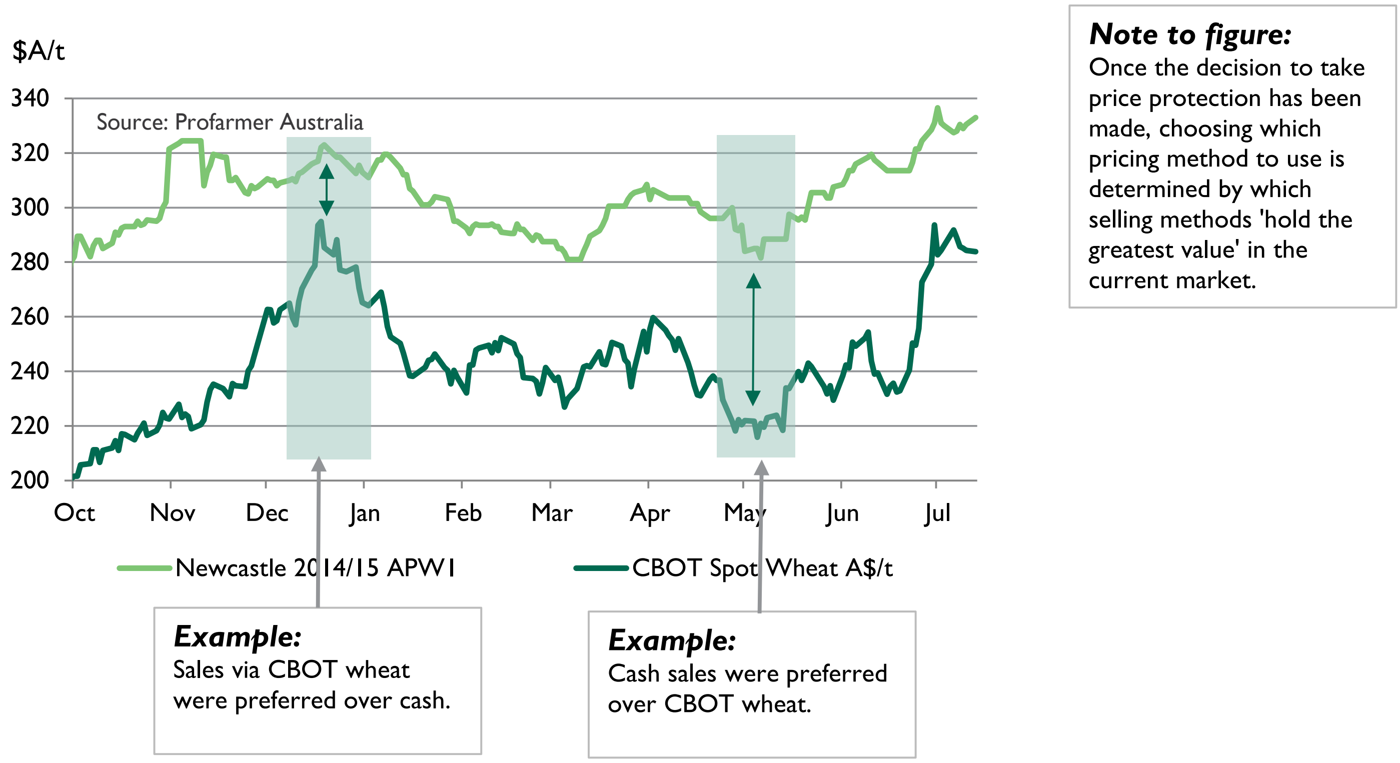


Figure 19: *By comparing prices for Newcastle APWI v. CBOT wheat, the grower can see which market to sell into.*

Source: Profarmer Australia

Contract allocation

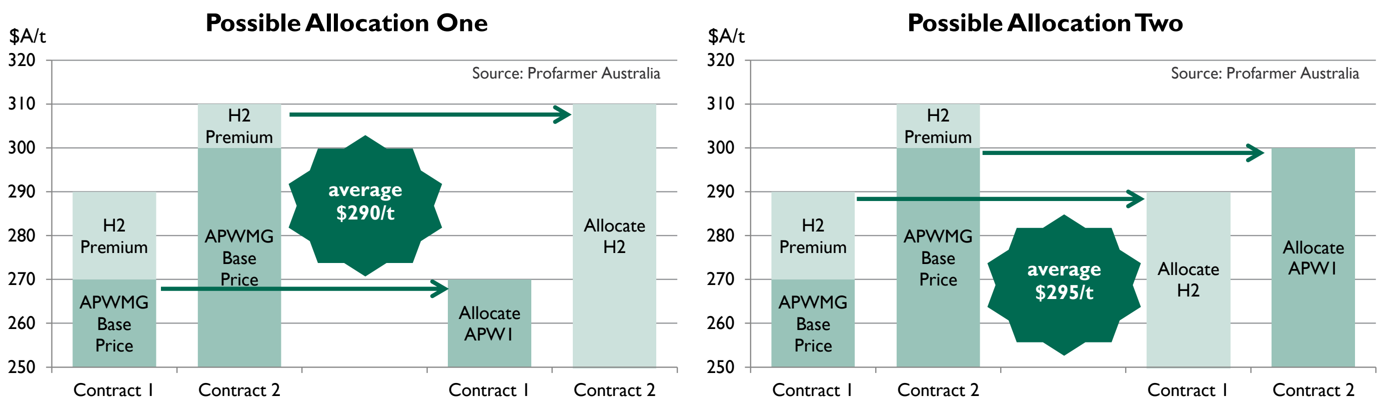
Contract allocation means choosing which contracts to allocate your grain against come delivery time. Different contracts will have different characteristics (price, premiums discounts, oil bonuses etc.), and optimising your allocation reflects immediately on your bottom line.

Principle: Don't leave money on the table.

Contract allocation decisions don't take long, and can be worth thousands of dollars to your bottom line.

To achieve the best average price for their crop growers should:

- allocate lower grades of wheat to contracts with the lowest discounts
- allocate higher grades of wheat to contracts with the highest premiums (Figure 20).



Note to figure:
In these two examples the only difference between acheiving an average price of $290/t and $295/t is which contracts each parcel was allocated to. Over 400/t that equates to $2,000 which could be lost just in how parcels are allocated to contracts.

Figure 20: *How the crop is allocated across contracts can have an impact of earnings from the crop. Although this example uses wheat, the same principle applies for faba beans.*

Source: Profarmer Australia

Read market signals

The appetite of buyers to buy a particular commodity will differ over time depending on market circumstances. Ideally growers should aim to sell their commodity when buyer appetite is strong and stand aside from the market when buyers are not very interested.

Principle: Sell when there is buyer appetite.

When buyers are chasing grain, growers have more market power to demand the price they want.

Buyer appetite can be monitored by:

- The number of buyers at or near the best bid in a public bid line-up. If there are many buyers, it could indicate buyer appetite is strong. However, if one buyer is offering $5/t above the next best bid, it may mean that cash prices are susceptible to falling $5/t as soon as that buyer satisfies their appetite.
- Monitoring actual trades against public indicative bids. When trades are occurring above indicative public bids it may indicate strong appetite from merchants and the ability for growers to offer their grain at price premiums to public bids. [8]

8 Profarmer Australia (2016), Marketing Field Peas, GRDC Northern Field Pea GrowNote

The selling strategy is converted to maximum business revenue by:

- ensuring timely access to information, advice and trading facilities
- using different cash market mechanisms when appropriate
- minimising counterparty risk by effective due diligence
- understanding relative value and selling commodities when they are priced well
- thoughtful contract allocation
- reading market signals to extract value from the market or prevent selling at a discount. [9]

15.3 Northern faba beans: market dynamics and execution

15.3.1 Price determinants for northern faba beans

Faba bean production in Australia has grown to become an important part of the Australian grain industry and an important part of many growers' rotations.

On average approximately 80% of Australia's faba bean crop is exported, principally for human consumption. The Middle East, and particularly Egypt, are the main export markets for Australian faba beans.

The main competitors in to this market are the UK and France. Although China is also a major producer, it is a net importer of faba beans. France and the UK have a freight advantage over Australian product into Middle Eastern and Egyptian markets, because they are so much closer; however, particular pests common in Europe and the United Kingdom, but not Australia, provide Australian product with a quality advantage.

The remaining 20% of the crop is used in the domestic stockfeed and aquaculture industries.

Hence the major price determinants for faba beans are:

- global supply and demand
- quality of the global crop
- the timing of Australian exports.

Due to the small relative size of pulse markets, markets can be illiquid. This may result in sharp spikes and reduction in prices from time to time.

When the Australian faba bean crop is sown (from late April to the end of June for most areas), the areas planted and predicted yields for France and United Kingdom should already be known. The sowing intentions in Egypt and Chinese southern production (mainly broad beans) should also be evident (Figure 21).

When the Australian crop is harvested, the French, UK and Egyptian beans have been harvested. So, too, have the Chinese northern beans (small and broad bean types).

These world production and sowing areas can affect demand for the Australian crop, and this will feed into bean prices achievable and how Australian farmers time marketing and selling. French and UK harvest yields and quality expectations have the most impact on demand for Australian beans. [10]

9 Profarmer Australia (2016), Marketing Field Peas, GRDC Northern Field Pea GrowNote

10 Profarmer Australia (2016), Marketing Field Peas, GRDC Northern Field Pea GrowNote

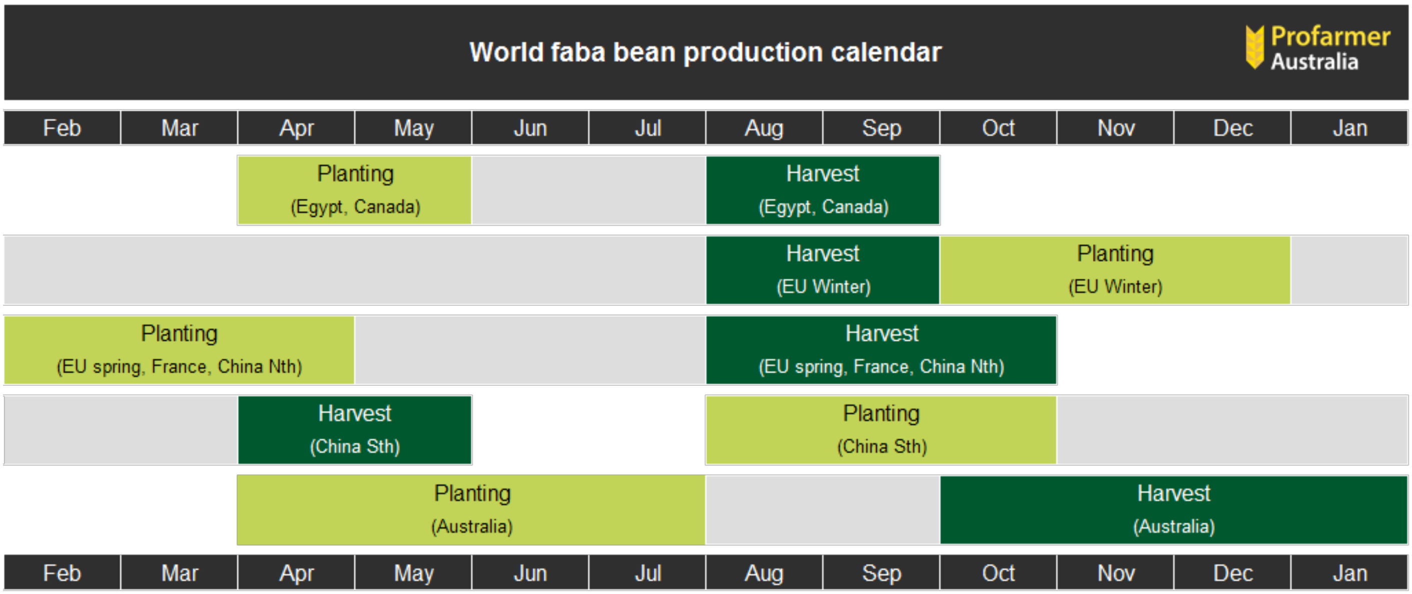


Figure 21: *Global faba bean production calendar.*

Source: Profarmer Australia

The pace of Australian faba bean exports is typically strongest shortly after our harvest (see Figure 22) as buyers seek to move crop ahead of the next Egyptian planting season and as supplies from the last northern hemisphere crop become more scarce. [11]

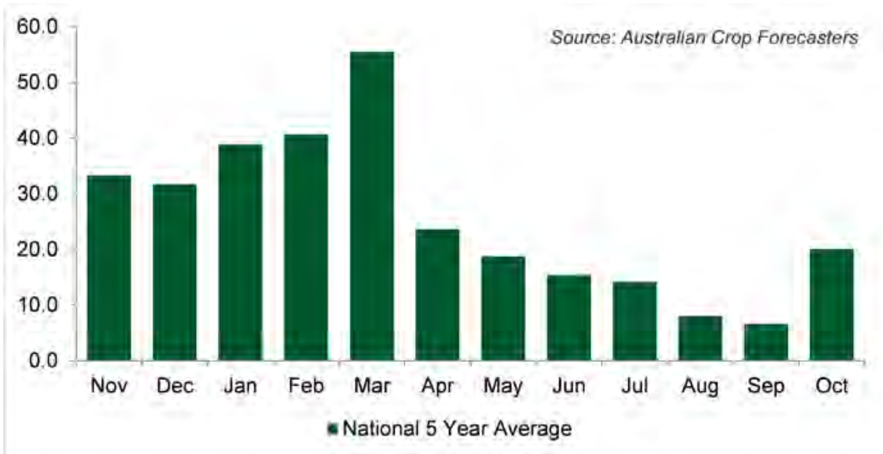


Figure 22: *Average monthly export pace ('000 t) of Australian faba beans and broad beans, averaged over five years.*

Source: Australian Crop Forecasters

15.3.2 Ensuring market access for northern faba beans

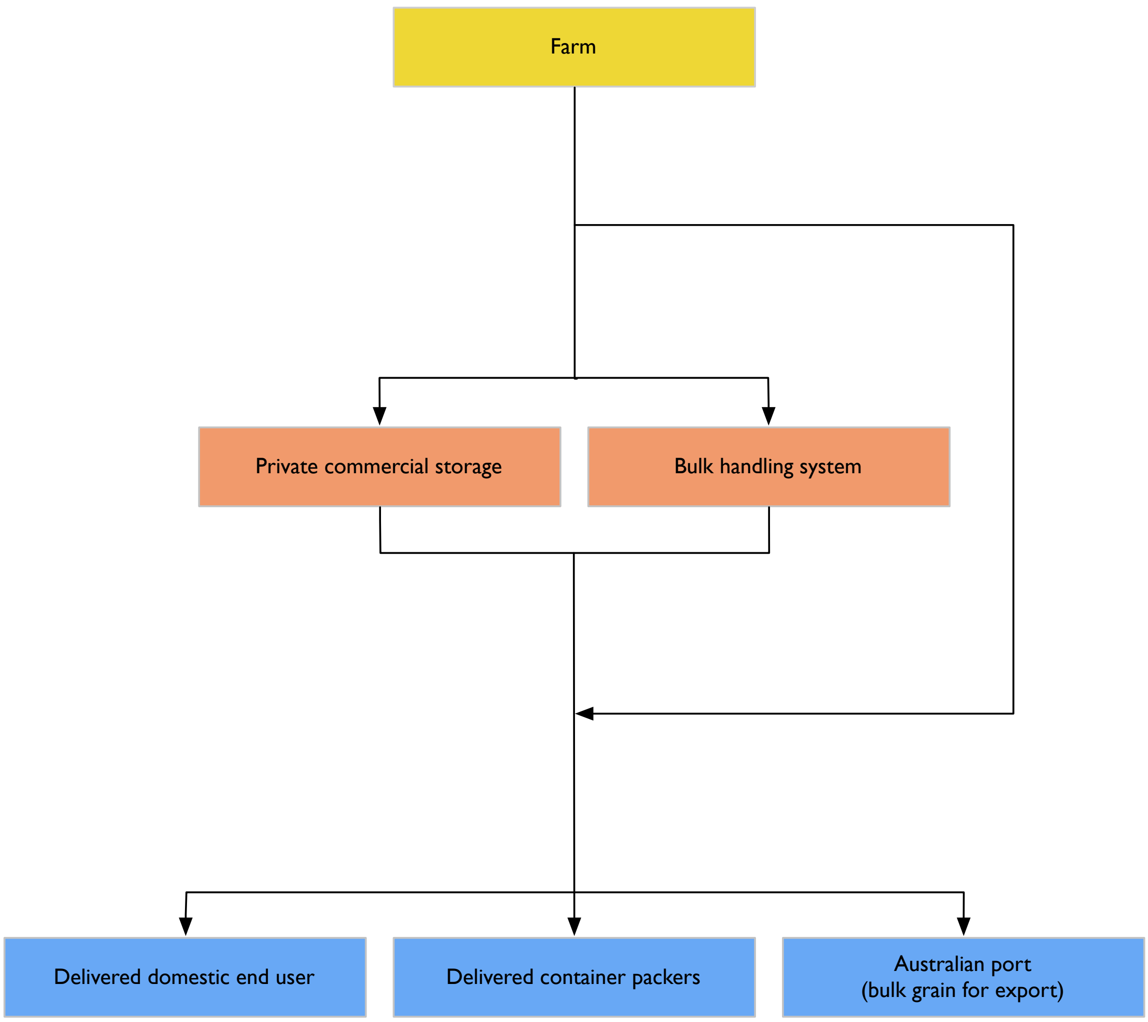
The major food markets for faba beans are in the Middle East and Egypt, with the latter being the largest importer. There are several other medium size importers and many small importers. Quality requirements in terms of size and colour differ between end uses and between markets. Australia is one of the major exporters of faba beans along with France and the UK.

The timing of Ramadan can also influence appetite for faba beans. Middle Eastern markets will tend to time purchases to arrive in advance of the Ramadan period, hence export activity can slow in the period before and during Ramadan.

11 Profarmer Australia (2016), Marketing Field Peas, GRDC Northern Field Pea GrowNote

For faba beans which are destined for export markets, understanding whether they are likely to ship via bulk export or in containers can help to inform storage decisions and ensure market access (Figure 23). Although the bulk-handling system can be cheaper for product destined for bulk export, storage on the farm and delivery direct to the end user is likely to be cheaper and also more flexible in the domestic and container-export markets.

Most human consumption markets prefer faba beans that are >8 mm in size. Smaller faba beans and broken beans (kibble) may be sold for the production of bean flour or stockfeed. Tolerances for seed discolouration are also much lower for human consumption markets, especially for canning beans. [12]



Note to figure:
Storage decisions should be determined by assessing market access. In Western Australia the large majority of wheat is exported in bulk. Hence the bulk handling system should provide efficiencies to market. Alternatively on-farm and private commercial storage may be a more reasonable method of accessing the container and end user markets.

Profarmer AUSTRALIA

Figure 23: *Australian supply chain.*

Source: Profarmer Australia

15.3.3 Converting tonnes into cash for northern faba beans

Given the volatile nature of faba bean prices, setting a target price using knowledge of the market outlined in section 15.2.2 will minimise the farmer's risk of having to accept an unprofitable price or of holding out for an unrealistically high price that may not eventuate.

12 Profarmer Australia (2016), Marketing Field Peas, GRDC Northern Field Pea GrowNote

MORE INFORMATION

World pulse production calendar, in Pulses: Understanding global markets

Australian pulse traders

Faba beans, in Understanding global markets

Faba bean production: southern and western region

AEGIC: Australian pulses

Agriculture Victoria: Growing faba bean

There are some forward price mechanisms available for faba beans, including area-contracts and traditional fixed-volume forward contracts. Area-based contracts tend to price at a discount compared to fixed-volume contracts, but this needs to be weighed up against the level of production risk inherent in each contract.

As with all sales, minimising counterparty risk and having an understanding the contract of sale is essential. Counterparty risk is especially important for pulse marketing as there is often a higher risk of contract default in international pulse markets than for canola or cereals. This is due to the markets they are traded into, a lack of appropriate price-risk tools (such as futures), and the visual and subjective nature of determining quality. These can place extra risk on Australian traders endeavouring to find buyers for their product.

Price discovery of export values for faba beans in northern markets can be difficult given the small size of the market, particularly relative to other grains produced. Hence South Australian markets, which have much greater market depth, can be an important source of price discovery, especially for those looking to understand export values (Figures 24 and 25). When pricing into domestic stockfeed markets, consideration of values of alternate feed grain can also provide an indication when setting a price for your faba beans. [13]

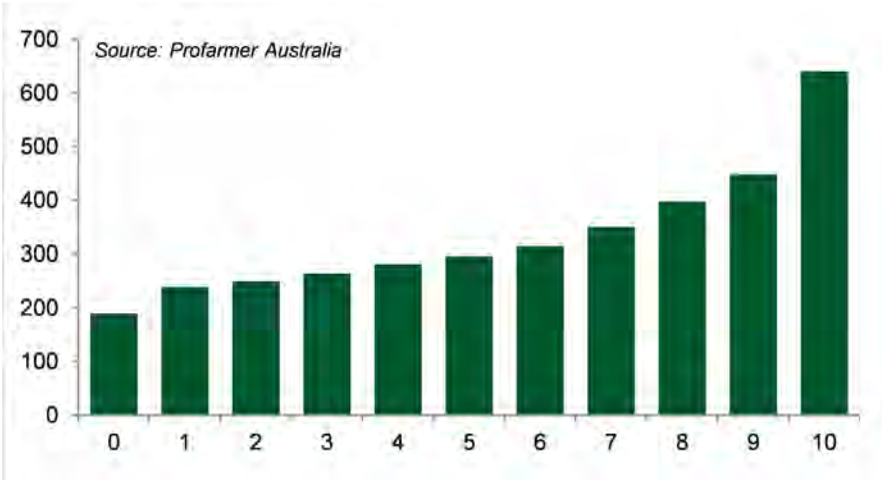


Figure 24: *Port Adelaide faba bean deciles. Deciles provide an indication of price performance relative to historical values. Decile 1 indicates values in the bottom 10% of historical observations, and a decile 9 indicates the top 10%.*

Source: Profarmer Australia

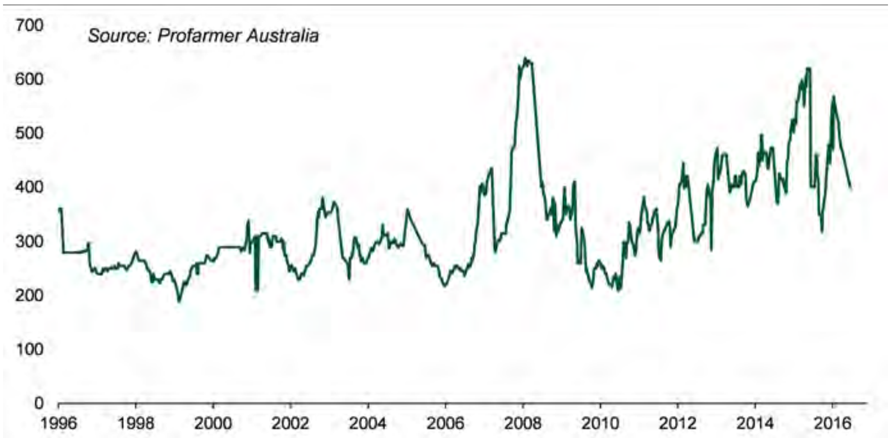


Figure 25: *Long-term Port Adelaide faba bean prices.*

Source: Profarmer Australia

13 Profarmer Australia (2016), Marketing Field Peas, GRDC Northern Field Pea GrowNote

15.4 World faba bean production

Eight of the regular and largest bean-producing countries are listed in Table 2 (FAO 2012 data), some of which have a major impact on world demand or on trade. [14] Some 36 countries have been in the top 20 producing countries during 1991–2010; Table 2 illustrates the percentage contribution of the top 20 producers.

Table 2: *World production of all Vicia faba types (dry) including top producing countries by year.*

Year	Production ('000 t) by country								
	World top 20 total	China	Ethiopia	Egypt	France	Australia	UK	Sudan	Morocco
1991	2,938,908	1,250,000	372,754	466,000	63,245	64,400	107,000	45,000	203,830
1992	2,372,898	1,000,000	326,442	382,000		99,000	143,000	35,000	67,520
1993	3,120,484	1,750,000	312,405	438,000		135,000	132,000	38,000	16,040
1994	3,239,316	2,000,000	260,095	357,000		50,000	138,000	55,000	111,110
1995	3,261,678	1,790,000	375,002	392,300	36,420	127,600	155,000	89,000	35,910
1996	3,351,726	1,750,000	361,051	442,394	37,655	170,800	100,000	83,000	143,530
1997	3,079,892	1,520,000	360,895	476,252	39,130	162,700	116,000	84,000	92,990
1998	3,453,145	1,827,000	338,844	523,129	53,613	194,300	81,000	85,000	107,670
1999	3,312,351	1,780,000	286,743	307,083	57,229	226,400	155,000	99,000	55,450
2000	3,464,971	1,788,000	389,343	353,909	69,665	253,000	153,000	131,000	32,600
2001	3,922,700	1,950,000	453,841	439,480	158,000	350,000	86,000	89,000	82,020
2002	4,065,791	2,100,000	453,125	400,910	310,437	147,313	94,800	146,000	88,780
2003	4,202,977	2,142,000	430,196	336,840	276,300	277,000	146,800	171,000	103,060
2004	3,990,806	1,806,000	551,984	330,490	364,549	167,500	113,500	173,000	109,250
2005	4,134,134	2,000,000	516,180	281,650	372,179	329,000	88,500	112,000	72,960
2006	3,767,583	1,730,000	599,128	247,490	290,480	108,000	94,000	160,000	180,490
2007	3,600,292	1,620,000	576,156	301,770	245,966		160,000	162,000	69,850
2008	4,049,240	1,800,000	688,667	244,109	314,683	217,000	73,000	140,400	108,680
2009	4,034,579	1,650,000	610,845	297,620	438,338	192,000	100,000	112,500	153,040
2010	4,118,197	1,700,000	606,800	233,523	480,935	202,300	87,000	152,000	149,380

Source: FAOStat, Food and Agriculture Organization, United Nations.

15.5 Australian faba bean exports

Australia's larger scale production of faba bean started after 1980 with the release of the variety Fiord. Before that, a few crops of horse beans were grown sporadically from the 1920s to 1970s to supply the domestic horse-racing trade, for green manure crops or for export to the UK. Production in Australia steadily increased as the industry developed, reaching two plateaus, the first in 1992–95 when South Australian production stabilised. Production was decreasing in Victoria at that time but increasing in New South Wales and Western Australia. From 1995, most states increased production area, to peak at 206,000 ha in 2000 before dropping in all states, except South Australia, to 156,000 ha in 2004. Major influences were the ability to deal with foliar disease and tight bean rotations.

14 Southern/Western Faba and Broad Bean—Best Management Practices Training Course. Module 3—Varieties. 2013. Pulse Australia.

After the 2002 drought, Australia lost market share to UK and France because of inability to supply sufficient product.

The area sown to faba bean has fluctuated over the past 30 years, and during the latter period, interest in lentil, chickpea and canola had increased. Faba bean area in Australia has now stabilised at ~150,000 ha (in 2011), with production at around 270,000 t. Broad bean production is largely confined to specific high-rainfall areas in South Australia particularly. The combined area of faba and broad beans is estimated at 196,000 ha in 2012, and indications are that the demand from the Middle East has not diminished. Export destinations are shown in Figure 26, and yearly export quantities by total yearly tonnage in Figures 27 and by destination in Figure 28.

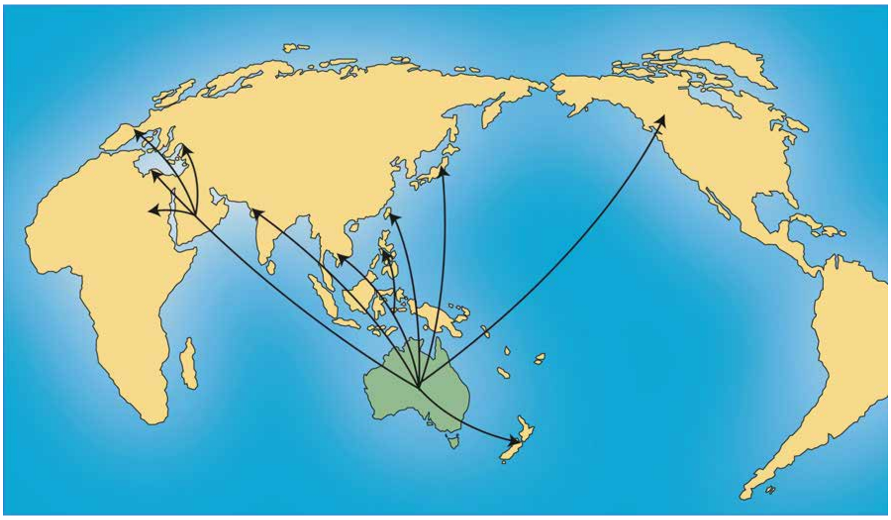


Figure 26: *Destinations for faba and broad beans from Australia.*

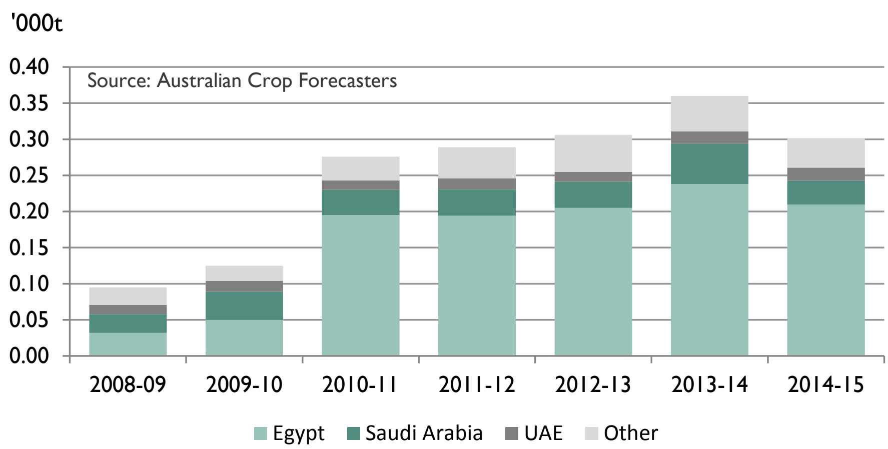


Figure 27: *Australian faba bean exports 2008–09 to 2014–15.*

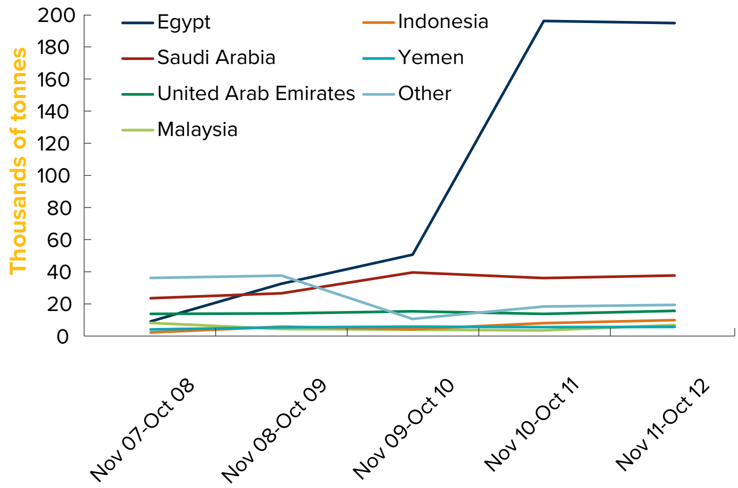


Figure 28: *Major destinations and tonnages of beans exported from Australia.*

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Using Pulses as Forage Crops. Pulse Australia Bulletin, http://www.pulseaus.com.au/growing-pulses/publications/using-pulses-forage

British Pulse exporters web site: http://www.bepa.co.uk/

PGRO web site http://www.pgro.org/

Market web sites:

http://www.alibaba.com/showroom/dry-broad-beans.html

http://importer.tradekey.com/egyptian-beans-importer.html

http://www.wakalex.com/

FAO (2003) WTO Agreement on agriculture: the implementation experience – Egypt, http://www.fao.org/docrep/005/Y4632E/y4632e0c.htm

Current and past research

Project Summaries www.grdc.com.au/ProjectSummaries

As part of a continuous investment cycle each year the Grains Research and Development Corporation (GRDC) invests in several hundred research, development and extension and capacity building projects. To raise awareness of these investments the GRDC has made available summaries of these projects.

These project summaries have been compiled by GRDC's research partners with the aim of raising awareness of the research activities each project investment.

The GRDC's project summaries portfolio is dynamic: presenting information on current projects, projects that have concluded and new projects which have commenced. It is updated on a regular basis.

The search function allows project summaries to be searched by keywords, project title, project number, theme or by GRDC region (i.e. Northern, Southern or Western Region).

Where a project has been completed and a final report has been submitted and approved a link to a summary of the project's final report appears at the top of the page.

The link to Project Summaries is www.grdc.com.au/ProjectSummaries

Final Report Summaries http://finalreports.grdc.com.au/final_reports

In the interests of raising awareness of GRDC's investments among growers, advisers and other stakeholders, the GRDC has available final reports summaries of projects.

These reports are written by GRDC research partners and are intended to communicate a useful summary as well as present findings of the research activities from each project investment.

The GRDC's project portfolio is dynamic with projects concluding on a regular basis.

In the final report summaries there is a search function that allows the summaries to be searched by keywords, project title, project number, theme or GRDC Regions. The advanced options also enables a report to be searched by recently added, most popular, map or just browse by agro-ecological zones.

The link to the Final Report Summaries is http://finalreports.grdc.com.au/final_reports

Online Farm Trials http://www.farmtrials.com.au/

The Online Farm Trials project brings national grains research data and information directly to the grower, agronomist, researcher and grain industry community through innovative online technology. Online Farm Trials is designed to provide growers with the information they need to improve the productivity and sustainability of their farming enterprises.

Using specifically developed research applications, users are able to search the Online Farm Trials database to find a wide range of individual trial reports, project summary reports and other relevant trial research documents produced and supplied by Online Farm Trials contributors.

The Online Farm Trials website collaborates closely with grower groups, regional farming networks, research organisations and industry to bring a wide range of crop research datasets and literature into a fully accessible and open online digital repository.

Individual trial reports can also be accessed in the trial project information via the Trial Explorer.

The link to the Online Farm Trials is Online trials - http://www.farmtrials.com.au/

Key contacts

GRDC Panel

John Minogue, Chair

John Minogue runs a mixed broadacre farming business and an agricultural consultancy, Agriculture and General Consulting, at Barmedman in south-west NSW. John is chair of the local branch of the NSW Farmers' Association, has formerly sat on the grains committee of the NSW Farmers' Association and is a winner of the Central West Conservation Farmer of the Year award. John has also been involved in the biodiversity area as a board member of the Lachlan Catchment Management Authority. His vast agricultural experience in central west NSW has given him a valuable insight into the long-term grains industry challenges.

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Penny Heuston, Deputy Chair

Penny Heuston is an agronomist based in Warren, NSW. She is passionate about the survival of the family farm and its role in the health of local economies. Penny is dedicated to ensuring research is practical, farm-ready and based on sound science and rigour. She sees 'two-way communication' as one of the panellists' primary roles and is committed to bringing issues from the paddock to 'the lab' and conversely, the science to the paddock.

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Loretta Serafin

Loretta Serafin has extensive experience as an agronomist in north-west NSW and works with the NSW Department of Primary Industries in Tamworth. As the leader northern dryland cropping systems, she provides expertise and support to growers, industry and agronomists in the production of summer crops. Loretta is a member of numerous industry bodies and has a passion for helping growers improve farm efficiency. She sees her role as a conduit between advisers, growers and the GRDC to ensure growers' research needs are being met.

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Jules Dixon

Jules Dixon has an extensive background in agronomy and an established network spanning eastern Australia and WA including researchers, leading growers and agronomy consultants through to the multinational private sector. Based in Sydney, Jules operates a private consultancy specialising in agronomy, strategy development and business review.

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Dr Neil Fettell

Neil Fettell is a part-time senior research adviser with Central West Farming Systems and runs a small irrigation farm near Condobolin, NSW. Neil has a research agronomy background, conducting field research in variety improvement, crop physiology and nutrition, water use efficiency and farming systems. He is a passionate supporter of research that delivers productivity gains to growers, and of grower participation in setting research goals.

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Andrew McFadyen

Andrew McFadyen is an agronomist and manager with Paspaley Pastoral Company near Coolah, NSW, with more than 15 years' agronomy and practical farm management experience. He is an active member of the grains industry with former roles on the Central East Research Advisory Committee, NSW Farmers Coolah branch and planning committees for GRDC Updates. He is also a board member and the chair of Grain Orana Alliance.

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Jack Williamson

Jack Williamson is a private agricultural consultant and helps run a family broadacre farm near Goondiwindi, Queensland. Six years of retail agronomy and three years of chemical sales management have given Jack extensive farming systems knowledge, and diverse crop management and field work experience. He is a member of the Northern Grower Alliance local consultative committee and Crop Consultants Australia.

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Arthur Gearon

Arthur Gearon is a grain, cotton and beef producer located near Chinchilla, Queensland. He has a business degree from the Queensland University of Technology in international business and management and has completed the Australian Institute of Company Directors course. He is vice-president of AgForce Grains and has an extensive industry network throughout Queensland. Arthur believes technology and the ability to apply it across industry will be the key driver for economic growth in the grains industry.

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Dr Tony Hamilton

Tony Hamilton is a grower from Forbes, NSW, and managing director of an integrated cropping and livestock business. He is a director of the Rural Industries Research and Development Corporation. He has worked as an agricultural consultant in WA and southern NSW. With a Bachelor of Agricultural Science and a PhD in agronomy, Tony advocates agricultural RD&E and evidence-based agriculture.

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Brondwen MacLean

Brondwen MacLean was appointed to the Northern Panel in August 2015 and is the GRDC executive manager for research programs. She has primary accountability for managing all aspects of the GRDC's nationally coordinated R&D investment portfolio and aims to ensure that these investments generate the best possible return for Australian grain growers. Prior to her current appointment, Brondwen was senior manager, breeding programs, and theme coordinator for Theme 6, Building Skills and Capacity.

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David Lord, Panel Support

David Lord operates Lord Ag Consulting, an agricultural consultancy service. Previously, David worked as a project officer for Independent Consultants Australia Network, which gave him a good understanding of the issues growers are facing in the northern grains region. David is the Northern Panel and Regional Grower Services support officer.

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