Optimum sowing time for rainfed safflower in southern Australia is affected by soil water availability

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Abstract

Two field experiments were undertaken in the Victorian Wimmera to assess the effect of sowing time on the development, growth and yield of safflower (*Carthamus tinctorius*). The sites had different amounts of stored soil water at sowing. For the latitude at which the experiments were conducted and cultivar Sironaria, the mean thermal duration of 713 ?Cd_8 predicted the flowering date of all observations with a standard deviation of 2.8 d, even though flowering dates were 22 – 24 d earlier in the warmer season in 2000, compared to 2001. Yield declined at a rate of ~0.04 t/ha (5%) for each week that sowing was delayed after mid July at the drier site. On the wetter site, yields were similar for the July, August and September sowings (mean = 4.18 t/ha), but declined to 3.41 t/ha as the delay continued into October. The main yield component affected by delayed sowing was capitula number, suggesting that some of the yield loss could be overcome by increasing seeding rates for later sowings.

Media summary

Delayed sowing of safflower results in yield penalties similar to other winter crops (~5% per week), but the rate of decline is less where more soil water is available at sowing.

Key words

Wimmera, phenology, biomass, water use efficiency

Introduction

Safflower (*Carthamus tinctorius)* is a deep-rooted, oilseed crop which in southern Australia is generally grown in rotation with winter cereals, pulses or other oilseeds. Although safflower is usually a minor component of these rotations, it is potentially valuable as it is normally sown in late winter or spring after the sowing window for these other species has closed. Spring sown crops provide growers with opportunity to generate income from paddocks that become too wet during winter to sow, or allow the survival of common winter crops. Although Stanley *et al.* (1995) suggested that safflower can produce satisfactory yields when sown in September or October in South Australia, Colton (1988) advised that delaying sowing beyond mid-July results in reduced yields in New South Wales. A survey of growers across southern Australia indicated that safflower is mostly sown in August or September, but the range was July to December (Wachsmann *et al.* 2001). About 19% of respondents believed one of the major strengths of safflower to be its flexible time of sowing, however, 41% reported that poor or variable yields were a significant weakness. This paper presents data from two experiments which compared the effect of sowing time (July to October) on the growth, yield and water use of safflower under different seasonal conditions in southern Australia.

Methods

The experiments were conducted at Longerenong (36.7 ?S, 142.3 ?E) in the Wimmera region of Victoria. Average annual rainfall is 420 mm and both sites were producing lucerne (*Medicago sativa*) in the season prior to these experiments. The site sown in 2000 was entirely rainfed (RF00), whilst the site sown in

2001 was pre-watered (~200 mm) to fill the soil profile in late June (PW01). The soil type was a deep, cracking grey clay (Vertosol) with a topsoil (0 – 15 cm) $pH_{(CaCl2)}$ of 7.5 at RF00 and 6.3 at PW01. Grain legume super (15% P, 7% S, 2% Zn) was drilled at each site in early July (RF00 = 171, PW01 = 126 kg/ha) and urea was drilled (46% N) prior to sowing each treatment (RF00 = 110, PW01 = 93 kg/ha). Weed control was achieved by applying the herbicides trifluralin before sowing and metsulfuron at stem elongation. Glyphosate was used to control weeds in unsown plots until their appropriate sowing time. The safflower cultivar used was Sironaria and the sowing rate was 17 kg/ha to achieve a target plant population of 40 plants/m^2. The row spacing was 220 mm. Pests were controlled with recommended insecticides as required.

A Latin square (4 ? 4) experimental design was used for both sites and the plot size was 20 m (RF00) or 15 m (PW01) ? 6.8 m. The sowing time treatments were 14 July, 14 August, 15 September and 16 October at RF00 and 25 July, 15 August, 14 September and 10 October at PW01. Climate data were recorded by a Bureau of Meteorology weather station located at RF00 and less than 1 km from PW01. The thermal duration (?Cd_8) between sowing and flowering was calculated as the sum of mean daily temperatures above a base temperature of 8 ?C for this period. Soil water contents were estimated from cores of 42 mm aperture, taken to 2 m depth when each treatment was sown and at physiological maturity (PM). Total water use (TWU) is given as the change in soil water between sowing and PM to 2 m depth, plus rainfall received during this period. Crop growth and seed yields presented here were estimated from hand samples taken at PM (4.5 m row). Seed yields are given at 8% moisture, but harvest indices (HI) were calculated with seed moisture at 0%. The oil content of composite samples for each treatment was determined by the Agseed Oilseed Laboratory in Horsham. Data were analysed with ANOVA and linear or curvilinear regression techniques were used to further investigate some relationships using Genstat 5th Edition.

Results and discussion

The two years provided contrasting seasonal conditions with mean daily temperatures between budding and PM (November to January) being 2.1 ?C warmer than the long term mean (LTM) at RF00, but 2.3 ?C cooler than the LTM for these months (19.1 ?C) at PW01. Rainfall received for the duration of these experiments (July to January) was 36 and 12 mm below the LTM (254 mm) at RF00 and PW01, respectively. Depending on sowing time, the total soil water content at sowing (2 m depth) ranged from 647 to 702 (mean = 680 mm) at RF00 and 779 to 822 (mean = 804 mm) at PW01, with no statistically significant ($P>0.05$) differences between treatments within each site. This indicates that the amount of water lost by soil evaporation between sowing the first and last treatments was similar to the amount of rainfall received over this period (RF00 = 116, PW01 = 131 mm). Most of this rain fell in small events, with daily rainfall exceeding 10 mm on only three occasions between sowing the July and October treatments at each site (three day totals; RF00 = 44, PW01 = 54 mm). All treatments established satisfactory and did not appear to be injured by several frosts between July and October, when temperatures of -1 (PW01) and -2 ?C (RF00) were recorded.

Delayed sowing between July and October progressively reduced the duration between sowing and PM from 169 to 90 d at RF00 and 191 to 137 d at PW01 (Figure 1). This was mainly due to the shortening of pre-flowering phenophases, with sowing time having only small affects on the duration of post-flowering phenophases within each site. Subsequently, despite the 94 (RF00) and 77 d (PW01) range in sowing times, all treatments commenced flowering within 17 and 19 d periods at RF00 (4 – 21 December) and PW01 (26 December – 14 January), respectively. The increased rate of development with later sowing is ascribed to rising temperatures between July (winter) and October (spring), with the thermal duration between sowing and flowering for all observations only ranging from 687 to 759 (mean = 713 ?Cd_8). At least for this cultivar (Sironaria) and latitude (daylength), this mean thermal duration predicted the flowering date of all observations with a standard deviation of 2.8 d, even though flowering dates were 22 – 24 d earlier in the warmer season at RF00, compared to PW01. The post-flowering phenophases were completed in 11 – 17 d (106 – 161 ?Cd_8) less time in the warmer and drier conditions at RF00, compared to PW01. All treatments reached PM between 30 December and 14 January (RF00) or 1 and 24 February (PW01).

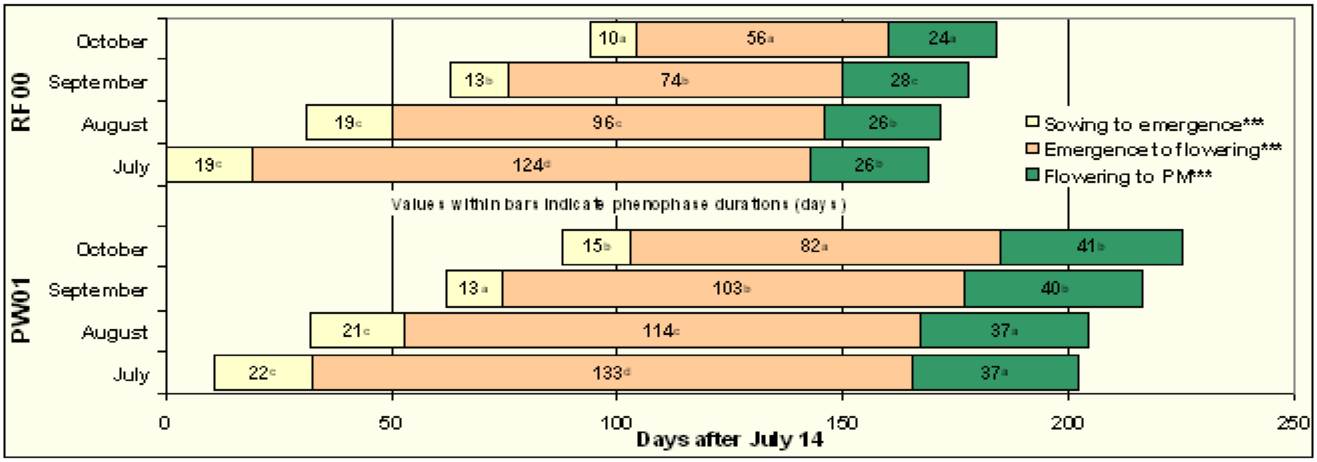

Figure 1. Effect of sowing time on the development of safflower at two sites in the Wimmera (RF00 and PW01)

^{a,b,c} for each phenophase, means with same superscript are not significantly different at *P*=0.05 at each site; ****P*<0.001.

The degree of leaf senescence indicated that all plots became highly water stressed before flowering at RF00, but less so PW01. Subsequently, biomass and seed yields varied substantially between the two sites (Figure 2), with the lowest yielding treatment at PW01 (October) producing almost twice the biomass and four times the seed of the highest yielding treatment at RF00 (July). Relative responses to sowing time were stronger at RF00 where biomass (DM = dry matter) declined linearly resulting in a fourfold difference between the July (5.87 t DM/ha) and October (1.38 t DM/ha) treatments. The additional biomass produced by sowing in July and August at this site is attributed to a combination of longer growing seasons and higher (*P*<0.01) mean growth rates between sowing and PM (34.7 and 32.8 kg DM/ha/d), compared to September and October (23.7 kg and 15.4 kg DM/ha/d). At PW01, the July and August treatments produced similar amounts of biomass (mean = 16.8 t DM/ha), but further delays in sowing reduced biomass exponentially (September = 14.6, October = 11.2 t DM/ha). Mean growth rates at this site only ranged from 81.4 (October) to 95.7 kg DM/ha/d (August) and despite significant (*P*<0.05) differences between some sowing times, variation in biomass at maturity between sowing times can be largely ascribed to differences in growing season duration.

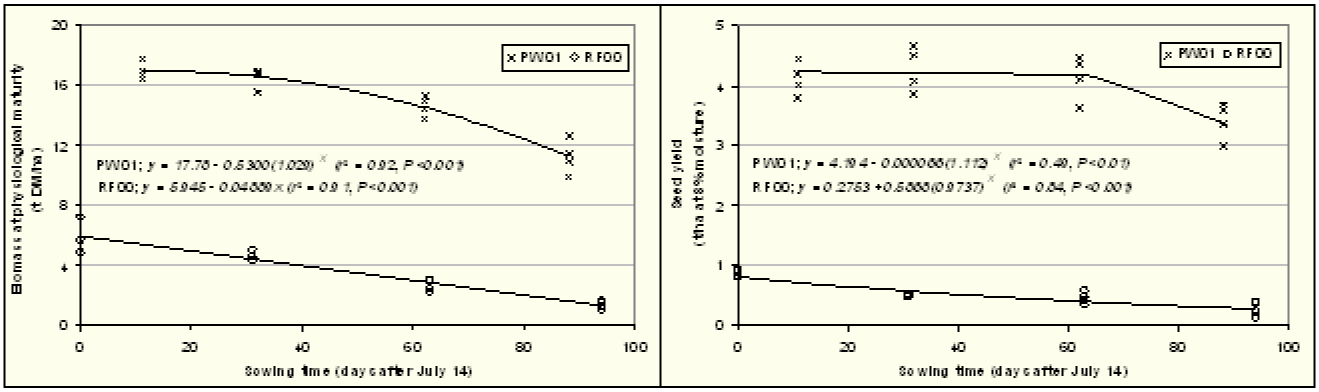

Figure 2. Effect of sowing time on the biomass (left) and seed yield (right) of safflower at two sites in the Wimmera (RF00 and PW01).

At RF00, seed yield declined almost linearly with delayed sowing between July (0.87 t/ha) and October (0.29 t/ha), equating to a yield penalty of 0.04 t/ha for each week that sowing was delayed beyond 14

July. The response to sowing time differed at PW01, where treatments sown between July and September produced similar yields (mean = 4.18 t/ha), but delaying sowing until October reduced ($P<0.01$) yield to 3.41 t/ha. Because sowing time had a stronger relative affect on biomass production than seed yield, the HI generally increased with delayed sowing from 0.14 (July) to 0.19 (October) at RF00 and 0.22 (July) to 0.28 (October) at PW01, although it was only 0.10 for the August sowing at RF00. The decline in seed yield with delayed sowing at RF00 was mainly due to a reduction in the number of seeds per capitulum from 17.2 (July) to 8.4 (October) and in the number of capitula produced from 202 (July) to 115/m^2 (October). Seed mass showed no consistent trend with sowing time at this site (mean = 26.1 g/1000 seeds). At PW01, sowing time had no significant effect on seed mass (36.9 – 41.0 g/1000 seeds) or seed number per capitulum (29.8 – 31.2). However, later sowing did tend to reduce the number of capitula produced by the October (299/m^2), compared to the August or September sown treatments (355 and 366/m^2). Oil contents ranged from 25.5% (September) to 29.1% (August) at RF00 and 33.1 (July) to 34.6% (September) at PW01.

Sowing time had no significant effect on the total amount of water extracted from soil to 2 m depth between sowing and PM (mean; RF00 = 81, PW01 = 299 mm) and the residual water content at PM was similar for all treatments within each site (RF00 = 576 – 616, PW01 = 495 – 513 mm). These values would approach the lower extractable limit for this soil type, suggesting that all treatments were able to exploit all available water. The lower extraction at RF00, compared to PW01 is attributed to drier profiles at sowing and a narrow band (~0.1 m) of dry, hard setting, calcareous soil which fluctuated between 0.6 and 1 m depth. Subsequently, on average 90% of soil water extracted between sowing and PM came from the upper 0.75 m at RF00, compared to only 42% at PW01, where the balance was sourced from deeper in the profile, including 20% from between 1.50 and 2.00 m. These results are consistent with observations on soil cores taken at flowering, when the mean rooting depth for all treatments was only 0.79 m at RF00, compared to 1.75 m at PW01. With July to October rainfall (up to 131 mm) not being effectively stored in the profile, TWU between sowing and PM tended to decline with delayed sowing according to the amount of rainfall received over this period, but daily water use was similar for all sowing times within each site (Table 1).

Table 1. Total water use (mm), mean daily water use (DWU, mm/d) and water use efficiency of biomass (WUE_{DM}) and seed (WUE_{seed}) production (kg/ha/mm) based on estimates at the time of sowing and PM for each of the four sowing time treatments two sites in the Wimmera (RF00 and PW01).

	RF00				PW01			
Month	TWU	DWU	WUE_{DM}	WUE_{seed}	TWU	DWU	WUE_{DM}	WUE_{seed}
July	243	1.44	24.3^b	3.59	532^c	2.78	32.1	7.78^a
August	196	1.39	23.9^b	2.58	470^b	2.72	35.4	9.17^b
September	204	1.77	13.5^a	2.25	449^b	2.86	33.0	9.29^b
October	166	1.84	9.6^a	1.98	371^a	2.69	30.4	9.20^b
Mean	202	1.61	17.8	2.63	456	2.76	32.7	8.86

LSD (5%)	n.s.$_{(P=0.20)}$	n.s. $_{(P=0.39)}$	8.8*	n.s.$_{(P=0.12)}$	54.7*	n.s.$_{(P=0.62)}$	n.s.$_{(P=0.24)}$	0.90*
CV%	21.6	26.2	28.4	31.7	7.0	9.7	9.4	5.8

^{a,b,c} means with the same superscript are not significantly different at P=0.05, $^{*}P<0.05$, n.s. denotes not significant at P=0.05.

At RF00, the WUE of biomass production (WUE$_{DM}$) declined with delayed sowing reflecting the steady decline in the amount of biomass produced with delayed sowing at this site (Table 1). The WUE of seed production (WUE$_{seed}$) followed a similar pattern to biomass, although differences were not statistically significant at $P<0.05$ with the high variability in soil water data at RF00. There were no significant differences in WUE$_{DM}$ at PW01 meaning that maturity biomass decreased parallel to TWU with delayed sowing between July and October at this site. Here, the July treatment had a lower WUE$_{seed}$ than later sowings and this may be related to differences in water use partitioning between soil evaporation and transpiration. With a lower degree of water stress and cooler growing conditions, the WUE$_{DM}$ and WUE$_{seed}$ for all sowing times was significantly ($P<0.01$) higher at PW01, compared to RF00.

While growers routinely delay the sowing of safflower until September or October (Wachsmann *et al*. 2001), it is clear from these experiments that this practice can incur a significant yield penalty, particularly under drier conditions. Safflower does have good high temperature tolerance, but the delay in sowing reduces the amount of growth, which in turn reduces yield potential. Earlier sowing enables good establishment and growth does not appear to be penalised by the cooler conditions during August. The magnitude of yield decline with delayed sowing at RF00 was ~5% per week (from July), which is similar to the decline reported by Farr? *et al.* (2002) for canola (*Brassica napus*) in the moderate rainfall zones of Western Australia when sowing was delayed beyond its optimum sowing time (April). As observed in these experiments with safflower, Farr? *et al.* (2002) also reported that yield loss in canola due to late sowing was less under high, compared to low soil water conditions.

Conclusion

For low rainfall areas, early sowing appears important to achieve good safflower yields, but where the soil profile is reasonably wet at sowing and/or where follow up rains are likely, safflower can produce economic yields (>1 t/ha) when sown as late as mid October in southern Australia. The common practice of sowing safflower in spring can lead to yield loss and growers should consider earlier sowing to achieve more reliable yields in drier environments. In these experiments, late sowing did not lead to more water being available at the end of the safflower growing season as all treatments dried the soil within the root zone to the lower extractable limit. Because capitula number was the major yield component affected by late sowing, it may be that increased seeding rates could be used to overcome some of the yield decline recorded in these experiments.

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