Effect of sowing date on phenology, plant morphology and yield components in linseed grown in northern NSW in 2015

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Abstract
Linseed (*Linum usitatissium*) is a profitable oilseed crop recognised for its role within a rotation for managing cereal crop diseases and pests such as the economically important root lesion nematode species. Consultation with growers and agronomists in northern NSW identified a range of views regarding the ideal sowing window, and a significant knowledge gap of available linseed varieties. A linseed phenology experiment was conducted in 2015 to evaluate the effect of sowing date (SD) on the phenology and yield components of four linseed varieties sown at five SDs (17 April, 8 May, 28 May, 22 June, 13 July). In general, as SD was delayed, the length of key phases such as start of flowering were reduced, plant height and height of lowest capsules decreased and thousand seed weight (TSW) declined. The results show the temperature-driven response of growth and development of four varieties, providing baseline data that could be utilised in crop growth simulations of variable climate scenarios for regional adaptation.

Keywords
Variety, flowering, yield components, seed size, agronomy

Introduction
Linseed (*Linum usitatissium*) is grown in the medium to high rainfall areas of northern NSW (Sykes and Green 1988). Grown in rotation with cereal crops, linseed is recognised for its beneficial role in northern farming systems, principally the resistance to *Pratylenchus thornei* and *P. neglectus,* two important pathogenic species of root lesion nematode, as a cereal disease break crop, and for its frequent high grain prices making linseed a profitable crop in its own right. The variety Glenelg is commonly grown, with small areas of the variety Croxton. New cultivars available through licensing arrangements have generated greater interest, however industry consultation has highlighted gaps in the knowledge of varieties and their optimal sowing windows. A linseed phenology experiment was conducted in 2015 at Narrabri, to evaluate the response of four linseed varieties to sowing date (SD). This paper reports on the findings of the effects of SD on traits including time to start of flowering and yield components.

Methods
Experimental design
A replicated linseed experiment was conducted at the Plant Breeding Institute, Narrabri, New South Wales in 2015. The experiment was a complete randomised block design comprising five SDs approximately three weeks apart (17 April, 8 May, 28 May, 22 June, 13 July). SDs were selected to include the complete range of sowing options for the area including earlier and later sowing dates. Linseed genotypes consisted of four commercial varieties – Glenelg, Croxton, LM14 and LM17.

Di-ammonium phosphate (DAP) fertiliser was pre-drilled into seeding furrows using a small plot seeder at 80 kg/ha. Plot size was 8 m x 1.65 m, consisting of 6 rows at 0.28 m row spacing. Linseed was hand-sown in single rows into soil moisture suitable for germination at sowing. Plants were thinned at early establishment to a population of 300 plants/m^2. Weeds and insect pests were managed with registered pesticides and crop nutrition was managed using pre-sowing soil tests and fertilisers applied to avoid nutritional deficiencies.

Measurements and statistical analysis
Rainfall data was collected from an on-site rainfall gauge. Minimum and maximum temperatures and relative humidity were measured hourly for the duration of the experiment using a Tiny Tag® placed at an above ground height of 1.2 m. Phenology was measured in Degree Days (°Cd) using a base temperature of 0°C. Thermal time was calculated as SUM (maximum daily temperature minus base temperature) and (minimum daily temperature minus base temperature) divided by 2. Accumulated growing degree-days (GDD) was calculated by summation of °Cd for each stage of development.

Plants were selected and tagged within each experimental unit. Phenology was monitored every 2 to 3 days using the BBCH scale to code phenological growth stages (Smith and Froment 1998). Crop measurements included first flower, 50% flowering, end of flowering and maturity date. At physiological maturity, one metre linear rows of plants were cut at ground level and dried. Measurements on each plant included total plant height, height of lowest capsule, number of branches, and number of capsules on main stem, number of capsules on branches, number of fertile and infertile capsules. Seed was removed from capsules, cleaned, and weighed for seed size. All data was analysed using the ANOVA command, using Genstat 19th Edition (VSN International 2018).

Results

Weather

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 (Table 1). Rainfall in June, July, September and October were below the long-term average. Growing season rainfall (GSR: April to November) was 273 mm, lower than the long-term average of 306 mm.

Table 1: Monthly temperature and rainfall data at experiment site compared with long-term average at Narrabri, 2015.

	April	May	June	July	Aug	Sept	Oct	Nov
Rainfall (mm)	36.0	25.4	45.2	21.0	31.4	10.2	20.6	83.0
Long term (LT) mean rainfall (mm) ◊	24.6	24.2	54.5	31.3	27.3	31.9	33.7	78.5
Mean minimum temperature (°C)	11.2	9.1	6.1	4.2	4.4	6.3	13.7	17.1
LT mean minimum temperature (°C) ◊	12.2	7.1	5.7	4	4.8	8.1	12	16.4
Mean maximum temperature (°C)	29.8	27.0	23.1	20.5	26.1	31.6	37.8	42.0
LT mean maximum temperature (°C) ◊	22.5	21.3	18.5	16.3	19.5	24.2	32.8	33.6
Mean temperature	16.5	14.7	13.2	9.7	11.4	14.6	23.0	25.3
LT Mean temperature (°C) ◊	19.6	14.8	12.0	11.0	12.4	16.2	20.1	23.8

◊ Source: Bureau of Meteorology data for Narrabri Airport AWS

As SD was delayed, the average maximum temperature increased (Table 2). GSR ranged from 103.6 mm (SD4) to 272 mm (SD1).

Table 2: Growing season temperature and rainfall data for five sowing dates at Narrabri, 2015.

	Temperature (°C)				Rainfall (mm)
Sowing date	Mean maximum	Mean minimum	Maximum	Minimum	In-crop
17-Apr-15	23.7	9.0	42.0	-0.9	273
8-May-15	23.8	8.8	42.0	-0.9	230
28-May-15	24.1	8.9	42.0	-0.9	222
26-Jun-15	25.1	9.2	42.0	-0.9	104
13-Jul-15	26.0	9.9	42.0	-0.9	151

Phenology

There was a significant interaction (P<0.05) between SD and variety on days to 50% flowering (DTF) (Figure 1). The effect of SD on the DTF of linseed varieties ranged from 81 days to 125 days (Figure 1). As sowing was delayed DTF decreased in all genotypes with the exception of SD2, where DTF increased. Glenelg was consistently the quickest to flower and Croxton the slowest, at all SDs.

Delaying sowing after 8 May reduced the number of DTF by 1 to 1.3 days for every 2 days of delay in sowing (Figure 2). Delaying sowing after 28 May reduced the number of DFT by 2 days for every 2 days of delay.

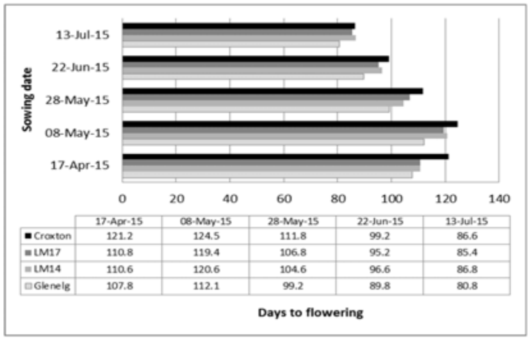

Figure 1. Days to flowering of linseed varieties in response to sowing date (l.s.d. = 1.2; *P*<0.05).

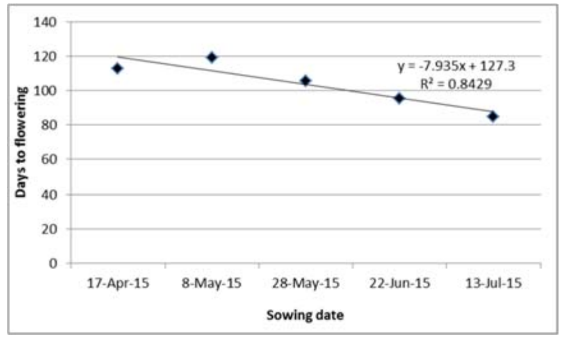

Figure 2. Effect of sowing date on average days to flowering for linseed at Narrabri, 2015.

There was a significant interaction (*P*<0.05) between SD and variety in accumulated growing degree days (GDD) from sowing to the end of flowering (GS69) (Table 3). Significant differences were also measured for SD (*P*<0.05) and varieties (*P*<0.05) (data not shown). Glenelg was the first variety to cease flowering, with no significant difference between SD1 and SD2 at 1890GDD and 1808GDD respectively, but significantly different at SD3 at 1425GDD. There was no significant difference between varieties at SD4 and SD5, all varieties ceasing at 2486GDD and 2202GDD respectively. End of flowering occurred after maximum daily temperatures had reached 41.6°C after several weeks of daily maximum temperatures of 30–35°C with minimum daily temperatures rapidly increasing from below 10°C to 15–23.7°C. Rainfall events throughout the late spring period, totalling 104 mm, extended the duration of the flowering period.

Table 3. Effect of sowing date and days to end of flowering expressed as growing degree days

Growing degree days (°Cd$_{base\ 0}$)	Genotype			
Sowing date	Glenelg	LM14	LM17	Croxton
17 April	1890	2042	2048	2136
8 May	1808	1977	1977	1958
28 May	1425	1651	1551	1669
22 June	2486	2486	2486	2486
13 July	2202	2202	2202	2202
l.s.d. (*P*<0.05)		112		

Plant morphology

Plant height at physiological maturity was significantly affected by SD (Table 4) and genotype (data not shown), but there was no interaction between genotype and SD (data not shown). SD had a significant effect on the height above ground of the lowest capsule, where height decreased as SD was delayed (Table 4). Capsule height would present no issues for efficient grain capture at harvest. Stem diameter was measured to assess stem strength and hence susceptibility to lodging. Average stem diameter was 3.13 mm. SD had no significant effect (Table 4), however the stem diameter of Croxton at 2.9 mm was significantly less than Glenelg and LM17 (data not shown). No lodging was observed in any treatment. Branch number per plant ranged from 2.0 to 3.2, but was significantly affected only by SD (Table 4).

Table 4. Effect of sowing date on linseed plant morphology

Sowing date	Height (cm)	Height of lowest capsule (cm)	Stem diameter (mm)	No. of branches/plant
17 April	92 a	79.4 a	3.08 a	2.0 b
8 May	84 ab	66.4 bc	3.08 a	2.0 b
28 May	88 ab	70.2 b	3.23 a	2.0 b
22 June	80 b	59.7 cd	3.28 a	3.2 a
13 July	75 b	53.7 d	3.00 a	2.6 ab

l.s.d. (*P*<0.05)	9	8.4	ns	0.6

Yield components

Various structures that contribute to grain yield accumulation were measured. The number of capsules per plant and the number of fertile capsules per plant were significantly (P<0.05) affected by SD (Table 5), but effects were not significant for variety or SD x variety interaction (data not shown). SD had a significant effect on seed number per plant with greatest seed numbers recorded for SDs 2 and 4 (early May and mid-June) (Table 5). Genotype and its interaction with SD had no significant effect on seed number per plant (data not shown).

Seed size expressed as thousand seed weight (TSW) declined with delayed SD (Table 5). Variety and its interaction with SD had significant effects on seed size. Seed size of LM14 was significantly smaller than all other varieties. Seed size of the remaining three varieties was not significantly different (data not shown). Seed size of Glenelg was largest at SDs1 to 4, but significantly smaller at SD5 (data not shown). The trend in seed size in all varieties was to decrease as SD was delayed.

Table 5. Effect of sowing date on yield components of linseed at Narrabri, 2015.

Sowing date	Capsules (/plant)	Fertile capsules (/plant)	Seed number (/plant)	Seed size (g /1000 seeds)
17 April	43.3 b	39.1 c	301 b	5.91 a
8 May	76.5 a	66.4 a	483 a	5.11 bc
28 May	56.2 ab	48.6 bc	344 ab	5.30 ab
22 June	76.8 a	63.4 ab	472 a	4.84 c
13 July	47.3 b	40.4 c	272 b	4.62 c
l.s.d. (*P*<0.05)	21.6	18.8	157	0.73

Conclusions

The study highlighted differences in flowering and maturity of four linseed varieties and their responses to SD, variety and SD x variety interactions. Analysis showed significant effects on yield-contributing factors and plant morphology. Based on the probabilities of environmental stresses, particularly heat and moisture stress during flowering and seed fill, the data suggests the optimal sowing window for the four varieties to be late April to early May at Narrabri.

The results indicate there is enormous scope to improve the understanding of the processes driving growth and development in linseed. This includes yield components and their inter-relationships that are genetically controlled and influenced by environmental factors and management practices, and their interactions. This will enable management guidelines and practices to be developed to improve agronomic potential and production reliability. Further research is required to validate these results.

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