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Linseed genotype growth and development response to varying sowing date – Narrabri 2015

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Key findings

- Time to flowering progressively decreased in all genotypes when sown after mid April on all sowing dates (SD) with the exception of the early May SD.
- The Glenelg variety genotype was quickest to start flowering and the quickest to mature on all sowing dates. Croxton was the slowest to start flowering.
- The genotypes LM14 and LM17 showed no significant difference in the time to flowering. Differences between genotypes decreased as sowing was delayed beyond 28 May (SD3).
- Glenelg was the quickest to finish flowering when sown in April and May. Flowering ceased in all genotypes in late September and early–mid October for April and May SDs.
- Environmental conditions, principally high temperatures, halted flowering in all genotypes for SD4 (26 June) and SD5 (13 July). The flowering duration was greatest for SD4 and SD5, due to the short vegetative growth period.
- The flowering period was shortest in all genotypes for SD3 (28 May).
- LM14 and LM17 displayed no significant difference in growth and development traits and agronomic characteristics, including days to the start and end of flowering, plant height, height of lowest capsule, branching, number of seeds per capsule, and the number of infertile capsules per plant.
- Overall plant height and the height above ground of the lowest capsule decreased as SD was delayed. The Glenelg plant structure was the most compact of the genotypes tested.
- Sowing date had a significant effect on seed size. Linseed sown in July (SD5) was 22% smaller than that sown in April (SD1). Glenelg had the largest seed size at 5.34 g/1000 seeds.
- The data suggests that the optimal sowing window for the four genotypes was late April to early May at Narrabri.

Introduction

The 'Tactical agronomy of minor crops' (DAN00197) was a joint project between NSW DPI and the Grains Research and Development Corporation (GRDC). A major objective was to determine the agronomic constraints to yield potential in the oilseed crops linseed, safflower and sunflower.

Linseed is grown in the medium to high rainfall areas of northern NSW and grown in rotation with winter cereal crops. Linseed is recognised for its beneficial role as a cereal disease break crop in the northern farming systems. It has resistance to the root lesion nematodes *Pratylenchus thornei* and *P. neglectus*, which are major pathogens in the region. Linseed is also recognised as having frequently

high grain prices, making it a profitable crop in its own right. Agronomic research had been extremely limited in linseed for many years until 2015.

The linseed variety Glenelg is the most widely grown variety in northern NSW, with small areas of the variety Croxton. New cultivars, available through licensing arrangements, have generated greater interest. Consultation with industry has identified a range of views regarding optimal sowing windows and a significant knowledge gap regarding the varieties' agronomic attributes.

A linseed phenology experiment was conducted in 2015 at Narrabri to evaluate the response of four linseed varieties to varying SDs, including characterising crop growth and development. This paper reports on the effects of SD on traits including time to flowering and yield components. The data forms the initial information needed to refine sowing time recommendations for northern NSW.

Site details	Location	Plant Breeding Institute (PBI), Sydney University – Narrabri
	Soil type and nutrition	Self-mulching grey vertosol with low sodicity. Di-ammonium phosphate (DAP) fertiliser was pre-drilled into seeding furrows at 80 kg/ha.
	Experiment design	Complete randomised block design; five replications. Plot size 8 × 1.65 m.
	Plant population	Experiments were sown into seedbed conditions suitable for even germination and emergence. Plant rows were hand-thinned to achieve the target plant population of 300 plants/m^2.
	Seed quality	Seed was tested before sowing. Germination percentages ranged between 91% and 97% and vigour (medium to high) 90–95%. Seed size expressed as the weight of 1000 seeds were Glenelg: 5.30 g, LM14: 5.20 g, LM17: 5.75 g and Croxton: 6.35 g. Seed quality information was used to calculate the sowing rate for each genotype.
	Climate	In 2015, growing season rainfall (GSR) for each SD ranged from 273 mm to 104 mm (Table 1). Long-term GSR (April to November) at Narrabri averages 306 mm (Bureau of Meteorology). In 2015, average monthly temperatures were lower than the long-term average during the winter and early spring, but higher in mid to late spring. shows the daily minimum and maximum temperatures and rainfall at the experiment site. Rainfall in June, July, September and October were below the long-term average.
Treatments	Genotypes	Glenelg, LM14, LM17, Croxton
	Sowing dates	SD1: 17 April; SD2: 8 May; SD3: 28 May; SD4: 22 June; SD5: 13 July

Table 1 Rainfall for the five sowing dates.

Sowing date	In-crop rainfall (mm)	Wet days
17 April (SD 1)	273	33
8 May (SD 2)	230	28
28 May (SD 3)	222	26
26 June (SD 4)	104	10
13 July (SD 5)	151	17

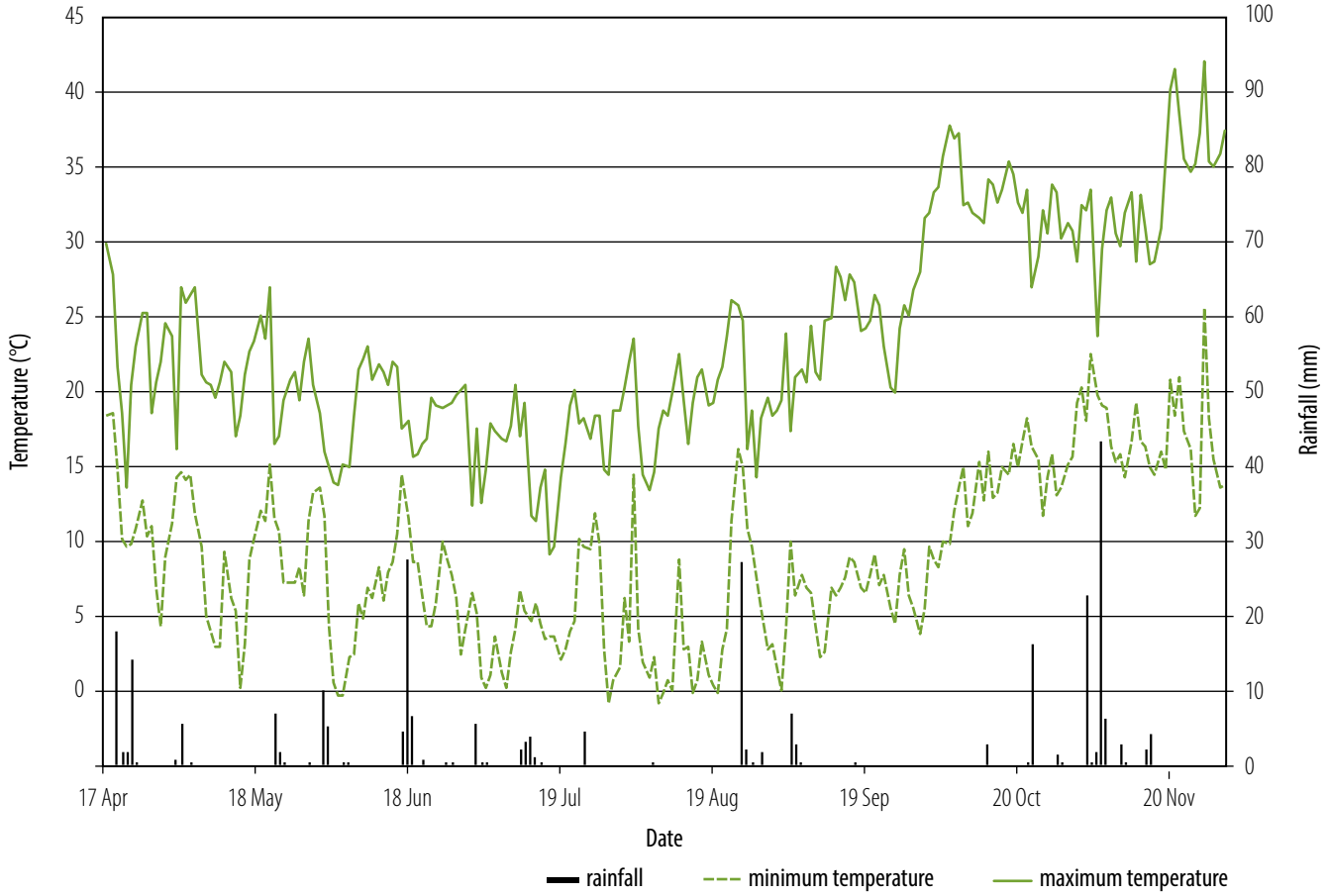

Figure 1 Temperature and rainfall at Narrabri in 2015.

Results

Start of flowering

The SD significantly affected the time taken to reach the start of flowering (A). Flowering started 119 days after sowing (DAS) for SD2, which decreased to 85 DAS for SD5.

Genotypes showed distinct responses to SD. Glenelg was significantly quicker to flower than the three other genotypes, whilst Croxton was the slowest (B). Glenelg started flowering 11 days earlier than Croxton for SD1. There was no significant difference between LM14 and LM17, but these genotypes were significantly slower than Glenelg. At SDs 1–4, they were significantly quicker to flower than Croxton.

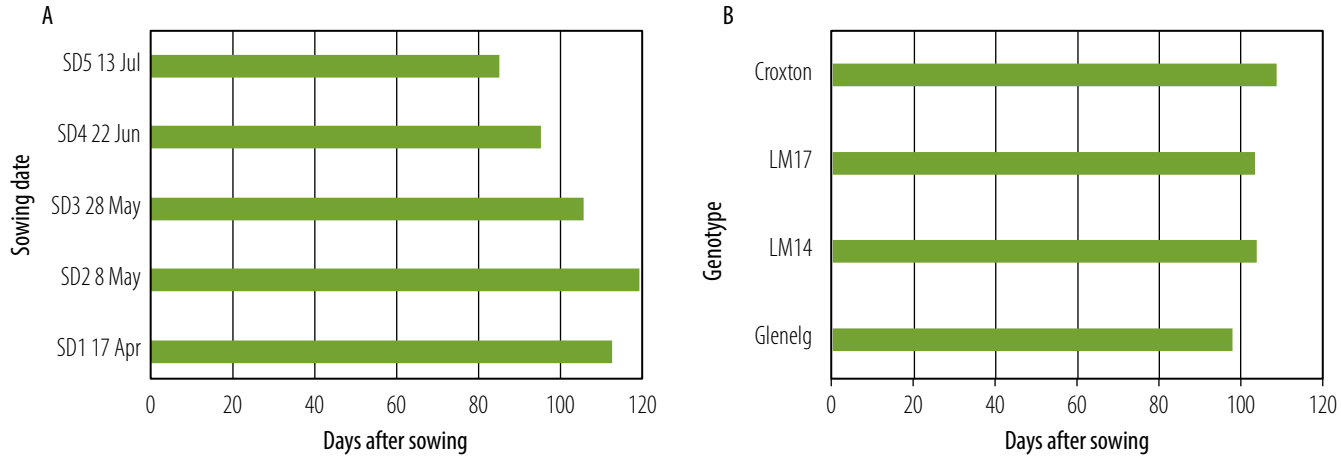

Figure 2 Linseed flowering response to (A) sowing date (l.s.d [*P*<0.001] = 3 days); and (B) genotype (l.s.d [*P*<0.001] = 1 day).

The interaction between SD and genotype ( ) significantly affected the start of flowering. Flowering started later in the season as SD was progressively delayed. Delaying sowing after SD2 hastened the start of the flowering phase by one to 1.3 days for every two days of delay in sowing. Sowing after SD3, reduced the number of days to the start of flowering by two days for every delay of two days.

For SD3, SD4 and SD5, differences between genotypes progressively decreased, with Glenelg flowering just six days earlier than Croxton for SD5. Croxton was the slowest to flower at all SDs except SD5, where LM14 was similar.

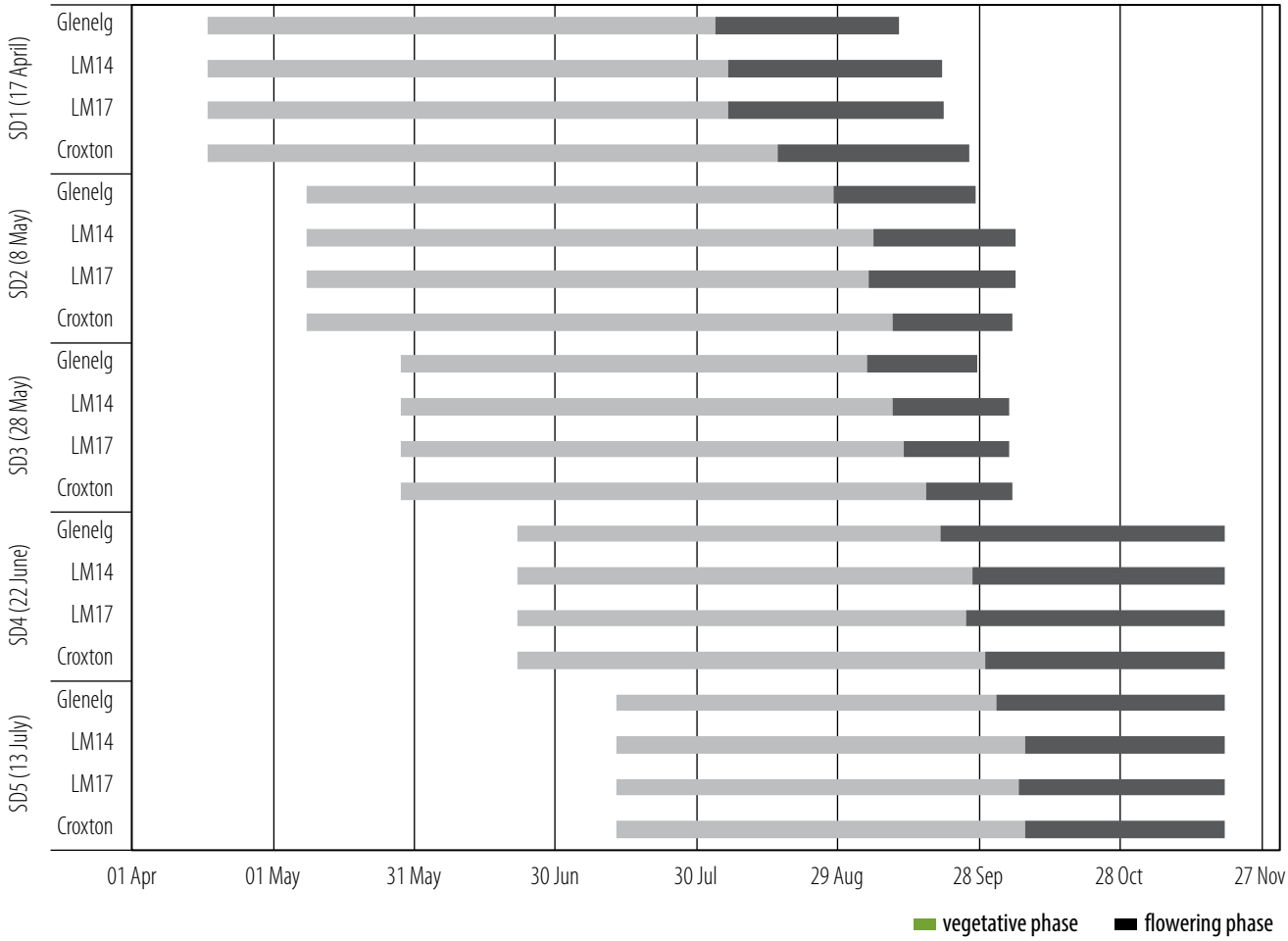

Figure 3 Effect of sowing date and genotype on the duration of linseed vegetative growth (light grey bars) and flowering (dark grey bars).

End of flowering

Linseed is an indeterminate crop, with its flowering period overlapping with continued vegetative growth. Flowering continues until plant resources or environmental conditions are limiting. Sowing date significantly affected the flowering duration ( ).

For SDs 1–3, Glenelg ceased flowering significantly earlier than the other genotypes, but there was no significant difference between LM14 and LM17 ( ). Flowering in Croxton was the last to finish, but this was not significantly different from LM14 and LM17 for SD2–SD5. All genotypes finished flowering in early to mid October for SD1, and by the end of September and early October for SD2 and SD3.

There was no significant difference in the end of flowering between any genotypes for SD4 and SD5. All genotypes ceased flowering simultaneously at SD4 and SD5. These dates coincided with a rapid increase in maximum temperatures, exceeding 40 °C ( ). Plant available water (PAW) was not limiting at the time, with 83 mm of rainfall recorded since 1 November.

Plant structure

Plant height

Plant height decreased significantly as SD was delayed. Plant heights measured 92 cm, 85 cm, 88 cm, 80 cm and 75 cm respectively for SDs 1–5 (l.s.d. 9 cm; $P<0.05$) across all varieties. There was no significant difference in plant height between LM14, LM17 and Croxton, all measuring 86 cm at maturity. Glenelg was significantly shorter at 78 cm (l.s.d. 5 cm; $P<0.001$). There was no significant interaction between SD and genotype for plant height.

Position of lowest capsule

The position of the lowest capsule was measured to assess potential harvest efficiency problems. Sowing date significantly affected the height above ground of the lowest seed capsule, measuring 79 cm, 66 cm, 71 cm, 60 cm and 54 cm respectively for SDs 1–5 (l.s.d. 8 cm; $P<0.001$).There were no significant differences between genotypes or the interaction between SD and genotypes (data not shown).

Figure 4 represents the overall plant structure for each SD, showing the seed capsule position on the plant and the stem length below the capsule. The effect of SD on the combination of overall plant height and the position of seed capsules was significant, but did not indicate any difficulties in seed capture during harvest.

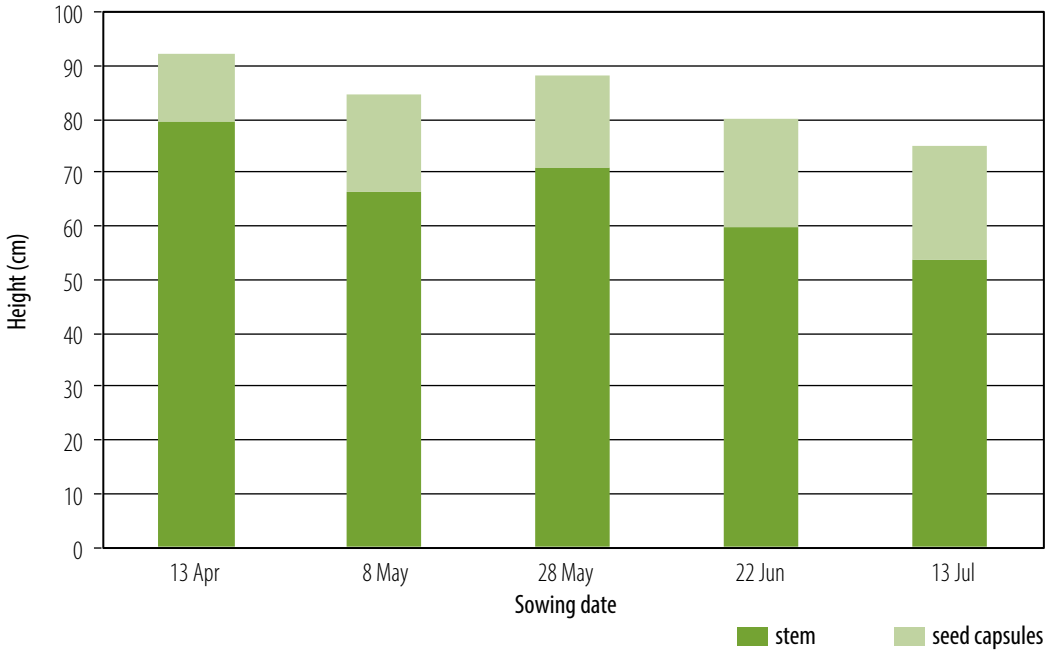

Figure 4 Effect of sowing date on height to the lowest capsule. Plant height (l.s.d [$P<0.05$] = 9 cm); height above ground of lowest capsule (l.s.d [$P<0.001$]

Stem diameter

Stem diameter was measured to assess stem strength and susceptibility to lodging. The average stem diameter was 3.13 mm. Sowing date had no significant effect on stem diameter, however, small significant differences were measured between genotypes (l.s.d. 0.2 mm; $P<0.001$) (Table 2). No persistent lodging was observed in any treatment.

Table 2 Effect of linseed genotype on stem diameter at five sowing dates.

	Glenelg	LM14	LM17	Croxton
Stem diameter (mm)	3.2[ab]	3.0[bc]	3.4[a]	2.9[c]
l.s.d. ($P<0.001$)	0.2			

Note: Values with the same letter are not significantly different at 99.9% ($P<0.001$)

Yield components

A range of plant characteristics commonly contribute positively to yield. Referred to as yield components, they are inter-related and can affect yield directly and indirectly. Some yield components correlated with crop yield include the number of capsules per plant, number of fertile and infertile capsules on the main stem, the number of branches per plant, seed size, number of seeds per capsule and the number of seeds per plant.

At physiological maturity, one linear metre row of plants were cut at ground level and dried. The above traits were measured; seed was removed from capsules, cleaned, and weighed for size.

Number of capsules

Sowing date significantly affected the number of capsules per plant with SD2 and SD4 recording 77 capsules per plant, significantly more than at all other SDs (Table 3). There was no significant difference between genotypes (Table 4) or the interaction between SD and genotype (data not shown) on the total capsule number per plant.

Fertile and infertile capsules

Sowing dates SDs 1–4 significantly affected the number of fertile capsules on the main stem, which produced the highest number of fertile capsules – between 24 per plant and 29 per plant.

- SD3 was not significantly different from SD5 (Table 3).
- Glenelg and LM17 produced significantly more fertile capsules than LM14 and Croxton on the main stem (Table 4).

Sowing date similarly affected the number of fertile capsules on branches compared with that on the main stem. The number of fertile capsules on branches was 4–6 times less (Table 3). Genotype did not significantly affect the number of fertile capsules on branches (Table 4).

- SD2 and SD4 recorded the highest number of infertile capsules on the main stem, however, SD2 was not significantly different from SD3 and SD4.
- SD1 and SD5 produced the fewest infertile capsules, 1.8 and 2.9 respectively (Table 3).
- Across genotypes, LM14 and LM17 recorded the fewest infertile capsules; 2.8 and 2.3 capsules, respectively.
- Glenelg had the highest number of infertile capsules at 6.6, significantly more than Croxton (Table 4).

Sowing date significantly affected the numbers of infertile capsules on branches, though total numbers did not exceed three capsules per branch (Table 3). Glenelg and Croxton had significantly more infertile capsules on branches than the other genotypes (Table 4).

Branching

Varieties sown on SD4 had significantly more branches (3.2) than SD1, SD2 or SD3, which only had two branches per plant. There was no significant different between SD4 and SD5 (Table 3). Of the genotypes tested, there were no significant differences in branching (Table 4) or any significant interaction between genotype and sowing date (data not shown).

Seeds per capsule

Each linseed capsule has the capacity to produce 10 seeds. On average, each capsule produced 7.3 seeds. Sowing date had no significant effect on the number of seeds per capsule ( ). There were small, but significant, differences between genotypes; for example LM14 produced significantly more seed per capsule than Glenelg (Table 4). There was a significant interaction between SD and genotype on the numbers of seeds per capsule (data not shown).

Seeds per plant

Sowing date significantly affected the total number of seeds per plant. Seed numbers per plant from SD2, and SD4 were significantly greater than SD1 and SD5 (Table 3). There was no significant difference in seed numbers between SD1, SD3 and SD5. The average numbers of seeds per plant was 374 seeds. Genotype differences were not significant (Table 4). There was no significant interaction between SD and genotype (data not shown).

Table 3 Effect of sowing date on yield components.

Sowing date	Capsules per plant	Fertile capsules on main stem	Infertile capsules on main stem	Branches per plant	Fertile capsules per branch	Infertile capsules per branch	Seeds per capsule	Seeds per plant
SD1	43^{b}	15.3^{d}	1.8^{c}	2.0^{b}	4.5^{b}	1.2^{c}	7.8^{a}	301^{b}
SD2	77^{a}	29.3^{a}	4.9^{ab}	2.0^{b}	5.6^{a}	2.1^{a}	7.5^{a}	483^{a}
SD3	56^{ab}	23.6^{abc}	4.1^{b}	2.0^{b}	4.8^{ab}	1.7^{bc}	7.1^{a}	344^{ab}
SD4	77^{a}	27.3^{ab}	6.2^{a}	3.2^{a}	6.0^{a}	2.5^{a}	7.3^{a}	472^{a}
SD5	47^{b}	20.6^{c}	2.9^{c}	2.6^{ab}	4.4^{b}	1.8^{ab}	6.7^{a}	272^{b}
Site mean	60	23.2	4.0	2.3	5.0	1.8	7.3	374
l.s.d. (P<0.05)	22**	6.3**	1.8**	0.6**	1.2*	0.7**	ns*	158*

Note: values with the same letter are not significantly different at 99.9% (P<0.001)

Table 4 Effect of genotype on yield components.

Genotype	Capsules per plant	Fertile capsules on main stem	Infertile capsules on main stem	Branches per plant	Fertile capsules per branch	Infertile capsules per branch	Seeds per capsule	Seeds per plant
Glenelg	70^{a}	26.2^{a}	6.6^{a}	2.7^{a}	5.2^{a}	2.3^{a}	6.8^{b}	379^{a}
LM14	54^{a}	21.2^{b}	2.8^{c}	2.2^{a}	4.9^{a}	1.6^{b}	7.8^{a}	385^{a}
LM17	61^{a}	27.0^{a}	2.3^{c}	2.2^{a}	5.0^{a}	1.5^{b}	7.4^{ab}	416^{a}
Croxton	55^{a}	18.5^{b}	4.3^{b}	2.2^{a}	5.0^{a}	2.0^{a}	7.1^{ab}	318^{a}
Site mean	60	23.2	4.0	2.3	5.0	1.8	7.3	374
l.s.d. (P<0.05)	ns*	3.9**	1.4**	ns*	ns*	0.5**	0.8	ns*

Note: values with the same letter are not significantly different at 99.9% (P<0.001)

Grain yield and seed characteristics

Seed size

Seed number and size are important contributors to yield. There was a significant interaction between SD and genotypes on seed size or thousand seed weight (TSW) (Figure 5). Seed size was the largest in all genotypes for SD1.

Seed size declined in all genotypes after SD1; Glenelg progressively declined with each successive SD.

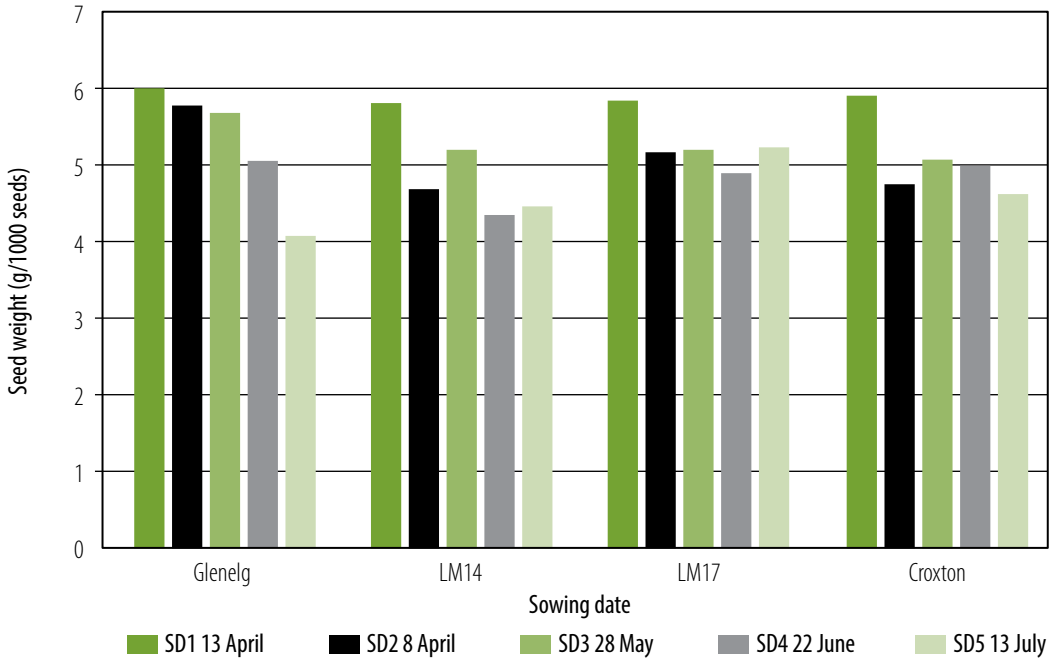

Figure 5 Seed size relationship with sowing date x genotype. Sowing date × Genotype (l.s.d. [P<0.05] = 0.94 g).

Yield

Yield was calculated from 1 m row hand cuts from each treatment. The average site yield was 1.81 t/ha. Sowing date significantly affected yield with SD4 yielding significantly more than SD5 (Table 5). There was no significant difference in yield for SD2, SD3 or SD4.

Table 5 Effect of sowing date on grain yield.

Sowing date	Yield (t/ha)
SD 1	1.65^{bc}
SD 2	2.13^{ab}
SD 3	1.72^{abc}
SD 4	2.30^{a}
SD 5	1.27^{c}
Site mean	1.81
l.s.d. (P<0.05)	0.62

Note: values with the same letter are not significantly different at 99.9% (P<0.001)

There was no significant difference in yield between Glenelg and LM17, yielding 2.10 t/ha and 1.90 t/ha respectively. There was also no significant different between LM14, LM17 and Croxton (Table 6).

Table 6 Effect of genotype on grain yield.

Sowing date	Yield (t/ha)
Glenelg	2.10 a
LM14	1.57 b
LM17	1.90 ab
Croxton	1.67 b
Site mean	1.81
l.s.d. (P<0.05)	0.39

Note: values with the same letter are not significantly different at 99.9% (P<0.001)

There were significant interactions between SD and genotype (P<0.05). Glenelg sown at SD2 yielded significantly higher than all other genotypes at other SDs (data not shown).

Harvest index

Harvest index (HI) is a measure of reproductive efficiency, calculated as the ratio of harvested grain to total shoot dry matter. HI was greatest for SD2 and SD4. There was no significant difference between SDs1, 3, 4 and 5 (Figure 6A).

The average site HI was 0.23. There was no significant difference in HI between Glenelg, LM14 and LM17. Croxton HI was significantly less (Figure 6B).

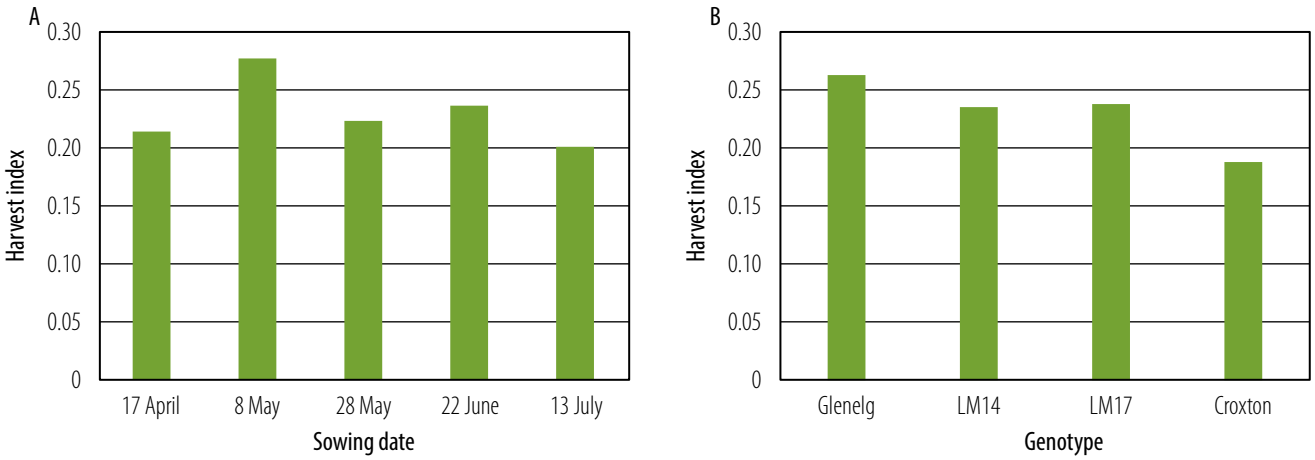

Figure 6 Harvest index relationship with (A) sowing date and (B) genotype. Sowing date (l.s.d = 0.04 [P<0.05]); Genotype (l.s.d. = 0.03, [P<0.001]).

Conclusions

This experiment highlighted differences in flowering and maturity between four linseed genotypes and their responses to SD, genotypes, and SD × genotype interactions. These factors had significant effects on yield-contributing factors and plant structure.

The earliest sowing in mid April allowed flowering to be completed by mid to late September in all genotypes. This enabled seed fill to be largely completed before the likelihood of heat and/or moisture stress. Delaying sowing after late May moved sensitive crop phases such as flowering and seed-fill into periods when seasonal conditions are characterised by rapidly increasing temperatures and evapotranspiration rates in northern NSW. Sowing date had a much larger effect on plant yield components than genotype.

Glenelg was the earliest flowering and quickest maturing of the four genotypes. Croxton was the latest to start flowering and LM14 and LM17 in between. For most of the traits measured, there was no significant difference between LM14 and LM17.

The data suggests that the optimal sowing window at Narrabri for the four varieties of linseed was late April to early May. This assessment was based on the probabilities of environmental stresses, particularly heat and moisture stress during flowering and seed fill.

These findings were part of the research into determining key traits and characteristics of linseed genotypes and their optimum sowing date in northern NSW. The research demonstrated the first comparative data in northern NSW of commercially available linseed varieties. Additional experiments at geographically diverse locations and several seasons are required to better characterise these genotypes to refine crop growth response curves and agronomic management.

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