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GRAINS RESEARCH & DEVELOPMENT CORPORATION

FABA BEAN

SECTION 4

PLANT GROWTH AND PHYSIOLOGY

FABA BEAN GROWTH STAGES | GROWTH AND DEVELOPMENT | CROP DEVELOPMENT

Plant growth and physiology

Key messages

- Faba bean flowers are white with some purple or black markings, and are both self-pollinated and cross-pollinated.
- A rigid plant, the faba bean is 0.5–1.8 m tall with stout, hollow but erect stems of a square cross-section.
- Faba beans will survive despite periods of waterlogging, especially in cool winter conditions.
- Faba bean seeds contain about 25% protein, 10% fat and 55% carbohydrate.

4.1 Faba bean growth stages

Uniform growth-stage descriptions were developed for the faba bean plant based on visually observable vegetative and reproductive events.

Germination is hypogeal, with the cotyledons remaining below the soil surface. This enables it to emerge from sowings as deep as 25 cm. 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.

The vegetative stage is determined by counting the number of developed nodes on the main stem, above ground level. Nodes are counted from the point at which the first true leaves are attached to the stem. The last node counted must have its leaves unfolded (Figure 1).

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).

The reproductive stages begin when the plant begins to flower at any node.

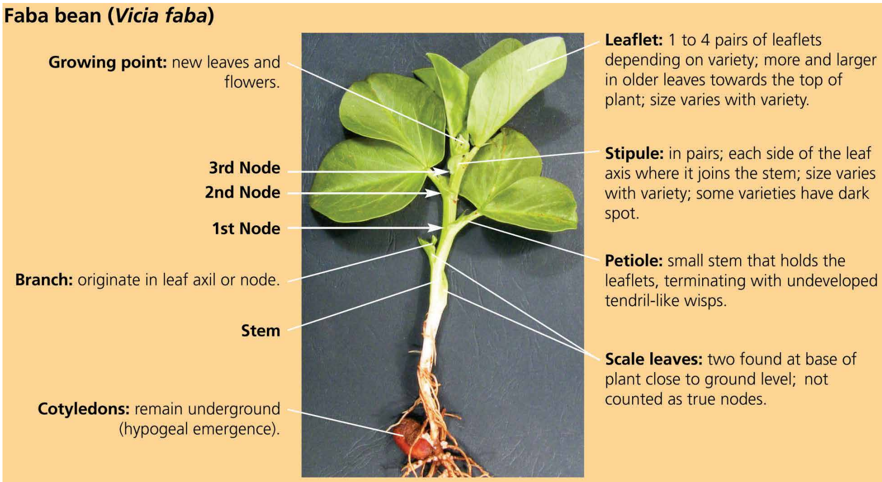

Figure 1: *Faba bean early growth stages.*

Source: Holding and Bowcher (2004) Weeds in Winter Pulses, CRC for Australian Weed Management

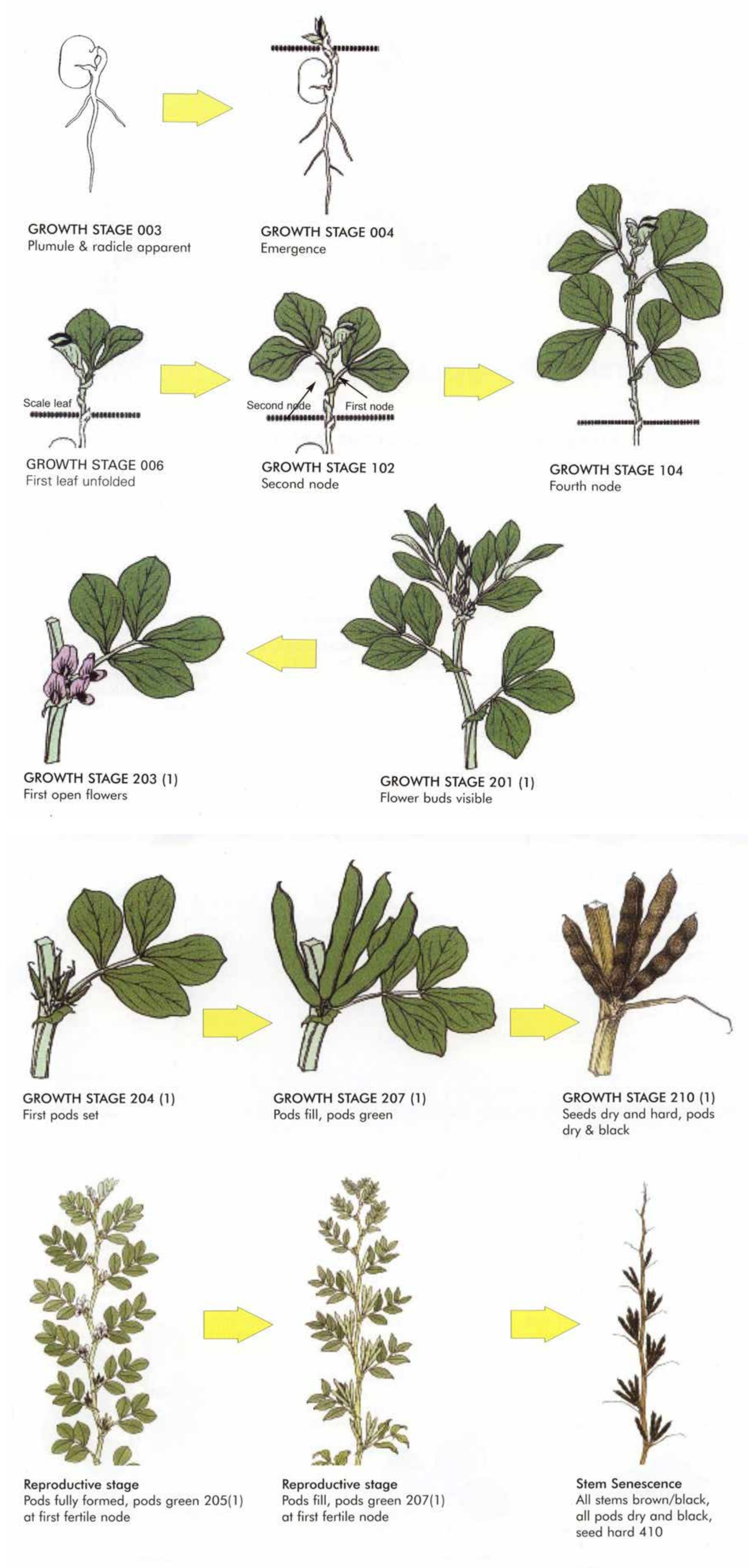

Figure 2: *Stages in the development of the faba bean (Vicia faba).*

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	First leaf fully unfolded with one pair leaflets
	GS 10(X) X node	X, leaf fully unfolded with more than one pair of leaflet
	GS1(N) N, Last recorded node	N, any number of nodes on the main stem with fully unfolded leaves according to cultivar
20 Reproductive	GS 201 Flower buds visible	First buds visible and still green
	GS 203 First open flower	First open flowers on fist raceme
	GS 204 Pod set	First pods visible at first fertile node
	GS 205 Green pods fully formed	Small immature seeds within
	GS 207 Pod fill	Seeds maximum size and fill pod cavity
	GS 209	Seeds rubbery, pods still pliable turning black
	GS 210 Dry seed	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.

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 (Photo 1).

Photo 1: *An Australian semi-determinate faba bean type that is typical of our current varieties.*

Photo: W. Hawthorne, Pulse Australia

Photo 2: *A breeding line that is determinate. No new growth appears above the pods.*

Photo: W. Hawthorne, Pulse Australia

Flower terminals develop from the auxiliary bud at the base of each node, with flowering commencing at ~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. [1]

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. [2]

1 Pulse Breeding Australia (2013) Southern/Western Faba & Broad Bean—Best Management Practices Training Course. Module 2–Plant Physiology.

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4.2 Growth and development

4.2.1 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 seedling cotyledons (embryonic leaves) remain underground inside the seed coat while providing energy to the rapidly growing roots and shoots.

Emergence occurs seven to 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–8th node, leaves have two or three pairs of leaflets. The development of multiple pairs of leaflets per leaf generally corresponds with the 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, 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. 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 the phase 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 a 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 (Photo 3). 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 the 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.

Photo 3: *Germinating bean seed.*

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. [3]

Implications of this information are that:

- Seeds 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 has 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.
- 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. [4]

4.2.2 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. Leaflets are not serrated. Unlike most other members of the *Vicia* genus, the faba beans 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). [5]

4.2.3 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.

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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.

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) (Photo 4). The plant provides carbohydrates for the bacteria in return for N_2 fixed inside the nodules.

These nodules are visible within about a month of 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. Nitrogen fixation is highly sensitive to waterlogging; hence, faba beans need well-aerated soils.

Photo 4: *Nodulated roots.*

Source: W. Hawthorne, Pulse Australia

Waterlogging and drainage

Faba beans are considered tolerant of waterlogging. They will survive despite periods of waterlogging, especially in the cool conditions of winter. However, waterlogging will reduce yields.

Soil nitrate and temperature effects on nodulation

Nitrate in the soil can delay nodulation, decrease nodule number and decrease nodule activity. Nodulation can be markedly reduced by 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 beans may in part be due to better nodulation under warm (15°C) soil conditions.

Root mass and penetration

Faba-bean roots do not penetrate to the same soil depths as those of wheat or barley. Studies have shown water use by wheat and barley over the growing season was unaffected by row spacing; however, both cereals were more effective than faba beans at extracting soil water. In contrast to the cereals, faba beans 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 3). [6]

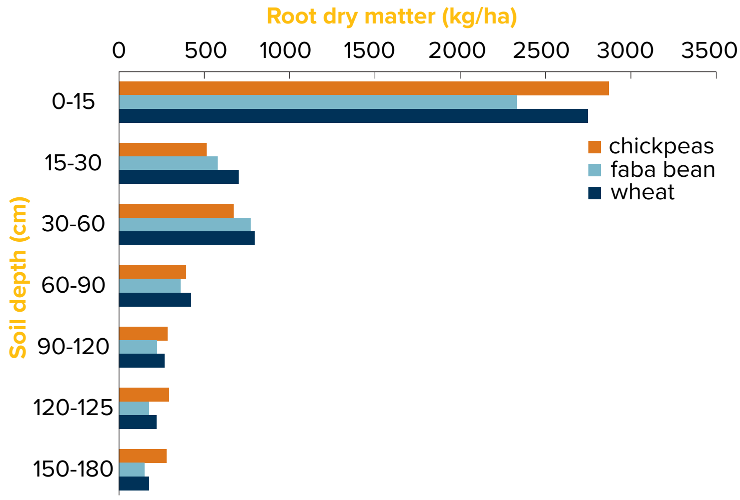

Figure 3: *Root biomass (kg/ha) at each soil depth of chickpea, faba bean, and wheat.*

Source: Turpin et al. 2002

4.2.4 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.

Primary branches, starting from ground level, grow from buds at the lowest nodes or plumular shoot, as well as from the lateral branches of the seedling (Photo 5). 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. [7]

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Photo 5: *Maturing, well-podded faba bean plants showing their basal branching habit and multiple-podding nodes.*

Photo: W. Hawthorne, Pulse Australia

4.2.5 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 three consecutive 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 sustain the flowers. Necessity for sunlight to improve podset has implications for time of sowing, sowing rate and for row spacing in faba beans.

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 five to seven 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.

Photo 6: *Flowering faba bean.*

Photo: Drew Penberthy, Penagcon

Faba bean flowers are large, borne on short pedicels in clusters of 1–5 on each axillary raceme, usually from the node where flowering commences (Photo 6). 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) (Photo 7).

Photo 7: *Faba bean flowers are not completely white, because of the tannins that occur in their seeds. Only tannin-free faba beans that lack anthocyanin, will produce white flowers.*

Photo: W. Hawthorne, Pulse Australia

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). In general, warmer temperatures hasten development, as reflected in thermal-time calculations.

Progress toward flowering follows a conventional thermal-time model. For commercial faba bean varieties, ~830–1000 degree-days (>0°C) are 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

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.

If there is a critical mean or average daily temperature for faba beans to flower, in most current varieties it would be <10°C.

Once true flowers are produced in faba beans, a period of cool weather or lack of sunlight for 3 days can cause flower or pod abortion to varying degrees.

If moisture and temperature conditions are favourable, additional crop growth, node production, flowering and crop height occur until flowering ceases. Hot conditions (maximum temperatures >30°C) or lack of moisture cause flowering, and hence additional crop growth, to cease.

Pollination

Pollination takes place after the flower bud opens. Faba beans are allogamous, or have a mixed mating system with both self- and cross-pollination. Faba bean pollen is very heavy and sticky and 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 this varies with environmental conditions, the presence of insect vectors and variety. The main insect pollinators are honeybees.

If low numbers of bees are present, introducing commercial pollinating bees through the crop in a grid of at least two hives/ha can increase yield by 30–100% and has been useful in South Australia. [8]

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Photo 8: *Bee hives need to be strategically placed within crops in SA to aid pollination.*

Photo: W. Hawthorne, Pulse Australia

Pod development

Faba bean plants generally produce many flowers; however, a large proportion (~80–90%) do not develop into pods, depending on the variety, sowing date and other environmental conditions (Figures 10–12). Some pods that set do not progress to fill seeds either.

Photo 9: *Flower raceme indicates flowers that did not set pods.*

Photo: W. Hawthorne, Pulse Australia

Photo 10: *Faba bean pod and dead flowers that, when removed, may show small pods.*

Photo: W. Hawthorne, Pulse Australia

Photo 11: *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

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.

Under favourable temperature and soil-moisture conditions, the time taken from fertilisation of the ovule (egg) to the first appearance of a pod (podset) is about six days. The seed then fills over the next three to four 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.

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.

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 (Photo 13). 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 podset and therefore the yield potential.

Photo 12: *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 WA. The amount of radiation hitting the flower from when it opens and for the following three days is the main contributing factor.

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. [9]

Some growers have associated poor podset with early sowing. However, poor light in dense canopies, and hence low photosynthesis, is likely to be the major cause, often in conjunction with low levels of pollinator activity and possible chocolate spot 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 three to six 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. [10]

Seed development

Faba bean pods vary greatly in size between varieties because of varying seed sizes. Seed-filling and subsequent seed size are highly dependent on variety, the number of seeds set and weather conditions.

Seeds are characteristically oval and flat, with a ridged, dimpled or smooth seed coat. Seed colour varies between varieties from white (tannin-free) to light tan or green (commercial varieties), brown (aged beans), and even purple or black (specific lines).

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Kernel colour is yellow. Seed numbers vary from one to eight per pod, and not every ovule in a pod necessarily develops.

The 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. [11]

4.3 Crop development

Crop duration is highly correlated with temperature: crops will take different times from sowing to maturity under different temperature regimes. The concept of thermal time is the method used to represent a crop's need 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 need 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. The base temperature for calculating thermal time for faba bean is 0°C.

Thermal time is also referred to as heat units, degree-days or growing degree-days. 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 beans is significantly reduced. Low light or low average daily temperatures (<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 podset and yield.

The phenology of most crops can be described using nine phases:

1. Sowing to germination.
2. Germination to emergence.
3. A period of vegetative growth after emergence, called the basic vegetative phase (BVP), during which the plant is unresponsive to photoperiod.
4. A photoperiod-induced phase (PIP), which ends at floral initiation.
5. A flower development phase (FDP), which ends at 50% flowering.
6. A lag phase prior to commencement of grain-filling. This period is relatively short in faba beans.
7. A linear phase of grain-filling.
8. A period between the end of grain-filling and physiological maturity.
9. A harvest-ripe period prior to grain harvest.

These stages of development are generally modelled as functions of temperature (phases i–iii, and v–viii) and photoperiod (phase iv).

Faba beans are a medium-duration crop, usually beginning flowering within 29 to 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.

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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. [12]

Photo 13: *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

4.3.1 Erectness

Faba beans are prone to lodging, 'necking', or both. They are different processes; either way, the end result is a crop that is no longer erect and becomes more difficult to harvest.

Lodging occurs when the stems bend and the crop is less erect as it becomes taller late in the season. Taller (e.g. early-sown) and dense crops are more prone to lodging than shorter, thinner crops. Strong winds and rain can also 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.

Necking occurs when the stem bends over sharply, virtually snapping at about pod height, so the upper part of the plant either dies or becomes less able to assist in grainfill. It occurs under strong winds or conditions causing moisture stress. Sometimes plants recover somewhat from necking, and the growing points turn to grow upright again. These plants then appear to have stems that are bent into an S-shape, and are often considered to be lodged. [13]

12 Pulse Breeding Australia (2013) Southern/Western Faba & Broad Bean—Best Management Practices Training Course. Module 2–Plant Physiology.

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4.3.2 Maturity

Soon after the development of pods and seed-filling, the 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.

Under mild moisture stress, faba beans 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 Western 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. Faba beans are ready to harvest when >90% of the stems and pods lose their green colour and become black (Photo 15). At this point, seeds are usually hard but do not rattle when the plant is shaken.

Photo 14: *Mature faba beans are black, and in this photo have been desiccated (front and right) for earlier maturity and harvest compared with those 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. Timing of desiccation is based on crop stage, and is similar to, or later than that for windrowing. See Section 11.