WESTERN
SEPTEMBER 2018

GRDC GROWNOTES™

GRDC™ GRAINS RESEARCH & DEVELOPMENT CORPORATION

CHICKPEA

SECTION 3

PLANTING

INOCULATION | SEED TREATMENTS | TIME OF SOWING | SEED RATE | TARGETED PLANT POPULATION AND ROW SPACING | ROW PLACEMENT | SOWING DEPTH | SOWING EQUIPMENT

Planting

Key messages

- The strain of rhizobia used for inoculating chickpeas is highly specific (Group N, CC1192). Inoculation is essential for effective nodulation and will result in a crop that is self-sufficient for N and provide soil health benefits in subsequent seasons.
- All seed, regardless of source, should be treated with a registered thiram-based fungicide seed dressing prior to sowing.
- The chickpea sowing window for low rainfall is April 20–May 25, and in medium rainfall from May 15–June 15.
- In WA, the greatest seed yields have been produced by sowing from mid to late June at southern sites, and early May at central and northern sites.
- While yields are relatively stable within the range of 35–50 plants/m^2, higher seeding rates (50 plants/m^2) produce the highest yields in western and southern areas.
- Sowing at 30–50 cm spacing is becoming common. Some innovators are sowing in 50–100 cm row spacing and using inter-row spraying for weed control. Understand the advantages and disadvantages of row spacing.
- Sow chickpeas 5–7 cm deep into good moisture. The seedlings are robust, provided high quality seed is used. There are also benefits to deep planting chickpea.

3.1 Inoculation

Pulses have the ability to 'fix' their own N from the air via nodules on their roots if specific nitrogen-fixing bacteria (rhizobia) are available. Grain legume crops (such as pulses) and pasture legumes initiate a symbiotic relationship with rhizobia bacteria, to form nitrogen-fixing root nodules. The chickpea is an introduced crop to Australia and, as such, seeds must be treated (inoculated) with the correct strain of rhizobia (symbiotic N-fixing bacteria) before planting.

The strain of rhizobia used for chickpeas is highly specific (Group N, CC1192). Inoculation is essential for effective nodulation and will result in a crop that is self-sufficient for N and provide soil health benefits in subsequent seasons. This N fixation process has a national benefit of close to $4 billion annually in Australian cropping systems. Growers can treat seed before sowing with inoculants containing live bacteria to stimulate nodulation and the N-fixation capacity of legumes. It is important to match the correct inoculant group to each legume. [1] The Group N bacteria are regarded as an 'aggressive nodulator'. This effectively means that nodulation will be successful in meeting the crop's N requirements provided the inoculants are handled and stored in a manner that will ensure bacterial survival and that growers adopt effective inoculation practices on-farm.

1 DAFWA. Desi Chickpea Essentials. https://www.agric.wa.gov.au/chickpeas/desi-chickpea-essentials

WATCH: GCTV13: Legumes – Sowing preparation.

WATCH: GCTV13: Legumes – Inoculant compatibility.

The most common method of inoculating chickpea is to coat the seed with a slurry of peat based inoculum immediately before planting (Figure 1). It is important to treat only the seed that can be planted the same day. Exposure to drying winds, high temperatures or direct sunlight will rapidly kill the bacteria. [2]

Figure 1: *Forms of rhizobia (left to right): Easyrihiz freeze-dried, Nodulator granules, Alosca granules, N-Prove granules and peat inoculant.*

Photo: M. Denton, DPI Vic

2 DAFF (2012) Planting chickpeas. Department of Agriculture, Fisheries and Forestry August 2012, http://www.daff.qld.gov.au/plants/field-crops-and-pastures/broadacre-field-crops/chickpeas/planting

Only purchase refrigerated (but not frozen) inoculum from a reputable supplier and then store it in a cool, dry place. 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, because the rhizobia population may have dropped to an unacceptable level. Treat seed within 24 hours of sowing and sow into moist soil. Consider new technologies that are now also available and may suit your operations, e.g. freeze-dried inoculums, water liquid injection, granular inoculums. Dry sowing of chickpeas is now possible if using granular inoculums that enable rhizobia survival until rain arrives to germinate seed. [3]

Inoculated seed must be planted into moisture within 12 hours of treatment. The sooner the better, as fungicide seed dressings can affect survival of the bacteria. Inoculated seed and acidic fertilisers should not be sown down the same tube. The acidity of some fertilisers will kill a high proportion of the rhizobia and render inoculation ineffective. Neutralised (e.g. Super lime) and alkaline fertilisers (e.g. DAP, Starter NP, lime) can be safely used. [4]

MORE INFORMATION

Inoculating pulse crops

IN FOCUS

Nutrient uptake and yield of chickpea (Cicer arietinum L.) inoculated with plant growth- promoting rhizobacteria

Plant growth promoting rhizobacteria (PGPR) represent a wide variety of soil bacteria which, when grown in association with a host plant, result in stimulation of growth of their host plant. Several mechanisms have been suggested by which PGPR can promote plant growth, including phytohormone production, N_2 fixation, stimulation of nutrient uptake and biocontrol of pathogenic microorganisms.

One study evaluated the effects of single and combined inoculation with plant growth-promoting rhizobacteria from four genera including Azospirillum, Azotobacter, Mesorhizobium and Pseudomonas on nutrient uptake, growth and yield of chickpea plants under field conditions. Nodulation and nutrient concentration in shoots were significantly affected by the treatments at the beginning of flowering stage. The maximum dry weight of root nodules was recorded by applying the combined inoculation with Azospirillum spp. + Azotobacter chroococcum 5 + Mesorhizobium ciceri SWRI7 + Pseudomonas fluorescens P21. All inoculants were statistically superior over uninoculated control with respect to nitrogen concentration of shoots. The treatments containing Azospirillum + Azotobacter significantly improved phosphorus concentration in shoots. Grain yield, biomass dry weight and nitrogen & phosphorus uptake of grains were statistically improved by applying every inoculation treatment in comparison with control plants. Group comparisons between treatments showed that the occurrence of Azospirillum or Azotobacter inoculants in the treatment composition caused an expressive improvement in grain yield and plant biomass. In conclusion, application of every inoculation treatment studied here, especially treatments which contained Azospirillum or Azotobacter may stimulate growth and yield of chickpea as compared with uninoculated plants. [5]

---

3 Pulse Australia. Southern Pulse Bulletin PA 2010 #05 – Chickpea checklist for southern growers. http://www.pulseaus.com.au/storage/app/media/crops/2010_SPB-Chickpea-checklist-south.pdf

4 Pulses Australia. Chickpea Production: Southern and Western region. http://www.pulseaus.com.au/growing-pulses/bmp/chickpea/southern-guide

5 Rokhzadi, A., & Toashih, V. (2011). Nutrient uptake and yield of chickpea (Cicer arietinum L.) inoculated with plant growth-promoting rhizobacteria. Australian Journal of Crop Science, 5(1), 44.

3.1.1 Inoculation checklist

Important points when purchasing and using inoculants:

- Check the expiry date on packet.
- Packets should be stored at around 4°C.
- Do not freeze (below 0°C) or exceed 15°C.
- Use Group N chickpea inoculum
- Prepare slurry and apply in the shade, avoiding 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 and inoculate at the top of the auger not the bottom.
- 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. [6]

3.1.2 Inoculant types

Peat inoculum

The traditional method of supplying rhizobia to seed is with peat inoculum. Read the label and apply the inoculant according to the directions. Most pulse crop inoculums for application to seed contain a pre-mixed sticker which helps adhesion to the seed. Be cautious and read the inoculant label regarding adding any approved insecticides, fungicides, herbicides, detergents or fertilisers into the slurry as these may be toxic to the rhizobia. Inoculated seed should be used within 24 hours when applied alone, and within four hours is applied in conjunction with a fungicide.

In-furrow water injection

Water or fluid injection of inoculants into the seed row is becoming more common as it has been adapted to pulse growing and modern machinery. It can be used where machines are set up for liquid N on cereals, and where fungicides are used to treat seeds before sowing. Water injection of inoculant requires at least 40-50 litres of water per hectare and is better with more.

The slurry-water solution is sprayed under low pressure into the soil in the seed row during seeding. Benefits of the new inoculant carrier types over peat are that they are convenient, 'dissolve' more readily, and do not have the requirement for filtering out peat hairs etc. Read the label before mixing any fungicides.

Granular forms

Granular inoculants are applied like fertiliser as a solid in the seed furrow or near to the seed and avoid many of the compatibility problems that rhizobia have with fertilisers and fungicides. They also eliminate the application procedures needed with peat inoculum. Granular inoculants also offer some advantages when dry sowing.

Granules contain fewer rhizobia per gram than peat-based inoculants, so they must be applied at higher application rates. The size, form, uniformity, moisture content and rate of application of granules differ between products. Depending on the product or row spacing sown, application rates can vary from 4 kg/ha to 10 kg/ha to deliver adequate levels of nodulation.

Several granular inoculant formulations are now available, and they are not all the same in composition, practicalities of use and performance. Seek independent trial information for your area when making comparisons between products.

---

6 Pulse Australia (2013) Northern chickpea best management practices training course manual—2013. Pulse Australia Limited.

ALOSCA is a dry clay (Bentonite) granule now used in significant areas of Western Australia. BASF produces moist clay granules (Nodulator), while Novozymes Australia also produces a moist granular product.

Even application is best achieved through a dedicated third box on the seeder (Figure 2). Maintaining an even application rate when mixed with the seed is difficult as the granules shake down in the seed lot. Achieving an even distribution rate in the fertiliser box is also difficult, and rhizobia survival becomes an important consideration. Only ALOSCA claim compatibility when mixed with fertiliser. [7]

Figure 2: *An 'after-market' third box fitted to a Flexicoil box to enable application of granular inoculums. Note that granular inoculums cannot be applied mixed with the seed (uneven distribution of seed and/or inoculums occurs). Rhizobial survival is severely jeopardised if granular inoculums are applied mixed with fertiliser.*

Source: Grain Legume Handbook, 2008

3.1.3 Choosing an inoculant type

All types of inoculants will result in a well-nodulated crop in good conditions (Table 1). The choice of inoculant type by growers will depend on:

- experience
- paddock history; i.e. the need for added rhizobium
- product availability
- relative cost
- perceived efficacy
- ease of use
- the suitability of machinery to deliver the inoculum.

Granules can vary and, depending on the product, may be dry or moist, uniform, variable, powdery, coarse or fine.

When conditions are less than ideal, making the right choice becomes more critical.

The rhizobia bacteria need moisture to survive. When contained in the carrier; i.e. the peat material or the granule form, they will survive for up to 12 months when stored well. Read the expiry date before use.

However, once applied the survival rate is highly dependent on available soil moisture. This particularly applies to inoculum applied to the seed or to the soil as slurry. Dry soil conditions after sowing will kill off the rhizobia. Moisture will be needed within 2–3 days after sowing to maintain adequate numbers. If introduced rhizobia

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

are essential for crop health, dry sowing should be avoided and caution should be used if sowing into a drying seed bed with a poor forecast for follow-up rain.

Granules by comparison are ideally suited to maintaining rhizobia numbers in dry soil for extended periods before rain arrives. The rhizobium is maintained within the granule which continues to protect it until the soil wets and the rhizobia can start multiplying. They are ideal to use if dry sowing is being considered. Additionally, they enable fungicides, which may be toxic to the rhizobia, to be applied to the seed without causing a reduction in rhizobia numbers. [8]

Table 1: *Inoculant types available.*

Inoculant product	Application method
BASF (NODULAID™NT)	Peat inoculant, applied as a slurry/powder/ liquid to the seed or in furrow to the soil
BASF (NODULATOR™)	Clay granular inoculant to be applied in furrow to the soil
New-Edge Microbials (EasyRhiz™)	Freeze-dried inoculant, made up into a liquid and applied to the seed or in furrow by water injection into the soil
New-Edge Microbials (Nodule N)	Peat inoculant, applied as a slurry to the seed
ALOSCA Technologies	Dry clay (bentonite) granular inoculant, applied in furrow to the soil
Novozymes Australia (Cell-Tech™)	Peat inoculant. Applied as a slurry/powder/ liquid to the seed or in furrow to the soil
Novozymes Australia (Tag-Team™)	Peat inoculant with phosphate-mobilising soil fungi *Penicillium bilaii.*

Source: Pulse Australia

3.1.4 When to inoculate

If crops within an inoculum group have not previously been grown in the paddock to be sown, then seed of the crop should be inoculated immediately prior to sowing; otherwise, a nodulation failure may occur (Figure 3).

If conditions for nodulation are likely to be adverse; i.e. waterlogged, acid soils, or lighter soils, then it may help to use some starter N, e.g. mono- or di-ammonium phosphate (MAP or DAP). This will stimulate early root growth until the numbers of naturally occurring rhizobia build up and begin fixing N. [9]

The current recommendation is to inoculate chickpea every time it is grown due to poor rhizobium survival on alkaline soils.

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

9 Pulse Australia (2013) Northern chickpea best management practices training course manual—2013. Pulse Australia Limited.

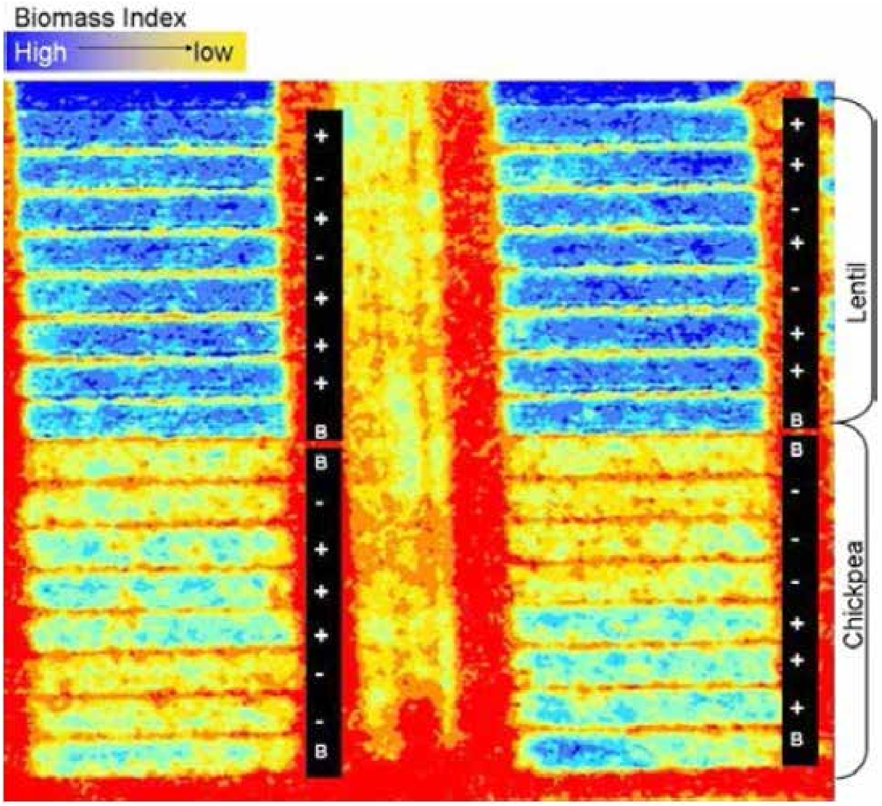


Figure 3: *Biomass image of lentil (top) and chickpea (bottom) inoculant plots at Paskeville SA 2009. Blue represents high biomass, yellow represents low biomass and red is bare earth. Note the responsiveness of chickpea but not lentil, plots to inoculation and inoculant type. B, buffer; +, inoculated; –, uninoculated.*

Photo: National Rhizobium Program trial by J. Heap, SARDI

Rhizobia will persist in the soil and, depending on a range of conditions, can inoculate a subsequent pulse. If the paddock has previously grown the same pulse, the number of rhizobia remaining in the soil will be affected by the:

- time since the pulse was last grown
- health of the crop
- type of rhizobia
- soil pH and texture.

Rhizobia types vary in their ability to persist in the soil until the host pulse crop is regrown. Lupin rhizobia (Group G) are most resilient and survive very well in low pH (down to pH 5) sandy soils. Pea and bean rhizobia (Groups E & F) survive well in neutral to alkaline soils with good texture (loams or clays).

If a well-nodulated lupin or pea crop has been grown in the previous four years, a response to inoculation is less likely. However, pea and bean rhizobia survive poorly in low pH or sandy soils. The safest and least risk option is to inoculate the crop, especially on light textured soils.

Less is known of the survivability of chickpea rhizobia (Group N). Inoculating at sowing is recommended regardless of other considerations.

The cost of inoculation is low and worth the effort if there is any doubt about the viability of residual soil rhizobia.

A benefit of inoculating a crop where rhizobia already exist is that an improved strain will be introduced which could result in better persistence for future pulse crops. Research continues to find more robust and efficient rhizobia strains for all pulse species. The strain used today in any group will be more advanced than those introduced to a paddock in the past. [10]

3.1.5 Inoculum survival

Moist peat provides protection and energy while the unopened packet is being stored. Inoculated seed should be sown directly into moist soil. 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.

Most peat inoculants now contain an adhesive, which delays drying and increases survival of the rhizobia. Use a peat slurry mixture within 24 hours. Sow seed inoculated with peat slurry as soon as possible, but certainly within 12 hours, being sure to keep the seed in a cool place, away from sunlight.

With non-peat based inoculants, such as freeze-dried rhizobia, it is recommended that treated seed be sown within 5 hours of inoculation. The rhizobia survive for longer in granules than when applied on seed. Hence, when drysowing pulses, granular inoculant is preferred over peat and liquid injection methods.

Dry-dusting the peat inoculant into the seed box is not an effective means of distributing or retaining rhizobia uniformly on seed. Under some conditions, rhizobial death is so rapid where dry dusting is used that no rhizobia remain alive by the time the seed reaches the soil. [11]

3.1.6 Inoculant quality assurance

Legume inoculants sold to Australian farmers must pass a rigorous quality assurance (QA) program. Cultures of inoculant are tested by the Australian Legume Inoculants Research Unit (ALIRU) to establish that the correct rhizobial strain is present and the viable cell number exceeds a minimum value (Table 2).

Table 2: *ALIRU Quality Assurance rhizobia minimum numbers.*

Product	Viable rhizobia (no./g)	Rate per ha	Rhizobia (no./ha)	Expiry (months)
Peat	1 × 109	250 g	3 × 1011	12–18
Liquid	5 × 109	300 mL	2 × 1012	6
Granular	1 × 107	10 kg	1 × 1011	6
Freeze-dried	1 × 1012	0.15 g	2 × 1011	24

Source: Grain Legume Handbook, 2008

3.1.7 Inoculation methods

Pulses have historically been inoculated with rhizobia slurry onto the seed, but now rhizobia can be purchased in a form suitable to be applied with water injection into the soil, or as granules that are sown with the seed from a separate box. For water injection, the inoculant is mixed with water and applied at low pressure through tubes into each seed furrow. Using granules usually requires a third seed box as granules will shake out if mixed with seed and can lose viability if mixed with fertiliser (Table 3).

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

11 Pulse Australia (2013) Northern chickpea best management practices training course manual—2013. Pulse Australia Limited.

Table 3: *Survival of different inoculant types with various application methods.*

Inoculant type	Where inoculant is applied	Survival in dry or drying soil*	Compatibility with seed-applied fungicide
Peat	Seed	Low	Some (check label)
Freeze-dried	Seed or in-furrow (water injection)	Very Low	Very Low
Granular	Seeding furrow of below seed	Yes	Yes
In-furrow water injection	Seeding furrow or below seed	Very low	Yes

*Survival will depend on duration of dry conditions and soil pH

Source: Pulse Australia, 2013

For chickpeas:

- Peat formulation: as slurry to seed (most common) or in furrow
- Freeze-dried formulation: as slurry to seed or liquid in furrow
- Granular formulation: in furrow at sowing [12]

3.1.8 Inoculum slurry

Most inoculants now 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. Add the inoculant suspension (slurry) to the seed and mix thoroughly until all seeds are evenly covered.

How to apply slurry to the seed:

- in a cement mixer (practical for small lots only unless a cement truck is used)
- through an auger (Figure 4)
- through a tubulator

When applying via an auger, 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 falling and cracking. Meter the slurry in, according to the flow rate of the auger (remember 250 g packet per 100 kg seed). Too much water means sticky seed and blockage problems in the planter.

12 GRDC. (2013). Inoculating legumes: The Back Pocket Guide. https://grdc.com.au/GRDC-BPG-InoculatingLegumes

Figure 4: *Pumping a slurry of rhizobia inoculant into the auger to coat seed before sowing.*

Source: GRDC

Applying the slurry through a tubulator is similar to applying through an auger, except that the tubulator reduces the risk of damaging the seed (Figure 5). Its mixing ability is not as effective as an auger.

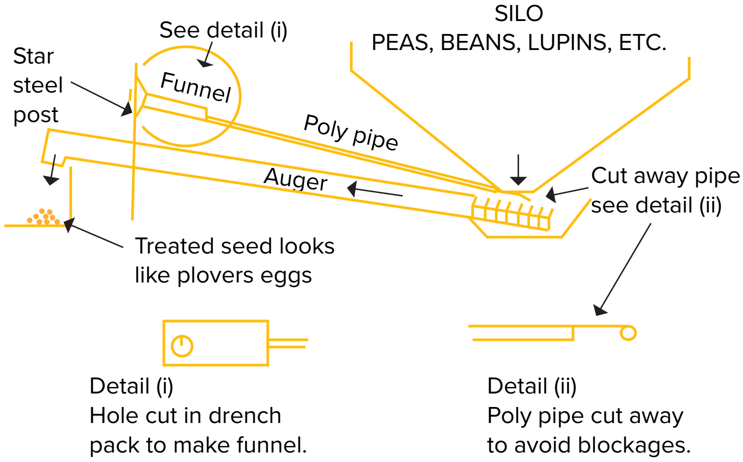


Figure 5: *Application of inoculum to seed through a tubulator.*

3.1.9 In-furrow water injection

Injection of inoculants mixed in water is becoming more common. It can be used where machines are set up to apply other liquids at seeding, such as liquid N or phosphorus (P). Water injection of inoculant requires at least 40–50 L/ha of water, and is better with more water. The slurry–water solution is applied 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 extreme caution is advised because water pH is critical, and trace element types, forms and products behave differently between products and inoculants groups.

Trials have consistently shown superior nodulation from water injection of inoculum (Figures 6 and 7). This is likely to be due to the larger numbers of live bacteria being delivered into the soil in close proximity to the seed.

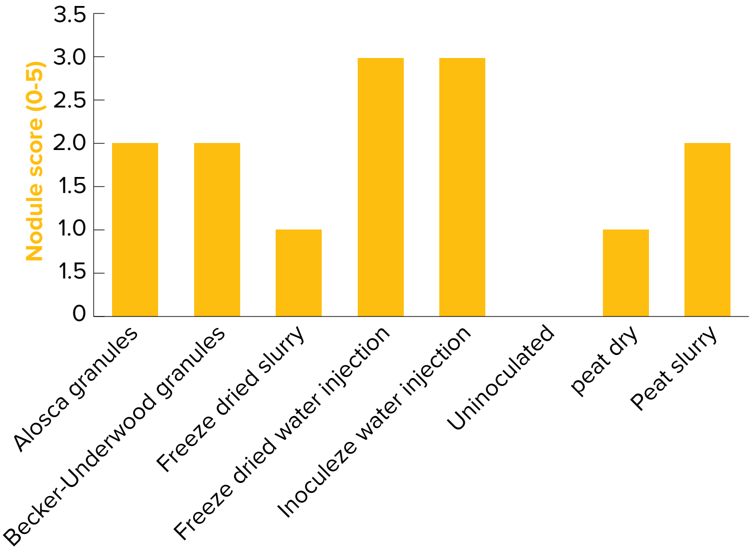


Figure 6: *Inoculation trial with nodule scores assessed at 4 weeks after planting.* [13]

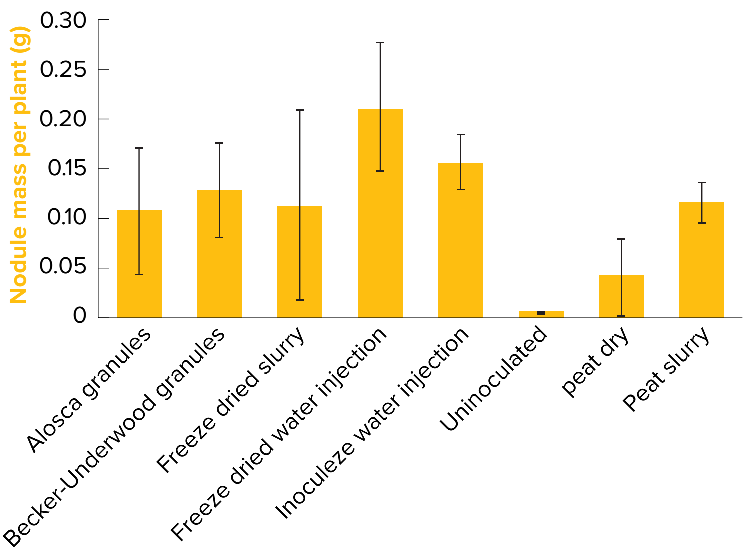


Figure 7: *Inoculation trial at Emerald (2005), nodule biomass at flowering.* [14]

13 Pulse Australia (2013) Northern chickpea best management practices training course manual—2013. Pulse Australia Limited.

14 Pulse Australia (2013) Northern chickpea best management practices training course manual—2013. Pulse Australia Limited.

3.1.10 Inoculant application trials

Inoculation of chickpea seed with Group N rhizobia is recommended regardless of paddock history. The standard method of mixing slurry and applying direct to seed still appears adequate; however, recent research has shown potential improvements by injecting the rhizobia into the seed furrow with water as a carrier. Peat granules have on average performed as well as the standard slurry method, whereas attapulgite clay granules and bentonite clay granules have generally resulted in nodulation levels higher than the untreated control, but equal to or less than the standard slurry method.

Trials from 2008 to 2010 have compared the use of the available inoculant treatments. Figure 8 presents trial results in terms of nodule score by product type.

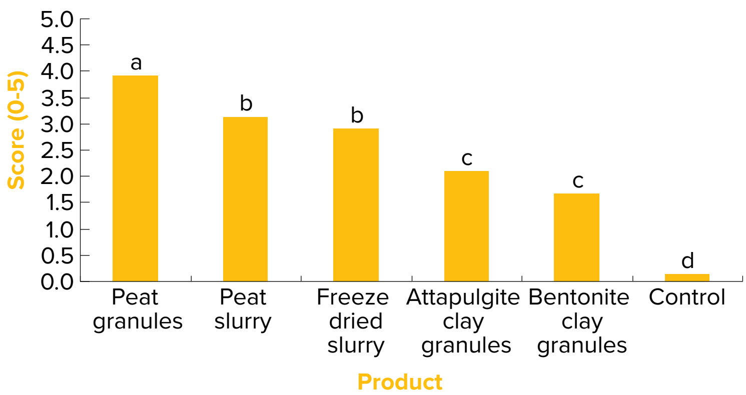


Figure 8: *Effect of inoculant treatment on nodulation of chickpea roots.* [15]

Limited trial data show that the most effective of the new technologies appears to be the application of rhizobia in-furrow with water (water-inject). This reduces the need to mix and apply slurry to the seed, but requires large volumes of water at sowing, as well as a liquid tank and plumbing to be incorporated into the seeder. Clay granules (attapulgite and bentonite) have often resulted in less nodulation than the standard slurry treatments.

However, where chickpeas are a regular crop in the rotation, the reduced efficacy provided by the clay granules compared with the standard slurry treatment is likely to be less pronounced. Granules can reduce labour and downtime at sowing, so would only be recommended where real efficiency gains can be made. Peat granules resulted in nodulation levels greater than the clay granules in one of two trials. The use of standard slurry treatment (peat slurry) still appears to be a reliable method of application. In some cases, nodulation may be less than with the 'water inject', but this needs to be balanced with the extra machinery cost of liquid injection.

In one trial, nodulation from the slurry applied to seed method was significantly affected by fungicide (thiram + thiabendazole), where the fungicide and slurry were applied within one hour of each other. In the trials where the fungicide did not affect nodulation, the seed had been treated with fungicide at least several days before inoculation. In the fungicide-affected trial, the freeze-dried slurry treatment showed a greater reduction in nodulation from fungicide than what was seen from the peat slurry treatment.

For growers planting small areas of chickpeas, or who are content with current treatments methods, the traditional method of peat slurry application still appears

15 R Brill, G Price (2011) Chickpea inoculation trials 2008–10. GRDC Update Papers March 2011, http://www.nga.org.au/results-and-publications/download/67/grdc-update-papers-general-/rhizobia-innoculation-methods-inchickpeas/grdc-adviser-update-paper-goondiwindi-march-2011.pdf

reliable. Where the requirement for N fixation is high (e.g. chickpeas cropped straight into sorghum stubble), liquid injection may improve outcomes. Liquid injection (once set up on a machine) may also provide logistical benefits.

Where chickpeas have been a regular crop in the rotation, granules may provide adequate nodulation and give logistical benefits such as reduced labour requirement.

Note: These results present only one year of data. To gain a full understanding of the individual treatments used, the trials need to be replicated over several seasons and as part of different farming systems. [16]

3.1.11 Compatibility with other major factors

Pesticides

Rhizobia are living organisms. As a general rule, pesticides are toxic to rhizobia.

Almost all pulses require a fungicide applied to the seed to provide protection during early growth against foliar diseases. Occasionally an insecticide may also be needed.

Peat inoculants are also applied to the seed, bringing together two largely incompatible products. Mixing inoculum with a pesticide for seed treatment is possible with some products. Read the inoculum label to check for compatibility. BASF claims compatibility between its peat inoculum and Rovral®. However, the seed must be sown within several hours into moist soil to avoid reducing rhizobia viability.

Applying the fungicide to the seed prior to the inoculum is a safer method to reduce the risk of rhizobia death. The fungicide can be applied at any time leading up to sowing. The inoculum is then applied immediately before sowing into moist soil. If in doubt, do not mix the inoculant and any pesticide.

Granular inoculants remove this risk because the rhizobia and the pesticide are not in contact. If you need to use a potentially toxic seed pesticide treatment, granular inoculant may be worth considering.

Always read the inoculant label or contact the manufacturer for up-to-date information on compatibility. [17]

Fungicides

Caution should be used when treating pulse seed with a fungicide. 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.

Effect of fungicidal seed dressings on inoculum survival

While fungicide seed dressings reduce the longevity of the N-fixing bacteria applied to the seed, the effect can be minimised by keeping the contact period to as short as possible (Table 4).

Inoculate fungicide-treated seed as close as possible to the time of sowing.

Re-inoculate if not planted within 12 hours of treatment.

16 R Brill, G Price (2011) Chickpea inoculation trials 2008–10. GRDC Update Papers March 2011, http://www.nga.org.au/results-and-publications/download/67/grdc-update-papers-general-/rhizobia-innoculation-methods-inchickpeas/grdc-adviser-update-paper-goondiwindi-march-2011.pdf

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

Table 4: *Effects of fungicide seed dressings on plant growth and nodulation in chickpeas.*

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 + 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 + Apron	106	173	279	54	1.8
Inoculum then Arpon	114	207	321	59	3.3
Apron then inoculum	113	206	319	55	3.6
l.s.d (P = 0.05)	19	33	31	9	0.6

Source: Trevor Bretag, formerly DPI Victoria

Trace elements

Rhizobia can be compatible with a few specific trace element formulations, but many are not compatible with rhizobial survival. Mixing inoculants with trace elements should only occur if the trace element formulation being used has been laboratory-tested against the rhizobial type being used.
Note the differences between inoculant types for a given trace element product, as well as differences between trace element products with a given inoculant.

3.1.12 Nodulation and nitrogen fixation

Different pulses need different strains of rhizobia, so are grouped into inoculation groups. Unless the right strain is present in the soil or has been supplied by adding a commercial inoculant at seeding time, effective root nodulation will not take place and little if any N will be fixed. These effects are not always immediately obvious above ground.

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, that nodules are abundant and that the strain of rhizobia forming the nodules is effective at fixing N (Figure 9).

MORE INFORMATION

Inoculating legumes: a practical guide (GRDC)

Inoculating legumes: the back pocket guide (GRDC)

Rhizobia inoculants fact sheet (GRDC)

Figure 9: *Well-nodulated chickpea plants.*

Photo: G. Cumming, Pulse Australia

When the legume germinates, the rhizobia enter the plant's roots, multiply rapidly and form a nodule. Effective nodule formation and function for the all-important N fix requires good growing conditions, the appropriate rhizobia and a host plant. Rotation lengths of 3–4 years are recommended between successive chickpea crops as a disease management strategy (i.e. ascochyta blight). At this re-cropping interval, sufficient levels of surviving Group N rhizobia are unlikely for effective nodulation.

Nodules remain inactive until the soil nitrate supply is exhausted (ineffective nodules remain white inside due to the absence of leghaemoglobin). Effective N-fixing nodules on the other hand, are rusty red or pink colour inside (Figure 10).

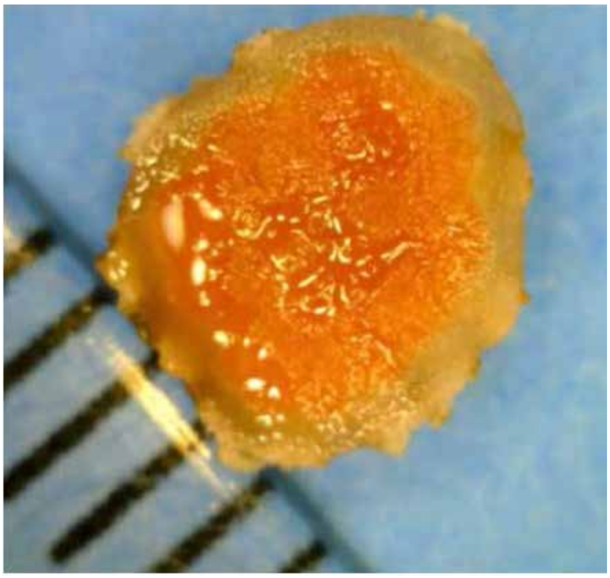


Figure 10: *Active nodules have a rusty red or pink centre.*

Photo: G. Cumming, Pulse Australia

IN FOCUS

Chickpea Water Use Efficiency in relation to cropping system, cultivar, soil nitrogen and Rhizobial inoculation in semiarid environments

Crops grown in semiarid rainfed conditions are prone to water stress which could be alleviated by improving cultural practices. One study determined the effect of cropping system, cultivar, soil nitrogen status and *rhizobium* inoculation (*Rz*) on water use and Water Use Efficiency (WUE) of chickpea in semiarid environments. Four varieties were grown in no-till barley, no-till wheat, and tilled-fallow systems and under various rates of N fertiliser (0, 28, 56, 84, and 112 kg N ha−1) coupled with or without *Rz*. On average, chickpea used about 10 mm of water from the top 0–15 cm soil depth. In the tilled-fallow system, chickpea extracted 20% more water in the 15–30 cm depth, 70% more in the 30–60 cm depth, and 156% more in the 60–120 cm depth than when it was grown in the no-till systems. Water Use Efficiency increased from 4.7 to 6.8 kg ha−1 mm−1 as N fertiliser rate was increased from 0 to 112 kg N ha−1 when chickpea was grown in the no-till barley or wheat systems, but chickpea grown in the tilled-fallow system did not respond to changes in the fertiliser N rates averaging WUE of 6.5 kg ha−1 mm−1. In the absence of N fertiliser, the application of *Rz* increased WUE by 33% for chickpea grown in the no-till barley system, 30% in the no-till wheat system, and 9% in the tilled-fallow system. Chickpea inoculated with *rhizobium* achieved a WUE value similar to the crop fertilised at 84 kg N ha−1. Without the use of *Rz*, chickpea increased WUE in a linear fashion with increasing fertiliser N rates from 0 to 84 kg N ha−1. Cropping system, cultivar, and inoculation all had greater impact on WUE than on the amount of water extracted by the crop from the soil. The improvement of cultural practices to promote general plant health along with the development of cultivars with improved crop yields will be keys for improving Water Use Efficiency of chickpea in semiarid environments. [18]

3.1.13 Monitoring nodulation

Grain growers are encouraged to assess their legume crops for nodulation levels. Late winter and early spring is the best time to sample crops. It's important that growers who have used inoculants and also those who have not, check crops to see whether adequate nodulation is occurring. For farming systems to derive maximum benefits from legume N-fixation, optimal nodulation is necessary.

The best approach is to:

- Collect three samples of about 10 plants from three different spots within a paddock (suggested to be 20 m, 60 m and 100 m in from the edge), putting each sample of 10 plants in a separate bucket;
- Carefully wash off the soil in a bucket of water and rinse the roots to remove the remaining soil (soak for up to 30 minutes for heavy soil);
- Score each sample for the percentage of plants adequately nodulated and work out an average of scores for the three sampling locations.

Growers should look for:

18 Gan, Y. T., Warkentin, T. D., Bing, D. J., Stevenson, F. C., & McDonald, C. L. (2010). Chickpea Water Use Efficiency in relation to cropping system, cultivar, soil nitrogen and Rhizobial inoculation in semiarid environments. Agricultural water management, 97(9), 1375–1381.

- The number of nodules on a plant. The desirable number of nodules varies for different legumes (Figure 11). For example, 50 per plant is adequate for field pea, vetch and faba bean. The number of nodules also varies between soil types (lower numbers per plant are found on lighter soils);
- The location of nodules on the plant. Where growers have inoculated seed, expect to see more nodules around the crown of the plant (where root meets shoot). These will boost the early growth of seedlings. Non-inoculated legumes will have nodules spread over the root system on crown, taproots and laterals, if rhizobia are already present in the soil;
- The colour inside the nodules. A red/pink colour means the nodules are effective and are fixing N (Figure 12). White or green nodules mean they are ineffective.

Score 0: taproot, absent; lateral, absent/few.

Score 1: taproot, few/medium; lateral, absent.

Score 2: taproot, medium; lateral, absent/low.

Score 3: tap root, medium/high; lateral, low.

Score 4: taproot, high; lateral, medium.

Score 5: taproot, high; lateral, medium.

Figure 11: *Assessment of nodulation.*

Photos A. Gibson. Source: GRDC

Figure 12: *A strong pink colour inside the nodules indicates that the rhizobia are actively fixing nitrogen.*

Photo: J Howieson. Source: Pulse Australia

If poor nodulation is apparent, growers should check their inoculation strategy to ensure best management practices are being followed. If both nodulation and plant performance are poor, reasons for poor nodulation need to be identified.

Poor nodulation can cause 10–50% yield loss in pulse crops, not to mention the lower potential N benefits to following crops. While a visual assessment will not indicate the actual level of N being fixed, which requires sophisticated scientific methods, looking at the roots to determine if there has been a nodulation failure or delay is worthwhile.

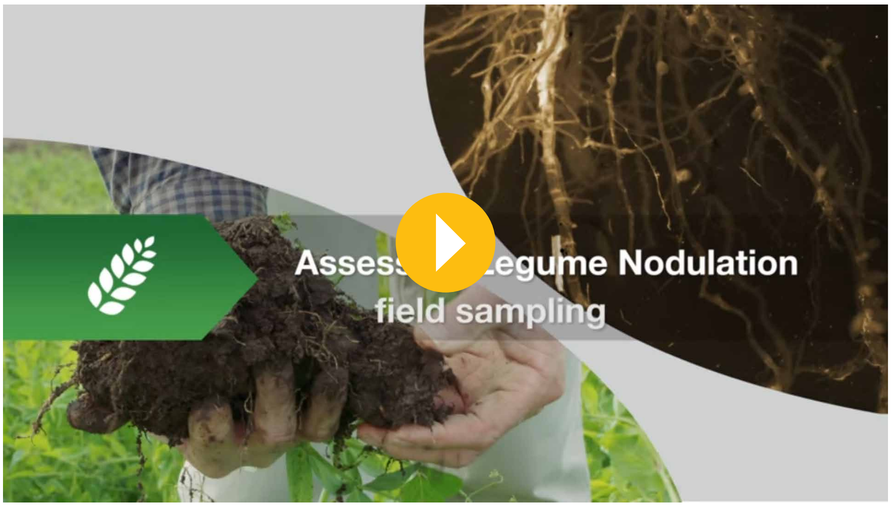
When looking at plants in the field, it is likely growers will find nodules on lateral roots as well as the main tap root. Look at all nodules when comparing the total nodule numbers in order to work out good or poor nodulation. Pulse crops that are poorly nodulated will be using more soil N than adequately nodulated crops, and fixing less N from the air.

Nodulation assessment will indicate whether this year's inoculation has been successful or whether troubleshooting is necessary. It will also tell a grower if non-inoculated legume should be inoculated next time it is grown in that paddock.

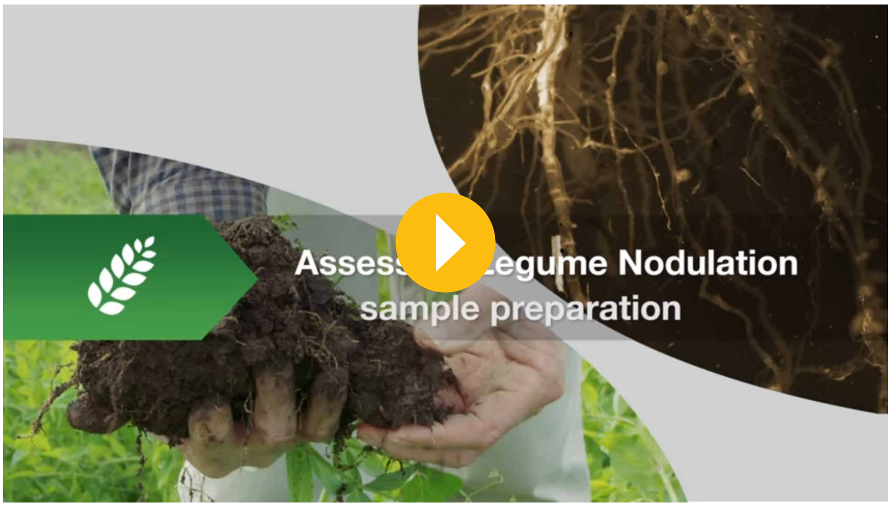
Poor nodulation can be caused by: no inoculation where low rhizobia numbers are present in soil; incorrect inoculant group or inoculant not being stored in cool conditions before use; inoculant effectiveness that has been reduced after mixing with certain types of seed dressings or liquid in-furrow treatments (trace elements, pesticides, fertilisers or organic amendments); inoculated seed left for more than one day before sowing; and crop stress, such as nutrition, waterlogging, diseases or herbicides causing root damage. [19]

19 GRDC. 17/08/16 Media Releases. Growers get the nod to check legumes for nitrogen fixation. www.grdc.com.au/media-news

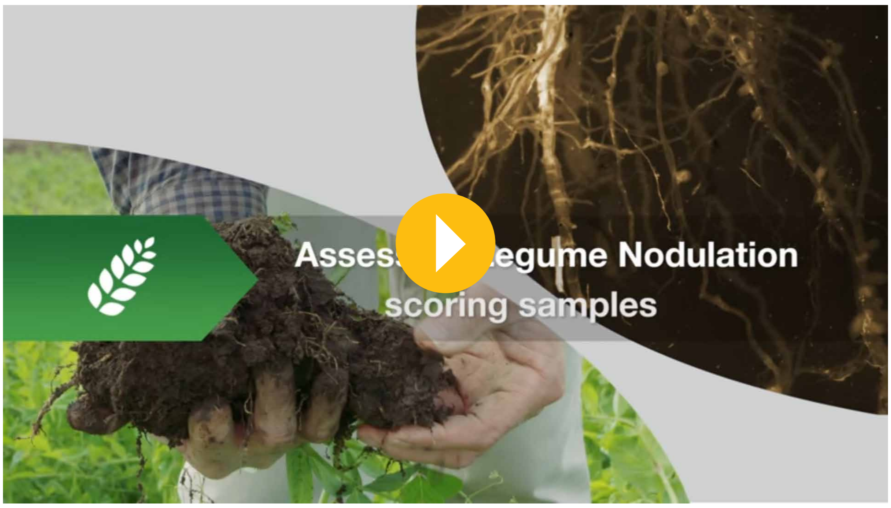
WATCH: GCTV17: Legume nodulation – field sampling.



WATCH: GCTV17: Legume nodulation – sample preparation.



WATCH: GCTV17: Legume nodulation – sample scoring.



3.1.14 Use of nitrogen in inoculation

There has been some research into the effects of adding N to inoculated chickpea. One study applied inorganic N fertiliser at four levels (0, 50, 75 and 100 kg ha–1 (applied in urea form)) and two levels of inoculation with rhizobium bacteria (with and without inoculation) as sub plots. Application of N and rhizobium inoculation continued to have positive effect on growth indices and yield components of chickpea. Lower levels of N application and non-inoculated plants showed less growth indices including total dry matter (TDM), leaf area index (LAI), crop growth rate (CGR), relative growth rate (RGR) and net assimilation rate (NAR) while the highest values of these indices were observed at the high levels of N application and inoculated plants. The highest plant height, number of primary and secondary branches, number of pods per plant and number of grains per plant were obtained from the highest level of N fertiliser (100 kg urea ha–1) and rhizobium inoculation. Application of 75 and 100 kg urea ha–1 showed no significant difference in these traits. Moreover, the highest grain yield was recorded in the inoculated plants that were treated with 75 kg urea ha–1. The results indicated that the application of suitable amounts of N fertiliser (i.e. between 50 and 75 kg urea ha–1) as a starter can be beneficial in improving growth, development and total yield of inoculated chickpea. [20]

3.2 Seed treatments

It is recommended that whenever possible seed should be obtained from a source where the crop was free from ascochyta blight and botrytis grey mould.

All seed, regardless of source, should be treated with a registered thiram-based fungicide seed dressing before sowing (Table 5).

These seed treatments will help minimise the levels of seed-borne ascochyta and botrytis grey mould. Research has shown that thiram plus thiabendazole products (e.g. P-Pickle-T®) and thiram-only products (e.g. Thiraflo®) are equally effective against ascochyta and botrytis.

A fungicidal seed dressing to suppress early development of ascochyta blight is also essential. Use thiram or thiabendazole and thiram combined, which is also effective against botrytis grey mould. There are no known fungicide seed dressings or treatments to control sclerotinia, although grading may assist by physically reducing the number of small sclerotes (fungal fruiting bodies) in the seed sample.

Kabuli chickpeas may show a response to the application of fungicide seed dressings even in the absence of known fungal diseases. This is because kabulis have a thinner seed coat than desi types and a lower content of phenolic compounds, which help protect the seed against fungal attack. [21]

Table 5: *Seed dressings registered for the control of seed borne ascochyta blight and botrytis grey mould.*

Active ingredient	Example of trade name	Rate (per 100 kg seed)
thiram (600 g/L)	Thiraflo	200 mL
thiram (800 g/kg)	Thiragranz	150 g
thiram + thiabendazole (360 + 200 g/L)	P-Pickel T	200 mL

Refer to the current product label for complete 'Direction for use' prior to application.

20 Namvar, A., Sharif, R. S., & Khandan, T. (2011). Growth analysis and yield of chickpea (Cicer arietinum L.) in relation to organic and inorganic nitrogen fertilisation. Ekologija, 57(3).

21 Pulses Australia. Chickpea Production: Southern and Western region. http://www.pulseaus.com.au/growing-pulses/bmp/chickpea/southern-guide

All chickpea seed should be inoculated with Group N inoculant. Fungicide seed dressings can reduce the longevity of this nitrogen fixing bacteria. But if contact is kept to a minimum duration, satisfactory nodulation will be obtained in most cases.

Fungicide seed dressings can be applied at any convenient time leading up to sowing. However, inoculation of seed needs to occur as close as possible to the time of sowing.

All inoculated seed should be sown into moist soil within 12 hours of treatment (or as per the inoculant's label directions), and the sooner the better. If inoculated seed is not sown within 12 hours, re-inoculate before sowing. [22]

MORE INFORMATION

Inoculating pulses

Seed treatment is very effective against seed rot, permitting early seeding of kabuli types to help offset the later maturity of currently available kabuli chickpea varieties. Because the large-seeded kabuli varieties mature later than the desi varieties, they may need to be sown earlier than desi in some districts.

If the seed is treated, it should be planted immediately after inoculation, as seed treatments can be toxic to the inoculant. The longer the inoculant is in contact with the seed treatment, the less effective it will be. [23]

3.3 Time of sowing

Time of sowing has been identified as a major factor affecting chickpea yield and disease incidence. [24] The key to planting chickpeas is to be mindful that the crop is susceptible to stress during flowering. Selecting a planting date that will limit this stress is a practical way to give the crop the best chance of achieving its potential yield.

The later a crop is planted the shorter the potential season for growth and development, especially if the season has a hot dry spring. When this occurs, plants have less time to develop canopies and roots, resulting in only partial use of soil water and a yield that is below potential. Reducing the row spacing of late-planted crops and ensuring an adequate plant density is one method to help late-planted crops access all available soil water. [25]

Chickpea shows a marked response to time of sowing. Crops sown 'on time' have an excellent chance of producing very high yields. However, crops sown earlier or later than recommended often suffer reduced yields. Spring sowing is a preferred option in high rainfall areas (greater than 550 mm). [26]

The chickpea sowing window for low rainfall is April 20–May 25, and in medium rainfall from May 15–June 15.

Yield increases exhibited by winter sown chickpea have been ascribed to the longer vegetative growth periods leading to a larger vegetative structure. This larger vegetative structure intercepts photosynthetically active radiation (PAR) more effectively in spring and supports a proportionally larger reproductive sink with adequate partitioning of dry matter. [27]

One study found that chickpea yield per unit area increases with both earlier sowing and increased supplemental irrigation. However, WUE under supplemental irrigation decreases with earlier sowing, due to the relatively large increase that occurs in the

22 L Jenkins, K Moore, G Cumming. Pulse Australia. Chickpea: High Quality seed. http://www.pulseaus.com.au/growing-pulses/bmp/chickpea/high-quality-seed

23 Pulses Australia. Chickpea Production: Southern and Western region. http://www.pulseaus.com.au/growing-pulses/bmp/chickpea/southern-guide

24 Knights EJ, Siddique KHM (2002) Chickpea status and production constraints in Australia. In: Integrated management of botrytis grey mould of chickpea in Bangladesh and Australia. Summary Proceedings of a Project Inception Workshop, Bangladesh Agricultural Research Institute, Joydebpur, Gazipur, Bangladesh. (Eds MA Bakr, KHM Siddique, C Johansen). June 2002, pp 33–41.

25 J Whish, B Cocks (2011) Sowing date and other factors that impact on pod-set and yield in chickpea. GRDC Update Papers 20 April 2011, http://elibrary.grdc.com.au/ark!!33517/vhnf54 t/tj680np

26 W Hawthorne, W Bedggood. (2007) Chickpeas in South Australia and Victoria. http://www.pulseaus.com.au/storage/app/media/crops/2007_Chickpeas-SA-Vic.pdf

27 Croser, J. S., Clarke, H. J., Siddique, K. H. M., & Khan, T. N. (2003). Low-temperature stress: implications for chickpea (Cicer arietinum L.) improvement. Critical Reviews in Plant Sciences, 22(2), 185–219.

amount of evapotranspiration at early sowing dates. [28] WUE is commonly in the range of 8–12 kg grain/ha/mm for sowings made during the preferred sowing window. This drops away to 4–6 kg/ha/mm for very late or very early sowings.

Sowing before the recommended sowing window tends to result in greater vegetation and crops suffer from:

- poor early pod set because of low temperatures (<15°C) at flowering commencement
- higher risk of botrytis grey mould at flowering–podding (Figure 18)
- greater pre-disposition to lodging
- increased frost risk at early podding
- high water use prior to effective flowering and the earlier onset of moisture stress during podding
- increased risk of ascochyta blight

Late-planted crops are more likely to suffer from:

- high temperatures and moisture stress during podding
- greater native budworm pressure
- shorter plants, which are 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'.

Ideal sowing dates should ensure that all chickpea crops:

- finish flowering before they are subjected to periods of heat stress, generally when maximum day temperatures over a week average 30°C or more; and
- flower over an extended period to encourage a better pod set and produce sufficient growth to set and fill an adequate number of pods.

Sowing must not be too early, otherwise:

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

This means that there can be a significant difference between the optimum sowing time for maximum potential yields and the ideal sowing time for reducing yield loss factors. The ideal seeding time for pulses depends largely on where the crops are being grown. 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, it is essential to have adequate soil moisture at seeding time.

In some areas, the ideal sowing date will be a compromise. Optimum yields achieved by early sowing may have to be sacrificed, with sowing being delayed until risk factors have been reduced to an acceptable level (Figure 13). [29]

---

28 Oweis, T., Hachum, A., & Pala, M. (2004). Water Use Efficiency of winter-sown chickpea under supplemental irrigation in a Mediterranean environment. Agricultural water management, 66(2), 163–179.

29 Pulse Australia (2013) Northern chickpea best management practices training course manual—2013. Pulse Australia Limited.

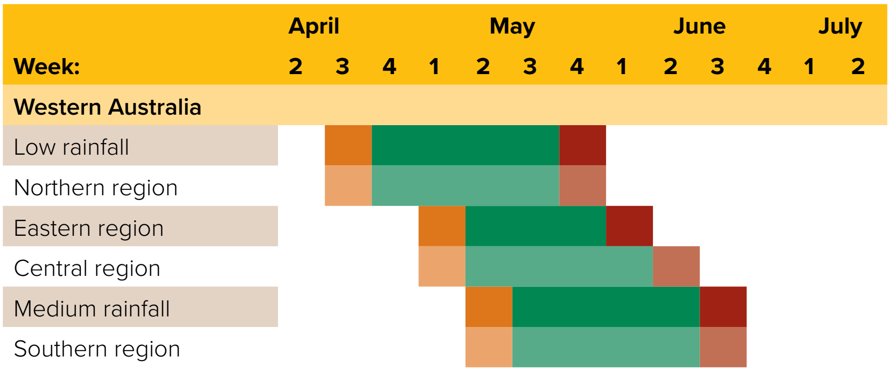


Figure 13: *Preferred chickpea planting times for districts with in the Western growing region.*

Source: Pulse Australia

WATCH: Early Seeding, WA.

IN FOCUS

When to sow chickpea in south-western Australia.

The optimum time of sowing of several desi chickpea varieties varying in phenology over a range of dryland Mediterranean-type environments in south-western Australia has been examined. Chickpea showed good adaptation, particularly in the northern grain belt where growing conditions are warmer than southern areas. Seed yields were not clearly increased by altering sowing time to match the phenology of the current varieties to the growing season rainfall and temperatures, except at the early sowing times (April and early May). Generally, the greatest seed yields were produced by sowing between mid to late June at southern sites, and early May at central and northern sites.

In chickpea grown in the Mediterranean regions of Australia, early phenology is associated with higher seed yield because it facilitates escape from terminal drought. However, flowering too early exposes chickpea to temperatures that are too low to support podset. Unlike cereal crops, chickpea has an indeterminate growth habit and is able to continue flowering and podding if environmental conditions are favourable, hence varietal responses to time of sowing may differ. This study examined the optimum time of sowing for several desi chickpea varieties varying in phenology over a range of dryland Mediterranean-type environments in south-western Australia.

Several desi chickpea varieties were sown at three or four times between early-April and mid-July at 19 sites between 1994 and 1998, corresponding to southern, central and northern production zones in south-western Australia. Entire plots (34- 36 m^2) were machine harvested to determine seed yield. Seed yields were analysed across sites and seasons using a linear mixed model to determine interactions between variety, time of sowing and region. For this analysis, regions were specified as north, central or south and sowing time was grouped into early, mid or late periods of each month.

Conclusions

Chickpea showed good adaptation to the dryland environments of south-western Australia, particularly in the northern and central agricultural regions where growing conditions are warmer than southern areas. This may be a consequence of the lack of chilling tolerance in chickpea. The optimal time of sowing for chickpea was from mid to late June at southern sites, and early May at central and northern sites. Seed yield of chickpea was not clearly increased by matching sowing time of current varieties with varied phenology in this study. [30]

3.3.1 Frost damage

Chickpea seedlings are tolerant of frost. Desi chickpea seed can germinate in soil as cold as 5°C, but seedling vigour is greater if soil temperatures are at least 7°C. Kabuli chickpea seed is more sensitive to cold soils and should not be seeded into excessively wet soil or into soil with temperatures below 12°C at the placement depth.

Damage to vegetative growth:

Damage is more likely to occur where the crop has grown rapidly during a period of warm weather, and is then subjected to freezing temperatures. The visible effect may occur as patches in the field, or on individual plants or branches of plants. Damage is usually more severe where stubble has been retained. Regrowth will generally occur provided soil moisture levels are adequate.

Damage to flowers and pods:

Freezing temperatures destroy flowers and young developing seed (Figure 14). Pods at later stage of development are generally more resistant and only suffer from a mottling and/or darkening of the seed coat. Varieties with an extended podding period can compensate for damage better than varieties that tend to pod up over a shorter period provided soil moisture levels are adequate.

Frost is most damaging to yield:

- when it occurs during later flowering–early pod fill
- under dry conditions where moisture limits the plant’s ability to re-flower and compensate for frost damage.

30 Regan, K., & Siddique, K. H. (2006, September). When to sow chickpea in south-western Australia. In Proceedings of the 13th Australian Agronomy Conference (pp. 10–14).

Figure 14: *Frosted chickpea at flowering.*

For more information on frost damage and management in chickpeas, see Section 14: Environmental issues.

3.4 Seed rate

Sowing rate affects plant establishment and is an important crop management decision. While yields are relatively stable within the range of 35–50 plants/m^2, higher seeding rates (50 plants/m^2) produce the highest yields in western and southern areas (Table 6). High populations planted on wide rows often result in thin main stems and a higher risk of lodging.

Higher populations are justified for late sowings, while lower populations of around 20 plants/m^2 are often recommended for crops grown on wide row spacing (e.g. 100 cm). High populations sown on wide rows often result in thin main stems and a higher risk of lodging. [31]

Table 6: *Seeding rate (kg/ha) required for targeted plants/m^2 for a range of chickpea varieties at 95% germination and 80% establishment.*

Example variety type		Seed weight (g/100)	Seeding rate (kg/ha):		
			20 plants/m^2	25 plants/m^2	30 plants/m^2
Almaz(D)	Large Kabuli	42	111	138	166
Genesis™079	Small Kabuli	26	68	86	103
Genesis™090	Small Kabuli	30	79	99	118
Genesis™114	Large Kabuli	44	116	145	174
Genesis™425	Small Kabuli	29	76	95	114
Genesis™Kalkee	Larger Kabuli	46	121	151	182
Flipper(D)	Medium Desi	18	47	59	71
Genesis™509	Small Desi	16	42	53	63
Genesis™510	Small Desi	16	42	53	63
Genesis™836	Medium Desi	18	47	59	71
Kyabra(D)	Large Desi	25	66	82	99
PBA Boundary(D)	Medium Desi	20	53	66	79
PBA HatTrick(D)	Medium Desi	21	55	69	83
PBA Slasher(D)	Medium Desi	20	53	66	79
Yorker(D)	Medium Desi	21	55	69	83

Source: Pulse Australia

31 L Jenkins, K Moore, G Cumming. Pulse Australia. Chickpea: High Quality Seed. http://www.pulseaus.com.au/growing-pulses/bmp/chickpea/high-quality-seed

IN FOCUS

Optimum plant density of desi chickpea (Cicer arietinum L.) increases with increasing yield potential in south-western Australia

The response of chickpea (cv. Tyson) seed yield to sowing rate (30ñ180 kg/ha) was examined in 18 field experiments across three years in south-western Australia. The economic optimum plant density was estimated at each site and the point where the cost of extra seed equalled the return from additional seed yield was calculated, allowing a 10% opportunity cost for the extra investment. When averaged across all sites and seasons, plant densities varied from 14 plants/m^2 when sown at 30 kg/ha, to 84 plants/m^2 when sown at 180 kg/ha. Therefore, only about 54% of seeds sown established into viable plants, even though the germination test of the seed was about 80%. The poor establishment rate is thought to be mainly due to physical damage to the seed during transport and sowing, as well as unfavourable seedbed moisture and temperature conditions. At most experimental sites the seed yield of desi chickpea responded positively to an increase in sowing rate up to about 120 kg/ha. Increased yields at high sowing rate can be directly attributed to large plant populations. Although in many cases the number of pods per plant, seed size, and harvest index were reduced at high plant populations, increased plant density compensated for these effects and seed yield tended to increase. There was a good relationship between economic optimum plant density and yield potential derived in this study and this improves the ability of desi chickpea producers to select the most profitable sowing rate, depending upon their yield potential. These results suggest that the optimum plant density is 50 plants/m^2 for most chickpea crops in south-western Australia yielding about 1.0 t/ha, whereas in high-yielding situations (>1.5 t/ha), plant densities >70 plants/m^2 produce the most profit. Although not observed in these experiments, high plant densities can exacerbate fungal diseases, and hence, reduced plant densities are desirable in disease-prone situations. Differences in sowing rate responses may be expected between Tyson and new large-seeded cultivars such as Heera and Sona, which have longer branches and more open canopy, or kabuli types, and this deserves further investigation. [32]

3.4.1 Calculating seed requirements/sowing rate

Seeding rate for the target plant density can be calculated using germination percentage, 100 seed weight and establishment percentage (Figure 15).

Adjust sowing rates to take account of seed size, germination percentage and estimated establishment conditions.

32 Jettner, R. J., Loss, S. P., Siddique, K. H. M., & French, R. J. (1999). Optimum plant density of desi chickpea (Cicer arietinum L.) increases with increasing yield potential in south-western Australia. Crop and Pasture Science, 50(6), 1017–1026.

$$\text{Seeding Rate (kg/ha)} = \frac{\text{100 seed weight\# x Target plant population* x 1000}}{\text{Germination \% x Estimated Establishment \%*}}$$

Example

100 seed weight = 21 grams

Target plant density = 25 plants/m^2 (i.e. 250,000 plants/ha)

Germination % = 95%

Estimated establishment % = 85%

$$\text{Seeding rate (kg/ha)} = \frac{21 \times 25 \times 1000}{95 \times 80}$$

= 69.08 kg/ha

#100 seed weight in grams from the variety characteristics table.
*Target plant population for your location (seek local advice)

Figure 15: *Seeding rate calculation – desi chickpea example.*

Source: Pulse Australia

3.5 Targeted plant population and row spacing

As part of an overall farming system, there is a move towards using row spacing configurations with chickpeas wider than the standard 15–25 cm [33] (Table 7).

Sowing at 30–50 cm spacing is becoming common. There was a need to look at the effect of row spacing under situations of high yield potential, with current varieties and newer agronomic practices.

The research shows that new varieties have a lower rate of yield decline at wider row spacing than older varieties. Researchers recommend the following rules of thumb when sowing within the optimum window of mid-May–mid-June under conditions of high yield potential:

- For yield potential ≥2.0 t/ha, sow on narrow rows (≤40 cm).
- For yield potential ≤2.0 t/ha, row spacing has less of an impact on yield.
- When sowing very late, sow on narrow rows at adequate plant density.
- When sowing very early, sow on wider rows to reduce early soil water extraction. [34]

Some innovators are sowing in 50–100 cm row spacing and using inter-row spraying for weed control. Wider rows require adequate stubble presence to minimise soil evaporative losses and viruses. Weed control must be considered too. Standing stubble and wider rows improve chickpea harvestability and may have advantages in:

- low yielding or lower rainfall situations, or
- when dense canopies would otherwise reduce pod set and potentially lead to Botrytis grey mould.

Fitting the farming system is the important issue. Disadvantages are normally more than offset by the advantages offered by machinery access and zero or minimum tillage systems with stubble retention. [35] The advantage of row-cropping chickpea outweigh any potential yield reductions as no-till weed control methods can be applied and may be the difference between farmers electing to no-till or continue to cultivate their fallow. [36]

33 Felton, W. L., Marcellos, H., & Murison, R. D. (1996, January). The effect of row spacing and seeding rate on chickpea yield in northern New South Wales. In Proceedings of the 8th Australian Agronomy Conference. Queensland, Australia: The Australian Society of Agronomy (pp. 250–253).

34 A Verrell (2013) Row placement strategies in a break crop wheat sequence. GRDC Update Papers 26 Feb 2013, http://www.grdc.com.au/Research-and-Development/GRDC-Update-Papers/2013/02/Row-placement-strategies-in-a-break-crop-wheat-sequence

35 Pulse Australia. Southern Pulse Bulletin PA 2010 #05—Chickpea checklist for southern growers. http://www.pulseaus.com.au/storage/app/media/crops/2010_SPB-Chickpea-checklist-south.pdf

36 Felton, W. L., Marcellos, H., & Murison, R. D. (1996, January). The effect of row spacing and seeding rate on chickpea yield in northern New South Wales. In Proceedings of the 8th Australian Agronomy Conference. Queensland, Australia: The Australian Society of Agronomy (pp. 250–253).

Table 7: *The effects of row spacing on grain yield in various chickpea trials.*

Crop	Row spacing (cm)	Grain yield (kg/ha)	Source
Chickpea	18	2480	Beech and Leach 1988
	36	2620	
	53	2520	
	71	2490	
	18	690	
	36	890	
	53	850	
	71	740	
Kabuli chickpea	18	933	Kleeman and Gill 2010
	36	900	
	54	883	
Desi chickpea	18	1601	
	36	1383	
	54	1117	
Kabuli chickpea	22.5 (stubble removed)	1300	Hart Trial Cropping Results 2009
	45 (stubble removed)	1270	
	22.5 (standing stubble)	1350	
	45 (standing stubble)	1270	

Source: GRDC

Chickpeas are successfully grown using a wide range of planting equipment and row spacings ranging from 18 cm to 1 metre. Stubble retention, preferably standing stubble, is essential with wide rows.

The recent trend is toward an increasingly higher proportion of crops (in the northern region) being grown in either:

- wide rows of 0.5–1.0 metres.
- controlled traffic layouts with a modified 'broadacre' configuration.

3.5.1 Wide rows (50–100 cm) offer:

- Greater ability to plant into heavy stubble cover. Zero tillage systems have shown a consistent 10–15% yield advantage over cultivated systems.
- Precision planters often provide more accurate seed placement, resulting in better establishment and more even plant stands. This often results in more even crop maturity.
- Improved harvestability due to plants being more erect, with a higher pod set as a result of 'within row' plant competition (Figure 16). This is particularly important in low yielding situations.
- In low yield situations, crops planted on wide rows often 'feed in' better over the knife section of the header due to the concentration of growth within the row.
- Reduced input costs through band-spraying of insecticides and defoliants.
- Relatively cheaper weed control using glyphosate through shielded spraying equipment.

- Easier access and 'marking' for ground spraying pesticides and desiccants in permanent controlled traffic (CT) lanes.
- Better yields under severe moisture stress conditions attributed to the combination of wide-rows and heavy stubble cover than narrow rows configurations (Figure 17).
- Easier access to the crop when checking for pests such as *Helicoverpa*.
- Improved air circulation in the crop, which lowers humidity levels and can reduce the severity of foliar fungal diseases.
- Allows interow cultivation and 'directed' herbicide sprays e.g. Broadstrike®.

Figure 16: *Wide row pulses held erect on standing stubble for harvest.*

Source: Pulse Australia

Figure 17: *Chickpeas planted 1 June on a full moisture profile at 65 kg/ha on 800 mm row spacing and showing good growth despite cold conditions.*

Source: Farmnet

3.5.2 Narrow rows (15–40 cm) offer:

- Potential yield advantage at yields levels above 1.5 t/ha. Any yield advantage is often negated however, by the inability to maintain a zero-till system when planting on narrow row spacings.

MORE INFORMATION

Wide rows and stubble retention

- Relatively fewer lodging problems in high yield situations.
- Suits conventional wheat planting equipment. [37]

IN FOCUS

Yield response of kabuli and desi chickpea (Cicer arietinum L.) genotypes to row spacing in southern Australia

A field experiment was undertaken to investigate the response of kabuli (three varieties) and desi (three varieties) chickpea genotypes to row spacing (RS) (18, 36 and 54 cm). The response of chickpeas to RS was related to the branching habit of the genotype. Among kabuli genotypes Almaz⁽ᵇ, which had a lower branch number per plant, showed greater yield loss at the wider row spacing than Genesis 079 and Genesis 090, which had greater branch number. All three desi genotypes showed similar sensitivity to widening row spacing. In the three desi cultivars, grain yield decreased by 4–21% as RS increased from 18–36 cm and by 17–36% at 54 cm RS. Grain yield of desi genotypes was correlated to podding (r2=0.60–0.69) and branch number (r2=0.62–0.75). Of the kabuli types, there was a strong correlation between pod number and grain yield for Almaz⁽ᵇ (r2=0.70) with seed number per pod and seed size stable across all genotypes. Although Genesis kabuli genotypes showed lower yield potential (694–1158 kg ha^{-1}) than desi genotypes (1036–1636 kg ha^{-1}), they were less sensitive to widening row spacing which could be related to their greater branching capacity and appear better suited to wide row cropping systems in southern Australia. [38]

3.6 Row placement

A break crop (pulse or oilseed) following a wheat crop should be sown between the standing stubble rows. In the next year, the wheat crop should be sown directly over the previous season's break crop row. Then in the next year of the rotation, the break crop should be shifted back and be sown between the standing wheat rows. Finally, in the fifth year, the wheat crop again should be sown directly over the previous year's break crop row.

There are two simple rules that need to be followed:

1. Sow break crops between standing wheat rows, which need to be kept intact.
2. Sow the following wheat crop directly over the row of the previous year's break crop.

Following these two rules will ensure the following:

- that four years elapse between wheat crops being sown in the same row space
- substantial reduction in the incidence of crown rot in wheat crops
- improved germination of break crops, especially canola, not hindered by stubble
- benefit to chickpeas from standing stubble, reducing the impact of virus infections
- better protection to break-crop seedlings from standing wheat stubble. [39]

37 Pulses Australia. Chickpea Production: Southern and Western region. http://www.pulseaus.com.au/growing-pulses/bmp/chickpea/southern-guide

38 Kleemann, S., & Gill, G. Yield response of kabuli and desi chickpea (Cicer arietinum L.) genotypes to row spacing in southern Australia. Genesis, 79, 0–10.

39 A Verrell (2013) Row placement strategies in a break crop wheat sequence. GRDC Update Papers 26 Feb 2013, https://grdc.com.au/Research-and-Development/GRDC-Update-Papers/2013/02/Row-placement-strategies-in-a-break-crop-wheat-sequence

3.6.1 Row orientation

Every grain grower has seen how well weeds grow when they have a blocked seeding tube creating extra-wide row spacing. Instinctively, we all know how important crop competition is for good weed management. The competitive ability of cereal crops can be increased by orientating crop rows at a right angle to the sun light direction; i.e. sow crops in an east-west direction. East-west crops more effectively shade weeds in the inter-row space than north-south crops. The shaded weeds have reduced biomass and seed set. The advantage of this technique is that it's free!

East-west crop orientation

The competitive ability of cereal crops can be increased by orientating crop rows at a right angle to the sun light direction; i.e. sow crops in an east-west direction. East-west crops more effectively shade weeds in the inter-row space than north-south crops. The shaded weeds have reduced biomass production and reduced seed set. In particularly weedy fields, the reduced weed growth leads to increased crop yield.

Altering the orientation of a broadleaf crop has less impact on weed growth. This is because broadleaf plants will alter the angle of their leaves over the course of the day to 'track' the sun as it moves across the sky. Therefore, as the leaves of the broadleaf crop move to catch the most sunlight, they cast less shade over the inter-row space.

In paddocks with a high weed burden, crop orientation has a significant impact of crop and weed growth. Trials at Merredin and Beverley Western Australia (WA) (2002-2005) indicated that weed biomass was reduced by 51% in wheat crops and 37% in barley crops, when crops were sown in an east-west rather than north-south orientation. Grain yield increased by 25% in wheat and 17% in barley crops. When the weed burden is low (due to herbicides use) the impact of crop orientation on grain yield and weed biomass may not be apparent. However, there is still a significant reduction in weed seed production. Trials at Merredin, Katanning and Wongan Hills WA (2010-2011) indicated that annual ryegrass seed production in east-west wheat and barley crops was halved (Table 8). Annual ryegrass in east-west crops produced an average of 2977 seeds per square metre (seeds/m^2), compared to the 5691 seeds/m^2 in north-south crops. The only exception was Katanning 2010 where annual ryegrass emerged two weeks after the crop, ensuring that the crop was highly competitive regardless of crop orientation.

Table 8: *Annual ryegrass seed production/m^2 in east-west and north-south orientated crops, at six trials in WA. Seed production was reduced in east-west crops in five out of six trial sites.*

Year	Location	Annual ryegrass seeds/ m^2 in east-west crops	Annual ryegrass seeds/m^2 in north-south crops
2010	Merredin	503	911
	Wongan Hills	24	300
	Katanning	529	465
2011	Merredin	27	125
	Wongan Hills	2610	6155
	Katanning	14113	26276

Consider the weed species in the field. Broadleaf weeds can alter the angle of their leaves to 'track' the sun throughout the day. So while a crop can shade broadleaf weeds, the weeds will still be able to get maximum benefit from any sunlight that reaches them through the crop canopy. Further, any weeds that grow taller than the crop will not be effectively shaded by the crop canopy.

Consider the layout of the paddock. It may not be possible to sow a paddock in an east-west direction, depending of the shape of individual fields.

Consider the location of the paddock. The sun angle in winter is highest at the equator (where the sun is close to being directly overhead at midday). Sun angle becomes lower south of the equator. A low sun angle in winter will cause an east-west crop to cast shade on the inter-row space for a great proportion of the day. Therefore, a crop orientation will have a greater impact in southern Australia, compared to northern Australia.

Using an east-west orientation may be more practical with auto-steer. Without auto-steer, driving directly into the sunrise/sunset for seeding/spraying/harvest of an east-west crop will be unpleasant and potentially dangerous.

Increased shading by an east-west crop reduces the soil surface temperature in the inter-row space and reduces evaporation, leading to increased soil moisture. This increased moisture occasionally increases crop yield where moisture is limited. However, the cool, moist environment of the inter-row space may influence the development of crop disease in some locations (although altered levels of disease were not noted in previous trials). [40]

3.7 Sowing depth

Depth of sowing is an important agronomic practice affecting the emergence and establishment of crops, especially with early sowing under dryland conditions when temperatures and soil evaporation rates are high. Chickpeas have hypogeal emergence where their cotyledons remain where the seed is sown while only the shoot emerges from the soil surface.

Chickpea seed is best sown into friable soil, with direct drilling often possible following a cereal crop. Good depth and adequate seed-to-soil contact is required and the large seed size of chickpeas assists in this regard.

Deeper sowing depths are used when the top soil layer is dry or where greater 'depth' protection is needed from residual herbicides used on the soil surface. However, deeper sowing can result in greater soil disturbance and delayed crop emergence although it helps to reduce lodging of the crop. [41]

Sow chickpeas 5–7 cm deep into good moisture. The seedlings are robust, provided high quality seed is used. The agronomic advantages of sowing at 5–7 cm include:

- reduced risk of damage from pre-emergent residual herbicides such as simazine, Balance® etc.
- improved early formation of lateral roots in the top soil
- enhanced inoculum survival in moist soil
- a significant proportion of ascochyta-infected seed is eliminated due to high mortality of diseased seed

Avoid sowing deeper than 5 cm on soils prone to surface sealing and crusting.

Press-wheels can improve establishment, although heavy pressures should be avoided. V shaped press-wheels will leave a furrow down the planting line that can lead to a concentration of residual herbicides in the furrow after rainfall and subsequent crop damage. [42]

It is generally recommended that chickpea seed should be sown 5–7 cm deep into moist soil. The preferred depth when using Balance® or simazine herbicides is 7 cm.

Sowing poor quality seed too deeply, into cold and/or wet soils, hard setting (crusting) soils and with some PSPE herbicides can reduce the ability of the germinating seedling to quickly reach the soil surface, which increases the seedling's susceptibility to both soil and seed-borne pathogens, and soil-borne insect pests.

40 C Borger. (2016). East-west orientation for improved crop competition. DAFWA. https://www.agric.wa.gov.au/grains-research-development/east-west-orientation-improved-crop-competition

41 http://www.regional.org.au/au/asa/2012/crop-production/8197_haighb.htm

42 Pulses Australia. Chickpea Production: Southern and Western region. http://www.pulseaus.com.au/growing-pulses/bmp/chickpea/southern-guide

Moisture seeking strategies (i.e. planting at a depth of 10–15 cm below the soil surface) should be avoided for all weather damaged or low vigour seed. [43]

One study showed that lodging increased with shallower (5 cm vs. 10 cm) sowing depth on grey clay soil. [44]

IN FOCUS

Sowing Depth for Chickpea, Faba Bean and Lentil in a Mediterranean-type Environment of South-western Australia

Pulses such as chickpea, faba bean and lentil have hypogeal emergence and their cotyledons remain where the seed is sown, while only the shoot emerges from the soil surface. The effect of three sowing depths (2.5, 5 and 10 cm) on the growth and yield of these pulses was studied at three locations across three seasons in the cropping regions of south-western Australia, with a Mediterranean-type environment. There was no effect of sowing depth on crop phenology, nodulation or dry matter production for any species (Table 9). Mean seed yields across sites ranged from 810 to 2073 kg ha–1 for chickpea, 817–3381 kg ha–1 for faba bean, and 1173–2024 kg ha–1 for lentil. In general, deep sowing did not reduce seed yields, and in some instances, seed yield was greater at the deeper sowings for chickpea and faba bean (Figure 18). We conclude that the optimum sowing depth for chickpea and faba bean is 5–8 cm, and for lentil 4–6 cm. Sowing at depth may also improve crop establishment where moisture from summer and autumn rainfall is stored in the subsoil below 5 cm, by reducing damage from herbicides applied immediately before or after sowing, and by improving the survival of rhizobium inoculated on the seed due to more favourable soil conditions at depth. [45]

Table 9: *Time from sowing to emergence in days after sowing, nodulation score (0=none, 5=crown nodulation) and dry matter production at approximately flowering (g m^{-2}) of chickpea at Merredin and Northam in 1995.* [46]

Seeding depth (cm)	Days to emergence		Nodulation score		Dry matter production	
	Merredin	Northam	Merredin	Northam	Merredin	Northam
2.5	19	25	2.6	2.4	182	-
5	19	25	2.5	2.0	183	-
10	19	25	2.4	2.2	180	-
l.s.d. (P<0.05)	-	-	0.6	0.66	82.2	-

43 L Jenkins, K Moore, G Cumming. Pulse Australia. Chickpea: High Quality seed. http://www.pulseaus.com.au/growing-pulses/bmp/chickpea/high-quality-seed

44 B Haigh, G McMullen. (2012). The Influence of planting date, sowing depth and soil type on chickpea production with no-tillage in northern New South Wales. http://www.regional.org.au/au/asa/2012/crop-production/8197_haighb.htm

45 Siddique, K. H. M., & Loss, S. P. (1999). Studies on sowing depth for chickpea (Cicer arietinum L.), faba bean (Vicia faba L.) and lentil (Lens culinaris Medik) in a Mediterranean-type environment of South-western Australia. Journal of Agronomy and Crop Science, 182(2), 105-112.

46 Siddique, K. H. M., & Loss, S. P. (1999). Studies on sowing depth for chickpea (Cicer arietinum L.), faba bean (Vicia faba L.) and lentil (Lens culinaris Medik) in a Mediterranean-type environment of South-western Australia. Journal of Agronomy and Crop Science, 182(2), 105-112.

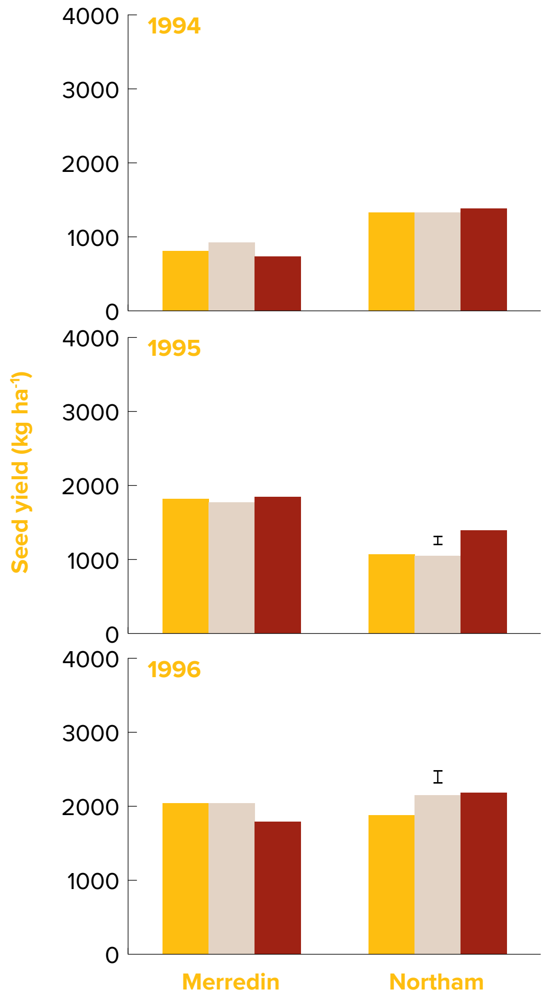


Figure 18: *Seed yield of chickpea sown at 2.5 cm (yellow), 5.0 cm (grey) and 10.0 cm (red) at Merredin and Northam in 1994, 1995, and 1996. Vertical bars denote l.s.d. (P= 0.05) where differences are significant.*

3.7.1 Deep seeding strategies

Deep planting has proven to be an extremely valuable risk management tool in many seasons. It has allowed chickpea to be planted in situations where winter crop planting rains have either been very late or have failed to eventuate altogether. In these conditions, a large proportion of the Australian chickpea crop is planted using deep-planting techniques. Crops are commonly planted at depths of 10–20 cm and this has often been the difference between achieving a reasonably profitable crop or no crop at all. Note that when deep planting, growers should use seed that show good vigour in seed testing.

Deep-planting is not only an extremely valuable tool under drought conditions, but can also offer major advantages in most years. It allows growers to plant chickpea at the optimum time for their district regardless of highly variable rainfall events. This maximises crop Water Use Efficiency, grain yield, crop height and profitability.

Critical issues that need to be addressed include:

- seed quality and vigour
- planter configuration and operation
- filling in the seed trench (furrow)
- harvestability of the crop

Chickpea seedling features

Field research and commercial experience have shown that chickpea has the ability to emerge through over 15 cm of soil cover.

The chickpea seedling has clearly shown that it has a superior ability to emerge from depth than most other grain crops. Research on alluvial clay soils demonstrated that chickpea was much better suited to deep-planting situations than wheat (cv Hartog).

Chickpea are different to most other pulses in that their cotyledons (seed storage organs) remain underground, with the seed sending up a narrow shoot to emerge through the soil. This hypogeal emergence allows chickpea to emerge from depths of over 15 cm with little or no reduction in emergence and seed yield. Research in WA and overseas has shown that deeper plantings can actually increase yields through:

- avoidance of residual herbicide damage
- improved nodulation
- better development of lateral roots near the soil surface.

The plant's capacity to emerge from depth clearly provides an opportunity for growers to use deep-planting methods to establish crops during the optimum sowing window. This can readily be achieved by varying planting depth from 5–20 cm according to seasonal conditions at the time.

Deep planting checklist

- **Plan ahead if you are considering deep-planting of chickpea.** Growers can use this technique in most years to ensure that they plant at the optimum time for chickpea in their district rather than relying on highly variable rainfall events. This is preferable to using deep planting as a last resort after planting rains fail to eventuate and the optimum planting window has already passed. **The key to deep planting is to make the decision early and sow on time.**
- **Exercise caution** when deep planting on hard setting or crust-prone soils.
- **Decide on the best combination of sowing point, press-wheel, and operational speed for your planter and soil type.** Be prepared to alter this combination depending on soil conditions at the time of planting. Speed is critical as it can have a major impact on depth control, as well as the amount of soil coverage over the seed.
- **Ensure you have high quality planting seed.** The deeper you plant, the greater the importance of using high quality planting seed. Check your germination percentage and seed counts (seeds/kg) and adjust seeding rates accordingly. Only use the highest quality seed when attempting deep planting. There are two additional seed tests that can be used to better determine seed quality.
- **The Accelerated Ageing (AA) Test.** This test is normally undertaken after harvest or well before planting and gives an indication of the seed vigour at planting time providing storage conditions are good. The value of this test is that seed showing poor vigour can be identified early and alternative actions can be taken. This test is highly recommended for seed that is likely to be deep sown. A germination test should also be done at the same time. If the results from the AA test are similar to the germination test then the seed has good vigour. If there is a significant difference between the two tests then advice on the interpretation of the test should be sought.
- **The Vigour or Soil Germination Test.** This test is recommended before planting and gives a guide to seed vigour in soil conditions at that time. The guidelines for interpreting the results of this test are the same as for the AA test above.

- **Increased weed pressure.** When deep planting under dry conditions, the first general winter rain will now fall in-crop and winter weeds will germinate on this in-crop rainfall.
  This places a lot more pressure on broadleaf and grass weed control as growers can no longer rely on a glyphosate spray at planting to tidy up winter weeds. Growers need to ensure that they have an appropriate weed strategy mapped out before planting.
- **Use fungicide treated seed.** As a precaution against the seed transmission of ascochyta blight.
- **Spray out fallow weeds prior to planting.** These can be difficult to control if moisture stressed and covered in dust (because of the dry conditions). Adjust herbicide rates and water volumes accordingly.
- **If you are using residual herbicides such as Balance® or simazine you will need to fill in the furrow (seed trench) prior to applying the herbicide.** If you cannot fill in the trench completely, then you should at least ensure you have 8–10 cm of soil coverage above the seed. Both these measures will ensure that the risk of herbicide damage after rain is minimised.
- **Avoid deep-planting into compacted wheel-tracks** as it usually results in variable depth control and poor seed coverage. Both are major contributors to patchy, uneven plant stands. Adopt the use of controlled-traffic systems wherever possible.
- **Decide on a planting depth that will ensure that all seeds are planted into moisture.** Thoroughly inspect seedbed moisture levels across paddocks and different soil types and ensure you plant into moisture. Experience indicates that you are better to err on the 'deeper side' rather than plant 'too shallow' into marginal moisture.
- **Ensure that the planter can maintain uniform depth control across the full width of the machine under normal operational speeds.** Poor or variable depth control will result in gappy, uneven plant stands.
- **Harvestability is a major issue.** Deep-planted crops can experience adverse, dry conditions where crop height and harvestability are significant problems.

The following management decisions can have a significant impact on harvestability of the crop:

- **Levelling of the soil surface at planting** Harvest losses of up to 50% have been reported in paddocks that were left unlevelled at planting, with mounds of dirt and stubble left either side of the furrow.
- **Choice of variety.** If harvestability is a major concern then consider planting a tall, upright variety that sets its pods higher up in the bush.
- **Planting time.** Planting during the recommended sowing window for your district will maximise plant height and harvestability.
- **Maintain plant populations of 20–25 established plants/square metre.** This will encourage a more upright growth habit and more even maturity.
- **Use wide-row spacings of 50–100 cm to encourage a taller, more erect plant.**

Deep planting method

The technique referred to as 'moisture seeking' has been used for over 20 years to plant cereals into stored fallow moisture without a planting rain. The practice usually requires the deliberate formation of a furrow or trench above the seed row because wheat and barley have relatively short coleoptiles, which limit the depth of soil they can successfully emerge through to approximately 8 cm.

This practice is referred to as 'deep-furrow planting' because the furrows are deliberately left intact at the completion of the planting operation.

Sweeps or 'shovels' may need to be mounted on the sowing tyne assemblies to help shift dry soil out of the furrow.

MORE INFORMATION

Chickpea: Deep Seeding strategies.

This technique of 'deep-furrow planting' is not suited to crops such as chickpea for two very good reasons:

- The short stature of the chickpea crop and the need to set the header front as close to the ground as possible
- The reliance on using pre-emergent, residual herbicides for broadleaf weed control. These herbicides can concentrate in the furrow after rain and cause considerable crop damage.

The more appropriate technique for chickpea is 'deep-planting' where growers fill in the furrow and level the soil surface after planting and rely on the chickpea plants' ability to emerge from depth to achieve crop establishment.

Levelling the soil surface considerably reduces the risk of herbicide residue damage and minimises harvest difficulties. [47]

3.8 Sowing equipment

There are few problems when sowing desi and most kabuli chickpeas with conventional seeding equipment, but occasionally cracking of seed may occur with the larger seeded kabuli types. [48]

Ensure that the seed handling equipment and seeder is not too aggressive on the seed (e.g. use shifters instead of augers and avoid high blower speeds in air seeders). [49]

Success with pulses may depend on the type of sowing equipment used. The large size of pulses can make sowing with conventional seeders extremely frustrating. If your 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 using manufacturer supplied optional parts
- modifying seed tubes to reduce blockages, particularly on older machines
- modifying or replacing dividing heads on airseeders

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.

Kabuli chickpeas can be sown with a standard airseeder or conventional harvester but care should be taken, as seeds tend to bridge over the outlets, causing very uneven sowing. This difficulty can be eliminated by filling the box to only a third or a half capacity or by fitting an agitator.

3.8.1 Seeders

Harvesters with fluted roller feeds have few problems feeding seed of <15 mm down to the metering chamber. Harvesters with peg roller and seed wheel feeds will seed grains up to the size of kabuli chickpeas without problems, provided adequate clearances are used around the rollers. Harvesters 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.

47 Pulse Australia. Chickpea: Deep seeding strategies. Australian Pulse bulletin.

48 Pulses Australia. Chickpea Production: Southern and Western region. http://www.pulseaus.com.au/growing-pulses/bmp/chickpea/southern-guide

49 Pulse Australia. Southern Pulse Bulletin PA 2010 #05 – Chickpea checklist for southern growers. http://www.pulseaus.com.au/storage/app/media/crops/2010_SPB-Chickpea-checklist-south.pdf

3.8.2 Airseeders

Airseeders that use peg-roller metering systems 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 can meter large seed at high rates with few problems. 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 19 shows a standard secondary distributor head (on the left) and a conversion to suit Connor Shea airseeders. The conversion head increased the bore from 23–41 mm. Four larger hoses replace the original eight, and row spacings are increased from 150–300 mm. This conversion allows large seeds such as kabuli chickpea or beans to be sown easily. Consult the dealer about possible modifications. Significant levels of seed damage can be caused in airseeders by excessive air pressure, so be careful to use only enough air to ensure reliable operation.

Figure 19: *Conversion heads, such as this one for a Connor-Shea airseeder, allow large seeds such as broad beans, faba beans and kabuli chickpeas to be sown with ease.*

Source: Grain Legume Handbook, 2008

3.8.3 Seeder and tyne comparisons

In the establishment of all crops, especially pulses, there are several key functional or mechanical issues with respect to seeding equipment, which should:

- Have an adequate seeding mechanism to handle the pulse seed without damaging it, especially when larger seeded types are being sown.
- Have adequate sizes of seed and fertiliser tubes and boots to prevent seed blockages and bridging during sowing.
- Sow into stubbles and residues, without blockages.
- Have sufficient down-pressure to penetrate the soil, sow at the desirable depth and place all seeds at a uniform depth.
- Cover the seeds to ensure good seed-to-soil contact and high moisture vapour, which will promote rapid germination.

- Compact the soil as required, by press-wheels or closers (Figure 20) (otherwise, a prickle chain or roller is required afterwards for many pulses).
- Disturb the soil to the extent required, which means none in no-till with disc sowing. It may also mean having sufficient soil throw to incorporate herbicides like 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 get adequate plant establishment is one of the bigger problems faced by pulse growers. This can lead to a multitude of problems later. Many different seeding mechanisms or openers are now available to pulse growers. Narrow points are widely used in minimum-till or no-till systems, but many different points can be used. Likewise, with disc seeders, 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.

Figure 20: *One of several seeding mechanisms for uniform sowing depth using the press wheel for depth control.*

A comparison of the key functions that are critical for seed drills and no-till is shown in Table 10.

In interpreting the functions listed in Table 10 it should be noted that:

- With tynes, the slot created is different depending on the type of tyne used. Some create a vertical slot, others a 'V, while the inverted 'T' (or 'baker boot') leaves a slot with a narrow entrance and wider trench underneath (Figure 21). These tynes do perform differently in some functions in Table 10.
- Residues need to be handled in all conditions, not just when dry.
- Hairpins' (stubble is pressed into the slot) needs to be avoided by not creating them or by placing seeds away from them. Note that tynes rarely make hairpins.
- Vertical slots are hard to self-close.
- Ability for openers to follow ground-surface variation is critical for uniform depth of sowing (Figure 22).
- 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.
- Tynes handle stones, but bring them up, hence requiring rolling to press them back again.

Table 10: *Comparison scores (rating basis: 1, poor; 5 excellent) of no-till openers by function (after Baker 2010) Note that this table is a broad guide only. Scores given*

in this table are subjective and may vary with individual openers, etc. You may wish to use your own scores for each function and not count those not relevant to your situation.

	Narrow point	Wide point	Sweep	Double disc	Single disc	Slanted disc	Combined winged tine & disc[B]
Ability to 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
Be able to handle sticky soils[A]	5	5	4	1	3	3	2
Be 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**

In Table 10, neither pure-disc nor pure-tyne openers rate highly over all functions using this scoring. Disc openers rated lowest (49–55%), and of the tynes (57–66%), narrow points were the best (66%). The combination of winged tyne and disc, known as the Bio Blade or Cross SlotTM, had the highest score (94%). It allegedly combines the best attributes of pure disc openers with the best attributes of pure tyne openers, and adds some unique features of its own. Its weaknesses were its lesser ability to handle 'sticky' soils, its horsepower requirement and its wear rate of soil-engaging components.

Use Table 10 as a guide only to help select your own openers to suit your conditions and circumstances.

Figure 21: *A Primary Precision Seeder fitted with hydraulic breakout for consistent penetration. It is also fitted with narrow points that form an 'inverted T' slot and is capable of deep or side placement of fertiliser.*

Figure 22: *The DBS system parallelogram for uniform seeding depth and deep placement of seed or fertiliser.*

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 also be able to handle pulses without blockages or bridging. This is especially true for larger seeded types such as kabuli chickpeas or faba and broad beans (Figure 23).

Figure 23: *Bio Blade or Cross slotTM disc opener with opening disc and seeding tine, followed by paired press wheels. Note that the seed and fertiliser tube has sharp bends and may not be wide enough to avoid blockages when larger seeded pulses like faba or broad beans are being sown.*

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 (Figure 24).

Figure 24: *A Case IH SDX-40 single-disc drill.*