GROWTH AND DEVELOPMENT OF SUNFLOWER IN A SEMI-ARID ENVIRONMENT.

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ABSTRACT

The growth and development of sunflower *(Helianthus annuus* L.) crops under rainfed conditions in Australia are frequently constrained by water stress and high temperature. The effects of these factors on the ontogeny of the crop and a number of important components of vegetative and reproductive growth were studied in crops grown over two seasons at Narrabri, N.S.W. High temperatures and limiting moisture hastened maturity in all three cultivars studied. A decrease in height, leaf area index, leaf area duration and an increase in senescence resulted from decreasing water availability late in the growing season. The magnitude of the decrease in seed yield (up to 75%) was dependent on the extent, duration and timing of the water stress. These results help to quantify the effects of environmental constraints on rainfed sunflower production and provide the basis for improved cropping strategies and for evaluation of the effect of crop maturity type on yield stability.

INTRODUCTION

Much of the cropping zone of Australia lies in semi-arid regions (Gentilli, 1972) and water stress is the major constraint to crop yields. High temperatures, and accompanying high evaporation rates, frequently add to the environmental stress experienced by crops. This is particularly so in northern New South Wales and Queensland where rainfall is summer dominant but is highly unreliable and frequently has a low effectiveness as it occurs as high intensity storms. Summer temperatures and evaporation rates are high. The production of summer-growing crops, such as sunflower, in these regions involves a considerable degree of uncertainty and yields vary widely from year to year.

To maximise returns in the environment it is necessary to devise cropping strategies and to develop cultivars which will confer a degree of yield stability from year to year. An ongoing research programme has provided estimates of the least risk sowing strategy for a single sunflower cultivar (Peredovik-type) at a number of locations in the region (Anderson *et al.,* 1978a & b; Smith *et al.,* 1978a & b). The work reported in this paper represents a continuation of this programme which was undertaken to examine whether cultivars of differing maturity types could be used to enhance yield stability in rainfed conditions, while maintaining production at an economic level. The work was carried out on the Research Station of the New South Wales Department of Agriculture at Narrabri.

MATERIALS AND METHODS

The cultivars*, Suncross 52 (late), Suncross 51 (mid-season) and Suncross 150 (early), were grown in two seasons (1979/80; 1980/81) in plots 100 m x 12 m at one meter row spacing and a constant population of 50,000 ha^{-1}. The area, on a deep (>3 m) self-mulching clay (Ug 5.25, Northcote, 1979) was prepared by pre-irrigating, treating with herbicide (trifluralin) and fertilising at recommended rates (A.B. Hearne, Pers. comm.). During crop growth, furrow irrigation was used to supplement rainfall to generate a range of soil water conditions. Uncropped areas four meters wide, which were pre-irrigated but not watered again, were used as buffer zones to prevent water movement between plots. All measurements were taken on the central six rows of the 12 row plots.

In the first season, crops of the late and mid-season cultivars were stressed from either preanthesis, anthesis, or mid-seed fill to physiological maturity by the application, respectively, of zero, one or two irrigations. A fully irrigated control received three irrigations. The early cultivar in the first season, and the early and late cultivars in the second season, were grown under rainfed and fully irrigated conditions. Crops were sown in the spring of the 1979/80 season (25/09/79), and in spring (23/09/80), early summer (15/12/80) and late summer (23/01/81) in the second season.

Phasic development was recorded as the time when 50% of the crop had reached the appropriate stage. Regular measurements were made of crop dry weight, leaf number, leaf area and plant height. Seed yields were estimated from 40 — 100 head samples. All results are presented as oven-dry weight.

Extractable soil water (ESW) was computed from regular soil water measurements and water use efficiency (WUE) was calculated from total water use (Dubbelde *et al.,* 1982).

Rainfall was measured on the site and other climatic measurements (temperatures, total radiation and evaporation) were taken from the Research Station meterological site approximately 1 km away. Class A pan evaporation values were increased by 10.2% to allow for the effect of a screen (Stanhill, 1962).

*Seed supplied by Yates Seed Co., Narromine, N.S.W.

RESULTS AND DISCUSSION

Climatic conditions during the trials are illustrated in Figures 1 and 2. Rainfall was below average in both seasons and this is reflected in low ESW of rainfed crops through much of their growth. Maximum temperatures exceeded 40°C on several occasions in both years. Evaporation rates during much of the growth of the spring and early summer-sown crops were of the order of 13 to 18 mm day^{-1}, but were reduced to 9 to 13 mm in growth of the later summer-sown crop.

The duration of crop growth, and the relative differences between the cultivars, was much more strongly influenced by the season than by different water status within the same sowing. The shorter duration of the spring-sown crop in the second season relative to the first season, and the severe reduction (to 30 days) with later sowings in the second season (Figures 1 and 2), are partially explained by the more rapid accumulation of heat sums (Table 1) due to higher temperatures. The vegetative growth stage was most consistently sensitive to temperature changes, being shortened by as much as 12 — 15 days, but the length of the seed-filling phase also varied by as much as 15 to 25 days in the late sown crops.

Leaf numbers remained constant throughout the trials which was to be expected as the ESW during vegetative growth was high for all crops (Figures 1 and 2). However, both leaf expansion and leaf retention were reduced by stress, resulting in a progressive decrease in LAI from the time of the onset of water stress (Figure 3). While this reduction in LAI could be expected to reduce the rate of water loss, an accompanying reduction in photosynthetic capacity would contribute to yield reduction. Reduction in the height of stressed crops (Table 1) reflects the degree of stress prior to anthesis. The greatest proportional reduction occurred in those crops in the second season which experienced both moisture and high temperature stress in the reproductive phase (spring and early summer sowings).

Table 1. Heat sums during development, height, yield and water use efficiency of three cultivars of sunflower grown in two seasons under fully irrigated and rainfed conditions in a semi-arid environment in northern New South Wales.

Sowing Date	Cultivar		**Heat Sums			height	Yield	WUE
			†S — BV	BV — A	A — PM	(cm)	kg ha^{-1}	kg ha mm^{-1}
Spring (25/09/79)	Suncross 52	*I	1115	650	1110	147	2465	2.97
		R	1115	600	1032	124	675	1.61
	Suncross 51	I	910	635	1175	123	2045	2.68
		R	910	635	970	115	1200	3.32
	Suncross 150	I	780	640	1090	105	1030	2.82
		R	780	640	1020	104	730	2.04
Spring (25/09/80)	Suncross 52	I	1190	685	925	157	3610	4.52
		R	1190	631	890	80	ϕNA	NA
	Suncross 150	I	930	520	1100	110	3135	5.29
		R	930	520	1045	81	1090	3.57
Early Summer (15/12/80)	Suncross 52	I	1010	590	715	145	2180	3.92
		R	980	590	725	74	625	2.54
Late Summer (23/01/81)	Suncross 52	I	1110	575	820	185	2660	3.93
		R	1110	575	750	115	715	2.85
	Suncross 150	I	935	550	600	157	2255	4.00
		R	935	550	550	108	605	2.33

*I = Irrigated; R = Rainfed **Base temperature = 0
†S = Sowing; BV = Buds Visible; A = Anthesis; PM = Physiological Maturity
ϕNot available due to bird damage

Figure 1. Daily maximum and minimum temperatue, radiation, Class A pan evaporation and rainfall (bar graph), crop phasic development and extractable soil water for irrigated and rainfed sunflower cultivars in the 1979/80 season. (s = sowing; bv = buds visible; a = anthesis; pm = physiological maturity; I = irrigation; R = rainfed).

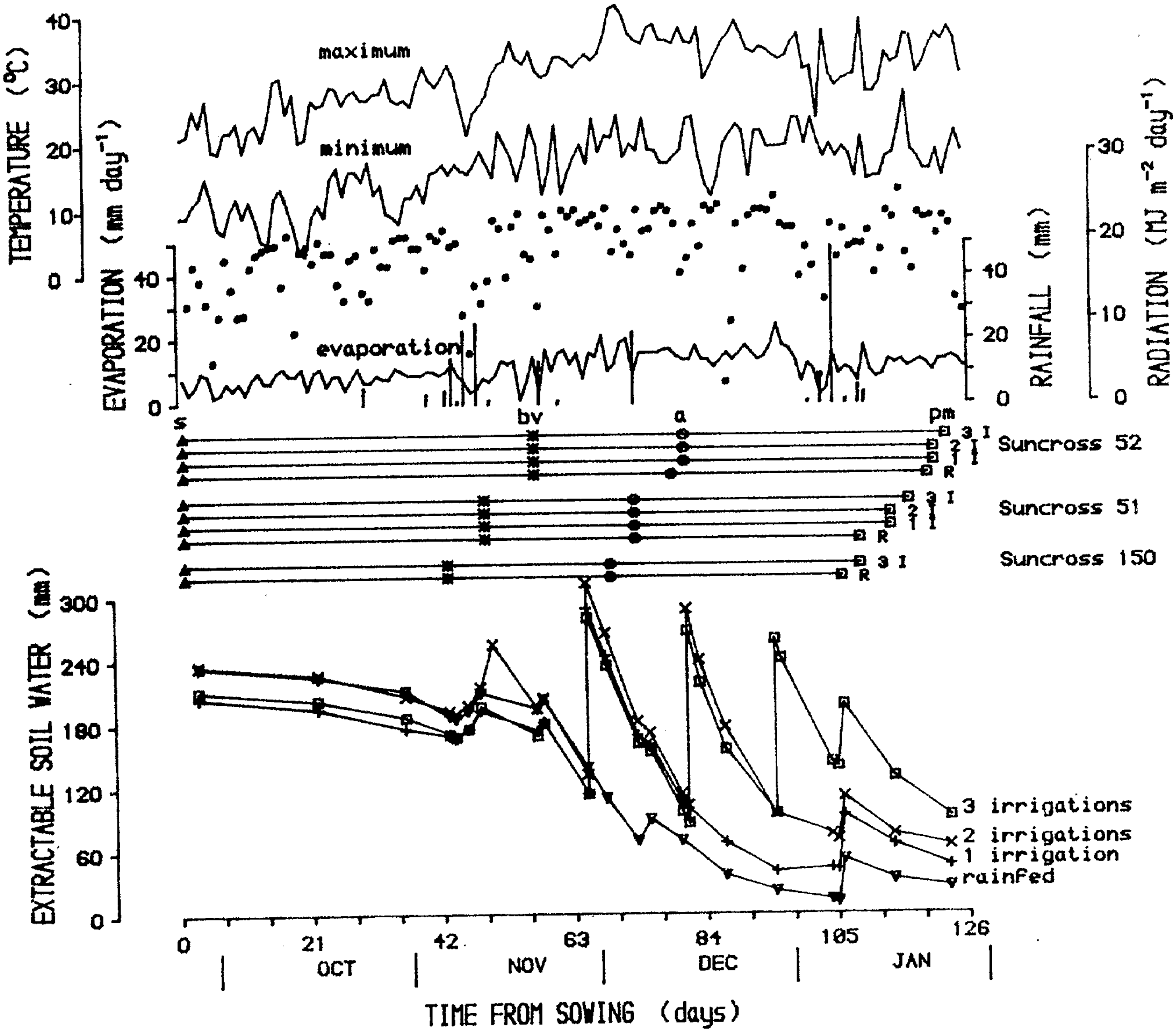


Figure 2. Daily maximum and minimum temperature, radiation, Class A pan evaporation and rainfall (bar graph), crop phasic development and extractable soil water for irrigated and rainfed sunflower cultivars in the 1980/81 season. (For key see Figure 1).

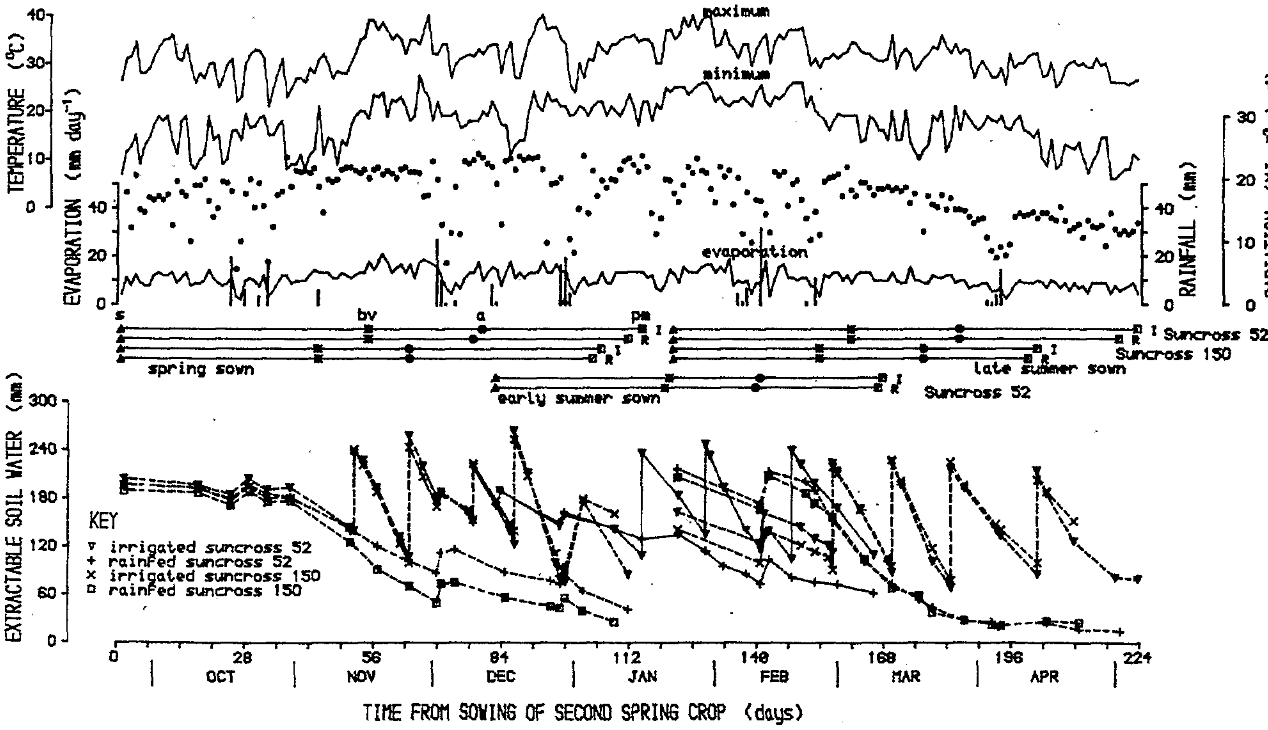
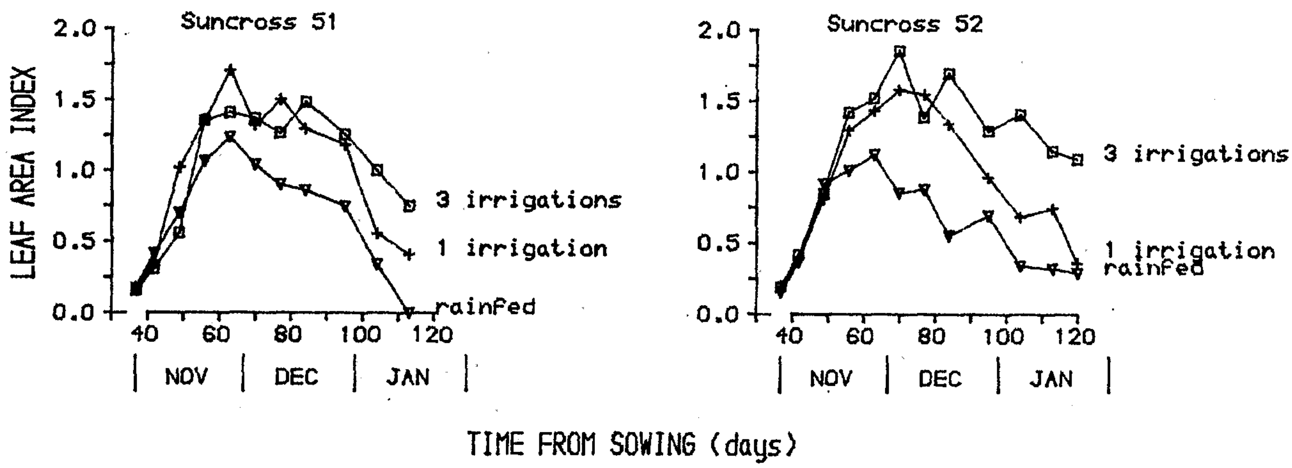


Figure 3. Leaf area index of mid-season and late cultivars of sunflower either fully irrigated (3 irrigations), stressed at anthesis (1 irrigation) or stressed pre-anthesis (rainfed).



The highest yield potential was shown by the late genotype under irrigation as would be expected. However, in rainfed conditions, yields were consistently only ≅ 25% of this potential. The highest rainfed yield was recorded from the mid-season cultivar in the first year. It should be noted that temperatures > 40°C at anthesis of the early cultivar in the first season (Figure 1) caused head blast in both rainfed and irrigated treatments. Heat waves occur as sporadic and unpredictable events in the region, and the yield of the early cultivar in the second season is considered to better reflect its long-term potential as a rainfed crop.

The yields of crops in the second season strongly reflect an effect of crop duration. A reduction in yield of irrigated crops of 1500 kg ha^{-1} was recorded as the length of crop growth was reduced by 30 days, relative to the spring sowing, when the crop was sown in early summer. A similar effect occurred when both cultivars sown in late summer yielded 100 kg ha^{-1} less than spring-sown ones. This latter result does not accord with earlier findings which indicated that the optimum sowing time in the region for rainfed crops is early February (Smith *et al.,* 1978b), when the period of maximum crop water requirement coincides with reduced evaporative demand, and the length of the seed-filling phase is increased by lower temperatures. It is not clear why these same principles did not apply but, in the current study, the length of the seed-filling growth phase of both cultivars was markedly shortened in the late sown crops and this undoubtedly contributed to the severe yield reduction. It may be that both cultivars are sensitive to reduced daylength.

Under rainfed conditions the yields of the early and late cultivars were not substantially different, indicating that there was no advantage to be gained from late genotypes when the water supply was limited to fallow storage and rainfall during crop growth. The earlier cultivars used the same total quantity of water as the late one (Dubbelde *et al.,* 1982) but, because of their shorter duration, there tended to be slightly more extractable water remaining in the profile at flowering (Figures 1 and 2). The yield potential demonstrated by the earlier cultivars under irrigation indicates they have the capacity to respond to seasons with better rainfall, and give yields comparable to those of late cultivars over a range of moisture conditions. It can be argued that this potential, coupled with the shorter duration, may lead to a reduced risk of yield loss with early cultivars in uncertain rainfall conditions.

If the shorter duration cultivars do use water more effectively in the development of yield, this should be reflected in better water use efficiency in the earlier cultivars under dryland conditions. A trend towards increased efficiency in the early and mid-season cultivars is suggested in the data (Table 1), but the variability in WUE was high. Evaluation over a wider range of seasonal rainfall conditions would be required to assess whether greater stability of production could be achieved with early cultivars.

CONCLUSION

This study was carried out in two seasons when the rainfall was well below the average for the area. The results for rainfed crops therefore can be expected to reflect the low end of a range of probable yields in the environment. The results relating to the effect of cultivar maturity type, while not conclusive, tend to suggest that earlier types may be more efficient in conditions of high rainfall variability. In order to test this, the results of this study will be used to further develop an existing simulation model of sunflower growth and development to allow the response of cultivars of different maturity types to be examined in a wide range of seasonal conditions.

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DETERMINATION OF REGIONAL STRATEGIES FOR SUNFLOWER PRODUCTION.

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ABSTRACT

Sunflower research by the Queensland Department of Primary Industries has been directed towards understanding crop adaptation via studies of the responses of growth and yield to climate and management variables. Results from these studies have been used to construct a dynamic crop simulation model which incorporates the interaction of climate with phenology, crop growth, leaf area development and water use.

To evaluate regional strategies, simulation studies using this model with historical weather records from sunflower production regions have been undertaken. This has enabled the determination of yield probabilities associated with the various strategies. A brief description of the model and an example of its use in determining the optimum time of planting and best cultivar type for a given region are presented.

INTRODUCTION

The development of oilseed sunflower production in Australia has been confronted with lack of knowledge on regional adaptation of the crop and on agronomic principles to guide husbandry practices. As climate is so variable, particularly in Queensland, no one agronomic practice is consistently superior to another. As a result, the optimum time of planting, plant population and most desirable cultivar vary from year to year and from site to site, depending on the conditions encountered during crop growth. Research by the Queensland Department of Primary Industries has therefore been directed towards understanding crop adaptation via studies of phenology, growth and yield responses to climate and management variables.

Traditional methods of conducting and analysing agronomic experiments lead to conclusions restricted to locations similar to the experimental sites and to a similar range of treatments. Little use is made of the data to extrapolate the findings to locations other than those in which the data were obtained. For crop adaptation studies this methodology requires long term experimentation at many sites. An alternative approach is to monitor relevant experimental variables and construct a comprehensive model of the crop system (Hammer, 1981).