



NORTHERN

FEBRUARY 2016

GRDC™ **GROWNOTES™**



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GRAINS RESEARCH
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WHEAT

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SECTION 3

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3.1 Time of sowing

Choosing the optimal planting time for wheat involves compromise. Planting early will increase the chance of frost damage at flowering. With late-maturing varieties, it can also increase the bulk of crops, i.e. vegetative growth, and lead to stored soil water being used before flowering. In early-maturing varieties, sowing late may reduce the bulk of the crop as development is hastened, as well as reduce rooting depth. This can lead to reduced yield potential and reduced access to deeper moisture and nutrients.

Key points:

- Early sowing can accelerate establishment and make full use of the available moisture and nutrients but can increase the risk of frost during critical growth stages and haying-off in a dry finish.
- Early-sown crops can have a larger root system that better enables them to handle dry conditions and forage for nutrients.
- Flowering time of wheat is controlled by the interaction of several factors, including temperature, day length and cold requirement.
- Most Australian wheat varieties flower in response to the accumulation of warm temperatures. Many varieties also have a cold temperature requirement, i.e. vernalisation, which is important in some winter wheats, and some varieties flower in response to longer days.
- To minimise risk, varieties with a range of flowering dates and maturities should be sown, provided other criteria such as disease resistance are also met.
- The relationship between sowing date and crop development can interact with disease development and nutrition management.
- Late sowing can increase severity of most root diseases. Early sowing can increase the severity of a number of leaf diseases, such as stem rust, due the bulk of growth. Rusts are not consistently affected by sowing time. ¹
- Late-sown crops that emerge in colder wetter conditions are more prone to leaf diseases such as yellow leaf spot, due to slower early growth.

Timing of wheat planting is critical and high soil temperatures can reduce establishment. The ideal temperature range for wheat germination is 12°–25°C, but germination will occur between 4° and 37°C. ² Different varieties have been bred to suit different planting times, and varieties differ in their ability to achieve high yield from different sowing times. See Tables 1 and 2 for suggested sowing times for different varieties and locations.

¹ GRDC (2011) Time of sowing. GRDC Fact Sheet 3 March 2011, <http://www.grdc.com.au/Resources/Factsheets/2011/03/Time-Of-Sowing#sthash.xzzV4fUO.dpuf>, <http://www.grdc.com.au/GRDC-FS-TimeOfSowing>

² NSW DPI Agronomists (2007) Wheat growth and development. PROCROP Series, NSW Department of Primary Industries, http://www.dpi.nsw.gov.au/_data/assets/pdf_file/0006/449367/Procrop-wheat-growth-and-development.pdf

i More information

NSW DPI Primefact:
<http://www.nvtonline.com.au/wp-content/uploads/2013/07/Yield-response-of-wheat-varieties-to-sowing-time-20121.pdf>

There are typically three types of variety response to sowing time:

- higher yield when sown early (negative slope)
- higher yield when sown late (positive slope)
- similar yield over all sowing times (flat slope) ³

Varieties also differ in the time they take from sowing to flowering. Late-sown (quicker maturing) varieties take fewer days to flower than early-sown (late-maturing) varieties. This difference is more marked from early sowings (April) than from late sowings (July). ⁴



Figure 1: EGA Gregory wheat in flower. Most Australian wheat varieties flower in response to the accumulation of warm temperatures. (Photo: Penny Heuston)

³ P Martin, P Matthews (2013) Yield response of wheat varieties to sowing time 2012. NSW Department of Primary Industries Primefact 914, May 2013, <http://www.nvtonline.com.au/wp-content/uploads/2013/07/Yield-response-of-wheat-varieties-to-sowing-time-20121.pdf>

⁴ P Matthews, D McCaffery, L Jenkins (2014) Winter crop variety sowing guide 2014. NSW Department of Primary Industries, <http://www.dpi.nsw.gov.au/agriculture/broadacre/guides/winter-crop-variety-sowing-guide>

Table 1: Suggested sowing times NSW Slopes and Plains ⁵

Variety	March				April				May				June				July			
	1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4
Slopes																				
Brennan ^(b) , Mackellar ^(b) , Tennant ^(b)	>	⦿	⦿	⦿	⦿	⦿	⦿	⦿	<	<										
EGA_Wedgetail ^(b) , Naparoo ^(b) , Rudd ^(b) , SQP_Revenue ^(b)		>	>	⦿	⦿	⦿	⦿	⦿	⦿	⦿	<									
Beaufort ^(b) , EGA_Eaglehawk ^(b) , Sunbrook						>	⦿	⦿	⦿	<	<									
Sunbri ^(b) , Sunzell ^(b)							>	⦿	⦿	⦿	⦿	<	<							
EGA_Gregory ^(b) , Gazelle ^(b) , Giles ^(b) , Sentinel3R ^(b) , Strzelecki ^(b) , Sunlin ^(b)								>	⦿	⦿	⦿	⦿	<							
EGA_Bounty ^(b) , EGA_Burke ^(b) , EGA_Wills ^(b) , EGA_Wylie ^(b) , Ellison ^(b) , Elmore CL PLUS ^(b) , Espada ^(b) , Gauntlet ^(b) , Impala ^(b) , Janz ^(b) , Lincoln ^(b) , Merinda ^(b) , Orion ^(b) , Sunco ^(b) , Sunguard ^(b) , Suntop ^(b) , Sunvale ^(b) , Sunvex ^(b) , Wallup ^(b)										>	⦿	⦿	⦿	⦿	⦿	<				
Baxter ^(b) , Petrel ^(b)										>	⦿	⦿	⦿	⦿	<	<				
Crusader ^(b) , Derrimut ^(b) , EGA_Stampede ^(b) , Kennedy ^(b) , Livingston ^(b) , Merlin ^(b) , Peake ^(b) , Spitfire ^(b) , Ventura ^(b)											>	⦿	⦿	⦿	⦿	<	<			
Axe ^(b) , Dart ^(b)												>	⦿	⦿	⦿	⦿	<	<		
Plains																				
EGA_Wedgetail ^(b) , Naparoo ^(b)					>	⦿	⦿	⦿	⦿	⦿	<									
EGA_Eaglehawk ^(b) , Sunbrook ^(b)						>	⦿	⦿	⦿	<	<									
Sunbri ^(b) , Sunzell ^(b)						>	>	⦿	⦿	⦿	⦿	<	<							
EGA_Gregory ^(b) , Gazelle ^(b) , Giles ^(b) , Sentinel3R ^(b) , Strzelecki ^(b) , Sunlin ^(b)								>	⦿	⦿	⦿	⦿	<							
EGA_Bounty ^(b) , EGA_Burke ^(b) , EGA_Wills ^(b) , EGA_Wylie ^(b) , Ellison ^(b) , Elmore CL PLUS ^(b) , Emu Rock ^(b) , Espada ^(b) , Impala ^(b) , Janz ^(b) , Lincoln ^(b) , Merinda ^(b) , Orion ^(b) , Sunco ^(b) , Sunguard ^(b) , Suntop ^(b) , Sunvale ^(b) , Sunvex ^(b) , Wallup ^(b)										>	⦿	⦿	⦿	⦿	⦿	<				
Baxter ^(b) , Petrel ^(b)										>	⦿	⦿	⦿	⦿	<	<				
Crusader ^(b) , Derrimut ^(b) , EGA_Stampede ^(b) , Kennedy ^(b) , Livingston ^(b) , Merlin ^(b) , Peake ^(b) , Spitfire ^(b) , Ventura ^(b)											>	⦿	⦿	⦿	⦿	<				
Axe ^(b) , Dart ^(b)												>	⦿	⦿	⦿	⦿	<	<		

> Earlier than ideal but acceptable, ⦿ Optimum sowing time, < Later than ideal but acceptable

* Winter wheat

Petrel sown in late May for hay/chaff production. Can be sown earlier if grazed.

⁵ P Matthews, D McCaffery, L Jenkins (2014) Winter crop variety sowing guide 2014. NSW Department of Primary Industries, <http://www.dpi.nsw.gov.au/agriculture/broadacre/guides/winter-crop-variety-sowing-guide>

Table 2: Suggested planting times for Queensland wheat regions⁶

Variety	April				May				June				July				
	1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4	
Central Highlands																	
Dawson, Callide – low frost risk (higher slopes or more northern areas)																	
Sunzell ⁽¹⁾ , EGA Eaglehawk ⁽¹⁾ , Strzelecki ⁽¹⁾ , EGA Bellaroi ⁽¹⁾ , Petrie ⁽¹⁾ , EGA Gregory ⁽¹⁾	>	>	0	0	0	0	0	<									
EGA Wylie ⁽¹⁾ , EGA Bounty ⁽¹⁾ , EGA Burke ⁽¹⁾	>	>	>	0	0	0	0	0	<	<							
Baxter ⁽¹⁾ , Sunvex ⁽¹⁾ , Sunvale ⁽¹⁾ , Sunguard ⁽¹⁾ , Caparoi ⁽¹⁾ , Hyperno ⁽¹⁾ , LongReach Gauntlet ⁽¹⁾	>	>	>	>	0	0	0	0	<	<							
Lang ⁽¹⁾ , EGA Kidman ⁽¹⁾ , EGA Hume ⁽¹⁾ , Elmore CL Plus ⁽¹⁾ , Sunco, Kennedy ⁽¹⁾ , GBA Hunter ⁽¹⁾ , Ventura ⁽¹⁾	>	>	>	>	0	0	0	0	0	0	<	<					
Hartog, Suntop ⁽¹⁾ , Leichhardt, LongReach Spitfire ⁽¹⁾ , LongReach Crusader ⁽¹⁾ , Wallup ⁽¹⁾ , Livingston ⁽¹⁾ , EGA Stampede ⁽¹⁾ , Jandaroi ⁽¹⁾ , LongReach Dart ⁽¹⁾		>	>	>	>	0	0	0	0	0	<	<					
Central Highlands																	
Dawson, Callide – high frost risk (river flats or areas known to be more frost-prone)																	
Sunzell ⁽¹⁾ , EGA Eaglehawk ⁽¹⁾ , Strzelecki ⁽¹⁾ , EGA Bellaroi ⁽¹⁾ , Petrie ⁽¹⁾ , EGA Gregory ⁽¹⁾			>	>	0	0	0	0	<								
EGA Wylie ⁽¹⁾ , EGA Bounty ⁽¹⁾ , EGA Burke ⁽¹⁾			>	>	0	0	0	0	0	0	<						
Baxter ⁽¹⁾ , Sunvex ⁽¹⁾ , Sunvale ⁽¹⁾ , Sunguard ⁽¹⁾ , Caparoi ⁽¹⁾ , Hyperno ⁽¹⁾ , LongReach Gauntlet ⁽¹⁾			>	>	0	0	0	0	0	0	<	<					
Lang ⁽¹⁾ , EGA Kidman ⁽¹⁾ , EGA Hume ⁽¹⁾ , Elmore CL Plus ⁽¹⁾ , Sunco, Kennedy ⁽¹⁾ , GBA Hunter ⁽¹⁾ , Ventura ⁽¹⁾			>	>	0	0	0	0	0	0	0	<	<				
Hartog, Suntop ⁽¹⁾ , Leichhardt, LongReach Spitfire ⁽¹⁾ , LongReach Crusader ⁽¹⁾ , Wallup ⁽¹⁾ , Livingston ⁽¹⁾ , EGA Stampede ⁽¹⁾ , Jandaroi ⁽¹⁾ , LongReach Dart ⁽¹⁾			>	>	0	0	0	0	0	0	0	0	<				
Western Downs - South West																	
Maranoa, Balonne																	
Sunzell ⁽¹⁾ , EGA Eaglehawk ⁽¹⁾		>	0	0	<												
Strzelecki ⁽¹⁾ , Petrie ⁽¹⁾		>	0	0	0	0	0	<									
EGA Gregory ⁽¹⁾ , Sunvex ⁽¹⁾ , Sunvale ⁽¹⁾ , EGA Bounty ⁽¹⁾ , EGA Burke ⁽¹⁾ , EGA Wylie ⁽¹⁾ , Baxter ⁽¹⁾			>	>	0	0	0	0	0	0	0	<					
EGA Kidman ⁽¹⁾ , Sunco, Lang ⁽¹⁾ , Sunguard ⁽¹⁾ , Elmore CL Plus ⁽¹⁾ , EGA Bellaroi ⁽¹⁾ , EGA Hume ⁽¹⁾ , Hyperno ⁽¹⁾ , GBA Hunter ⁽¹⁾ , LongReach Gauntlet ⁽¹⁾			>	0	0	0	0	0	0	0	0	<	<				
Kennedy ⁽¹⁾ , Leichhardt, Suntop ⁽¹⁾ , Jandaroi ⁽¹⁾ , Hartog, Ventura ⁽¹⁾ , Wallup ⁽¹⁾ , Caparoi ⁽¹⁾ , EGA Stampede ⁽¹⁾ , LongReach Spitfire ⁽¹⁾ , LongReach Crusader ⁽¹⁾ , Livingston ⁽¹⁾ , LongReach Dart ⁽¹⁾			>	0	0	0	0	0	0	0	0	<	<				
Darling Downs																	
Northern, Uplands																	
Sunzell ⁽¹⁾ , EGA Eaglehawk ⁽¹⁾			>	0	0	0	<										
Strzelecki ⁽¹⁾ , EGA Gregory ⁽¹⁾			>	0	0	<											
Sunvex ⁽¹⁾ , Sunvale ⁽¹⁾ , EGA Bellaroi ⁽¹⁾ , Hyperno ⁽¹⁾ , LongReach Gazelle ⁽¹⁾ , EGA Bounty ⁽¹⁾ , EGA Burke ⁽¹⁾ , EGA Wylie ⁽¹⁾ , Baxter ⁽¹⁾ , LongReach Orion ⁽¹⁾			>	>	0	0	0	0	<								
Sunco, Lang ⁽¹⁾ , Sunguard ⁽¹⁾ , Elmore CL Plus ⁽¹⁾ , EGA Kidman ⁽¹⁾ , GBA Hunter ⁽¹⁾ , LongReach Gauntlet ⁽¹⁾			>	>	0	0	0	0	0	0	<	<					

⁶ GRDC/DAFF (2013) National Variety Trials Queensland 2013 wheat varieties. GRDC/ Department of Agriculture, Fisheries and Forestry Queensland, [http://www.grdc.com.au/~media/8B7376A44F234BDD99374982D6771EF8.pdf](http://www.grdc.com.au/~/media/8B7376A44F234BDD99374982D6771EF8.pdf)

Variety	April				May				June				July			
	1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4
Kennedy ^(b) , Leichhardt, Suntop ^(b) , LongReach Impala ^(b) , Jandaroi ^(b) , Hartog, Ventura ^(b) , Wallup ^(b) , Caparoi ^(b) , EGA Stampede ^(b) , LongReach Spitfire ^(b) , LongReach Crusader ^(b) , Livingston ^(b) , LongReach Dart ^(b)								>	>	🌱	🌱	🌱	🌱	🌱	<	<
Darling Downs Central, Southern - high frost risk																
Sunzell ^(b) , EGA Eaglehawk ^(b)						>	🌱	🌱	<							
Strzelecki ^(b) , EGA Gregory ^(b)								>	🌱	🌱	🌱	<				
Sunvex ^(b) , Sunvale ^(b) , EGA Bellaroi ^(b) , Hyperno ^(b) , LongReach Gazelle ^(b) , EGA Bounty ^(b) , EGA Burke ^(b) , EGA Wylie ^(b) , Baxter ^(b) , LongReach Orion ^(b)									>	🌱	🌱	🌱	🌱	<		
Sunco, Lang ^(b) , Sunguard ^(b) , Elmore CL Plus ^(b) , EGA Kidman ^(b) , GBA Hunter ^(b) , LongReach Gauntlet ^(b)									>	>	🌱	🌱	🌱	🌱	🌱	<
Kennedy ^(b) , Leichhardt, Suntop ^(b) , LongReach Impala ^(b) , Jandaroi ^(b) , Hartog, Ventura ^(b) , Wallup ^(b) , Caparoi ^(b) , EGA Stampede ^(b) , LongReach Spitfire ^(b) , LongReach Crusader ^(b) , Livingston ^(b) , LongReach Dart ^(b)									>	🌱	🌱		🌱	🌱	🌱	<
Central Burnett, South Burnett and West Moreton*																
Sunzell ^(b) , EGA Eaglehawk ^(b) , Strzelecki ^(b) , Petrie ^(b) , EGA Gregory ^(b)						>	>	🌱	🌱	🌱	<					
Sunvex ^(b) , Sunvale ^(b) , LongReach Gazelle ^(b) , EGA Bounty ^(b) , EGA Burke ^(b) , EGA Wylie ^(b) , Baxter ^(b) , LongReach Orion ^(b) , EGA Kidman ^(b) , Sunco, Lang ^(b) , Sunguard ^(b) , Elmore CL Plus ^(b) , EGA Bellaroi ^(b) , Hyperno ^(b) , EGA Hume ^(b) , GBA Hunter ^(b) , LongReach Gauntlet ^(b)							>	>	🌱	🌱	🌱	🌱	<	<		
Kennedy ^(b) , Leichhardt, Suntop ^(b) , LongReach Impala ^(b) , Jandaroi ^(b) , Hartog, Ventura ^(b) , Wallup ^(b) , Caparoi ^(b) , EGA Stampede ^(b) , LongReach Spitfire ^(b) , LongReach Crusader ^(b) , Livingston ^(b) , LongReach Dart ^(b)								>	🌱	🌱	🌱	🌱	<	<		

> Early

Early planted crops face the risk of frost damage from pre-flowering to grain fill. Therefore, plant early in areas of low frost risk, such as higher slopes, and reduce the risk of frost damage by planting more than one variety and by varying planting times.

In Central Queensland, warm weather encourages rapid early plant development. Where possible, plant shallow into moisture and use press-wheels to aid establishment. Increase the plant population for all varieties to compensate for reduced tillering in warm growing conditions. Maturity groupings may differ from district to district, particularly from central to southern Queensland.

🌱 Conventional

Varieties sown at their most appropriate planting times flower after the main frost period, although late frosts may still cause damage.

> Late

The reliability of yield can be low following a very late planting due to high temperatures during flowering and grain filling.

Detailed wheat planting information for each region is available from DAFF (www.daff.qld.gov.au).

* Plant wheat varieties two weeks earlier in West Moreton.

Frost damage may be minimised by planting varieties within the range of dates recommended in Table 1. This table was compiled from currently available data.

3.1.1 Managing frosts with sowing time

Frosts can cause damage resulting in reduced yield and can affect grain quality. Some varieties sown too early will flower in late winter. Varieties sown too late have little chance of reaching their yield potential because flowering and grain-filling occur under hot, dry, stressful conditions.

Sowing time is a management compromise between having the crop flowering soon after the last heavy frost, and early enough to allow adequate grain-fill before the onset of moisture stress and heat in spring.

If varieties are sown within the optimum sowing period, they can produce their highest yields but the best sowing date varies with topography and variety. Locally, sowing dates may need to be extended (earlier or later) depending upon local climatic conditions, paddock topography and soil types.

While outlying severe frosts cannot be mitigated, the risk of seasonal frosts at flowering needs to be assessed and balanced. Frost damage (Figure 2) is a major consideration and the risk cannot be entirely eliminated; therefore, the potential for higher yields from earlier sowings needs to be balanced against the risk of frost damage at flowering.



Figure 2: Frosted wheat. (Photo: Rachel Bowman)

There are two ways of doing this:

1. In areas where the risk of frost is high (i.e. low-lying paddocks, regions with lower winter temperatures, such as the Slopes to the east of the region), sow later than the suggested optimum sowing period. As a rule of thumb, 3 days difference at planting makes 1 day of difference at heading.
2. Change varieties. Use maturity differences to have the crop flowering at a time when the seasonal frost risk is acceptable.

As rain for sowing is often erratic, varieties must be chosen carefully to achieve this balance.⁷

3.1.2 Risk and sowing decisions in western NSW

The GRDC-supported Variety Specific Agronomy Projects (VSAP) are conducting sowing-time trials for wheat and barley at Trangie and Condobolin. Up to 40 varieties, including all recent releases and advanced lines, have been sown at three or four sowing dates, and measurements include flowering time, biomass, tiller number, yield and grain quality (Figure 3).

i More information

For variety characteristics and reaction to diseases, and diseases and crop injury guide, download the 'NSW DPI Winter crop variety sowing guide 2014' and the DAFF/GRDC 'NVT Queensland 2014 wheat varieties':

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

<http://www.grdc.com.au/NVT-QLD-WheatVarietyGuide>

[Managing frost risk in warmer seasons may not be as easy as you think](#)

⁷ P Matthews, D McCaffery, L Jenkins (2014) Winter crop variety sowing guide 2014. NSW Department of Primary Industries, <http://www.dpi.nsw.gov.au/agriculture/broadacre/guides/winter-crop-variety-sowing-guide>

i More information

[Northern grains region trial results Autumn 2015](#)

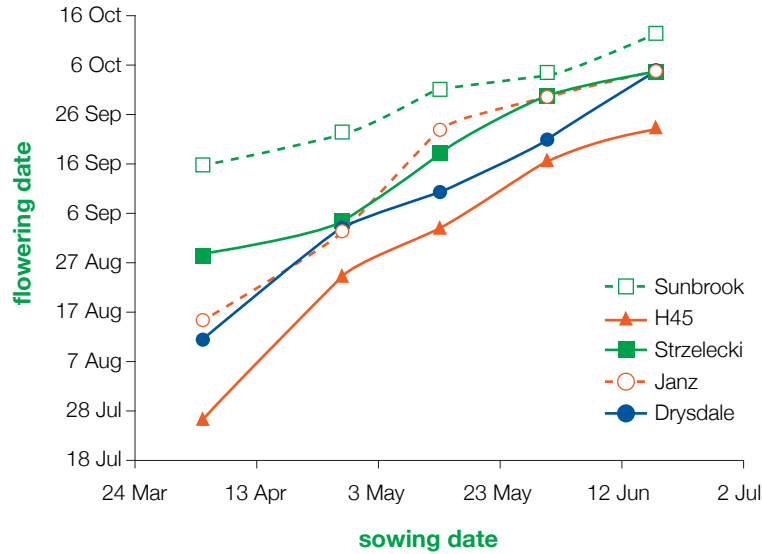


Figure 3: Flowering dates for five wheat varieties sown on five dates at Condobolin. (Sunbrook, H45, Strzelecki and Drysdale are protected under the Plant Breeders Rights Act 1994.)

Stresses such as frost, high temperature, high evaporative demand and low soil moisture in the period around flowering can be detrimental to yield. The typical timing of frosts and high temperatures for Condobolin is shown in Figure 5.

Frost frequency drops substantially between 14 and 24 September, but average maximum temperature and evaporative demand (not shown) also increase rapidly from 19 to 30 September; the third week of September appears, on average, to be the optimum flowering time at Condobolin. By contrast, frost frequency at Nyngan declines much earlier in late winter and the optimum flowering date is likely to be as much as 2 weeks earlier.



Figure 4: Stresses such as frost, high temperature, high evaporative demand and low soil moisture in the period around flowering can be detrimental to yield.

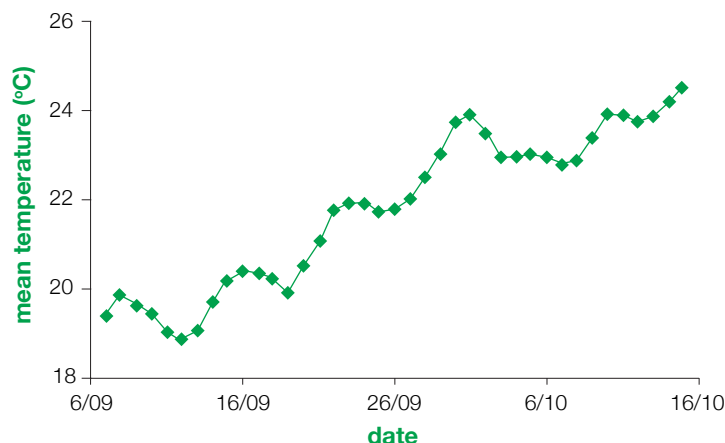
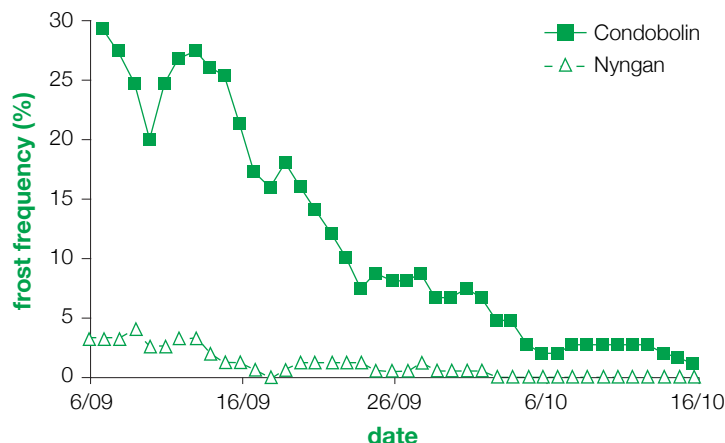


Figure 5: Daily frost frequency at Condobolin and Nyngan, and average maximum temperature at Condobolin 1973–2002.

Mid-season varieties (including Gregory⁽¹⁾, Lang⁽¹⁾, Sentinel⁽¹⁾) performed well at the first two dates but poorly sown late. Late varieties (including Wedgetail⁽¹⁾ and Sunzell⁽¹⁾) yielded reasonably when sown in late April but yield declined with later sowings; these varieties may have done better sown earlier in April. The rate of yield decline for each group averaged 0.17 t/ha, or almost 10% per week.⁸

More information

GRDC Update Paper:
<http://www.grdc.com.au/Research-and-Development/GRDC-Update-Papers/2011/03/Matching-wheat-varieties-and-sowing-time-the-impacts-of-water-stress-and-frost-risk>

More information

GRDC Update Paper:
<http://www.grdc.com.au/Research-and-Development/GRDC-Update-Papers/2003/09/Population-density-studies-in-sorghum-and-wheat>

3.2 Targeted plant population

Plant population, determined by seeding rate and establishment percentage, can be an important determinant of tiller density and, at a later stage, head density. Current recommendations for New South Wales (NSW) (see 'Winter crop variety sowing guide') range from 30–70 plants/m² for the North West Plains to 100–150 plants/m² for the higher rainfall south, and row spacing should be <30–40 cm.

Responses to plant population and row spacing on the Liverpool Plains are likely to be lower than elsewhere in northern NSW due to the cooler and wetter environment and higher water-holding capacity of most soils.⁹

⁸ N Fettell, R Brill, J Hunt (2013) Matching wheat varieties and sowing time—the impacts of water stress and frost risk. GRDC Update Papers 25 March 2013, <http://www.grdc.com.au/Research-and-Development/GRDC-Update-Papers/2011/03/Matching-wheat-varieties-and-sowing-time-the-impacts-of-water-stress-and-frost-risk>

⁹ G Butler, W Manning, L Serafin (2003) Population density studies in sorghum and wheat. GRDC Update Papers 19 Sept. 2003, <http://www.grdc.com.au/Research-and-Development/GRDC-Update-Papers/2003/09/Population-density-studies-in-sorghum-and-wheat>

High yields are possible from a wide range of plant populations, because wheat compensates by changing the number of tillers and the size of the heads in response to the environmental conditions, including weather, fertility and plant competition. Varieties differ in their ability to do this; for example, Spitfire⁽¹⁾ produces low tiller numbers, whereas Sunvale⁽¹⁾ produces very high tiller numbers (Figure 6).



Figure 6: Sunvale⁽¹⁾ wheat is an example of a variety with the ability to produce a high number of tillers. (Photo: Susan McDonnell)

Despite this ability to compensate, targeting a variety's optimum plant density at sowing makes the most efficient use of water and nutrients. To reach a target plant population for the environment and seasonal conditions, adjust sowing rates to allow for:

- sowing date—higher rates with later sowings
- seed germination percentage
- seed size
- seedbed conditions
- tillage, e.g. no-till
- double-cropping
- soil fertility
- soil type
- soil moisture and seasonal outlook
- weed seed burden—higher sow rates for increased plant competition, e.g. if combatting herbicide resistant ryegrass populations¹⁰

The responses of different varieties to target plant densities were monitored in 2003 at central-west NSW trial sites, where three varieties were measured at Dubbo and four at Condobolin.

At Dubbo, the trial looked at the impact of plant density on:

- grain yield
- head density
- grain number per head
- mean grain weight

¹⁰ NSW DPI Agronomists (2007) *Wheat growth and development*. PROCROP Series, NSW Department of Primary Industries 2007, http://www.dpi.nsw.gov.au/_data/assets/pdf_file/0006/449367/Procrop-wheat-growth-and-development.pdf

The trials showed that high plant populations (>140 plants/m²) do not necessarily lead to small grain or high screenings. The high yields of H45 were from high grain number per head, even though it had lower tiller and head density at maturity.

The response to plant population was very different at Condobolin, where stored soil moisture and September rainfall were much lower. The results are presented in Figure 8.



Figure 7: The trials showed that high plant populations do not necessarily lead to small grain or high screenings.

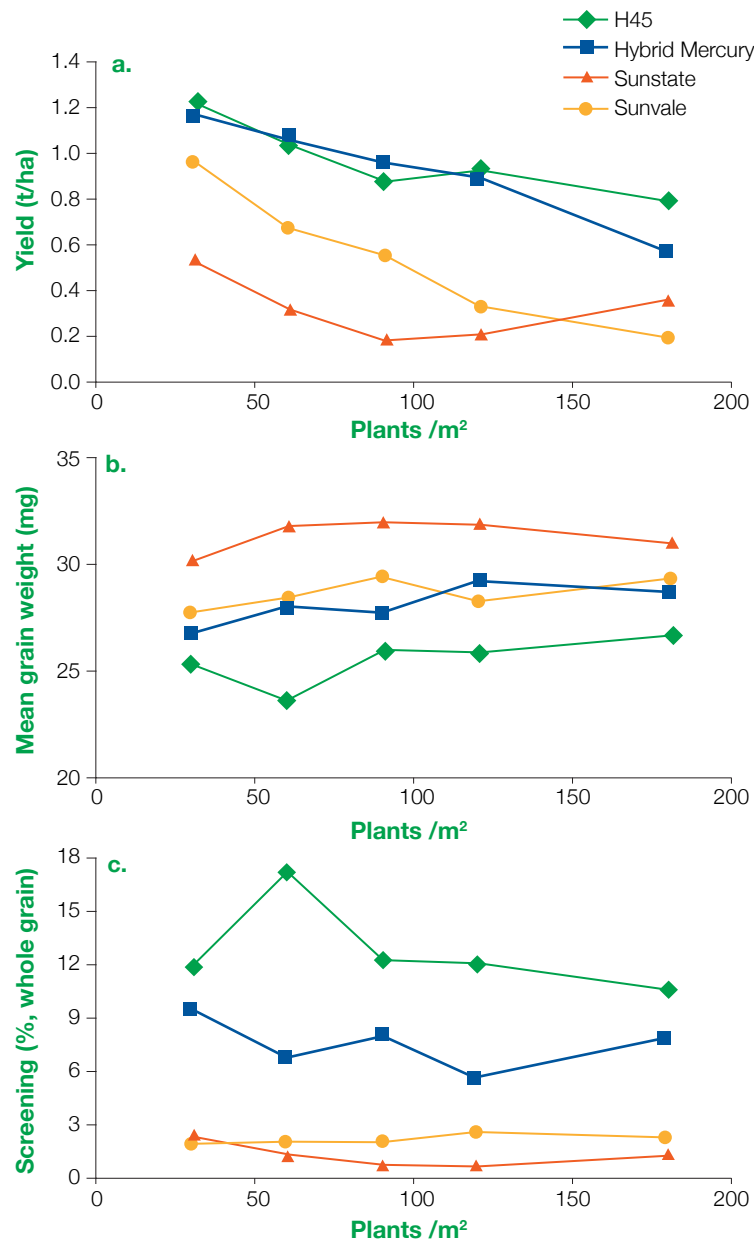


Figure 8: Effect of plant population in four wheat varieties on (a) grain yield, (b) mean grain weight and (c) screenings, Condobolin 2003. (Source: N Fettell, 2006 'Plant population responses in wheat', District Agronomist Technical Update, Orange, NSW.)

More information

http://www.dpi.nsw.gov.au/_data/assets/pdf_file/0006/449v367/Procrop-wheat-growth-and-development.pdf

Higher plant populations with the later flowering varieties led to excessive growth and water use prior to flowering, resulting in a low harvest index. (Harvest index is a method for measuring the proportion of aboveground dry matter that is grain.) The low harvest index was due to water stress around flowering causing a decrease in grain number, rather than a decrease in mean grain weight.

It is likely that post-flowering stress limited grain-filling, and that there were insufficient pre-flowering water-soluble carbohydrates to maintain grain size with the high grain number.¹¹

Wheat growers in Queensland should aim for a plant population of about 1 million plants/ha, or 100 plants/m².

¹¹ NSW DPI Agronomists (2007) *Wheat growth and development*. PROCROP Series, NSW Department of Primary Industries, http://www.dpi.nsw.gov.au/_data/assets/pdf_file/0006/449367/Procrop-wheat-growth-and-development.pdf

In Queensland over the last 20 years, plant populations of 100 plants/m² gave the best yields under most conditions. Higher populations did not adversely affect yield, whereas populations <50 plants/m² yielded significantly less (see Figure 9).

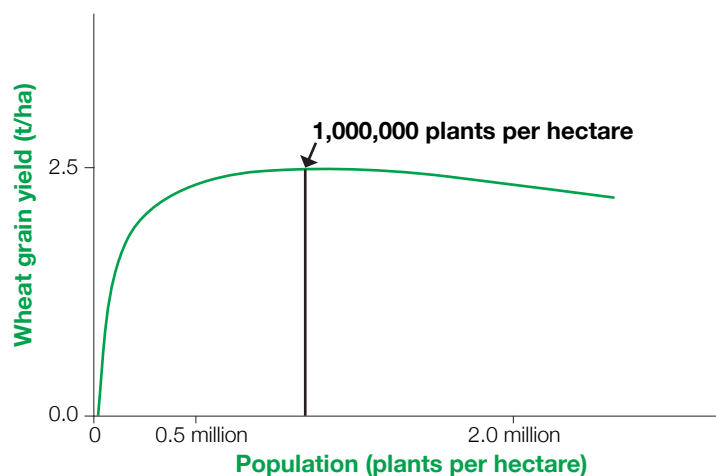


Figure 9: Grain yield response in wheat to plant population averaged over a wide range of growing conditions in Queensland.¹²

More information

<http://www.daff.qld.gov.au/plants/field-crops-and-pastures/broadacre-field-crops/wheat/plant-population>

This plant population helps:

- compensate for poor emergence from deep sowing (>40mm) and reduced coleoptile length in early-planted crops
- improve dry matter production of early and late crops, as high dry matter production is necessary for good grain yields
- varieties produce fewer tillers, which they tend to do under high plant populations (higher planting rates)
- suppress weeds by increasing crop competition—less herbicide is needed
- reduce lodging due to the high number of small heads
- escape grain damage during wet weather that causes downgrading of quality by enabling earlier flowering and harvest
- facilitate earlier harvest by reducing the incidence of late 'green' heads¹³

3.3 Calculating seed requirements

The following formula (Figure 10) can be used to calculate sowing rates, taking into account:

- target plant density
- germination percentage
- seed size
- establishment, usually 80%, unless sowing into adverse conditions (Table 3)

¹² P Keys, AM Bach (2010) Plant population for Queensland. Department of Agriculture, Fisheries and Forestry Queensland, <http://www.daff.qld.gov.au/plants/field-crops-and-pastures/broadacre-field-crops/wheat/plant-population>

¹³ P Keys, AM Bach (2010) Plant population for Queensland. Department of Agriculture, Fisheries and Forestry Queensland, <http://www.daff.qld.gov.au/plants/field-crops-and-pastures/broadacre-field-crops/wheat/plant-population>

Example

$$\begin{array}{|c|} \hline 1000 \text{ seed weight (grams)} \\ \hline \underline{\quad 35 \quad} \\ \hline \end{array} \times \begin{array}{|c|} \hline \text{target plant population (/m}^2\text{)} \\ \hline \underline{\quad 140 \quad} \\ \hline \end{array} \times 100 \div \begin{array}{|c|} \hline \text{establishment \%} \\ \hline \text{X germination \%} \\ \hline \underline{\quad 80 \text{ X } 90 \quad} \\ \hline \end{array}$$

= Your seedling rate $\underline{\quad 68 \quad}$ kg/ha

Your calculation

$$\begin{array}{|c|} \hline 1000 \text{ seed weight (grams)} \\ \hline \underline{\quad \quad \quad} \\ \hline \end{array} \times \begin{array}{|c|} \hline \text{target plant population (/m}^2\text{)} \\ \hline \underline{\quad \quad \quad} \\ \hline \end{array} \times 100 \div \begin{array}{|c|} \hline \text{establishment \%} \\ \hline \text{X germination \%} \\ \hline \underline{\quad \quad \quad} \\ \hline \end{array}$$

= Your seedling rate $\underline{\quad \quad \quad}$ kg/ha

Figure 10: Seeding rate calculator

Table 3: Plant establishment targets

Region	Sowing rate (kg/ha)	Plant establishment targets				Plants/m ²
		Plants/m row				
		18cm row spacing	25cm row spacing	30cm row spacing	36cm row spacing	
North-West Plains	15-35	-	8-18	10-22	12-26	30-70
North-West Slopes	35-55	-	18-28	22-34	26-40	70-110
Central	(higher rainfall)	14-21	20-30	24-36	28-42	80-120
	(lower rainfall)	25-45	9-17	12-22	14-26	50-90
Southern	(higher rainfall)	16-23	23-32	27-38	32-48	90-130
	(lower rainfall)	25-45	9-17	12-22	14-26	50-90
Irrigation	80-110	29-45	40-60	48-72	58-90	150-200
Cover crop - pasture, dryland	15-20	5-7	7-10	8-12	10-14	30-40

i More information

NSW DPI Sowing Guide: <http://www.grdc.com.au/Research-and-Development/National-Variety-Trials/Crop-Variety-Guides>

To calculate 1000-seed weight:

- count out 200 seeds
- weigh to at least 0.1 g
- multiply weight (g) by 5¹⁴

3.4 Sowing depth

Optimum planting depth varies with planting moisture, soil type, seasonal conditions, climatic conditions, and the rate at which the seedbed dries. The general rule is to plant as shallow as possible, provided the seed is placed in the moisture zone, but deep enough that the drying front will not reach the seedling roots before leaf emergence, or to separate the seed from any pre-emergent herbicides used.¹⁵

¹⁴ P Matthews, D McCaffery, L Jenkins (2014) Winter crop variety sowing guide 2014. NSW Department of Primary Industries, <http://www.dpi.nsw.gov.au/agriculture/broadacre/guides/winter-crop-variety-sowing-guide>

¹⁵ NSW DPI Agronomists (2007) *Wheat growth and development*. PROCROP Series, NSW Department of Primary Industries 2007, http://www.dpi.nsw.gov.au/_data/assets/pdf_file/0006/449367/Procrop-wheat-growth-and-development.pdf

Optimum planting depth is for wheat is 30–35 mm for semi-dwarf varieties ⁽¹⁶⁾ through to 50–70 mm for tall wheat varieties, which have a longer coleoptile length. Coleoptile length will be reduced with warm seedbed conditions and with the addition of some seed dressings.

Planting depth will therefore be more critical with early planting (e.g. April and early May), and varieties with short coleoptile length should be avoided at this time. In trials, although deeper sowing (10–15 cm) reduces establishment rate, the gains from maximising yield potential by sowing at the optimal time tended to compensate for the lower plant population. Thus, it was better to sow deeper and on time and chance a lower plant population than to wait for another rainfall event and plant outside the optimal window. ¹⁷

Sowing depth influences the rate of emergence and the percentage that emerges. Deeper seed placement slows emergence; this is equivalent to sowing later. Seedlings emerging from greater depth are also weaker, more prone to seedling diseases, and tiller poorly.

Crop emergence is reduced with deeper sowing because the coleoptile may stop growing before it reaches the soil surface, with the first leaf emerging from the coleoptile while it is still below the soil surface. As it is not adapted to pushing through soil (does not know which way is up), the leaf usually buckles and crumples, failing to emerge and eventually dying. ¹⁸

For more information on the effect of coleoptile length, see [Section 2. Pre-planting](#).

3.4.1 Deep planting

In some seasons, moisture seeking or deep sowing is a tool that growers use to ensure crops are established in their optimal window. A range of factors determines the ability of a seedling to emerge from depth, including seed size, seed treatments, coleoptile length, soil conditions and temperature.

Some of the disadvantages of deep sowing can be delayed emergence, poor establishment, reduced early vigour, increased disease susceptibility or reduced grain yield. Research trials are investigating wheat and durum varietal responses to seeding depth and the impact of triadimenol on emergence.

The main benefits from deep sowing are gained by establishing varieties in the optimal sowing window. When considering deep sowing or moisture seeking, use seed of large size and high germinative capacity. Also, consider increasing seeding rates to compensate for the reduced emergence of deep sown crops. ¹⁹

Trials from 2009 to 2011 showed that deep sowing could have a significant effect on the establishment and yield of wheat; however, none of the varieties evaluated showed an enhanced ability to establish from deep sowing compared with other commonly grown varieties in north-west NSW (Figure 11). Producers need to make several decisions when considering moisture seeking; however, there appears no resultant advantage in crop establishment from changing varieties.

It was unclear from the work whether the reduced yield from deep sowing was due to a reduced plant population or due to subsequent effects on crop growth and

¹⁶ GRDC (2013) Retaining seed. Saving weather damaged grain for seed. GRDC Fact Sheet Northern and Southern Regions Jan. 2011, http://storedgrain.com.au/wp-content/uploads/2013/06/GRDC_FS_RetainingSeed2.pdf

¹⁷ NSW DPI Agronomists (2007) *Wheat growth and development*. PROCROP Series, NSW Department of Primary Industries, http://www.dpi.nsw.gov.au/_data/assets/pdf_file/0006/449367/Procrop-wheat-growth-and-development.pdf

¹⁸ NSW DPI Agronomists (2007) *Wheat growth and development*. PROCROP Series, NSW Department of Primary Industries, http://www.dpi.nsw.gov.au/_data/assets/pdf_file/0006/449367/Procrop-wheat-growth-and-development.pdf

¹⁹ G McMullen, R Brill, N Fettell (2011) Row spacing and deep sowing. GRDC Update Papers 18 April 2011, <http://www.grdc.com.au/Research-and-Development/GRDC-Update-Papers/2011/04/Row-spacing-and-deep-sowing>

More information

NSW DPI Fact Sheet:
http://www.dpi.nsw.gov.au/_data/assets/pdf_file/0006/459006/Coleoptile-length-of-wheat-varieties.pdf

development. In trials sown at the same site and season as the 2009 sowing-depth trial, McMullen *et al.* (2011) reported no significant difference in wheat yield from plant populations in the range 60–180 plants/m². However, the lower plant populations in that work were still higher than the populations achieved in the deep sowing treatments of the sowing-depth trials. Researchers reported that maximum yield could be achieved by plant populations as low as 24 plants/m², provided the plants are arranged in a perfect matrix. This was not the case for the NSW DPI trials reported; hence, there was likely some yield effect due to reduced population. Deep sowing reduces tillering and subsequent head number per plant and per unit area, which might also have reduced yield in these trials.

The 2011 trial highlighted the potential benefits of moisture seeking; in that season, reduced establishment from a relatively early sowing sown deep resulted in higher yield than a shallow, late sowing that achieved a higher plant population. In this trial, the effect of delayed sowing on wheat yield was greater than the effect of deep sowing on wheat yield. A trial in northern NSW showed a 9–13.5% yield loss of wheat for each week that flowering was delayed beyond the optimal time for a particular region. Where producers and agronomists are faced with situations of low seed bed moisture but high plant-available water beyond the seedbed (>5 cm soil depth), planting decisions need to balance the potential effect of reduced yield from deep sowing with the potential yield loss from delayed sowing.²⁰

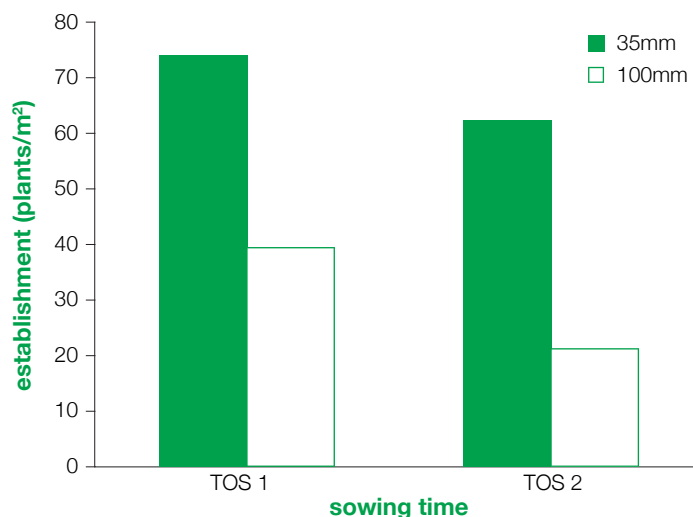


Figure 11: Effect of sowing depth and time of sowing on wheat establishment in a trial at Coonamble in 2011

3.4.2 Depth control

The addition of an airseeder unit will not necessarily convert an acceptable tillage implement into an acceptable planting implement. Positive depth control of planting machines in the form of mechanical depth stops or a hydraulic stop is essential to avoid hydraulic creep.

Some other compromises to minimise depth variation:

- Frame length and width affects seed depth. Flexible frames with sectional widths <3 m will assist, as will large-diameter tandem walking wheels.
- Planter units fitted behind tillage implements give good depth control. Depth control wheels should be as close as possible to the line of planting tines. Select planting tines on bars towards the centre of the planter rather than on the front or rear bar.

²⁰ R Brill, G McMullen, M Gardner (2012) The effect of sowing depth on the establishment of several commercial wheat varieties. 16th Australian Agronomy Conference. Australian Society of Agronomy/The Regional Institute Ltd, http://www.regional.org.au/au/asa/2012/crop-production/8196_brillr.htm#TopOfPage

- To overcome the problem of high breakout tines driving too deeply into small hills in the seedbed, some form of scraper on the tine may be useful. Flat chisel tines have some advantage in displacing surplus soil.
- In melon-hole country or in controlled traffic situations where crossing contour banks is necessary, ground following tools such as pivoting tines or parallelograms will give much better depth control and may justify the additional cost over fixed tines.
- Press wheels will often compensate for poor depth control.²¹

3.4.3 Deep moisture

If planting moisture is deeper than normal, deep-furrow planting techniques (using adapted scarifier or chisel ploughs or press-wheel planters) will allow seed placement in the moisture zone. Excessive planting speeds should be avoided; otherwise, excess soil will be thrown into the corresponding row. Common features of deep-furrow techniques include narrow tines with high breakout pressures, narrow points to minimise soil disturbance and moisture loss, and high-pressure narrow press wheels (that slot into the seed trench and help stabilise it), which reduce the seed-surface distance and help seed/soil contact.²²

3.5 Calculating a planting rate

Because seed sizes may vary depending on production years and variety type, a fixed quote for the weight of seed needed to plant one hectare is not always a true or accurate measure of obtaining a desired plant population per hectare (Table 4 and 5).

Table 4: Average graded seed size

Seed size	Seeds/kg
Large	24,000
Medium	27,500
Small	30,000

An actual seed count is required to calculate a more accurate planting rate. A two-part method of calculating the planting rate of a crop (in kg/ha) given a designated plant population is:

1. Target plant population (plants/ha) ÷ germination rate (decimal) ÷ expected field establishment rate (decimal) = seeds/ha
2. Seeds/ha ÷ seeds/kg = planting rate (kg/ha)

Example:

$$800,000 \div 0.9 \div 0.75 = 1,185,185$$

$$1,185,185 \div 27,500 = 43 \text{ kg/ha}$$

Alternatively, to calculate planting rate use the following formula:

$$\text{Target plants/ha} = (\text{seeds/kg}) \times \text{establishment rate (decimal)} \times \text{germination rate (decimal)}$$

²¹ DAFF (2012) Wheat – planting information. Department of Agriculture, Fisheries and Forestry, Queensland, <http://www.daff.qld.gov.au/plants/field-crops-and-pastures/broadacre-field-crops/wheat/planting-information>

²² DAFF (2012) Wheat – planting information. Department of Agriculture, Fisheries and Forestry, Queensland, <http://www.daff.qld.gov.au/plants/field-crops-and-pastures/broadacre-field-crops/wheat/planting-information>

Germination percentage and seeds/kg information can be found on bag labels, or you can do your own germination tests and/or seed counts. Divide units given as percentages by 100 to produce a decimal (e.g. 90% = 0.9).²³

Table 5: Planting rate (kg/ha) to establish a plant population of 1,000,000 plants/ha

Expected field establishment				
Seed size (seeds/kg)	50%	70%	80%	95%
25,000	80	57	50	42
27,500	73	52	45	38
30,000	67	48	42	35

3.5.1 Plant spacing

Wheat is normally planted in 15–30-cm rows. Row spacings up to about 36 cm have little effect on yield in most seasons, although some yield reduction may be expected in very good seasons in wide rows. With no-tillage and moisture-seeking machinery, there has been a trend to plant in rows as wide as 45 or 50 cm. When planting in wider rows, the normal plant population should be maintained. After assessing the planting rate of seed, ensure that the planter is spacing seed at the right distance. Using data from Table 6, calculate the right seed-placement distance to give the required established plant spacing and achieve the desired plant population density per hectare.²⁴

Note: 1,000,000 plants/ha is equal to 100 plants/m²; 50 000 plants/ha is equal to 5 plants/m².

Table 6: Plants per metre of row

Row spacing	Plant population/ha in 000s					
	100	200	300	500	800	1000
15 cm	1.5	3.0	4.6	7.6	12.2	15.2
17.5 cm	1.8	3.6	5.3	8.9	14.2	17.8
22.5 cm	2.3	4.6	6.9	11.4	18.3	22.9
22.5 cm	2.5	5.1	7.6	12.7	20.3	25.4
30 cm	3.0	6.1	9.1	15.2	24.4	30.5
50 cm	5.0	10.2	15.2	25.4	40.6	50.8

Example: In 25-cm rows, 20 plants/m row is equal to ~800,000/ha.

The trend in recent years to widen row spacings aims to accommodate stubble retention practices, as wider row spacing allows the passage of stubble between tines. However, manufacturers of some minimum-till seeders recommend 25-cm row spacings because, as soil is thrown behind the tines, it covers neighbouring seed rows, reducing establishment if harrows are not used to flatten out the seedbed.

Many row-spacing experiments have been conducted in temperate Australia for the past 50 years. Recently, the NSW DPI VSAP project has conducted a large number of row-space experiments in wheat, canola and lupins.

Data from all of these experiments have been analysed to estimate the effect of row-spacing changes on grain yield across temperate Australia. Widening row space of wheat decreased yields when yields were above ~1.3 t/ha (Table 7). However, at yields <1.3 t/ha there was a small increase in grain yield.

²³ DAFF (2012) Wheat – planting information. Department of Agriculture, Fisheries and Forestry, Queensland, <http://www.daff.qld.gov.au/plants/field-crops-and-pastures/broadacre-field-crops/wheat/planting-information>

²⁴ DAFF (2012) Wheat – planting information. Department of Agriculture, Fisheries and Forestry, Queensland, <http://www.daff.qld.gov.au/plants/field-crops-and-pastures/broadacre-field-crops/wheat/planting-information>

The value of these yield reductions should be taken into account when considering farming system options that use equipment with wider row spacing. The likely economic loss from row-space widening needs to be offset by the economic advantages of the minimum-till stubble-retention system. At low yield, it is easy to justify the decision to widen row space.

However, at higher yield levels (in the eastern NSW wheatbelt or under irrigation), the loss of yield with widening of rows increases, and the offset benefits of the stubble-retention system need to be carefully evaluated. If benefits are not sufficient to make up for the loss associated with wide rows, then alternative methods for retaining stubble, including sowing into stubble using narrower row spacing, should be investigated.²⁵

Table 7: Wide row-spacing cost or benefit

Yield (t/ha) and economic cost or benefit (\$/ha), using wide sowing with wheat and canola in central and southern NSW (wheat at \$250/t and canola at \$500/t).					
Row spacing			Row spacing		
18cm	30cm	42cm	18cm	30cm	42cm
Wheat yield (cost/benefit)			Canola yield (cost)		
1.00	1.03 (+\$6)	1.05 (+\$13)	1.00	0.95 (-\$25)	0.90 (-\$50)
2.00	1.95 (-\$12)	1.90 (-\$24)	2.00	1.91 (-\$47)	1.81 (-\$97)
4.00	3.81 (-\$48)	3.61 (-\$97)	3.00	2.86 (-\$71)	2.71 (-\$144)
6.00	5.66 (-\$85)	5.32 (-\$170)	4.00	3.81 (-\$94)	3.62 (-\$191)

3.5.2 Crop establishment

Poor seedling establishment occurs because of:

- inaccurate or variable seed depth
- poor seed–soil contact
- poor-quality seed
- unsuitable soil temperatures
- soil insects and soil disease
- herbicide residues

The impact of poor establishment and seedling vigour will be lessened if seedbed requirements are matched to machinery capabilities and seed quality (Table 8).

Surface sealing may be a problem if heavy rains fall immediately after sowing and prior to emergence. The emerging shoot is often unable to penetrate the hard surface crust that forms as the soil dries. The problem is more prevalent on soils with declining organic matter, especially red-brown earths and grey clays. Harrowing as soon as practical after sealing has occurred will break the soil crust and allow leaf development to proceed. In many instances, this has doubled the initial emergence. Gypsum application may help alleviate this problem on hard-setting clays.²⁶

More information

http://www.daff.qld.gov.au/_data/assets/pdf_file/0003/71229/Wheat-row-spacing.pdf

<http://www.grdc.com.au/Research-and-Development/GRDC-Update-Papers/2010/09/ROW-SPACING-INTER-ROW-SOWING-AND-PHOSPHORUS>

²⁵ NSW DPI (2012) Wide row spacing reduces wheat and canola yields. NSW Department of Primary Industries *Agriculture Today* May 2012, <http://www.dpi.nsw.gov.au/archive/agriculture-today-stories/ag-today-archive/may-2012/wide-row-spacing-reduces-wheat-and-canola-yields>

²⁶ P Keys, AM Bach (2010) Plant population for Queensland. Department of Agriculture, Fisheries and Forestry Queensland, <http://www.daff.qld.gov.au/plants/field-crops-and-pastures/broadacre-field-crops/wheat/plant-population>

Table 8: Likely field establishment

Soil type	Establishment %	
	No press wheels	Press wheels
Heavy clay	45	60
Brigalow clay	55	70
Red earth	70	80

Establishment—Queensland

Establishment depends on seedbed conditions, soil moisture, insect pests and climate. Establishment percentage is the percentage of seed planted that establishes on planting moisture. Establishment may be as high as 95% under ideal conditions, or drop to as low as 40% with rough seedbeds, early planting and limited moisture. Table 9 is a general guide to the expected establishment percentage on three Queensland soil types.

Poor quality seed with low laboratory germination will give poor establishment; for example, weathered seed that has been stored under high temperature and humidity, or seed that has been attacked by insects.

Table 9: Expected establishment % on three Queensland soil types

Soil type	Expected establishment %	
	No press wheels	Press wheels
Heavy clay	45	60
Brigalow clay	55	70
Red earth	70	80

Planting rates can be calculated as shown in Table 10.

Table 10: Planting rate to establish a plant population of 1,000,000 plants/ha²⁷

Seed size (seeds/kg)	Planting rate kg/ha			
	Expected field establishment %			
	50	70	80	95
25 000	80	57	50	42
27 500	73	52	45	38
30 000	67	48	42	35

How to measure your plant population

Here is a simple way to check the plant population in your wheat crop.

Cut to size a 1-m length of steel rod or wooden stick. While the crop is still young, preferably no later than day 20 after sowing (to easily identify individual plants), place the 1-m rule along a row and count the number of plants along this row. Do this 10 times at different locations to get a representative count and calculate the average.

To achieve 1,000,000 plants/ha (100 plants/m²), the number of plants in the 1-m row should equal your row spacing in centimetres. For example, if your row spacing is 25 cm, the number of plants in the 1-m section of row should be 25 plants for an establishment of 1,000,000 plants/ha. If your row spacing is 30 cm, your plant number should be 30 plants, and so on.

²⁷ P Keys, AM Bach (2010) Plant population for Queensland. Department of Agriculture, Fisheries and Forestry Queensland, <http://www.daff.qld.gov.au/plants/field-crops-and-pastures/broadacre-field-crops/wheat/plant-population>

If this is the case, you have achieved the desired plant population for maximum yield potential. In addition, your crop will be more uniform, flower and mature earlier, suppress weeds more effectively, and lodge less than crops of lower populations.²⁸

Chances of optimal yields are improved by establishing at least 700,000 plants/ha (70 plants/m²), even in seasons of low rainfall. With irrigation, high yielding dryland conditions, or very early and very late plantings, populations of at least 1,000,000 plants/ha are recommended. Plant populations <600,000 plants/ha may result in a reduction in yield and increased weed competition.

Establishment in the field can be affected by a number of factors such as:

- seedbed moisture
- high temperatures (central and western Queensland)
- disease
- soil insects
- depth of planting
- certain seed treatments that reduce coleoptile length
- germination and vigour of the seed

An establishment rate of 70% means that for every 10 seeds planted, only seven will emerge to produce a plant. A planting rate to achieve 700,000–1,000,000 plants/ha is normally in the range 30–50 kg/ha.²⁹

3.6 Causes of poor quality seed

The major causes of poor quality seed are:

- High moisture and temperature, which often cause seed to deteriorate during storage. Seed with <11% moisture content held <20°C is desirable if stored for 12 months. When using grain dryers, ensure maximum temperatures are not exceeded.
- Stored grain insect pests, which will cause damage. The use of aeration and/or a grain protectant is recommended.
- Mechanical damage through harvesting, handling and cleaning. This can cause cracks in seedcoats, and splits and breaks, which reducing seed quality.
- Sourcing seed from crops that have suffered nutritional disease or environmental stress. This may result in seed viability dropping quickly with prolonged storage.
- Sourcing seed from crops that have suffered rainfall prior to harvest.
- Sourcing seed from a diseased crop. For example, seed infected with Fusarium head blight or stripe rust will be affected in both seed size and viability.

Seed that is dry, cool and sound (not weather-damaged) will remain viable for longer. In well-managed storage, germination percentages can be expected to reduce by only 5% after 6 months. To achieve this, grain moisture content should be <12%. Grain temperature also has a major impact on germination. Aim for grain temperatures ≤20°C in seed storage by using aeration cooling (with auto control). Wheat at 12% moisture content stored at 30–35°C (unaerated grain temperature) will have reduced germination percentages and seedling vigour when stored over a long period. Position small seed silos in the shade or paint them reflective white to assist keeping grain cool.³⁰

For more information on grain storage, visit www.storedgrain.com.au

²⁸ P Keys, AM Bach (2010) Plant population for Queensland. Department of Agriculture, Fisheries and Forestry Queensland, <http://www.daff.qld.gov.au/plants/field-crops-and-pastures/broadacre-field-crops/wheat/plant-population>

²⁹ NSW DPI Agronomists (2007) *Wheat growth and development*. PROCROP Series, NSW Department of Primary Industries 2007, http://www.dpi.nsw.gov.au/_data/assets/pdf_file/0006/449367/Procrop-wheat-growth-and-development.pdf

³⁰ GRDC (2013) Northern and southern regions—Grain storage pest control guide. GRDC Fact Sheet June 2013, <http://storedgrain.com.au/northern-southern-regions-grain-storage-pest-control-guide/>

i More information

GRDC Update Paper 'Practical considerations and agronomic management for winter cereal cropping in the western regions of northern New South Wales and southern Queensland':
<http://www.grdc.com.au/Research-and-Development/GRDC-Update-Papers/2011/04/Practical-considerations-and-agronomic-management-for-winter-cereal-cropping-in-the-western-regions-of-northern-New-South-Wales-and-southern-Queensland>

3.7 Germination testing

See [Section 2. Pre-planting](#) for information on planting seed quality.

3.8 Planting techniques

The benefits of conservation farming—increased fallow stored moisture, less soil erosion, opportunity cropping and lower tillage costs—have resulted in a move away from finely worked seed beds and bare ground to less pulverisation of soil and more stubble retention. Even with zero tillage or reduced tillage planting, a seedbed is required in the zone where the seed is to be placed.

In some seasons, the opportunity to sow into old crop stubble where soil moisture replenishment is adequate, or to sow up to 6 weeks after rain, allows crops to be sown at their optimum time. Management decisions that allow for 'opportunity cropping' include:

- maintenance of stubble cover
- the substitution of herbicides for tillage to control weeds
- having planting machinery capable of handling no-till and deep sowing³¹

3.8.1 Row spacing

Of the agronomic tools examined in recent NSW DPI research into agronomic management of cereal cropping in the western regions of NSW and Queensland, the manipulation of row spacing is seen as the most effective tool in reducing the impact of large amounts of soil N and soil moisture early in the growing season on spike production in wheat.

In terms of soil N levels, it seems it is more important to have sufficient N available to achieve target yields and protein than it is to be concerned about having excessive soil N levels pre-plant, provided the appropriate agronomic management is employed.

There has been a trend to wider row spacings in recent years. Likely benefits include:

- an ability to sow into higher levels of retained stubble
- a reduction in fuel costs during sowing and/or increased sowing speed
- ability to inter-row sow subsequent crops
- reduced soil disturbance
- lower cost of sowing equipment

However, potential costs from wider spacings include:

- lower yields with wider row spacing, particularly under higher yielding conditions
- greater weed competition

Several studies are currently examining the responses of cereal and broadleaf crops to row spacing, and the interaction with plant population (Figure 12). In targeting a desired population, the likely establishment percentage has to be selected.

In practice, establishment rates rarely exceed 90% and can fall as low as 30% depending on sowing conditions and seed quality. Germination tests do not necessarily give a good indication that germinated seed will be able to establish a viable plant.

³¹ DAFF (2012) Wheat—planting information. Department of Agriculture, Fisheries and Forestry, Queensland, <http://www.daff.qld.gov.au/plants/field-crops-and-pastures/broadacre-field-crops/wheat/planting-information>

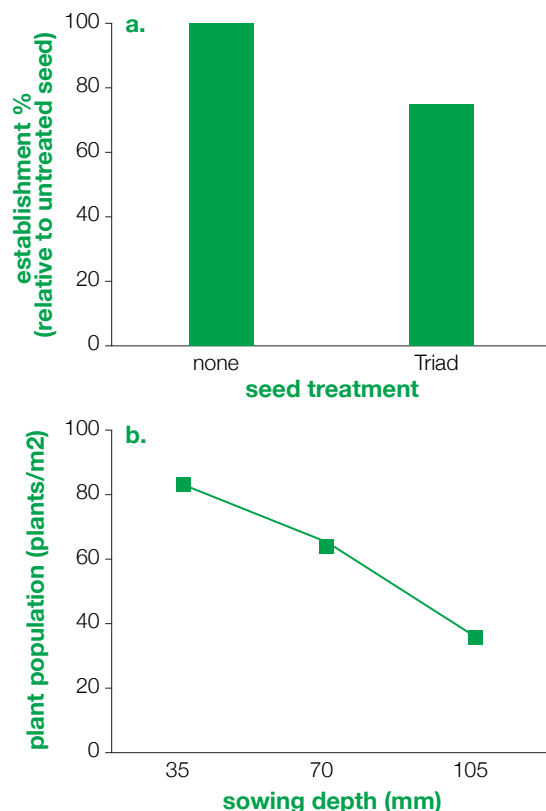


Figure 12: Effect of seed spacing on cereal establishment percentage at Coonamble in 2009 ³²

3.8.2 Inter-row sowing

Inter-row sowing has been shown to reduce the impact of crown rot and increase yield by up to 9% in a wheat–wheat sequence. Crop rotation reduces the incidence and severity of crown rot, resulting in yield gains of 17–23% over continuous wheat. Research reported in 2013 examined whether row–placement strategies coupled with a break crop–wheat rotation would result in differences in grain yield over a 5-year crop sequence.

Following a wheat crop, the break crop (pulse or oilseed) 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 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 to follow:

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

By adopting these rules, you ensure the following:

- four years between wheat crops being sown in the same row space
- a substantially reduced incidence of crown rot in wheat crops
- improved germination of break crops, especially canola, not hindered by stubble
- benefit to chickpea from standing stubble reducing the impact of virus
- standing wheat stubble providing better protection to break-crop seedlings ³³

³² G McMullen, R Brill, N Fettell (2011) Row spacing and deep sowing. GRDC Update Papers 18 April 2011, <http://www.grdc.com.au/Research-and-Development/GRDC-Update-Papers/2011/04/Row-spacing-and-deep-sowing>

³³ 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>

For more information, download the GRDC Update Paper 'Row placement strategies in a break crop wheat sequence':

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

3.9 Seed treatments

Seed treatments are applied to seed to control diseases such as smuts, bunts or rust, and insects. When applying seed treatments always read the chemical label and calibrate the applicator. Seed treatments are best used in conjunction with other disease management options such as crop and paddock rotation, clean seed, and resistant varieties, especially when managing weeds such as stripe rust.

There are some risks associated with using seed treatments. Research shows that some seed treatments can delay emergence by:

- slowing the rate of germination
- shortening the length of the coleoptile, the first leaf and the sub-crown internode

If there is a delay in emergence due to decreased vigour, it increases exposure to pre-emergent attack by pests and pathogens or to soil crusting; this may lead to a failure to emerge. The risk of emergence failure increases when seed is sown too deeply or into a poor seedbed, especially in varieties with shorter coleoptiles. As the amount of certain fungicides increases, the rate of germination slows (Figure 13).

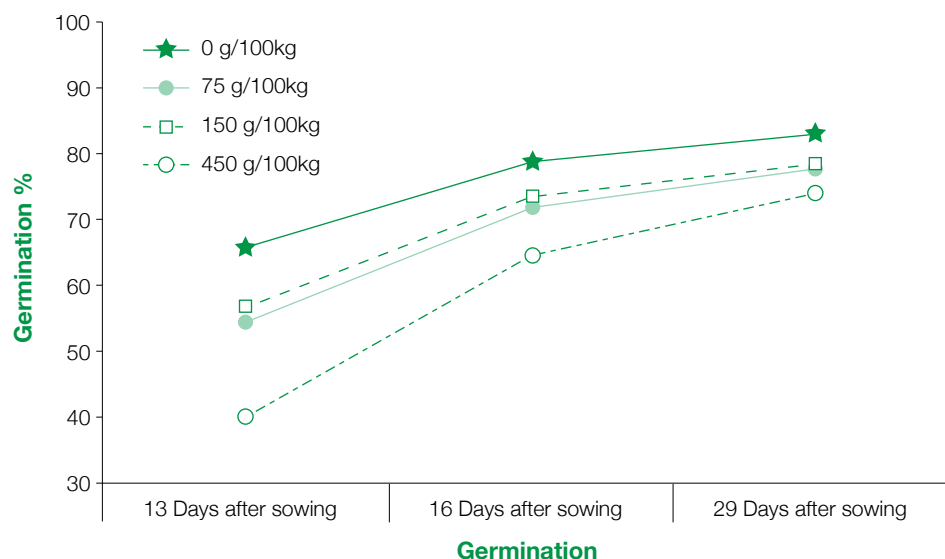


Figure 13: Impact of fungicide on the rate of germination

Some seed treatments containazole fungicides (triadimenol and triadimefon). Research has found that these seed treatments can reduce coleoptile length, and that the reduction increases as the rate of application increases.³⁴

Product registrations change over time and may differ between states and between products containing the same active ingredient. It is critical that the registration status for the intended use pattern in your state is checked on the current product label prior to use.

3.9.1 Choice of seed or in-furrow treatments

The principal reason for using a fungicide at sowing for wheat crops has been for the control of smuts, but with the increased incidence of stripe rust in recent years,

³⁴ NSW DPI Agronomists (2007) Wheat growth and development. PROCROP Series, NSW Department of Primary Industries, http://www.dpi.nsw.gov.au/_data/assets/pdf_file/0006/449367/Procrop-wheat-growth-and-development.pdf

i More information

[http://www.grdc.com.au/Resources/Links-Pages/DiseaseLinks#WSeed and in-furrow fungicides](http://www.grdc.com.au/Resources/Links-Pages/DiseaseLinks#WSeed%20and%20in-furrow%20fungicides)

<http://www.apvma.gov.au>

i More information

http://www.sardi.sa.gov.au/data/assets/pdf_file/0004/163282/cereal_seed_treatments_2012_web.pdf

http://www.grdc.com.au/Resources/Links-Pages/DiseaseLinks#WSeed_and_in-furrow_fungicides

<http://www.apvma.gov.au>

fungicide is being applied both to the seed and in-furrow. Jockey® (fluquinconazole) seed dressing is being used for stripe rust, along with Impact® (flutriafol) in-furrow.

Where growers think they may have a problem with seed-borne infection, it is recommended they have the seed tested by the cereal pathology group in South Australian Research and Development Institute.³⁵

3.10 Sowing equipment

As much as 60% of the final yield potential for a wheat crop is determined at planting. Seeding too thinly, using poor quality seed, and uneven stands result in end-of-season yield losses that cannot usually be overcome.³⁶

During the shift from conventional farming systems to no-till farming systems, the effective use of herbicides has become increasingly important. A well-planned herbicide strategy can mean the difference between making no-till work, or not. Over the last 5–6 years, it has become apparent that the rapid change in farming systems has overtaken farmer knowledge on how to use many herbicides in conservation farming systems. Older, more traditional herbicides that were designed for use in cultivated systems can still be used effectively in no-till systems; however, they are usually used in a different manner. In addition, many herbicide labels (especially older type or generic herbicides) have the same content today as they did 10–15 years ago. Some products with generic counterparts have different label claims for the same active ingredient. This creates problems for farmers and agronomists wanting to use these herbicides in our modern, no-till farming systems.

Residual herbicides at sowing are very effective for controlling a wide range of weeds both in-crop and into the following summer. Some residual herbicides also have valuable knockdown properties. This is very useful, because knockdown herbicide options prior to sowing are limited for hard-to-kill weeds.

Knowing the chemistry and mode of action of each herbicide is paramount to enable the best combination of crop safety and weed control. Heavy rainfall just after sowing when combined with certain soils can lead to crop damage.

Some herbicides are mobile with soil water, while others are less mobile. Mobility can also change with time for particular herbicides. For example, with Boxer Gold®, the longer it is allowed to bind to soil particles, the less chance of the herbicide becoming mobile in the soil. Other herbicides such as Logran® are mobile regardless of binding period.

The incorporation by sowing (IBS) application technique seems the safest way of using most residual herbicides, as the seed furrow is left free of high concentrations of herbicide. The soil from that furrow is thrown on the inter-row, where it is needed the most. In-furrow weed control is generally achieved by crop competition and/or small amounts of water-soluble herbicides washing into the seed furrow. For this reason, best results in IBS application occur when water-soluble herbicides are used either solely or in conjunction with a less-soluble herbicide.

Because of the furrow created by most no-till seeders, post-sowing pre-emergence (PSPE) applications of many herbicides are not ideal and are usually not supported by labels, as the herbicides can concentrate within the seed furrow if washed in by water and/or herbicide treated soil. Obviously, for volatile herbicides that need incorporation following application, PSPE is not a viable option.

Tine seeders vary greatly in their ability to incorporate herbicides. There are many tine shapes, angles of entry into the soil, breakout pressures, row spacings, and soil surface conditions. Each of these factors causes variability in soil throw, especially

³⁵ H Wallwork (2014) Cereal seed treatments. South Australian Research and Development Institute, www.sardi.sa.gov.au/data/assets/word_doc/0004/214645/cerealseedtreast2014_doc - 2013-12-17

³⁶ W Thomason (2004) Planting wheat: seeding rates and calibration. Virginia Cooperative Extension, <http://www.sites.ext.vt.edu/newsletter-archive/cses/2004-10/plantingwheat.html>

when combined with faster sowing speeds (>8 km/h). Consequently, residual herbicide incorporation is variable between each seeder. There are, therefore, no rules of thumb for sowing speed, row spacing and soil throw. It is important to check each machine in each paddock.

Disc machines show similar variability in their ability to incorporate herbicides. Disc angle, number of discs, disc size, disc shape, sowing speed, closer plates and press wheels all have an impact on soil throw and on herbicide-treated soil returning into the seed furrow. Some discs can throw enough soil for incorporation of herbicides such as trifluralin.

In all cases with tines and discs, crop safety is usually enhanced by IBS rather than PSPE application of herbicides.

Knife points and harrows cause a lot of herbicide-treated soil to return into the seed furrow, and are therefore not ideally used in IBS application. Knife points and press wheels do a much better job.³⁷

Increased sowing speeds are possible with wider row spacings. Wider row spacing reduces soil throw and the impact of pre-emergent herbicide being thrown from one row into an adjacent row, where it can reduce crop emergence. Soil throw distance increases with the square of speed (i.e. doubling the speed will increase soil throw distance by four). So, speed can increase approximately 1.4 times if row spacing is doubled.³⁸

Seeder calibration is important for precise seed placement and seeders need to be checked regularly during sowing.

TOPCROP Victoria investigated sowing rates for wheat to achieve target plant densities using large-scale paddock demonstrations during the 2000 season. TOPCROP farmer groups established 30 sites across Victoria comparing 75%, 100%, 150% and 200% of the district practice for sowing rate, using Silverstar and a farmer-selected wheat variety. Initial findings indicated that poor seeder calibration and a lack of understanding of the influence of grain size has led to target plant densities not being reached. This highlights the need for sowing recommendations to be based on target plant densities rather than sowing rates.³⁹

i See more at:

<http://www.grdc.com.au/Research-and-Development/GRDC-Update-Papers/2011/03/Options-for-using-more-residual-herbicides-in-northern-notill-systems>

http://www.grdc.com.au/Media-Centre/Media-News/North/2011/06/~/_/media/4CA071540A0F4E28AE0FF786D8BCB1DA.pdf



Figure 14: Seeder calibration is important for precise seed placement and seeders need to be checked regularly during sowing. (Photo: Rohan Rainbow)

³⁷ B Haskins (2010) Residual herbicides at sowing using disc and tyne no till seeding equipment. Industry & Investment NSW.

³⁸ GRDC Crop placement and row spacing fact sheet (2011) <http://www.grdc.com.au/Resources/Factsheets/2011/02/Crop-Placement-and-Row-Spacing-Northern-Fact-Sheet>

³⁹ A Johnson, M Evans, K Wansink (2001) Challenging sowing rates for wheat to achieve target plant densities, 10th Australian Agronomy Conference, Australian Society of Agronomy/The Regional Institute Ltd, <http://www.regional.org.au/au/asa/2001/p/10/johnson.htm>

3.10.1 Using pre-emergent herbicides with different seeding equipment

Seeder design has changed dramatically in recent years, aiming to maximise trash flow and seed placement uniformity while minimising soil disturbance. This has led to an increased uptake of knife-point and press-wheel seeders and, more recently, disc seeders.

Each seeder will create a different environment for an establishing crop, and it is essential to understand this before use of pre-emergent herbicides.

Knowledge of how this environment may change with IBS or PSPE incorporation methods is also necessary. In general, there is much difference in crop safety achieved between seeders in IBS systems, and less difference between PSPE application methods. The PSPE technique relies on uniform seeding depth and 'flatter' seedbeds without pronounced furrows. The focus here is on the IBS method of incorporation, as typically this method is preferred in conservation farming systems.

Pre-emergent herbicides that are incorporated by sowing rely on the sowing process to ensure the herbicide is incorporated effectively and that the seed is placed into a micro-environment that allows safe and effective germination. In all cases, the ideal situation is using a knife point or disc followed by a press wheel. Press wheels are essential, as they provide the seed with good soil contact, and minimise the amount of herbicide-treated soil from the inter-row being dragged into the seed furrow. They also allow seeders to pass through stubble without the machine becoming choked with trash. The key is to understand that all seeding gear is different, which, in turn, creates varying seedbed conditions.

In tined seeders variations include: angle of tine entry to the soil; width and shape of seeding point; breakout pressure of tine; depth uniformity across machine; trash-flow ability across machine; and press-wheel size and shape.

In disc seeders, variations include: ability to penetrate compacted soils; ability to achieve controlled soil throw onto the inter row; angle of disc entry to the soil; size, shape and width of disc; seed placement in furrow, i.e. bottom or side; closing plates or closing wheels that allow consistent closure of the seed slot without returning herbicide treated soil onto the seed; depth-gauge wheel placement and size; and press-wheel angle, size and shape.

Other factors not associated with the type of seeding system also importantly influence seedbed conditions. These include soil type, soil moisture, soil compaction, row spacings, seeding depth and sowing speed.

To ensure adequate soil throw, some users assume 1 km/h for every 1 cm of row spacing. This is not correct, and there is no rule for soil throw, row spacing and sowing speed because of the variability discussed previously. The only way to check for adequate soil throw is to check every situation.



Important information

The suitability for pre-emergent herbicides in both tine and disc seeding systems has attracted much research recently. Unfortunately, many herbicide labels will not support the use of some pre-emergent herbicides with disc seeders, as there is greater risk of crop damage due to varying machine designs that form very different seedbed conditions.

Regardless of the disc seeder, research in southern NSW has clearly shown that a well set-up tine seeder will offer greater crop safety than a well set-up disc seeder. This is mostly because a knife point and press wheel will place more soil on the inter row, minimising herbicide-treated soil washing into the seed furrow. Soil throw in tines is also 'better controlled', resulting in less herbicide-treated soil in a typically wider furrow.

As shown in Figure 15, this research has also shown that some herbicides and rates of particular herbicide are better suited to a disc seeder system than are others. This is usually correlated with how a seedling metabolises a particular herbicide if they come in contact. From Figure 15, trifluralin at higher rates is definitely not suited to disc seeding systems, as crop vigour may be adversely affected.⁴⁰

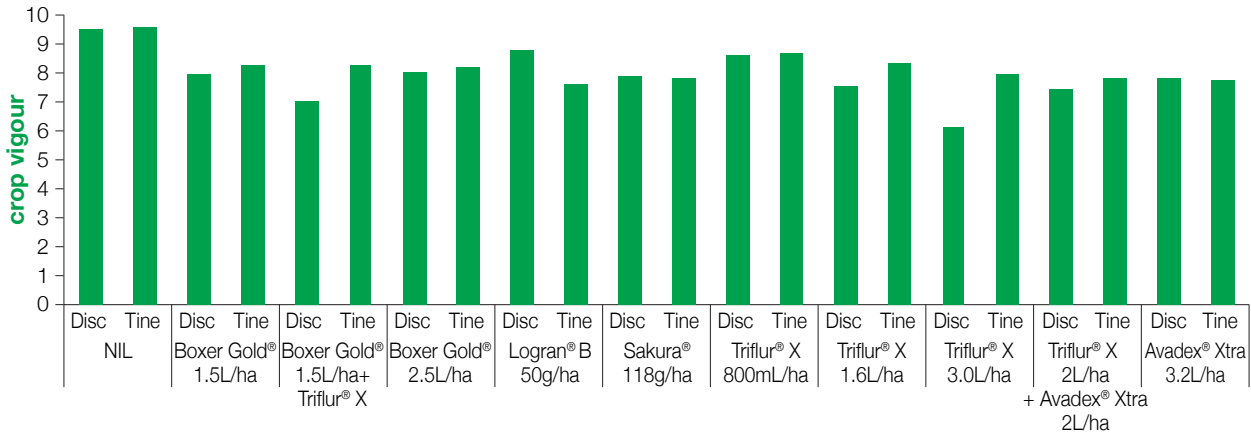


Figure 15: Difference in crop safety between discs and tines across a number of commonly used pre-emergent herbicides in trials held across southern and central NSW. Various disc and tine seeders were used for these trials. 0, No crop vigour; 10, vigorous.

⁴⁰ B Haskins (2012) Using-pre-emergent-herbicides-in-conservation-farming-systems, NSW Department of Primary Industries, http://www.dpi.nsw.gov.au/_data/assets/pdf_file/0003/431247/Using-pre-emergent-herbicides-in-conservation-farming-systems.pdf