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YIELD AND HARVEST INDEX OF SUNFLOWER CULTIVARS: INFLUENCE OF DURATION AND WATER STRESS.

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ABSTRACT

The yield and harvest index of 10 recent commercial Australian sunflower cultivars and 21 other lines and cultivars varying widely in maturity were measured with and without supplemental irrigation during a dry summer in Canberra, Australia. The harvest indices among the 10 commercial cultivars varied from 35 to 43% in the irrigated plots and from 33 to 38% in the unirrigated plots. The variation in the other 21 lines was greater, varying from 26 to 50% in the irrigated plants and from 16 to 43% in the unirrigated plants. The harvest indices were lower in the later lines than in the early lines in both the wet and dry plants, whereas seed yield increased linearly with time from sowing to anthesis in the irrigated sunflowers. Crop duration had no influence on yield in the unirrigated plants. A subsequent experiment with five of the cultivars showed that provision of water from just prior to anthesis increased the harvest index over that in the unirrigated and fully irrigated plots.

INTRODUCTION

The grain yield of a crop growing with a limited water supply can be conveniently considered as the product of three factors (Passioura, 1977), namely (i) the amount of usable water, (ii) the amount of dry matter produced per unit of water transpired, i.e. the water use efficiency, and (iii) the grain produced per unit of dry matter, i.e. the harvest index. Provided there are no negative interactions among these factors, improvement in any one will benefit yield. Donald and Hamblin (1976), working with cereals, suggested that selection for high harvest index rather than high yield may be desirable, particularly in early generation selections when single, spaced-plant yields will likely have little correlation with crop yield. The influence of water stress on harvest index has not been widely studied in sunflower. The present paper reports experiments in which the influence of water stress on the yield and harvest index of sunflowers was studied in a range of cultivars differing in duration.

MATERIALS AND METHODS

Ten recent commercial Australian sunflower cultivars — Rocket, Sunking, Sunace, Sungold, VNIIMK, Hysun 30, Hysun 31, Suncross 51, Suncross 52, Suncross 150 — were grown in a brown solodic soil (Sleeman, 1979) at the Ginninderra Experiment Station, near Canberra, Australian Capital Territory, during the 1979/80 growing season. Four rows, 0.75 m apart and 80 m long, of each cultivar were sown on 12 December 1979 with a pneumatic seeder to give a final plant population of 50,000 plants/ha. On an adjacent site 21 further sunflower lines and cultivars, containing four American-Indian lines (Arikara, Havasupai, Hopi, Seneca), seven early European and North American cultivars (Issanka, Majak, Manchurian, Polestar, Sunrise VNIIMK 6540, Yugor) and ten Queensland breeding lines (Q12349, Q12531, Q12353, Q12369, Q12463, Q12472, Q12721, A60 x R265, A60 x R226, A99 x R266), were planted in 42 plots, each 5 rows wide (0.75m between rows) and 3m long, to give a plant population of 50,000 per ha. The plants were sown into potting soil in 3.8 x 7.5 cm paper pots (Lannen Tehtaat, Finland) in the glasshouse on 27 November 1979. After emergence they were placed outdoors to harden and then were transplanted into the field on 12 December 1979. All plots were limed and given adequate fertilizer, and half the plots were irrigated regularly by overhead sprinkler to maintain the soil near field capacity. On 15 December 1980, five — Suncross 150, Polestar, Seneca, Havasupai and Manchurian — of the 21 cultivars were sown on an adjacent site in 30 plots; each plot was 4 rows wide (0.60 m between rows) and 4 m long with plants spaced to give the same population as previously. These plots were given one of four water treatments: WET, flood irrigated frequently throughout the season; DRY provided only with stored soil water by automatically covering the plot with a rain-out shelter whenever rain fell; REC 1, maintained as the DRY plots until 44 days after sowing and thereafter as the WET plots; REC 2, maintained as the DRY plots until 54 days after sowing and thereafter as the WET plots. Further details of the 1980/81 experiment are given in Rawson and Turner (1982a,b). The meteorologial conditions during the two seasons are given in Table 1.

Table 1. Mean monthly climatic variables at the Ginninderra Experiment Station, A.C.T. in the 1979/80 and 1980/81 growing seasons.

	December	January	February	March	April
1979/80					
Maximum temperature (°C)	27.8	25.6	27.7	25.8	21.
Minimum temperature (°C)	11.7	13.8	12.8	11.3	5.
Pan evaporation (mm)	277	228	204	184	107
Rainfall (mm)	0	49	44	23	3
Solar radiation (MJ)	28.3	22.9	23.2	18.6	13.
1980/81					
Maximum temperature (°C)	26.3	30.4	25.8	23.3	20.
Minimum temperature (°C)	12.4	16.0	14.9	9.8	6.
Pan evaporation (mm)	228	268	169	156	98
Rainfall (mm)	14	29	120	15	21
Solar radiation (MJ)	25.4	25.5	19.8	20.3	12.

In the 10 commercial cultivars studied in 1979/80, the mean date of first anthesis was recorded in the irrigated and unirrigated treatments. Shortly after anthesis, six 1 m lengths of row in each cultivar and treatment were randomly selected for harvesting. In the 21 lines and cultivars studied in 1979/80 and the 5 lines and cultivars studied in 1980/81, the date of first anthesis was recorded on 10 and 8 preselected average plants per plot, respectively. At physiological maturity (Browne, 1978), the plants were harvested, divided into head and stem plus leaves, oven dried at 85°C for 4 days and weighed. The seed was then threshed from the head, redried and weighed.

RESULTS

The range in time from sowing to first anthesis in the 10 recent Australian commercial cultivars was from 58 days in the irrigated Rocket to 73 days in the irrigated Sunking, Suncross 51, Suncross 52 and Hysun 31. The 21 lines and cultivars extended this range from 40 to 73 days: on average, the unirrigated plants reached first anthesis 2.8 days earlier than the irrigated plants. The date of first anthesis in the 5 lines and cultivars grown in 1980/81 ranged from 61 to 73 days from sowing and did not vary with treatment (Rawson and Turner, 1982a). Because of the warmer January temperatures in 1981 compared to 1980 (Table 1), the time from sowing to first anthesis was shorter in the 1980/81 season than in 1979/80; to make comparisons from year to year, the degree days from sowing to anthesis rather than days from sowing to anthesis was used as the index of crop duration:

$$\textbf{Degree days} = \sum_{s}^{a} (T - T_b)$$

where T is the daily mean temperature [(maximum temperature + minimum temperature)/2]; T_b is the base temperature (8°C; H.A. Nix, personal communication); S is sowing and A is anthesis.

Seed yields varied from 6 to 50 g/plant in the unirrigated plots and from 15 to 150 g/plant in the irrigated plots. Under unirrigated conditions, the American-Indian cultivars outyielded the other lines (Table 2) with Seneca yielding nearly 50 g/plant in 1980/81. Under irrigated culture, seed yield increased with increasing degree days from sowing to anthesis, but crop duration had no effect on yield in the unirrigated plants (Fig. 1).

The harvest index in the 10 recent commercial cultivars varied from 35 to 43% in the irrigated plots and from 33 to 38% in the unirrigated plots. The variation in the 21 lines and cultivars was greater, varying from 26 to 50% in the irrigated plants and from 16 to 43% in the unirrigated plants. In both irrigated and unirrigated plants the harvest index decreased with degree days from sowing to anthesis (Fig. 2). Since under irrigated culture the highest yielding cultivars were the late cultivars, this led to the harvest index decreasing with increasing seed yield per plant in this treatment (Fig. 3). Seed yield was similar at all harvest indices in the unirrigated sunflowers (Fig. 3).

Table 2. The mean time from sowing to first anthesis (days), seed yield per plant (g) and harvest index (%) of ten recent commercial cultivars, four American-Indian lines, seven earlier North American and European cultivars and ten Queensland breeding lines grown in 1979/80 with or without supplemental irrigation. Values are means ± one standard error of the mean.

Cultivar	Unirrigated			Irrigated		
	Days to Anthesis	Seed Yield	Harvest Index	Days to Anthesis	Seed Yield	Harvest Index
Recent Australian cultivars	69 ± 1	18.0 ± 2.4	35.6 ± 1.0	68 ± 2	36.1 ± 3.2	39.3 ± 0.8
American-Indian lines	60 ± 1	25.2 ± 3.2	34.2 ± 1.9	56 ± 1	58.4 ± 7.8	35.4 ± 2.8
Earlier cultivars	55 ± 2	12.5 ± 3.7	29.8 ± 2.8	51 ± 2	47.6 ± 8.0	40.7 ± 2.1
Queensland lines	56 ± 1	13.8 ± 2.5	32.7 ± 2.2	52 ± 2	50.5 ± 7.6	40.9 ± 2.2

Figure 1. Relationship between seed yield per plant and degree days from sowing to first anthesis for a range of sunflower lines and cultivars irrigated frequently (solid symbols) or unirrigated (open symbols). ●, ○, recent Australian commercial cultivars, 1979/80; ■, □ earlier commercial and non-commercial lines and cultivars 1979/80; and ▲, △, commercial and non-commercial lines and cultivars, 1980/81. The solid and dashed lines give the fitted linear regressions to the irrigated and unirrigated plants, respectively.

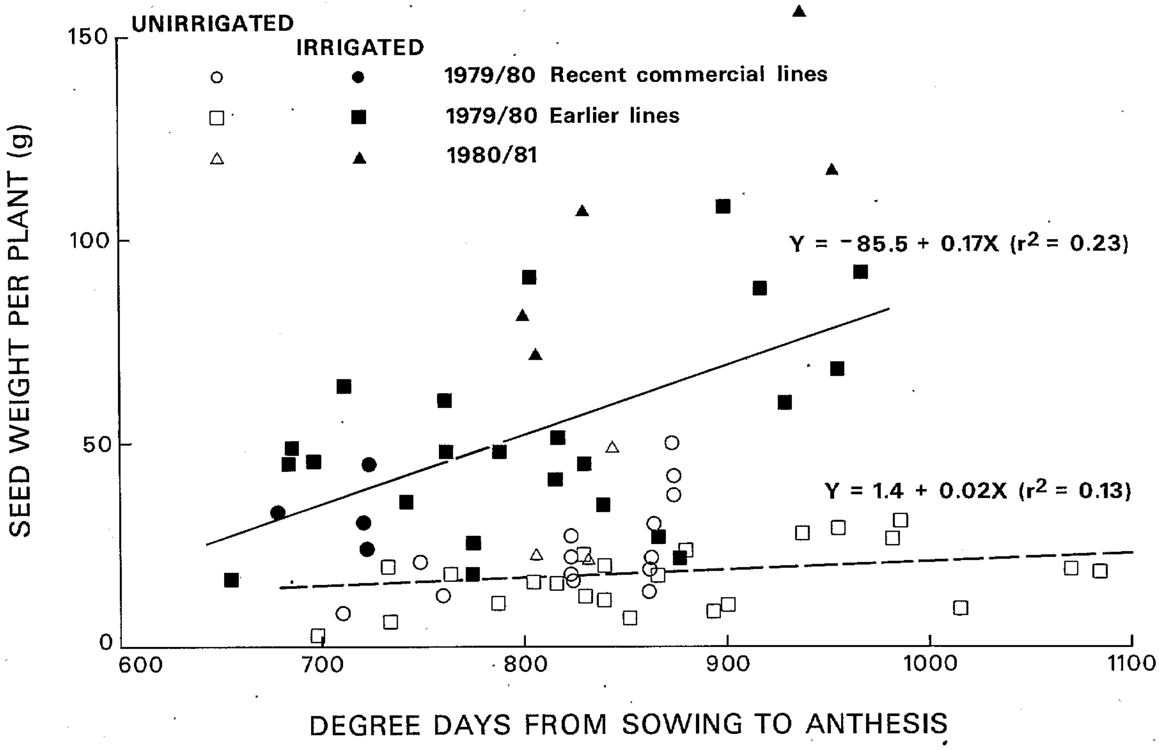
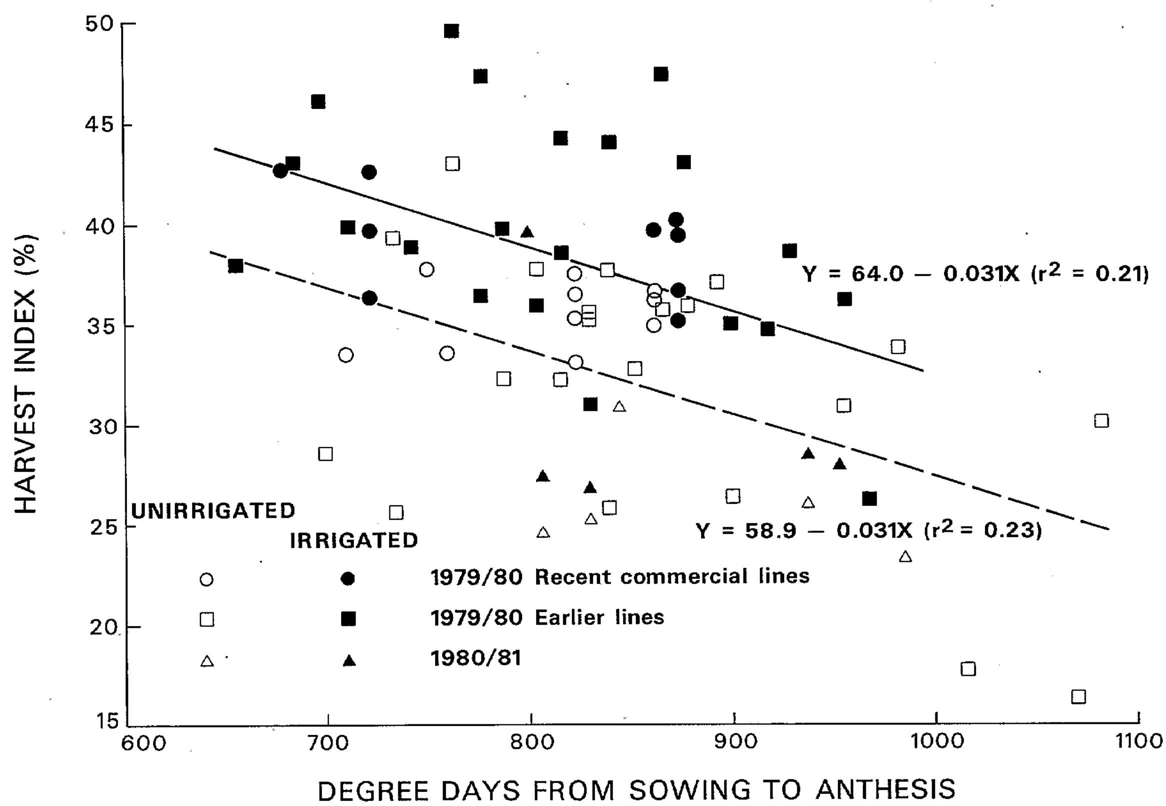


Figure 2. Relationship between harvest index and degree days from sowing to first anthesis for a range of sunflower lines irrigated frequently or unirrigated. Symbols as in Fig. 1.

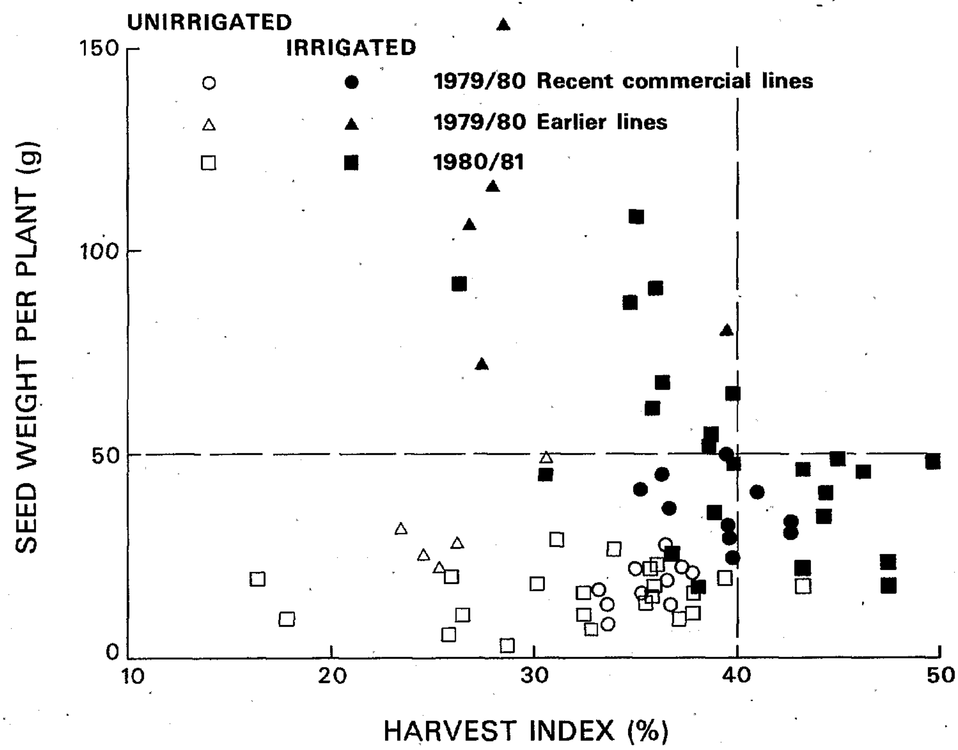


Delaying irrigation during vegetative growth led to an *increase in* the harvest index over that in plants that were frequently irrigated from shortly after sowing (Table 3). Moreover the delay did not cause any significant reduction in yield (Table 3).

Table 3. Mean seed yield per plant and havest index of five sunflower cultivars given four irrigation treatments: WET, frequent flood irrigation; DRY, grown on stored soil water only; REC 1, transferred from DRY to WET treatment 44 days from sowing; and REC 2, transferred from DRY to WET treatment 54 days after sowing. Means followed by the same letter are not significantly different at P = 0.05.

	WET	REC 1	REC 2	DRY
Seed yield per plant (g) (g)	.07a	117a	91ab	32b
Harvest index (%)	30.1b	33.2ab	38.6a	26.1b

Figure 3. Relationship between the seed yield per plant and harvest index in a range of sunflower lines irrigated frequently or unirrigated. Symbols as in Figure 1 except that the dashed lines depict a seed yield of 50 g per plant and a harvest index of 40.



DISCUSSION

The yield of irrigated sunflowers increased with increasing time from sowing to first anthesis (Fig. 1). Elsewhere we have shown that this arises because of the development of larger leaf areas and total dry matter yields in the later cultivars (Rawson and Turner, 1982a). The increase in yield in late cultivars was dependent in no part on harvest index as it in fact decreased in the late cultivars (Fig. 2).

Water stress reduced the yield in all cultivars to a constant low level which was independent of cultivar maturity (Fig. 1). This finding contrasts with that in cereals (see Turner and Begg, 1981), in which yields are reduced more by stress if they are late maturing. However, in these cereal studies the total water supply was generally fixed, whereas in the present study the soil water profile was fully recharged at the beginning of the experiment and later cultivars could have extracted more water from the profile than earlier cultivars. On average, severe water stress reduced the harvest index by about 5% in cultivars of all maturities (Fig. 2). Similar reductions in harvest index as a result of stress have been observed in cereals (Donald and Hamblin, 1976).

Water management also influenced the yield and harvest index of sunflower. Delaying the onset of irrigation reduced the total dry matter yield and presumably the seasonal water use, but did not reduce the seed yield because of the increase in harvest index. However, delaying the irrigation until too near anthesis did reduce yields because the water was applied too late for leaf expansion to recommence and the increase in the harvest index was insufficient to compensate for the loss in dry matter production (Rawson and Turner, 1982a,b). This suggests that the timing of stress rather than the degree of stress plays an important role in determining harvest index.

Under unirrigated conditions, the selections made by the American-Indians outyielded all other lines and cultivars, including the current hybrids and open pollinated lines. Indeed, in 1980/81 the highest yielding cutlivar under unirrigated conditions was an American-Indian cultivar, Seneca (Rawson and Turner, 1982a). The data in Fig. 2 suggest that the harvest index of sunflowers has increased as crop duration has decreased. The challenge for the breeder of irrigated sunflower is to increase the harvest index to greater than 40 in the later high yielding cultivars (Fig. 3) and for the breeder of sunflower for water-limited situations to incorporate high harvest indices into such high yielding dryland sunflowers as Seneca. However, as our data have demonstrated that harvest index and yield are not necessarily linked, it is essential to quantify both in any breeding programme.

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DETERMINATION OF PHYSIOLOGICAL AND HARVEST MATURITY IN SUNFLOWER.

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ABSTRACT

The time duration of two ontegenic periods was studied in several cultivars of sunflower. They were: the time from flowering to physiological maturity and the time from physiological maturity to harvest maturity. Grain weight, viability, oil and moisture content were measured weekly. The results show that physiological maturity was reached in all the cases 36 — 40 days after anthesis. The time from physiological maturity to harvest maturity was very variable ranging from 11 to 30 days. In both cases all variations were mainly due to climatic conditions without influence of the genotypic characteristics.

INTRODUCTION

Specifically for the sunflower crop, Anderson (1975) and subsequent works, consider physiological maturity as the time when the fruits of a head reach the maximum percentage of viability, oil content and dry weight.

This information if useful when it is necessary to predict the time of harvest of the sunflower crop.

Anderson (1975) determined that physiology maturity in sunflower is attained when cypsellae have a moisture content less than 40%, while Browne (1978) related the time at which the physiological maturity is attained to the natural fall of the floral vestiges.

Robertson (1978) determined that the maximum seed dry weight and the maximum oil content are attained 35 days after the beginning of flowering, and when the seed moisture content is 36%.

Ortegon Morales (1980) stated that physiological maturity was reached 25 days after the end of flowering in a trial conducted in Mexico.

MATERIALS AND METHODS

The trials were conducted at the Regional Agricultural Experimental Station, INTA, Balcarce. During the 1978/79 season, the determinations were done on two plots of the cultivar Continental P-75; in 1979/80 on a plot of the cultivar Continental P-75 and another on the cultivar Contiflor, and the last of the 1980/81 season was obtained on the cultivar Super-500. To do this, plants that flowered simultaneously were marked, considering that the flowering days was that on which the highest percentage of heads flowered, and discarding all the heads that had not yet flowered or that had begun to flower on previous days.

Ten heads were sampled every week till the natural drying of the plants. Of the seed obtained, 100 were dried in an oven with air circulation at 30°C, to determine viability. The rest of the seeds were weighed and dried in an oven with air circulation at 70°C, to determine the moisture content. Oil percentage was determined by the nuclear magnetic resonance method.

Germination percentage was determined in Petri dishes in an oven at 23°C, once the seeds had passed their dormant period.

The development of dry weight was studied by obtaining the weight of 1000 seeds of each head. In order to be able to relate the time in which the physiological maturity is attained with some morphological characteristics of the plant easily seen, color photographs of the plant were taken the day the samples were taken.

RESULTS AND DISCUSSION

The development of dry weight of 1000 seeds for the three cultivars used is shown in Table 1. In the 5 cases analysed, the maximum weight of 1000 seeds occurred between 36 and 40 days after flowering.