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GRDC GROWNOTES™

GRDC GRAINS RESEARCH & DEVELOPMENT CORPORATION

CHICKPEA

SECTION 3

PLANTING

INOCULATION | SEED TREATMENTS | TIME OF SOWING | SEEDING RATES | TARGETED PLANT POPULATION | ROW PLACEMENT | SOWING DEPTH | SOWING EQUIPMENT

SECTION 3

Planting

More information

www.grdc.com.au/Resources/Publications/2013/09/Inoculating-legumes-back-pocket-guide

QDAF (2015) Planting chickpeas, Inoculation and nodulation

GRDC (2012), Inoculating legumes: a practical guide

3.1 Inoculation

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

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.

Sampling of commercial paddocks in Queensland and New South Wales (NSW) has revealed that poor inoculation practices result in ineffective nodulation. The most effective method to ensure nodulation with the applied strain of inoculum is delivery of the highest possible concentration of live cultures onto the seed and sowing into good moisture as quickly as possible.

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.)

3.1.1 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.

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

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

Figure 2: Well-nodulated chickpea plants. (Photo: G. Cumming, Pulse Australia)

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 2).

More information

http://www.grdc.com.au/GRDC-FS-NFixation-Chickpeas

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.

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 inoculants are handled and stored in a manner that will ensure bacterial survival, and growers adopt effective inoculation practices.

Inoculated seed is best planted into moisture within 12 h of treatment, as fungicide seed dressings can affect survival of the bacteria.

Group N rhizobia are extremely sensitive to the level of available nitrate-N in the soil. Although high levels of nitrate-N have no significant effect on both the initial formation and number of nodules, they do markedly reduce both nodule size and activity.

Nodules remain inactive until the soil nitrate supply is exhausted (ineffective nodules remain white inside due to the absence of leghaemoglobin). Effective N-fixing nodules on the other hand, are rusty red or pink colour inside (Figure 3).

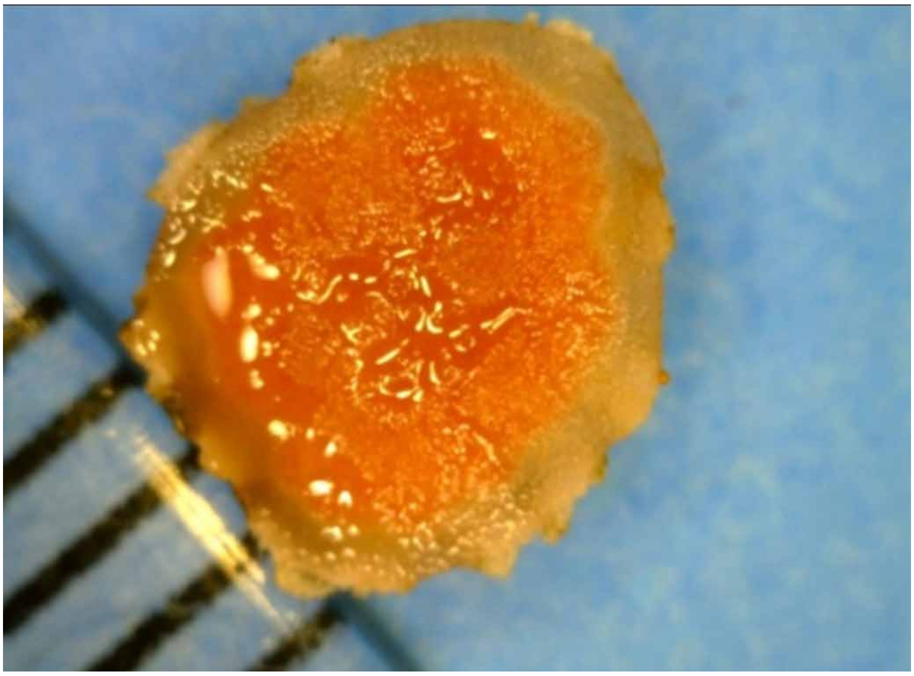

Figure 3: Active nodules have a rusty red or pink centre. (Photo: G. Cumming, Pulse Australia)

Growing chickpeas on long fallows or in a situation with high residual N will substantially reduce N fixation (Figure 4).

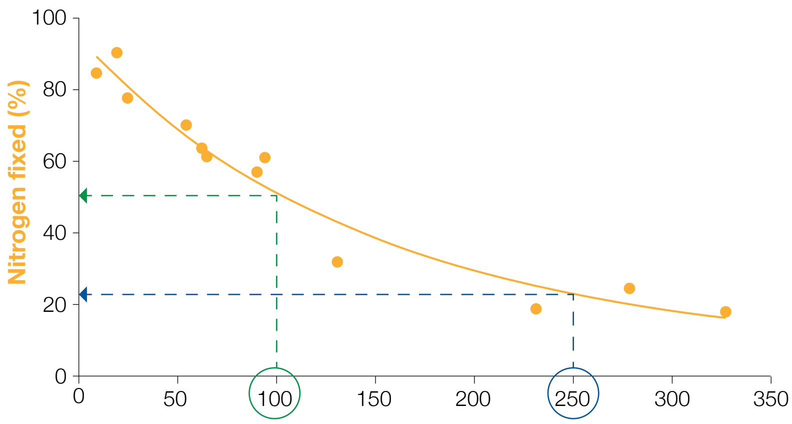

Figure 4: Effect of soil NO3-N at planting (kg/ha, 0–120 cm) on per cent nitrogen fixed in chickpea (cv. Reselected Tyson) shoots at 130 days after planting for various levels of soil NO3-N at crop establishment. For fitted curve, Y = 7.05 + 88.45e-0.0070X, R2 = 0.95. (Source: JA Doughton et al. 1993).

Even growing chickpeas on summer fallows after wheat (6-month fallow) will delay the onset of N fixation due to the mineralisation of 30–50 kg N/ha in the fallow period (Table 1). This nitrate-N, coupled with further in-crop mineralisation (15–20 kg/ha), provides a total soil supply of 45–70 kg N/ha, which is sufficient to grow a 1 t/ha chickpea crop. Yields above this level are completely dependent on N fixation (and effective nodulation practices).

If poor nodulation and N deficiency are to be eliminated as a major constraint to chickpea production, growers need to pay much greater attention to inoculation practices, and to treatment and handling of inoculant materials. [3]

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

Table 1: Nitrogen amounts fixed in chickpea crops

	Chickpea grain yield (t/ha)	Nitrogen fixation (kg/ha)
Double-cropped from sorghum	2.4	103
On long fallow (18 months)	2.4	27

Source: JA Doughton et al. 1993.

3.1.2 Management impacts on N fixation

- Changes to agronomy can change N fixation in grain legumes.
- In general, increasing row spacing may decrease amount of N fixed by legumes.
- Varieties can differ significantly in amount of N fixation and this is related to biomass.
- High soil nitrate levels can reduce legume nodulation and N fixation by rhizobia.

Average amounts of N fixed annually by crop and pasture legumes are about 110 kg N/ha (ranging from close to zero to >400 kg N/ha). The actual amount fixed depends on the species of legume grown, the site and the seasonal conditions as well as agronomic management of the crop or pasture. The legume crop uses this N for its own growth and may fix significantly more than needed, leaving a positive N balance in the soil for proceeding crops.

The amount of N fixed by a legume increases as legume biomass increases but is reduced by high levels of soil nitrate. In general, legume reliance on N fixation is high when soil nitrate levels are <50 kg N/ha in the top 1 m of soil. Above 200 kg N/ha, N fixation is generally close to zero. The fixed N is used for the growth of the legume itself (saving fertiliser application of the legume crop) as well as potentially leaving residual N for the following cereal or oilseed crop and providing a break from cereal stubble and soil-borne diseases.

Work by Doughton *et al*. (1993) clearly demonstrated the impact of increasing soil nitrate levels on N fixation of chickpeas (Figure 4), with no yield advantage being gained by applying N. Moreover, chickpea provided a positive soil N balance when fixation rates were high and a negative balance at low fixation rates. [4]

Individual trial results from a site near Bellata, NSW, in 2012, with a soil nitrate level of 69 kg N/ha at 0–90 cm, showed no yield advantage from applying N (Figure 5).

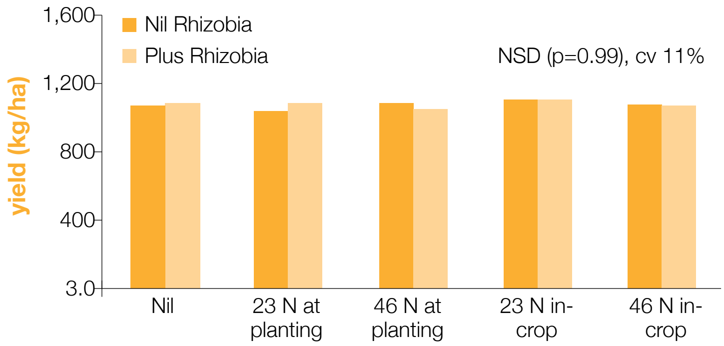

Figure 5: Yield of chickpea at high soil nitrate levels. No significant yield gain was obtained by applying N at planting or in-crop, or by adding rhizobia. (Source: NGA Project Reports 2012)

More information

http://www.nga.org.au/results-and-publications/download/223/project-reports-general/complete-summary/nitrogen-application-in-chickpeas-2012-complete-summary.pdf

[4] N Seymour, RCN Rachaputi, R Daniel (2014) Management impacts on N fixation of mungbeans and chickpeas. GRDC Update Papers 4 March 2014, http://www.grdc.com.au/Research-and-Development/GRDC-Update-Papers/2014/03/Management-impacts-on-N-fixation-of-mungbeans-and-chickpeas

More information

L Drew, R Ballard, M Denton (2011), Inoculation to optimise pulse performance

3.1.3 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 6).

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. [5]

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

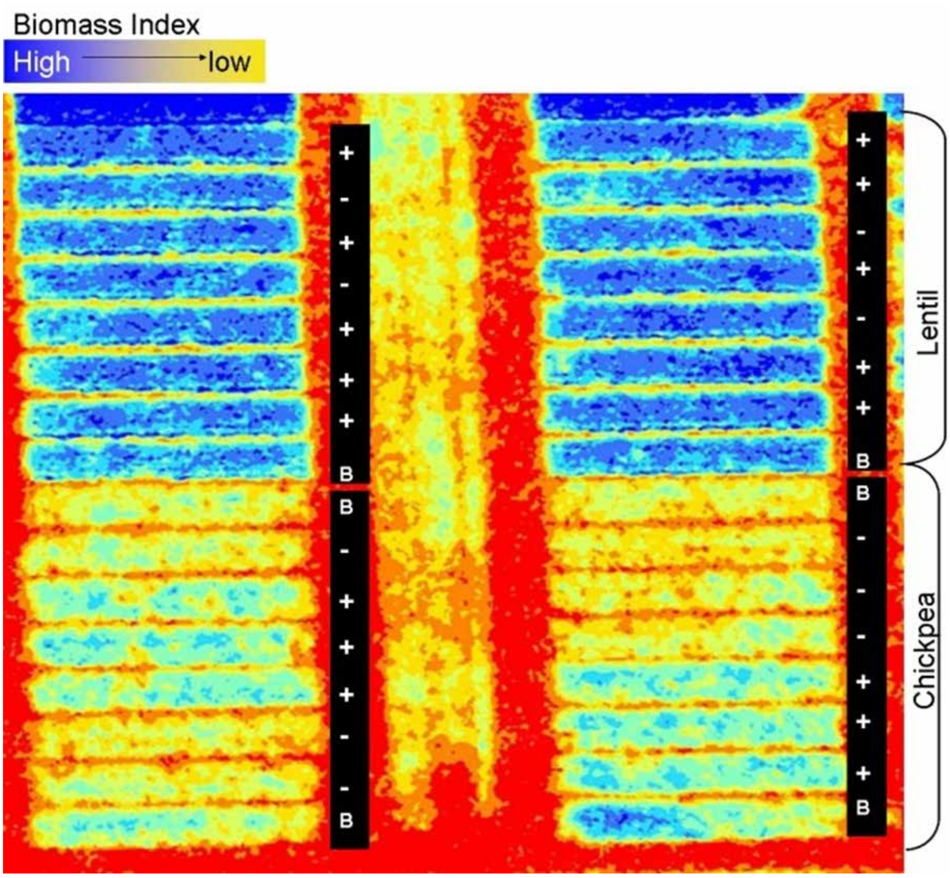

Figure 6: Biomass image of lentil (top) and chickpea (bottom) inoculant plots at Paskeville SA 2009. Blue represents high biomass, yellow represents low biomass and red is bare earth. Note the responsiveness of chickpea but not lentil, plots to inoculation and inoculant type. B, buffer; +, inoculated; –, uninoculated. (Photo: National Rhizobium Program trial by J. Heap, SARDI)

3.1.4 Storing inoculants

For maximum survival, peat inoculant should be stored in a refrigerator at about 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. [6]

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

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

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 h. Sow seed inoculated with peat slurry as soon as possible, but certainly within 12 h, 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 h of inoculation.

The rhizobia survive for longer in granules than when applied on seed. Hence, when dry-sowing 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. [7]

More information

[NSW DPI, Australian Inoculants Research Group]

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). [8]

Table 2: ALIRU Quality Assurance rhizobia minimum numbers

Product	Viable rhizobia (no./g)	Rate (/ha)	Rhizobia (no./ha)	Expiry (months)
Peat	1×10^9	250 g	3×10^{11}	12–18
Liquid	5×10^9	300 mL	2×10^{12}	6
Granular	1×10^7	10 kg	1×10^{11}	6
Freeze-dried	1×10^{12}	0.15 g	2×10^{11}	24

Source: Grain Legume Handbook

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). [9]

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

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

9 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[A]	Compatibility with seed-applied fungicide
Peat inoculums	Seed	Low	Some (check label)
Freeze-dried inoculums	Seed or in-furrow (water inject)	Very low	Very low
Granular forms	Seeding furrow or below seed	Yes	Yes
In-furrow water injection	Seeding furrow or below seed	Very low	Yes

[A]Survival will depend on duration of dry conditions and soil pH.

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 7)
- 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.

Figure 7: Two nozzles mounted into the top of the auger case 1 m apart.

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 8). Its mixing ability is not as effective as an auger. [10]

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

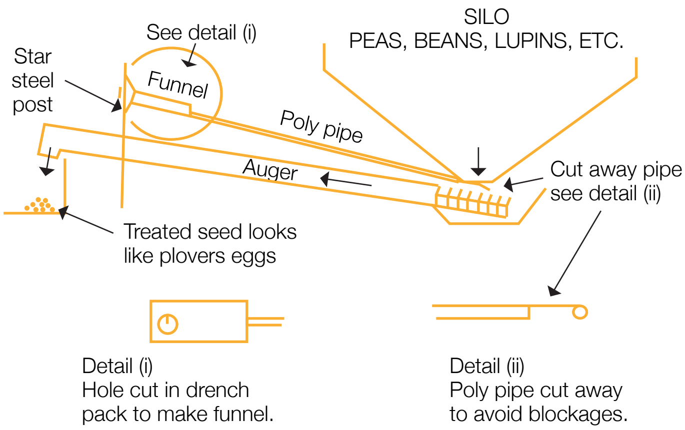

Figure 8: Application of inoculum to seed through a tubulator.

3.1.9 Newer inoculation methods

With new inoculant types and technologies, an appreciation is needed of each type's strengths and limitations. Rhizobial survival becomes more important under difficult circumstances such as prolonged dry soil conditions, when seed treatment of either fungicide or trace elements is used, and depending on soil pH. Much of the survival is associated with the degree of protection the rhizobia has against drying or against adverse conditions. Ease of inoculant application is increasingly important and needs to be accounted for in costing. [11]

3.1.10 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.

Queensland Department of Agriculture, Fisheries and Forestry (QDAFF) trials have consistently shown superior nodulation from water injection of inoculum (Figures 9 and 10). This is likely to be due to the larger numbers of live bacteria being delivered into the soil in close proximity to the seed.

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

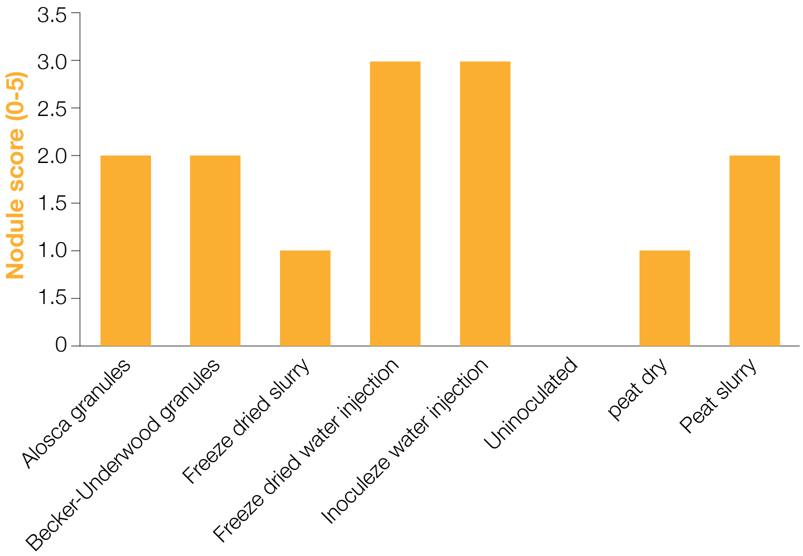

Figure 9: Inoculation trial at Emerald (2005), nodule scores assessed at 4 weeks after planting.

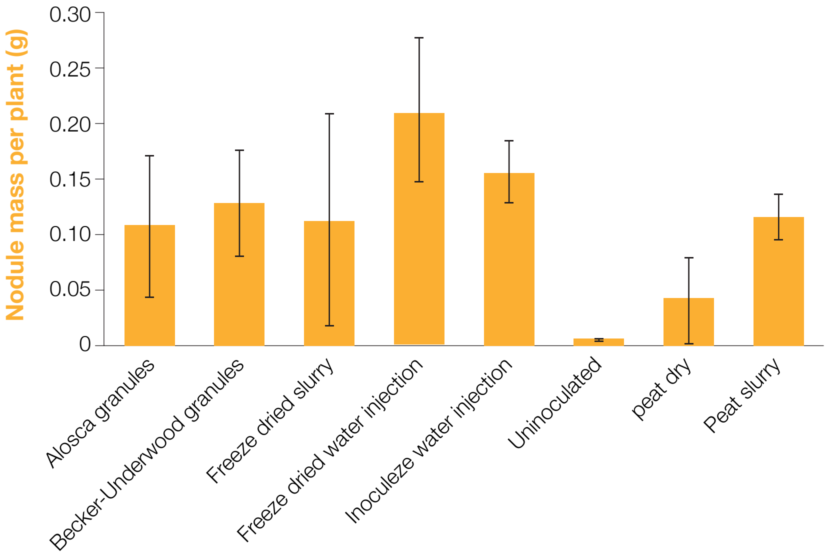

Figure 10: Inoculation trial at Emerald (2005), nodule biomass at flowering.

No significant differences were found in shoot weight (4 weeks after planting) or in final biomass and grain yield. [12]

Figures 11, 12 and 13 depict liquid injection set-ups on seeding equipment, and Figure 14 shows the liquid stream.

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

Figure 11: A seeder set up with Atom Jet narrow points, gang press wheels and liquid injection for either inoculum or trace element application during sowing.

Figure 12: A disc seeder set up with Yetter trash clearing wheels and tubing for liquid injection of either inoculum or trace elements during sowing. Note also the closer to cover the seeding slot and act like a 'press' wheel' from the side.

Figure 13: Tanks mounted on the seeding bar for liquid injection of either rhizobium or trace elements during seeding. Agitation is required. Note the tubes and manifold. Inoculum must be applied under low pressure only. Some machines have their tanks set up as a separate trailed tanker.

Figure 14: In furrow-liquid injection: Note the droplets from liquid injection, which can be used for either inoculating pulses or applying liquid trace elements. (Source: Grain Legume Handbook)

3.1.11 Granular inoculants

Granular inoculants are applied like fertiliser as a solid into the seed furrow, near to the seed or below. They avoid many of the compatibility problems of rhizobia with fertilisers and fungicides. They also eliminate the need to inoculate seed before sowing. Granulars may also be better where dry sowing is practiced or sowing into acidic soils because the rhizobia survive better than on seed (Table 3). A third, small seed box is required to apply granular inoculum (Figure 15). This is because rhizobial survival is jeopardized if the granular inoculum is mixed with fertilizer. If it is mixed with the seed, then distribution of both seed and inoculum is affected, causing either poor and uneven establishment and/or patchy nodulation.

Granules contain fewer rhizobia per gram than peat-based inoculants, so they must be applied at higher application rates. The size, form, uniformity, moisture and rate of application of granules differ between products. Depending on product or row spacing, rates can vary from 2–10 kg/ha to deliver comparable levels of nodulation. [13]

Figure 15: 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)

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

3.1.12 Inoculant 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, including those listed in Table 4. Figure 16 presents trial results in terms of nodule score by product type.

Table 4: Inoculant treatments

Inoculant	Description
Nodulaid™	Standard peat slurry applied to seed (PS)
Nodulaid™ Water Inject	Peat slurry injected into seed furrow with water as a carrier (PS WI)
Nodulator™	Attapulgite clay granules mixed with seed in furrow (ACG)
EasyRhiz®	Freeze-dried rhizobia mixed into slurry and applied direct to seed (FD)
EasyRhiz® Water Inject	Freeze-dried rhizobia slurry injected into seed furrow with water as a carrier (FD WI)
Alosca® granules	Bentonite clay granules mixed with seed in furrow (BCG)
N-Prove® granules (available now only as TagTeam®)	Peat granules mixed with seed in furrow (PG)

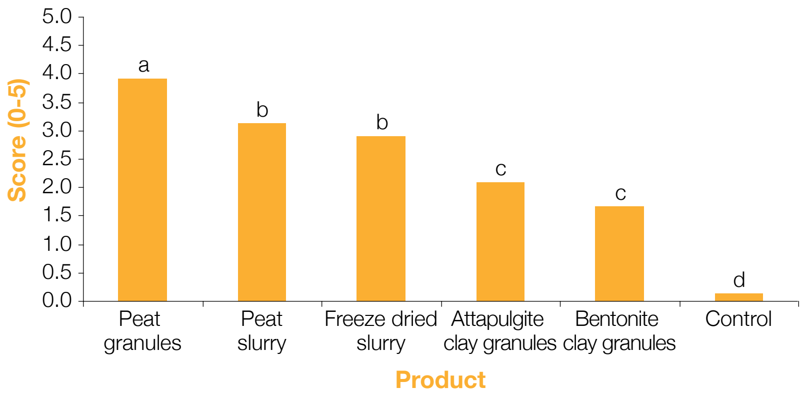

Figure 16: Effect of inoculant treatment on nodulation of chickpea roots, Narromine 2008.

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. This has been found in southern NSW, in work carried out by Denton *et al*. (2009). 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 2009 NSW Department of Primary Industries (NSW DPI)/Northern Grower Alliance (NGA) trial, nodulation from the slurry applied to seed method was significantly

More information

http://www.nga.org.au/results-and-publications/download/67/grdc-update-papers-general-/rhizobia-innoculation-methods-in-chickpeas/grdc-adviser-update-paper-goondiwindi-march-2011.pdf

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

http://www.publish.csiro.au/paper/EA02218.htm

http://espace.library.uq.edu.au/view/UQ:259646

http://digital.library.adelaide.edu.au/dspace/handle/2440/40723

http://www.grdc.com.au/Media-Centre/Ground-Cover/Ground-Cover-Issue-105-July-August-2013/Trials-explore-chickpea-wheat-rotations

affected by fungicide (thiram + thiabendazole), where the fungicide and slurry were applied within 1 h 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. [14]

For growers planting small areas of chickpeas, or who are content with current treatments methods, the traditional method of peat slurry application still appears 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. [15]

3.1.13 Inoculant and fungicide compatibility

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 (Table 5). [16]

Table 5: Effects of 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 plus thiram	103	182	285	55	1.8
Inoculum then thiram	119	208	327	58	3.2
Thiram then inoculum	117	212	329	55	3.8
Inoculum plus metalaxyl	106	173	279	54	1.8
Inoculum then metalaxyl	114	207	321	59	3.3
Metalaxyl then inoculum	113	206	319	55	3.6
l.s.d. (P = 0.05)	19	33	31	9	0.6

Source: Trevor Bretag, formerly DPI Victoria. (NB inoculum plus fungicide is tank-mixed and applied as a single treatment.)

3.1.14 Compatibility with 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 (Table 6).

[14] 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-in-chickpeas/grdc-adviser-update-paper-goondiwindi-march-2011.pdf

[15] R Brill, S Price (2012) Don't skimp on chickpea inoculation. *Australian Grain* Nov–Dec 2012, http://www.ausgrain.com.au/Back Issues/224ndgrn12/dont skimp on chickpea inoculation.pdf

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

Table 6: Rhizobial compatibility with different trace element products after 24 hours of tank mixing

TE formulation	Inoculant strain (by crop)				
	Field pea	Faba bean	Chickpea	Lupin	Soybean
Manganese 1	x	x	x	✓	✓
Manganese 2	✓	✓	✓	✓	✓
Zinc 1	x	x	x	x	✓
Zinc 2	x	x	x	x	✓
Zinc 3	x	x	x	x	✓
Zinc 4	x	✓	x	✓	✓
Zinc 5	x	✓	x	✓	✓

Source: Becker Underwood Pty Ltd.

Note the differences between inoculant types for a given trace element product, as well as differences between trace element products with a given inoculants. [17]

3.1.15 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 7).

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

Re-inoculate if not planted within 12 h of treatment. [18]

Table 7: Effects of 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
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Inoculum plus Thiram	103	182	285	55	1.8
Inoculum then Thiram	119	208	327	58	3.2
Thiram then inoculum	117	212	329	55	3.8
Inoculum plus Apron	106	173	279	54	1.8
Inoculum then Apron	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.

3.1.16 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.

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

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

- 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. [19]

3.1.17 Rating nodulation and nitrogen fixation (effectiveness)

The amount of N fixed is strongly correlated with nodule rating as detailed in the following photo-standards (Figure 17).

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

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

Rate the level of nodulation using the photo-standards provided. This is based on nodule number and their position on the root system.

Observe the pattern of nodules on the root system. Nodules on the main taproot clustered near the seed are a clear indication that nodulation occurred from the inoculation process. These are referred to as 'crown nodules'.

If there are no crown nodules, but nodules on the lateral roots, then it is likely that they have formed from native soil bacteria. These are usually ineffective in fixing N in chickpeas.

Nodules on both the crown and lateral branches indicate that inoculation was successful, and that bacteria have spread in the soil. The chickpea rhizobia are very aggressive and can spread short distances in the soil.

Inspect nodules for nitrogen fixation activity. The best method is to slice a few nodules open with a razor blade or sharp knife and look at their colour.

Young nodules are usually white and still need to develop. White nodules can also indicate the wrong bacteria in the nodule and these will not fix N.

Effective nodules are a rusty red or pink colour inside and these usually are actively fixing N. Effective red nodules can sometimes turn green when a plant is under stress, such as from water or disease, or is suffering from nutrient deficiencies. These do not fix N, but they can change back to red-coloured and start to fix again if the stress is relieved without too much damage being done. Finally, black nodules are usually dead or dying. These are often seen as the crop matures, or after a crop has suffered severe water logging. [20]

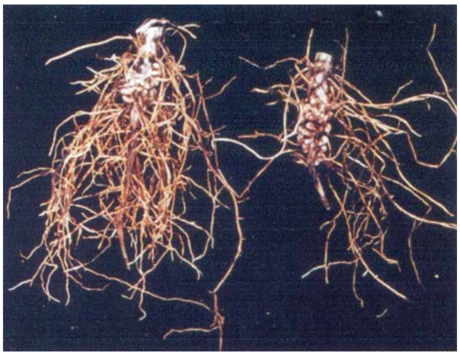
19 Pulse Australia (2013) Northern chickpea best management practices training course manual—2013. Pulse Australia Limited.

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

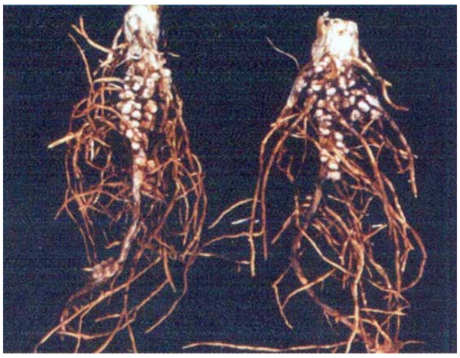
3.1.18 Key for assessing nodulation in winter pulse crops

Figure 17 parts *a–f* show nodulation scores of 0–5, based on nodulation number and distribution where 0–1 is inadequate nodulation; 2–3 is adequate nodulation; and 4–5, good nodulation.

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



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



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

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

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

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

Figure 17: Nodulation scores based on number and distribution of nodules.

- Where plant-available soil N is low, the crop relies heavily on good nodulation for its N supply. A score of 4–5 is desirable.
- Where plant-available N is high, nodulation may be partly inhibited and the crop will depend mainly on the soil to supply N.
- A high score indicates that the crop will yield well and conserve soil N for use by a following crop.
- A low score suggests that the crop will yield poorly and deplete soil N. [21]

[21] TopCrop—Growers guide to assessing nodulation in pulse crops

3.2 Seed treatments

No chickpea variety is resistant to seed infection by *Ascochyta* or *Botrytis*. All varieties will benefit from a seed dressing to protect against *Botrytis* and other seedling rots. Seed dressings may have a deleterious effect upon rhizobia, particularly under acid soil conditions, so minimize the contact time between these. Check the inoculum label. Apply seed dressing first then separately mix the inoculum and apply it to the seed immediately before sowing; or consider using granular or liquid injection inoculums. [22]

The use of P-Pickel T® or Thiraflo® is recommended for treating all planting seed throughout the northern region. These products are considered superior in minimising the risk associated with the spread of *Ascochyta* infection on seed. Seed retained on-farm should be from the cleanest paddocks, preferably where Ascochyta blight was not detectable in the previous season. [23]

NSW DPI trials clearly show that the fungus *Botrytis cinerea*, which causes chickpea pre- and post-emergence seedling disease, is readily controlled with registered seed treatments, provided they are applied correctly.

However, pathologists do not recommend using *Botrytis*-infected grain as planting material even if treated properly. The seed will have lower vigour and this will increase the risk of other seedling diseases, render weed management more difficult and may increase the risk of virus infection. Also, sowing rates will need to be increased to account for the reduced vigour, which may make using grower-retained seed uneconomical. [24]

More information

[GRDC (2013), Clean seed and care the recipe for chickpea success]

More information

http://www.grdc.com.au/Research-and-Development/GRDC-Update-Papers/2012/04/Chickpea-seed-treatment-improves-crop-establishment-and-increases-yields-2011-trials-using-seed-from-2010-crops

3.3 Time of sowing

The key to planting chickpeas in the northern grains region 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.

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

More information

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

Pulse Australia (2016), Chickpea production: northern region

QDAF(2015) Planting chickpeas, Planting time

22 W Hawthorne, J Davidson, L McMurray, K Hobson, L Lindbeck, J Brand (2012) Chickpea disease management strategy—southern region. Southern Pulse Bulletin 8, http://pulseaus.com.au/storage/app/media/crops/2012_SPB-Chickpea-disease-management.pdf

23 DAFF (2012) Planting chickpeas. Department of Agriculture, Fisheries and Forestry, 6 August 2012, http://www.daf.qld.gov.au/plants/field-crops-and-pastures/broadacre-field-crops/chickpeas/planting

24 K Moore, R Daniel, S Harden, A Mitchell, R Herron, P Nash, G Chiplin (2012) Chickpea seed treatment improves crop establishment and increases yields—2011 trials using seed from 2010 crops. GRDC Update Papers 10 April 2012, http://www.grdc.com.au/Research-and-Development/GRDC-Update-Papers/2012/04/Chickpea-seed-treatment-improves-crop-establishment-and-increases-yields-2011-trials-using-seed-from-2010-crops

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://cropit.net/sites/default/files/content/files/Sowing%20date%20impact%20on%20pod%20set_Jeremy%20Whish_GRDC%20Update%202011.pdf

Sowing prior to 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

Figure 18: Botrytis grey mould infected chickpeas. (Photo: Gordon Cumming, Pulse Breeding Australia)

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.

More information

[J Whish, B Cocks (2011). Sowing date and other factors that impact on pod-set and yield in chickpea](#)

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 (Table 8).

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 ≥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 <12°C at the placement depth. 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.

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.

More information

http://www.grdc.com.au/Research-and-Development/GRDC-Update-Papers/2013/02/Developing-a-plan-for-chickpeas-2013

http://www.grdc.com.au/Research-and-Development/GRDC-Update-Papers/2012/04/Chickpea-time-of-sowing-trial-Trangie-2011

http://www.grdc.com.au/Research-and-Development/GRDC-Update-Papers/2010/05/Chickpeas-in-2010-Low-temperature-effects-in-2009

Table 8: Preferred planting times for different regions

	April				May				June				July	
Week:	1	2	3	4	1	2	3	4	1	2	3	4	1	2
Central Queensland			Yellow	Green	Green	Yellow	Yellow							
Maranoa–Balonne				Yellow	Green	Green	Yellow	Yellow						
Western Downs					Yellow	Green	Green	Green	Yellow	Yellow				
Darling Downs						Yellow	Green	Green	Green	Green	Yellow	Yellow		
Moree–Narrabri						Yellow	Green	Green	Green	Green	Yellow	Yellow		
Walgett–Coonamble							Yellow	Green	Green	Green	Yellow			
Liverpool Plains							Yellow	Green	Green	Green	Green	Yellow	Yellow	Yellow
Central NSW (grey soil)							Yellow	Green	Green	Green	Green	Yellow		
Central NSW (red soil)					Yellow	Green	Green	Green	Green	Yellow				

Yellow boxes: marginal sowing time, increased costs and/or lower yields likely; green boxes, preferred sowing window

As the large-seeded Kabuli varieties mature later than the Desi varieties, they may need to be sown earlier than Desi in some districts. [26]

3.3.1 NSW DPI time-of-sowing trials

The two major constraints to chickpea production in the northern cropping region are disease and frost damage (Whish *et al* 2007). In each case, sowing date can influence yield by avoiding cold temperatures during flowering, and by reducing the impact of disease.

The optimal time to sow chickpea will depend on the interaction between the environment and the available varietal germplasm. Current chickpea genotypes have excellent frost tolerance when in the vegetative state, but conversely display one of the highest temperature thresholds for seed-set among cool-season (winter) pulse crops.

Mean daily temperature of <15°C has been shown to cause flower abortion (Clarke and Siddique 1998). Flowering initiation in chickpeas has been described as a photo-thermal response, but in most environments temperature is the main determinant. The optimum sowing date results in flowering when the risk of cold temperatures is low; it

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

is especially important to avoid frost during flowering, which can kill chickpea plants (Whish *et al*. 2007).

Choosing an optimum sowing time can also mean a compromise between maximising yield potential and minimising disease levels (Figure 19). Earlier sowing can expose the crop to more rain events, which can increase the risk of Ascochyta blight. It will also increase crop biomass, increasing the risk of Botrytis grey mould, lodging, and soil-moisture deficit during grain-fill. Later sowing can result in shorter plants (harvesting difficulties) and increased Heliothis pressure, but may reduce vegetative water use and reduce the exposure to Ascochyta and Phytophthora infection events and lessen the risk of Botrytis grey mould (Matthews and McCaffery 2011).

Figure 19: Choosing an optimum sowing time can be a compromise between maximising yield potential and minimising disease levels. (Photo: NSW DPI)

More information

http://www.grdc.com.au/Research-and-Development/GRDC-Update-Papers/2012/04/Chickpea-time-of-sowing-trial-Trangie-2011

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

http://www.grdc.com.au/Research-and-Development/GRDC-Update-Papers/2013/02/Virus-in-chickpea-in-northern-NSW-2012

Chickpea time-of-sowing trials were conducted in 2010, 2011 and 2012 by NSW DPI at Trangie Agricultural Research Centre, to evaluate the impact of sowing date on phenology and yield of current and potential release cultivars. The 2010 trial succumbed to in-crop waterlogging and wet weather at harvest and it was not harvested.

The time of sowing of chickpea has been debated as an issue at GRDC Northern Update sessions. The development and release of new chickpea varieties with high-yielding attributes (largely due to greater regional adaptation and improved disease tolerance) has led to the belief that early sowing (early May) would be the key to optimising water use, through the development of increased biomass and hence earlier flowering.

This trial has shown that earlier flowering does not necessarily translate into higher yield, due to the effect of lower temperatures during early flowering and a greater potential risk of disease. Conversely there is also a yield penalty from later sowing (late June), but these chickpea plants are able to compensate to some effect compared with very early sowing. Further research will be conducted over several seasons to develop sound recommendations for the region. [27]

3.3.2 Time-of-sowing trial results 2012

Chickpea time-of-sowing trials in both 2011 and 2012 were conducted with a full soil-moisture profile at planting. The 2011 season was characterised by wet conditions post planting in May, resulting in an increased incidence of Phytophthora root rot, followed

[27] L Jenkins, R Brill (2012) Chickpea time of sowing trial, Trangie 2011. GRDC Update Papers 10 April 2012, http://www.grdc.com.au/Research-and-Development/GRDC-Update-Papers/2012/04/Chickpea-time-of-sowing-trial-Trangie-2011

by a dry winter and spring. Chickpea foliar diseases did not affect yield in either trial due to fungicide applications and the dry conditions in July–September.

The 2011 trial showed a significant yield penalty from early sowing (5 May). This was due to both the increased incidence of Phytophthora root rot and the effect of low temperatures on pod development. Optimum yields were achieved from mid-season sowing (18 May and 9 June). The late sowing (27 June) in 2011 had lower yields than the two mid-season sowings, but still yielded higher than the early sowing.

The 2012 trial confirmed the results from 2011 (i.e. mid May to early June remains the optimum period to plant most current chickpea varieties with Jimbour-type maturity, e.g. PBA HatTrick⚲ and PBA Boundary⚲, in the central-western region (Table 9)). Early planting (early May) can increase the risk of exposure to disease infection events, as occurred in 2011 (resulting in lower yields), although this did not occur in 2012. Planting chickpeas in mid-late June resulted in significantly lower yields in both the 2011 and 2012 trials.

In 2011, PBA HatTrick⚲ was the overall highest yielding variety (mean yield 1.37 t/ha), although not significantly higher than PBA Boundary⚲. In 2012, PBA Boundary⚲ was the highest yielding variety (mean yield 1.62 t/ha), and higher yielding than PBA HatTrick ⚲ (1.5 t/ha). This reinforces the view that while Jimbour⚲-type maturities are ideal for the central-west of NSW, each year will be slightly different in terms of variety response to the season. Knowledge of soil type and paddock disease risk will assist in choice of variety, with PBA Boundary⚲ not recommended in paddocks known to have a history of Phytophthora root rot.

In 2012, the seeding rate component of the trial showed that targeting a lower plant population (15 plants/m^2) reduced yield potential, regardless of sowing time. Targeting a higher plant population (45 plants/m^2) had higher yields than the 15 and 30 plants/m□ treatments at all sowing times. [28]

Table 9: Grain yield (t/ha) of seven chickpea varieties sown at four sowing times at Trangie Agricultural Research Centre, 2012

Variety	9 May	21 May	1 June	20 June	Mean of variety
CICA-0912	1.44	1.56	1.50	1.24	1.43
Flipper⚲	1.65	1.55	1.45	1.13	1.44
Genesis™ 090	1.69	1.73	1.65	1.25	1.58
Genesis™ Kalkee	1.42	1.64	1.25	0.81	1.28
PBA Boundary⚲	1.60	1.71	1.76	1.42	1.62
PBA HatTrick⚲	1.51	1.68	1.46	1.35	1.50
Sonali⚲	1.55	1.52	1.41	1.09	1.39
Mean of sowing time	1.55	1.63	1.50	1.18	1.46
l.s.d. (P = 0.001)	Variety = 0.108 t/ha, sowing time = 0.08 t/ha				

More information

http://www.dpi.nsw.gov.au/__data/assets/pdf_file/0004/468328/Northern-grains-region-trial-results-autumn-2013.pdf

3.3.3 Frost damage

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.

[28] L Serafin, S Simpfendorfer, M Gardner, G McMullen (Eds) (2013) Northern grains region trial results, autumn 2013, DPI NSW, http://www.dpi.nsw.gov.au/__data/assets/pdf_file/0004/468328/Northern-grains-region-trial-results-autumn-2013.pdf

Damage to flowers and pods:

Freezing temperatures destroy flowers and young developing seed (Figure 20). 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.

Figure 20: Frosted chickpea crops at flowering.

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

Simulated frost risk for Amethyst planted across a range of sowing dates is presented in Table 10.

Values in the table are the percentage chance of receiving a –1°C frost or colder (at screen height) during late flowering–early pod-fill when combined with dry soil conditions that would limit further flowering.

The results show that:

- Frost risk is much higher in southern districts than in central Queensland
- Frost risk declines with later sowing dates
- Frost risk could be minimised to ≤10% by sowing:
- no earlier than mid-April in central Queensland
- no earlier than late May on the eastern Downs
- no earlier than mid-May for western Downs and Maranoa. [29]

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

Table 10: Percentage chance of receiving a frost during late flowering–early pod-fill combined with dry soil conditions

Location	Sowing date						
	15 April	1 May	15 May	1 June	15 June	1 July	15 July
Emerald	10	3	3	0	0	0	0
Dalby	71	35	29	10	3	3	0
Roma	87	35	13	6	3	0	0
Goondiwindi	35	13	10	3	0	0	0

Source: M Robertson, CSIRO.

3.4 Seeding rates

Yields are relatively stable within the range 20–30 plants/m^2; however, populations of 25 plants/m^2 will optimise yields in the northern region. Research has shown that slightly higher populations are required in relatively colder production areas in northern NSW.

Higher populations are justified for late plantings, while lower populations of about 20 plants/m^2 are often recommended for crops grown in wide row spacings (1 m). High populations planted in wide rows often result in thin main stems and a higher risk of lodging.

Seeds are not all equal, and some grow better than others. Before deciding on a seeding rate, take a representative sample and have it germination-tested.

Seeding rates can have a very significant effect on crop yields; however, there are considerable differences in seed size between individual pulse varieties.

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

Calculating seeding rates

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

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

Example

100-seed weight = 20 g

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

Germination% = 95%

Estimated establishment% = 80% (Note: an establishment percentage of 80–90 % is a reasonable estimate, unless sowing into adverse conditions.)

Seeding rate (kg/ha) = (20 x 25 x 1000)/(95 x 80) = 65 kg/ha

To determine seed weight, weigh 100 seeds (g).

If you have seeds per kg from a laboratory test, this can be easily converted to 100-seed weight, as follows:

100-seed weight = (1000/seeds per kg) x 100

Note: Optimum plant populations vary with the growing location and the pulse crop and variety being sown (Table 11). [30]

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

More information

[Pulse Australia (2016), Chickpea production: northern region](#)

L Jenkins, A Verrell (2015), Chickpea and mungbean research to maximise yield in northern NSW

K McKenzie, H Cox, R Rachaputi, B Raymond, N Seymour (2014), Impact of row spacing and populations on chickpeas

R Raymond, K McKenzie, R Rachaputi (2015), Impact of row spacing on chickpea fababean and mungbean

M Thomson (2014), New cultivars and narrow rows boost Darling Downs chickpea yields

K McKenzie, N Seymour, H Cox, B Raymond, RCN Rachaputi (2015), Chickpea and faba bean agronomy ideal row spacing and populations

A Verrell, L Jenkins (2014), Effect of row spacing on yield in chickpea under high yield potential

A Verrell, R Brill, L Jenkins (2014), The effect of plant density on yield in chickpea across central and northern NSW p39

Table 11: Seeding rate (kg/ha) required for targeted plants per m² 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/m²	25 plants/m²	30 plants/m²
Almaz⍉	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⍉	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⍉	Large Desi	25	66	82	99
PBA Boundary⍉	Medium Desi	20	53	66	79
PBA HatTrick⍉	Medium Desi	21	55	69	83
PBA Slasher⍉	Medium Desi	20	53	66	79
Yorker⍉	Medium Desi	21	55	69	83

3.5 Targeted plant population

Planted on a row crop configuration (up and back on 50–100-cm rows), chickpeas can benefit from a reduced incidence of Ascochyta blight by improving airflow between the rows.

The wider row spacing can reduce spray costs by allowing for banded spraying. Harvesting height is improved if the chickpeas are sown on the inter-row, between the rows of the previous cereal crop. This enables the standing stubble to act as a trellis.

Newer chickpea varieties with genetic resistance to Ascochyta blight may result in a re-evaluation of row spacing for this crop in the future. [31]

When sowing within the optimum sowing window mid-May–mid-June:

- For yield potential ≥1.5 t/ha, sow at ≥25 plants/m².
- For yield potential ≤1.5 t/ha, sow at ≥20 plants/m².

When sowing very late, sow at high plant density to reduce losses due to viruses; do not sow < 20 plants/m² (Table 12). [32]

Recent NSW DPI research builds on research work from the early 1990s, which gave rise to the rule of thumb commonly used in northern NSW and Queensland (i.e., that row spacing ranging from 25 to 75 cm results in no yield difference).

Chickpeas are successfully grown using a wide range of row spacings, from 20 to 100 cm, with wider rows (50–100 cm) becoming quite 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 such as PBA HatTrick⍉ have a lower rate of yield decline at wider row spacing than older varieties such as Amethyst. Researchers

[31] GRDC (2011) Northern region—A systems approach to row spacing. GRDC Factsheet January 2011, https://www.grdc.com.au/Resources/Factsheets/2011/02/Crop-Placement-and-Row-Spacing-Northern-Fact-Sheet

[32] A Verrell, R Brill, L Jenkins (2014) The effect of plant density on yield in chickpea across central and northern NSW. GRDC Update Papers 5 March 2014, http://www.grdc.com.au/Research-and-Development/GRDC-Update-Papers/2014/03/The-effect-of-plant-density-on-yield-in-chickpea-across-central-and-northern-NSW

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.

Table 12: Effect of sowing date and row spacing on the yield of different varieties over consecutive seasons.

Year	Sow date	Variety	Row spacing	Yield	Standard error
2008	30 May	Flipper⚳	40 cm	2.08	± 0.162
		Flipper⚳	80 cm	1.79	
		Jimbour	40 cm	2.31	
		Jimbour	80 cm	1.83	
2009	29 May	Flipper⚳	40 cm	2.70	± 0.190
		Flipper⚳	80 cm	2.25	
		Jimbour	40 cm	2.83	
		Jimbour	80 cm	2.23	
2010	1 June	Amethyst	40 cm	2.58	± 0.093
		Amethyst	80 cm	2.14	
		PBA HatTrick⚳	40 cm	2.98	
		PBA HatTrick⚳	80 cm	2.74	
2013	22 June	PBA HatTrick⚳	40 cm	2.20	± 0.033
	17 July	PBA HatTrick⚳	40 cm	1.45	± 0.028
		PBA HatTrick⚳	80 cm	1.08	

All sowings at a fixed plant density of 30 plants/m²

The significant yield advantage of narrow rows over wide rows for the very late sown (17 July) crop supports the findings of Whish and Cocks (2004) and Whish (2007), in which narrow-planted late crops produced higher yields. [33]

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 4 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

More information

http://grdc.com.au/Research-and-Development/GRDC-Update-Papers/2014/03/Effect-of-row-spacing-on-yield-in-chickpea-under-high-yield-potential

http://grdc.com.au/Research-and-Development/GRDC-Update-Papers/2014/03/The-effect-of-plant-density-on-yield-in-chickpea-across-central-and-northern-NSW

https://www.grdc.com.au/Resources/Factsheets/2011/02/Crop-Placement-and-Row-Spacing-Northern-Fact-Sheet

[33] A Verrell, L Jenkins (2014) Effect of row spacing on yield in chickpea under high yield potential. GRDC Update Papers 5 March 2014, http://www.grdc.com.au/Research-and-Development/GRDC-Update-Papers/2014/03/Effect-of-row-spacing-on-yield-in-chickpea-under-high-yield-potential

More information

http://www.grdc.com.au/Research-and-Development/GRDC-Update-Papers/2013/02/Row-placement-strategies-in-a-break-crop-wheat-sequence

- better protection to break-crop seedlings from standing wheat stubble [34]

3.7 Sowing depth

Chickpeas should be sown 5–7 cm deep into good soil moisture.

The seedlings are robust, provided high-quality seed is used. Sowing at 5–7 cm has several agronomic advantages, as it:

- reduces the risk of damage from pre-emergent residual herbicides (e.g. simazine, Balance®);
- promotes the early formation of lateral roots in the topsoil;
- enhances inoculum survival in moist soil; and
- eliminates a significant proportion of Ascochyta-infected seeds (due to mortality of diseased seed).

Press-wheels can improve establishment, although heavy pressures should be avoided.

V-Shaped press-wheels will leave a furrow down the planting line, which can lead to concentration of residual herbicides in the furrow after rainfall, and subsequent crop damage.

3.7.1 Deep planting

Deep planting is not only an extremely valuable tool under drought conditions, but can also offer major advantages in most years including:

- planting at the optimum time
- freeing up valuable time for planting wheat when suitable planting rains do fall
- avoidance of residual herbicide damage
- better development of lateral roots
- improved nodulation

Many growers have been deep-planting chickpeas for some time. Excellent plant emergence has been achieved from up to 15 cm deep, and planting depth can be varied from 5 to 20 cm according to seasonal conditions.

There are a few key points to remember:

- Plan ahead when deep planting. It pays to plant early in the planting window to allow for any delay in emergence (typically 10–14 days), ensuring that the plant is able to grow tall enough to facilitate harvest.
- Ensure you have high quality planting seed. Check your germination percentage, vigour and seed counts (seeds/kg) and adjust seeding rates accordingly.
- When deep planting, plan levelling of the paddock after planting to reduce the risk of herbicide damage when using a pre-emergent herbicide such as simazine and/or Balance®.
- Decide on a planting depth to ensure that all seeds are planted into moisture. Experience shows that it is better to err on the deep side rather than planting too shallow into marginal moisture.
- To maximise yield potential, paddocks should be selected carefully to avoid any subsoil constraints, such as salinity, to ensure that the crop can gain maximum access to all the stored soil moisture and nutrients. [35]

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

3.8 Sowing equipment

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 combine 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 Combine seeders

Combines with fluted roller feeds such as Chamberlain, Connor Shea, old Napier and some Massey combines have few problems feeding seed of <15 mm down to the metering chamber.

Combines with peg roller and seed wheel feeds (newer Napier, Shearer, Chamberlain-John Deere) will seed grains up to the size of Kabuli chickpeas without problems, provided adequate clearances are used around the rollers. Smaller faba beans can be metered with the more aggressive seed wheel system, but peg rollers are best replaced with ‘rubber stars’ for larger faba beans. Broad beans can be metered through the rubber stars, but how efficiently combines sow these seeds is still in question.

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

3.8.2 Airseeders

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

Airseeders using metering belt systems (Fusion, Alfarm, Chamberlain-John Deere, New Holland) 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 21 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 mm to 41 mm. Four larger hoses replace the original eight, and row spacings are increased from 150 mm to 300 mm. This conversion allows large seeds such as Kabuli chickpea or beans to be sown easily.

Airseeders with large, single fluted rollers cannot meter faba and broad beans >18 mm without modifications to the metering roller. 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 21: 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, http://www.grdc.com.au/uploads/documents/3 Seeding.pdf)

3.8.3 Seeder and tine 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 22) (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- 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.

A comparison of the key functions that are critical for seed drills and no-till is shown in Table 13.

In interpreting the functions listed in Table 13 it should be noted that:

- With tines, the slot created is different depending on the type of tine used. Some create a vertical slot, others a ‘V’, while the inverted ‘T’ (or ‘baker boot’) leaves a slot with a narrow entrance and wider trench underneath (Figure 23). These tines do perform differently in some functions in Table 13.
- 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 tines 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 24).
- Springs cannot apply consistent down force on openers throughout a range of soil conditions.
- Banding of fertiliser away from the seed is important for crop establishment, particularly when high rates or high-analysis products are applied and the seed is in a narrow opening slot.
- Tines handle stones, but bring them up, hence requiring rolling to press them back again.

The seeding mechanism of the seeder must be able to handle pulses, which are larger seeded than cereals and oilseeds. Hoses, distributor heads and boots must also be able to handle pulses without blockages or bridging. This is especially true for larger seeded types such as faba and broad beans or Kabuli chickpeas (Figure 25).

Table 13 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 26).

Figure 22: One of several seeding mechanisms for uniform sowing depth using the press wheel for depth control.

Figure 23: 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 24: The DBS system parallelogram for uniform seeding depth and deep placement of seed or fertiliser.

Figure 25: A Bio Blade or Cross slot™ 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.

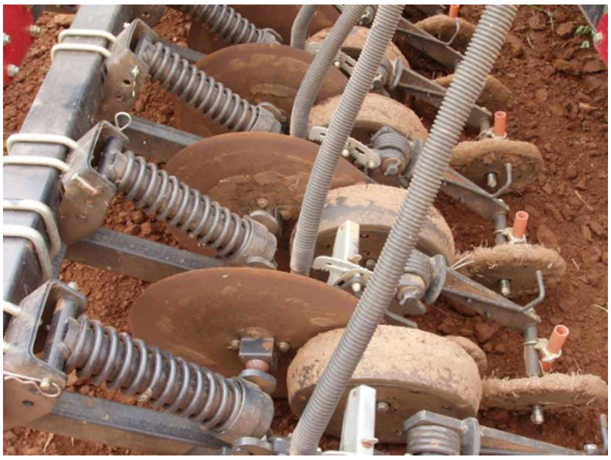


Figure 26: A Case IH SDX-40 single-disc drill.

Table 13: Comparison scores (rating basis: 1, poor; 5 excellent) of no-till openers by function (after Baker 2010)

	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 fertilizer banding is effective with high analysis fertilizers	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

	Narrow point	Wide point	Sweep	Double disc	Single disc	Slanted disc	Combined winged tine & disc[B]
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**

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

Source: C.J Baker (2010), SANTFA 12th Annual Conference pp. 7–13.
[A]Functions that may be deleted in some circumstances, but all other functions are universal.
[B]Combination is otherwise known as the Cross Slot™ or Bio Blade.

In Table 13, neither pure-disc nor pure-tine openers rate highly over all functions using this scoring. Disc openers rated lowest (49–55%), and of the tines (57–66%), narrow points were the best (66%). The combination of winged tine and disc, known as the Bio Blade or Cross Slot™, had the highest score (94%). It allegedly combines the best attributes of pure disc openers with the best attributes of pure tine 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 13 as a guide only to help select your own openers to suit your conditions and circumstances. [36]

[36] Pulse Australia (20130 Northern chickpea best management practices training course manual—2013. Pulse Australia Limited.