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GRDC GROWNOTES™

GRDC
GRAINS RESEARCH & DEVELOPMENT CORPORATION

LUPIN

SECTION 2

PLANTING

OVERVIEW | SEED QUALITY AND TESTING | INOCULANTS | CALCULATING NODULATION AFTER INOCULATION | TIME OF SOWING | GEOGRAPHIC LOCATION | VARIETIES | TILLAGE SYSTEMS | SEEDING RATES AND PLANT DENSITY | SOWING DEPTH

Planting

MORE INFORMATION

DPIRD hub 'Lupin essentials – Growing a successful lupin crop': https://www.agric.wa.gov.au/lupins/lupin-essentials-%E2%80%93-growing-successful-lupin-crop

DPIRD Bulletin 102008 'Producing Lupins': http://researchlibrary.agric.wa.gov.au/cgi/viewcontent.cgi?article=1009&context=bulletins

DPIRD Diagnostic Laboratory Services (DDLS)-Plant Pathology (formerly AGWEST Plant Laboratories): https://www.agric.wa.gov.au/ddls-seed-testing-and-certification

Agriculture Victoria: http://agriculture.vic.gov.au/agriculture/pests-diseases-and-weeds/plant-diseases/grains-pulses-and-cereals/seed-health-testing-in-pulse-crops

DPIRD seed testing hub: https://www.agric.wa.gov.au/plant-biosecurity/seed-testing

Plant Science Consulting: http://www.plantscienceconsulting.com.au

Primary Industries and Regions SA (PIRSA)/South Australian Research and Development Institute (SARDI) Seed and Plant Pathology testing Service: http://www.pir.sa.gov.au/research/services/crop_diagnostics/seed_and_crop_testing

FeedTest: www.feedtest.com.au

2.1 Overview

The ability of lupin and other legumes to fix their own nitrogen (N) make them an attractive break crop option in Western Australia.

But lupin require some specific soil types and seed quality, planting, inoculant, row spacing and seeding practices to ensure growers can take full advantage of this feature.

2.2 Seed quality and testing

- Always use high quality seed
- Test seed for vigour, germination weed seeds and disease
- Handle seeds carefully to protect from damage
- Tests for low manganese (Mn) and/or phosphorus (P) levels may be useful.

Poor quality seed can result in poor germination, less vigour and lower yields in WA lupin crops.

Quality of seed is affected by fungal or viral disease infection, physical damage (including from harvest practices, augers or bad weather) and low manganese (Mn) or phosphorus (P) levels.

Seed tests are available that can detect the most important seed-borne pathogens of lupin, especially anthracnose and Cucumber mosaic virus (CMV) in WA. Only pathogen-free seed should be used for sowing.

Testing can be carried out on lupin seed for: germination; vigour; thousand seed weight; Mn and P levels; and phomopsin.

Testing for purity – or weed seed contamination – can also be useful to reduce risks of introducing new weeds to paddocks and reducing reliance on herbicides.

2.2.1 Disease tests

Testing seed through an accredited laboratory before sowing will identify potential disease problems and help with risk management planning.

Lupin seed disease testing services for WA growers are available from:

- DPIRD Diagnostic Laboratory Services (DDLS) (formerly AGWEST Plant Laboratories) https://www.agric.wa.gov.au/ddls-seed-testing-and-certification
- Primary Industries and Regions SA (PIRSA)/South Australian Research and Development Institute (SARDI) Seed and Plant Pathology testing Service http://www.pir.sa.gov.au/research/services/crop_diagnostics/seed_and_crop_testing
- Plant Science Consulting http://www.plantscienceconsulting.com.au
- FeedTest www.feedtest.com.au
- Tasmanian Government TASAG ELISA Testing Service http://dpipwe.tas.gov.au/biosecurity/plant-biosecurity/plant-health-laboratories/tasag-elisa-testing
- SGS Australia www.sgs.com.au

MORE INFORMATION

GRDC Tips and Tactics: Legume N fixation: https://grdc.com.au/tt-legume-n-fixation

Disease tests typically require one kilogram of seed and will identify the common pathogens found in WA lupin crops that cause anthracnose, CMV, phomopsis stem blight and sclerotinia stem rot.

Results show the amount of disease inoculum in terms of:

- Proportion of infected seeds
- Degree or severity of infection (inoculum per individual seed)
- Viability of the inoculum (effectiveness of the pathogen in seed).

Low levels of seed-borne inoculum can lead to considerable disease incidence, so the most sensitive test should be used to determine the level of seed infection.

Where a high percentage of seed is infected, there is often more inoculum per seed associated with larger infections and deeper penetration.

It is recommended that diagnostic tests for viruses are conducted on germinated seed (seedlings), as disease may sometimes infect the seed testa without infecting the embryo or seedling.

Agriculture Victoria has prepared a summary, illustrated in Table 1, outlining common disease thresholds when considering using lupin seed for planting.

FEEDBACK

As indicated, seed with less than 0.1 percent infection is recommended for sowing in high-risk areas and seed with less than 0.5 percent infection is best for sowing in low-risk areas.[1]

Table 1: Seed health tests currently available and tolerance levels for seed infection in lupin[2]

Viruses	Laboratory A	Sample size submitted	Number of seeds tested	Seed infection threshold for acceptance of seedlot B	
				High-risk area	**Low-risk area**
AMV	1,2,5	3kg	1000	Less than 0.1%	Less than 0.5%
BYMV	2,5	3kg	1000	Lessthan 0.1%	Less than 0.5%
CMV	1,2,5	3kg	1000	Less than 0.1%	Less than 0.5%
PSbMV	2,5	3kg	1000	Less than 0.1%	Less than 0.5%
Bacteria					
Pseudomonas syringae pv pisi	2, 3	1kg	1000	Nil tolerance	Less than 0.1%
Pseudomonas syringae pv syringae	2,3	1kg	1000	Nil tolerance	Less than 0.1%
Fungi					
Ascochyta and Botrytis	1	1kg	400	Less than 1%	Less than 5%
Ascochyta fabae	2,4	1kg	400	Less than 1%	Less than 5%
Ascochyta lentis	2,4	1kg	400	Less than 1%	Less than 5%
Ascochyta pisi	2	1kg	400	Less than 1%	less than 5%
Ascochyta rabiei	2,4	1kg	1000	Nil tolerance	Nil tolerance
Botrytis cinerea	2,4	1kg	400	Less than 1%	Less than 5%
Botrytis fabae	2	1kg	400	Less than 1%	Less than 5%
Colletotrichum lupini	2	1kg	1000	Nil tolerance	Nil tolerance
Mycosphaerella pinodes	2	1kg	400	Less than 1%	Less than 5%
Phoma pinodella	4	1kg	400	Less than 1%	Less than 5%

[A]Seed testing services: 1. AgriFood, 2. AGWEST, 3 AsureQuality, 4 SARDI, 5 TASAG. BThresholds given are a guide only. Growers should discuss the likely disease risk on their farm with local advisers. Wherever possible, only pathogen-free seed should be used. This is most important when a crop is being grown in a new area. It is important to note that a negative result from a seed test does not guarantee that a seed lot will be free from disease.[3]

(SOURCE: Agriculture Victoria)

1 Agriculture Victoria (2016) Seed health testing in pulse crops, http://agriculture.vic.gov.au/agriculture/pests-diseases-and-weeds/plant-diseases/grains-pulses-and-cereals/seed-health-testing-in-pulse-crops

2 Agriculture Victoria (2016) Seed health testing in pulse crops, http://agriculture.vic.gov.au/agriculture/pests-diseases-and-weeds/plant-diseases/grains-pulses-and-cereals/seed-health-testing-in-pulse-crops

3 Agriculture Victoria (2016) Seed health testing in pulse crops, http://agriculture.vic.gov.au/agriculture/pests-diseases-and-weeds/plant-diseases/grains-pulses-and-cereals/seed-health-testing-in-pulse-crops

2.2.2 Damage and germination tests

Being large, lupin seeds are prone to mechanical damage during harvest and when being handled after harvest (especially with augers). Weather and chemicals can also cause damage and all of these factors can reduce seed viability and germination.

Vigour and germination tests for lupin seeds are available to WA growers through accredited seed testing laboratories and can provide an indication of the proportion of seeds that will produce normal seedlings and help to determine seeding rates.

Typically, these tests require a 1 kg sample for every 25 tonnes of seed and are carried out over a 10-day period. Seed samples will be classified into normal seedlings, abnormal seedlings, dead seed, fresh seed and hard seed.

Fresh and hard seed results are mostly irrelevant in lupin germination tests. The focus should be on normal seedlings, which are fully viable, and abnormal seedlings, which show significant defects that will prevent the plant from growing into a typical productive plant even under ideal conditions.

Examples of abnormal seedlings include those with missing or damaged root systems, missing or damaged first leaves and missing or damaged growing points.

During the past 20 years, lupin germination test results from WA growers' seed have generally been in the 80 to 90 percent range. Samples with lower germination percentages than this should not be used for sowing.[4]

2.2.3 Nutrient tests

Seed of narrow leafed lupin produced in WA often has low Mn concentrations because of low Mn availability in the soil during grain filling.

Seed from WA crops may also have low P levels that produce small seedlings.

In the 1990s, The University of Western Australia (UWA) researchers studied whether low Mn levels in lupin seeds contributed to poor seedling establishment by reducing emergence.

In glasshouse trials, they showed a 40 percent increase in emergence using seeds with high Mn concentrations compared to using seed with low Mn concentrations.

All high Mn seed were viable, compared to low Mn seed that had 34 percent completely or partly non-viable.

The researchers concluded that low Mn supply during seed filling may lead to production of non-viable seed that cannot be visually distinguished from viable seed.[5]

Subsequent research has found germination and seedling growth in WA can be compromised when lupin seed Mn concentration is less than 13 milligrams per kilogram.[6]

Applying Mn fertiliser at sowing does not correct the effects of low concentrations of Mn in the seed.

Lupin crops without visible symptoms of Mn deficiency (also known as split seed syndrome) may still contain less than 13 mg/kg of Mn in the seed and, if in doubt, it should be tested (FeedTest offers WA growers lupin nutrient testing services for Mn, P and other nutrients on request).[7]

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4 White, P, French, B, McLarty, A (2008) Producing Lupins. Department of Agriculture and Food WA Bulletin 1-2008, http://researchlibrary.agric.wa.gov.au/cgi/viewcontent.cgi?article=1009&context=bulletins

5 Crosbie, J, Longnecker, N, Robson, A (1994) Seed manganese affects the early growth of lupins in manganese-deficient conditions, The University of Western Australia, http://research-repository.uwa.edu.au/en/publications/seed-manganese-affects-the-early-growth-of-lupins-in-manganesedeficient-conditions(fd5a7f18-bf1d-4921-b107-5fa309467a7d).html

6 White, P, French, B, McLarty, A (2008) Producing Lupins. Department of Agriculture and Food WA Bulletin 1-2008, http://researchlibrary.agric.wa.gov.au/cgi/viewcontent.cgi?article=1009&context=bulletins

7 White, P, French, B, McLarty, A (2008) Producing Lupins. Department of Agriculture and Food WA Bulletin 1-2008, http://researchlibrary.agric.wa.gov.au/cgi/viewcontent.cgi?article=1009&context=bulletins

The easiest way to ensure the next year's lupin seed has sufficient Mn is to harvest from an area of the crop with the best soil type and that has been adequately fertilised with Mn.

The same applies for P, as using seed with P concentrations below 0.25 percent has been found to produce small seedlings that do not cope with stresses during early growth. Researchers have shown potential yield losses of 25 percent when seed with low concentrations of P is sown and, if in doubt, test seed to make sure it has at least 0.25 percent P.[8]

2.3 Inoculants

- Rhizobia inoculation can increase lupin yields and N fixation
- Gains are highest in low/no rhizobia soil
- Treat seed for paddocks sown to lupin for the first time
- Treat seed for neutral/alkaline soils every time a lupin crop is grown
- Treat seed for acidic soils every five years after a lupin crop
- Formulation options include peat, clay and peat granules, freeze-dried cultures and liquids
- Use a Group G or S inoculant.

Rhizobia are soil-dwelling root nodule bacteria that 'fix' atmospheric N in a form plants can use.

A fundamental characteristic of lupin (and other cultivated legumes) grown in Australia is the capacity to form a symbiotic relationship with these rhizobia.

This provides the total N requirements of the lupin plant, making it independent of the need for soil and fertiliser N, and injects N to the agricultural system for subsequent crops.

Some WA soils do not naturally contain rhizobia that form effective N-fixing symbioses with introduced lupin species and other legume crops, which has created a need to inoculate lupin seed with the appropriate rhizobia in some areas.

This inoculation increases lupin plant nodulation and biomass, grain production and yields, N fixation and post-crop soil nitrate levels to benefit subsequent crops.

All seed planted into paddocks that have not previously been sown to lupin requires inoculation.

On acidic soils (with a pH below 6.5 Calcium Chloride $CaCl_2$), after a well-nodulated lupin crop has been grown, a subsequent inoculation is not required for five years.

On neutral and alkaline soils (pH above 6.5), rhizobia do not survive for long and inoculation needs to be repeated every time a lupin crop is grown.[9]

Choice of inoculant group is critical for effective nodulation and N fixation to occur.

Lupin is nodulated by the slower-growing, acid-tolerant *Bradyrhizobium* from the commercial inoculant group G or S.

Lupin rhizobia G survive very well in low pH or sandy soils but, as the cost of inoculation is relatively low, it is advised that application can be worthwhile if there is any doubt about levels of residual soil rhizobia.

Commonly used inoculants for lupin in WA are moist peat and dry clay granules, which are cost effective and produce very good nodulation if handled and applied according to manufacturer instructions.

MORE INFORMATION

GRDC 'Inoculating legumes: A practical guide': https://grdc.com.au/Resources/Bookshop/2015/07/Inoculating-Legumes

GRDC Grain Legume Handbook 'Inoculants': www.grdc.com.au/grainlegumehandbook

GRDC booklet 'Inoculating legumes: The Back Pocket Guide': https://grdc.com.au/GRDC-BPG-InoculatingLegumes

GRDC booklet 'Rhizobial Inoculants': https://grdc.com.au/GRDC-FS-RhizobialInoculants

DAFWA Bulletin 102008 'Producing Lupins': http://researchlibrary.agric.wa.gov.au/cgi/viewcontent.cgi?article=1009&context=bulletins

Great Northern Rural Services YouTube video comparing inoculation and no inoculation in lupin crops: https://www.youtube.com/watch?v=jT6jOpPuBno

8 White, P, French, B, McLarty, A (2008) Producing Lupins. Department of Agriculture and Food WA Bulletin 1-2008, http://researchlibrary.agric.wa.gov.au/cgi/viewcontent.cgi?article=1009&context=bulletins

9 White, P, French, B, McLarty, A (2008) Producing Lupins. Department of Agriculture and Food WA Bulletin 1-2008, http://researchlibrary.agric.wa.gov.au/cgi/viewcontent.cgi?article=1009&context=bulletins

These products contain high numbers of living bacteria, which need to be maintained and protected from heat, excessive sunlight and cold to optimise effectiveness in the soil.

Table 2 outlines the suitability of a range of rhizobia inoculants available for lupin.

Table 2: Innocuation application methods and suitability http://pulseaus.com.au/growing-pulses/publications/pulse-inoculation[10]

Inoculant type	Applied to–	Suitable for dry sowing/ drying soil	Compatibility with seed applied fungicide	Time to sow after inoculation	Preparation or machinery requirements
Peat slurry	Seed	No	Some. Check the label	24 hours	Pre-sowing
	Seed furrow/ below seed	No	Yes	–	Liquid applicator on seeder
Freeze dried	Seed	No	No	Within hours	Pre-sowing
Granular inoculum	Seed furrow/ below seed	Yes	Yes	–	Mix with fertiliser
Liquid injection (peat or freeze)	Seed furrow	No	Yes	Within hours	Liquid applicator on seeder

(SOURCE: Pulse Australia)

Results from 2016 trials in south eastern Australia show liquid and granular rhizobia inoculants have some practical advantages in being easy to apply and separating rhizobia from potentially harmful seed-applied pesticides.

At two out of eight trial sites, inoculation significantly improved lupin crown nodulation from 0.05 to 13 nodules per plant. Nitrogen fixation increased by 175 kilograms of N per hectare at one site. For full results from these trials go to: https://link.springer.com/article/10.1007/s11104-017-3317-7[11]

2.3.1 Peat inoculum

This is a reliable and cost effective method of applying rhizobia to the lupin seed and is typically carried out using a water or gum (usually methyl-cellulose) slurry.

Gum slurry provides the best results and protects the rhizobia when on the seed.

The packet size of peat inoculant is typically 2.5 kg and application rates are clearly outlined in the accompanying instructions. Rates are typically based on a target of achieving 100,000 rhizobia per lupin seed.[12]

The inoculant is mixed with water or gum to make the slurry and an adhesive solution can be added to improve contact between inoculant and seed.

Mixing is typically carried out with a concrete mixer; shovelling on a cement floor; or using a rotary coater/auger to get even coverage.

10 Pulse Australia (2016) Australian Pulse Bulletin, Pulse inoculation techniques, http://pulseaus.com.au/growing-pulses/publications/pulse-inoculation

11 Denton, M. Phillips, L. Peoples, M. et at, Plant and Soil, July 2017, Legume inoculant application methods: effects on nodulation patterns, nitrogen fixation, crop growth and yield in narrow-leaf lupin and faba bean', https://link.springer.com/article/10.1007/s11104-017-3317-7

12 White, P, French, B, McLarty, A (2008) Producing Lupins. Department of Agriculture and Food WA Bulletin 1-2008, http://researchlibrary.agric.wa.gov.au/cgi/viewcontent.cgi?article=1009&context=bulletins

Label directions are important and caution is advised when adding insecticides, fungicides, herbicides, detergents or fertilisers – as these can be toxic to the rhizobia.

Rates of inoculum should be increased if seed has been treated with a fungicide and preferably sow this seed into moist soil within 24 hours (or as soon as possible).[13]

Bacteria in peat cultures is also vulnerable to damage from heat and direct sunlight, but will survive well if refrigerated at about 4 or 5°C until used (it is advised not to freeze this material).

Survival rates of rhizobia applied to seed using a slurry are higher when lupin is sown into wet soil than dry soil and it is recommended to double application rates when dry sowing.

In-furrow application of peat slurry (or liquid inoculants) directly into the seed row is gaining in popularity, as this is well adapted to both modern machinery and pulse growing.

This method is suitable when machines are set up for liquid N application on cereals, or where fungicides are used to treat seeds prior to sowing. It requires at least 80 litres or more of water per hectare.

The solution is sprayed into the soil, has the convenience of being dissolvable and does not require filtering – but caution is required before mixing with any fungicides.

It is also advisable not to sow trace element fertilisers containing copper (Cu) with slurry-inoculated lupin seed, as Cu is toxic to rhizobia.

Dry dusting peat inoculum on to lupin seed is not effective for WA conditions.

2.3.2 Clay granules

Granule inoculants are comprised of prilled peat, clay or a mixture of both and come in a range of forms that are dry or moist, uniform or variable, powdery, coarse or fine.

These are applied similarly to a fertiliser – as a solid, in the seed furrow or near to seed – and can be more flexible and practical than using peat slurry.

Clay granule products tend to contain fewer rhizobia than peat-based inoculants and typically need to be applied at higher application rates, in a range from 5 kg/ha to 10 kg/ha when sowing on 18 cm row spacings.[14]

These can be mixed with fertiliser when it is drilled with the seed (not banded).

When sowing lupin crops into dry soil, dry clay granules are best used compared to peat-based products.

2.3.3 Inoculants and fungicide seed treatments

Research has shown fungicide seed dressings for lupin (including iprodione, procymidone and thiram) do not interfere with the rhizobia population in soil from previous lupin crops, but are toxic to rhizobia applied to the seed in inoculants.[15]

If inoculating seed that has been dressed with fungicide using a peat-based product it is best to:

- Allow fungicide to dry before inoculating seed
- Apply inoculum at double the standard rate
- Apply inoculum immediately before sowing
- Sow seed into moist soil
- Alternatively, use a dry clay granule inoculant.

13 White, P, French, B, McLarty, A (2008) Producing Lupins. Department of Agriculture and Food WA Bulletin 1-2008, http://researchlibrary.agric.wa.gov.au/cgi/viewcontent.cgi?article=1009&context=bulletins

14 White, P, French, B, McLarty, A (2008) Producing Lupins. Department of Agriculture and Food WA Bulletin 1-2008, http://researchlibrary.agric.wa.gov.au/cgi/viewcontent.cgi?article=1009&context=bulletins

15 White, P, French, B, McLarty, A (2008) Producing Lupins. Department of Agriculture and Food WA Bulletin 1-2008, http://researchlibrary.agric.wa.gov.au/cgi/viewcontent.cgi?article=1009&context=bulletins

MORE INFORMATION

DPIRD-GRDC MyCrop website 'Monitoring pulse nodulation': https://www.agric.wa.gov.au/mycrop/monitoring-pulse-nodulation

GRDC 'Inoculating legumes': https://grdc.com.au/GRDC-Booklet-InoculatingLegumes; www.grdc.com.au/GRDC-BPG-InoculatingLegumes

2.4 Calculating nodulation after inoculation

Nodulation of lupin roots is important to maximise N fixation and plant growth.

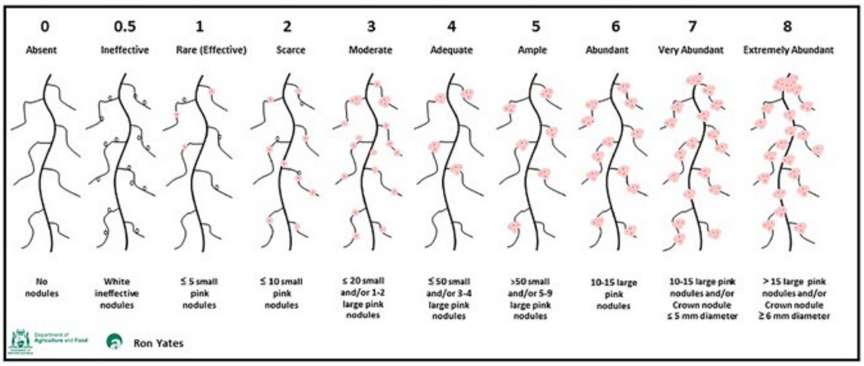
Healthy nodules need to be present on the taproot and lateral roots.

A healthy N fixing nodule is pink inside. Grey or green nodules do not fix N.

Nodulation of the lupin plant after treating with an inoculant can be assessed 10 to 12 weeks after sowing and typically the best time to check roots is late winter and early spring.

Abundant levels of nodules will appear pink as indicated in Figure 1.

Figure 1: *Degree of nodulation found on pulse plants.*[16]



(SOURCE: DAFWA)

Guidelines for assessing lupin nodulation include:

- Carefully dig 10 plants at random across the area to be assessed
- A minimum of three sites should be sampled
- Best areas are 20 m, 60 m and 100 m in from crop edges
- Keep the soil intact around the root ball
- Wash dirt off roots in a bucket of water
- Soak roots from heavy soil if necessary
- Observe the size, number and colour of the nodules on the root system
- Score the root system for each sample for the percentage of plants adequately nodulated – as shown in Figure 1.
- Calculate an average score for the three (or more) sites sampled.[17]

It is advisable to look for the number of nodules on a plant and where these are located.

There should be more nodules around the crown of the plant (where root meets shoot) if an inoculant was used and these will boost early seedling growth.

Lupin crops that were not inoculated tend to have nodules spread across the root system on crown, taproots and laterals if rhizobia is present in the soil.

Poor nodulation may be due to agronomic factors that could include:

- » Poor environmental conditions (cold temperatures, moisture stress) during emergence and crop growth
- » Soil pH (may not suit survival of the particular rhizobia for the crop)
- » Poor establishment of soil rhizobia by previous crops grown in the paddock
- » Poor inoculation
- » Fertiliser practices
- » Root diseases, such as rhizoctonia.[18]

16 DPIRD-GRDC MyCrop (2016) Monitoring pulse nodulation, www.agric.wa.gov.au/mycrop/monitoring-pulse-nodulation

17 DPIRD-GRDC MyCrop (2016) Monitoring pulse nodulation, www.agric.wa.gov.au/mycrop/monitoring-pulse-nodulation

18 DPIRD-GRDC MyCrop (2016) Monitoring pulse nodulation, www.agric.wa.gov.au/mycrop/monitoring-pulse-nodulation

2.5 Time of sowing

- Early sowing optimises yields and profits
- Early sowing is more important in low rainfall areas
- Delayed sowing can assist weed control in some high rainfall areas and helps avoid poor pod set from excessive plant height, lodging and biomass production
- Variety choice will impact on time of sowing.

Early sowing is a key to successful lupin crop establishment and profitability in WA, along with good weed control, achieving optimum plant density, incorporating pre-planting residual herbicides, seed depth placement and adequate fertiliser.

Sowing lupin crops early allows seed to germinate in warmer temperatures, promoting early root growth and nodulation.

But there is a balance and sowing too early can result in issues with excessive growth, lodging and poor pod set in some years and environments.

Early sowing is more critical in WA's low rainfall zones because potential yield is lower. Research has shown the highest rates of yield loss caused by delayed sowing in these areas start to occur early in the season.

In high rainfall zones, the highest rates of yield loss caused by delayed sowing do not start until the second half of May and this can be an advantage for weed control in these areas.

Lupin will typically perform best when sown into a moist seedbed to ensure good and even establishment, nodulation and activation of soil herbicides such as simazine.

But lupin crops are increasingly sown dry in WA, mainly to fit in with timing of cereal sowing programs.

Tables 3-5 show the pros and cons of dry, moist and delayed sowing for lupin crops in WA.

Table 3: Advantages and disadvantages of dry sowing lupin[19]

Dry Sowing	
Positives	**Negatives**
Crop is given longest growing season possible	Simazine incorporation is uneven when applied in dry soil. Simazine activity can be poor and weed burdens high
Enables rapid establishment in warm soil	Germination on marginal moisture can lead to poor and uneven crop establishment
Logistically simple	Weeds grown through ineffective control are difficult and expensive to control
Brings forward time of sowing for other crops	Paddocks prone to wind erosion if ground cover is sparse
Improves machinery efficiency	Paddocks with WA blue lupin require a knockdown prior to sowing, as there is no selective herbicide for blue lupin control

(SOURCE: DAFWA)

In situations where growers decide to dry sow, it is recommended to consider sowing into paddocks with good stubble cover to avoid erosion. Sowing into paddocks with low weed burdens can assist with poor simazine incorporation and increasing seeding rate can assist in counteracting poor establishment.[20]

19 DPIRD (2016) Lupin essentials – growing a successful lupin crop, https://www.agric.wa.gov.au/lupins/lupin-essentials-%E2%80%93-growing-successful-lupin-crop?page=0%2C1#smartpaging_toc_p1_s0_h2

20 DPIRD (2016) Lupin essentials – growing a successful lupin crop, https://www.agric.wa.gov.au/lupins/lupin-essentials-%E2%80%93-growing-successful-lupin-crop?page=0%2C1#smartpaging_toc_p1_s0_h2

Table 4: Advantages and disadvantages of moist sowing lupin[21]

Wet sowing (on the break of 15 millimetres over two days)	
Positives	**Negatives**
Higher potential for even, competitive lupin crop emerging	Rapidly drying soil after the break can reduce crop establishment success
Simazine applied prior to break will wash into soil, giving maximum weed control	Sowing naturally dries soil, reducing remaining soil moisture for germination and establishment
Trifluralin effectiveness is increased when applied into moist soil on first rain	
Even crops assist effective post-emergent herbicide use	
Opportunity to achieve a knockdown of weeds, including WA blue lupin	

(SOURCE: DAFWA)

Wet sowing success will hinge on effective use of pre-seeding herbicides to ensure weeds that germinate with the crop remain under control.[22]

Table 5: Advantages and disadvantages of delayed sowing after the break of lupin into wet soil[23]

Delayed sowing (after the break)	
Positives	**Negatives**
Allows the full benefit of knockdown herbicides to take affect	Risk of long gap between break and follow up rains can affect crop success
	Rate of yield loss from delayed sowing is greater in low rainfall zones
No simazine application prior to season break allows greater sowing flexibility	Slower germination and establishment due to cooler soil temperatures
Wet soil guarantees even competitive crop emergence	Potential delay to cereal program
Well suited to earlier maturing new varieties such as PBA Leeman, PBA Jurien, PBA Gunyidi and PBA Barlock	

(SOURCE: DAFWA)

2.6 Geographic location

Optimum sowing dates for WA lupin crops can be loosely calculated on rainfall areas. Northern region crops are typically best sown from the end of April and before the first week of June and southern region crops are best sown from early May.

Typically, lupin will perform best in areas with an annual average rainfall of less than 350 mm when sown from mid-April to early May.

Areas with an annual average rainfall of 350 mm to 450 mm suit a mid-April to early May sowing date (although loam soils in both of these zones require later sowing).

Higher rainfall zones with average annual rainfall of 450 mm and above suit sowing of lupin from mid to late May.

MORE INFORMATION

DAFWA 'Producing Lupins' Bulletin: http://researchlibrary.agric.wa.gov.au/cgi/viewcontent.cgi?article=1009&context=bulletins

21 DPIRD (2016) Lupin essentials – growing a successful lupin crop, https://www.agric.wa.gov.au/lupins/lupin-essentials-%E2%80%93-growing-successful-lupin-crop?page=0%2C1#smartpaging_toc_p1_s0_h2

22 DPIRD (2016) Lupin essentials – growing a successful lupin crop, https://www.agric.wa.gov.au/lupins/lupin-essentials-%E2%80%93-growing-successful-lupin-crop?page=0%2C1#smartpaging_toc_p1_s0_h2

23 DPIRD (2016) Lupin essentials – growing a successful lupin crop, https://www.agric.wa.gov.au/lupins/lupin-essentials-%E2%80%93-growing-successful-lupin-crop?page=0%2C1#smartpaging_toc_p1_s0_h2

If sowing is too late in any of these areas, potential yield losses can be significant for every week's delay.[24]

Research in the central grainbelt in 2006 found that by delaying sowing by three to four days, lupin yield loss was similar to the yield loss caused by one wild radish plant/m² growing in the crop.[25]

Optimum flowering time for lupin varies little throughout the State and, typically, should start in early August.

Very early sown crops can be more exposed to damage from frost or heat/drought stress during flowering and early podding in conducive seasons.

In areas with long growing seasons, such as the South Coast, sowing too early can result in excessive vegetative growth and lodging in some years.

2.7 Varieties

MORE INFORMATION

Online Farm Trials report 'The effects of sowing time and radish density on lupin yield': http://www.farmtrials.com.au/trial/10449

Narrow leafed varieties PBA Leeman, PBA Jurien, PBA Barlock, PBA Gunyidi, Mandelup and Coromup – and the albus lupin Amira – are early maturing and provide opportunities to delay sowing into late May.

This can improve pre-planting weed and disease control without compromising yield.

These newer lupin varieties for WA carry a high proportion of yield on the main stem relative to other varieties.

This allows them to be high-yielding without relying heavily on late maturing lateral branches. This further reduces the need for early sowing, compared with older lines, such as Tanjil and Wonga, that rely more on the lateral branches for yield.

The newer narrow leafed and albus varieties tend to perform better in WA's high and medium rainfall areas, where season length is long and early sowing is not as critical to ensure that seed in lateral pods will fill.

But the interaction of sowing time with variety is usually much lower than the interactions between sowing time and location.

(More information about lupin varieties is outlined in Chapter 3).

2.8 Tillage systems

Machinery used to sow lupin crops should ideally be able to:

- Handle thick stubble
- Uniformly incorporate simazine into the top 5 cm of soil
- Kill germinated weeds
- Place seed and fertiliser uniformly at desired depth/s
- Leave a good seedbed with water-harvesting furrows
- Leave loose soil above the seed
- Sow quickly and cheaply.[26]

Most WA lupin crops are sown with tyned machines, often with press wheels.

This provides good seed-to-soil contact and forms a furrow that harvests water, which is particularly important in achieving a uniform establishment of lupin crops in non-wetting sands and protecting seedlings from sandblasting.

Knife point machines provide good stubble handling and reasonable incorporation of herbicides, depending on row spacing.

24 White, P, French, B, McLarty, A (2008) Producing Lupins. Department of Agriculture and Food WA Bulletin 1-2008, http://researchlibrary.agric.wa.gov.au/cgi/viewcontent.cgi?article=1009&context=bulletins

25 Harries, M (2006) Interaction of time of sowing and weed management of lupins, DAFWA, http://www.farmtrials.com.au/trial/10420

26 White, P, French, B, McLarty, A (2008) Producing Lupins. Department of Agriculture and Food WA Bulletin 1-2008, http://researchlibrary.agric.wa.gov.au/cgi/viewcontent.cgi?article=1009&context=bulletins

These systems kills germinating weeds in the seeded row, allow flexibility for placing seed and fertiliser and are relatively fast and easy to use.

The weight of the press wheel should be set no higher than 2 kg/cm width of the press wheel.

Where deep furrows are created, there is a danger that soil-applied herbicides, such as simazine, will wash into these and concentrate at toxic levels.

This can be avoided in knife point systems by applying herbicide prior to sowing, but it is important to control herbicide throw.

Disc machines are ideal for stubble retention, but triple discs are less efficient at herbicide incorporation and pre-planting weed control than tyned or culti-trash machines.

Disease spores tend to be found near the soil surface and will remain there with minimal soil disturbance. Seed placed below the spore layer at a depth of 2–3 cm will have a much lower exposure to infection.[27]

Management of rhizoctonia bare patch, an issue that cannot be controlled by rotating crops, is complex in crops established using zero or minimum tillage. The chances of this occurring can be reduced by sowing at a depth of 3–5 cm and cultivating 5–10 cm below this in a direct drilling operation.

2.9 Seeding rates and plant density

Narrow leafed lupin tends to respond best to seeding rates of 80-120 kg/ha (of 75 percent germinable seed), depending on seed size and germinability, to meet a target plant density of 45 to 70 plants/m^2.[28]

But trials across WA have found optimum plant densities will change depending on location and season.

There is typically little or no yield penalty if plant densities are higher than the recommended range of up to 70 plants/m^2, but yield losses in newer varieties can be substantial if lupin plant populations fall below 40 plants/m^2.[29] This is because these varieties rely on pod set on the main stem, rather than on branches.

A high-density crop may produce fewer pods per plant, but have more pods/m^2 and a higher yield than a low-density crop.

Aside from yield, a high plant density crop also has benefits of:

- Less weed growth
- Better crop competition with weeds
- Less risk of Brown leaf spot and CMV incidence/severity
- Better compensation from root disease losses
- More compensation if there is poor establishment (especially on water repellent sands)
- Lower susceptibility to wind erosion and sandblasting
- Greater ease of harvesting.

Table 6 outlines thresholds for narrow leafed lupin sowing rates (kg/ha) required to achieve 45 plants/m^2, assuming a 90 percent establishment rate.

27 White, P, French, B, McLarty, A (2008) Producing Lupins. Department of Agriculture and Food WA Bulletin 1-2008, http://researchlibrary.agric.wa.gov.au/cgi/viewcontent.cgi?article=1009&context=bulletins

28 White, P, French, B, McLarty, A (2008) Producing Lupins. Department of Agriculture and Food WA Bulletin 1-2008, http://researchlibrary.agric.wa.gov.au/cgi/viewcontent.cgi?article=1009&context=bulletins

29 White, P, French, B, McLarty, A (2008) Producing Lupins. Department of Agriculture and Food WA Bulletin 1-2008, http://researchlibrary.agric.wa.gov.au/cgi/viewcontent.cgi?article=1009&context=bulletins

Table 6: Thresholds for narrow leafed lupin sowing rates (kilograms per hectare) to achieve a plant density of 45 plants per square metre[30]

	Lupin Seed Weights g/1000seeds		
Germination rate %	140g	160g	180g
70	100	114	129
80	88	100	113
90	78	89	

(SOURCE: DAFWA)

Albus lupin does not tend to require quite as high a plant density as narrow leafed lupin.

Taking into account a larger seed, the suggested sowing rate is about 160 kg/ha to achieve a density of 45 plants/m^2 (based on limited trial data).[31]

The following formula can be used to calculate lupin sowing rates for albus and narrow leafed varieties:

$$\text{Sowing rate (kg/ha)} = \frac{\text{Seed size (g/1000 seeds)} \times \text{Target density (plants/m}^2) \times 100}{\text{Germination rate (\%)} \times \text{Establishment rate (\%)}}$$

(SOURCE: DAFWA)[32]

Table 7 shows the sowing rates needed to achieve the ideal plant density of 45 plants/m^2 for seed with a range of germination rates, determined by commercial seed tests.

Table 7: Sowing rate (kg/ha) required to achieve 45 plants/m^2 (target plant density for seed with different germination rates %

	Sowing rate (kg/ha) using various seed weights (140-180g g/1,000 seeds)				
Germination Rate (%)	Small		Medium		Large
	140	150	160	170	180
70	100	107	114	121	129
75	93	100	107	113	120
80	88	94	100	106	113
85	82	88	94	100	106
90	78	83	89	94	100
95	74	79	84	89	95
100	70	75	80	85	90

Note: Sowing rates assume wet sowing where establishment rate is 90 percent. For dry sowing where establishment rate is 85 percent, add a further 5 percent to the sowing rate.

(SOURCE: DAFWA Producing Lupins Bulletin)[33]

30 DPIRD (2016) Lupin essentials – growing a successful lupin crop, https://www.agric.wa.gov.au/lupins/lupin-essentials-%E2%80%93-growing-successful-lupin-crop?page=0%2C2#smartpaging_toc_p2_s1_h2

31 DPIRD (2016) Lupin essentials – growing a successful lupin crop, https://www.agric.wa.gov.au/lupins/lupin-essentials-%E2%80%93-growing-successful-lupin-crop?page=0%2C2#smartpaging_toc_p2_s1_h2

32 White, P, French, B, McLarty, A (2008) Producing Lupins. Department of Agriculture and Food WA Bulletin 1-2008, http://researchlibrary.agric.wa.gov.au/cgi/viewcontent.cgi?article=1009&context=bulletins

33 White, P, French, B, McLarty, A (2008) Producing Lupins. Department of Agriculture and Food WA Bulletin 1-2008, http://researchlibrary.agric.wa.gov.au/cgi/viewcontent.cgi?article=1009&context=bulletins

2.10 Sowing depth

Ideally, the sowing depth for lupin across the WA grainbelt is 3-5 cm, but this varies marginally depending on soil type.

Shallow sowing at a depth of 2-3 cm can be used on harder setting heavier soils. This can reduce rhizoctonia hypocotyl rot because the stem or hypocotyl of the seedling has less soil to grow through and less chance coming in contact with the fungus.

Sowing to a depth of 5 cm will reduce occurrence of pleiochaeta root rot, as seed is placed below most of the spores that have fallen to the ground from previous brown leaf spot infections.

It is recommended to not sow lupin seed deeper than 7 cm in most areas of WA, as crop establishment can be very uneven and poor.[34]

34 White, P, French, B, McLarty, A (2008) Producing Lupins. Department of Agriculture and Food WA Bulletin 1-2008, http://researchlibrary.agric.wa.gov.au/cgi/viewcontent.cgi?article=1009&context=bulletins