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WATER REQUIREMENT OF SUNFLOWER IN A SEMI-ARID ENVIRONMENT.

E.A. DUBBELDE, HAZEL C. HARRIS and J.R. McWILLIAM
Department of Agronomy and Soil Science, University of New England, Armidale, N.S.W. 2351. Australia.

ABSTRACT

In Australia much of the sunflower *(Helianthus annuus* L.*)* production occurs under rainfed conditions; most crops experience moisture stress at some stage of development. An understanding of crop water use patterns is necessary to devise production strategies which minimize stress. Sunflower cultivars, Suncross 150 (early), 51 (mid) and 52 (full season), were grown on an alluvial grey cracking clay soil at Narrabri, N.S.W., during 1979/80 and 1980/81. Furrow irrigation supplemented rainfall, allowing a range of soil moisture availabilities to be imposed from pre-anthesis, anthesis and mid-seed development to physiological maturity. Total crop water use ranged from 246 to 957 mm, consumption increasing with maturity type. Peak daily water use was 1.2 times Class A pan evaporation but declined after ≅ 30 percent of extractable soil water had been used. All cultivars under rainfed conditions extracted water to a depth of greater than 1.8 metres and dried the soil to the same water content. Crops sown in early summer were unable to dry the soil to the same moisture contents as either early spring or late summer-sown crops. These results are relevant to the management of rainfed sunflower crops.

INTRODUCTION

In Australia the major area of oilseed sunflower (*Helianthus annuus* L.) is grown under rainfed conditions in the semi-arid regions. This area is characterised by high temperatures, high radiation, high vapour pressure deficits and high rainfall variability, conditions which enhance the probability that periods of low soil moisture availability will occur. The successful growth of a crop species in the semi-arid regions is dependent upon the total water supply from both fallow storage and rainfall during crop growth, the pattern of utilization of this water during growth, the response of the crop to moisture deficits at different growth stages and the efficiency with which water is utilized in the development of yield. Species or cultivars capable of stress avoidance by establishment of a deep root system, rapid phasic development and restricted water usage under conditions of limited soil water supply are considered to have the best adaptation to the conditions of erratic moisture supply and terminal drought which characterizes many semi-arid environments (Turner, 1981). Manipulation of the time of sowing so that the period of maximum daily water usage coincides with an interval of reduced evaporative demand represents a management strategy which can contribute to stress avoidance.

Several studies have examined the water requirement of the sunflower crop. Estimates of evapotranspiration range from 150 mm for moisture-limited rainfed crops (Alessi *et al.*, 1977; Anderson, 1979) to 930 mm for a crop grown under moisture non-limiting conditions (Muriel *et al.*, 1974). Total evapotranspiration for irrigated crops is usually between 650 and 800 mm (Talha and Osman, 1975; Browne, 1977; Unger, 1978). Daily evapotranspiration is closely related to plant growth (Paltineanu and Sipos, 1974; Anderson, 1979) with maximum rates up to 1.3 times Class A pan evaporation at maximum leaf area (Anderson, 1979). The timing of the onset of conditions which restrict water use is closely related to the size of the soil moisture reserves and the pattern of their replenishment. Extractable soil moisture is dependent upon soil type and depth of rooting of the species. Measured depths of soil utilized by the sunflower range from 1.5 metres (Browne, 1977) to greater than 2.5 metres (Unger, 1978) on deep clay soils.

The work reported in this paper was designed to examine the effect of cultivar maturity type on a) to total water use, b) the pattern of water use during crop development and c) the ability to utilize soil water reserves under conditions of varying moisture supply and evaporative demand.

MATERIALS AND METHODS

The experimental work was conducted on the New South Wales Department of Agriculture Research Station at Narrabri in north-western N.S.W. Plots of the sunflower hybrids, Suncross 150 (early maturity), Suncross 51 (mid maturity) and Suncross 52 (late maturity), were sown and irrigated as shown in Table 1. Where appropriate, furrow irrigation was used to prevent Extractable Soil Water (ESW) from declining below 40 percent of maximum storage in the root zone. In the spring 1979 sowing, additional treatments were managed to induce severe stress from either the pre-anthesis, anthesis, or seed fill phase of development to physiological maturity. Detailed description of the experimental treatments, phasic development and ESW and climatic conditions during growth have been presented by Harris *et al.*, (1982).

Table 1. Cultivars, sowing dates and number of supplementary irrigations applied for sunflower sowings one to four at Narrabri during 1979/80 and 1980/81. Zero = rainfed; blank spaces indicate that the cultivar was not sown.

		Number of Irrigations Applied		
Sowing No.	Sowing Date	Suncross 150 (early maturity)	Suncross 51 (mid maturity)	Suncross 52 (late maturity)
1	25/09/79	0, 4	0,1,2,3,5	0,1,2,3,5
2	23/09/80	0, 4		0, 4
3	15/12/80			0, 3
4	21/01/81	0, 4		0, 4

Measurements: Soil moisture contents were measured by gravimetric sampling to 20 cm and with a neutron probe, calibrated for the site, at 20 cm intervals from 30 cm to either 170 or 210 cm depth. Crop water use was computed using the hydrological balance equation. Class A pan evaporation values were increased by 10.4 percent to compensate for the mesh screen (Stanhill, 1962) before calculation of the crop factor (Ea/Epan). Total Extractable Soil Water (ESW_{max}) (Ritchie, 1981) was calculated from the difference betwen the wettest soil moisture profile and the driest measured on the rainfed plots. The −1.55 MPa soil moisture profile was calculated from Mason (1979) using bulk densities measured at the site.

RESULTS AND DISCUSSION

Total water use ranged from 246 mm for rainfed Suncross 52 sown early summer (Sowing 3) to 957 mm for the same cultivar sown in early spring and fully irrigated (Sowing 1) (Table 2). Earling sowings (Sowings 1 and 2) of all cultivars consumed more water than the later sown crops under all conditions of moisture supply. Under irrigation, total use increased with increasing maturity type and increasing frequency of irrigation. The lower total water use by the irrigated early summer sown Suncross 52 (Sowing 3) (Table 2) was due to shortened crop duration in high temperatures. In contrast, virtually no effect of crop maturity type was found in rainfed crops in which total water use was limited to the ESW present at sowing, plus rain during growth. The only exception was when Suncross 52 utilized rain which fell after maturity of the other cultivars (Sowing 1). Differences in ESW at sowing and rainfall during crop growth account for differeces in total water use by rainfed crops sown at different times.

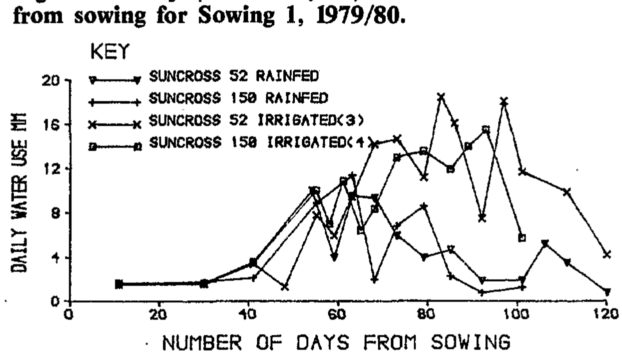
Table 2. Total water use by sunflower cultivars as influenced by time of sowing and number of irrigations.

				TOTAL WATER USE (mm)					
					Number of Irrigations				
Cultivar	Sowing No.	ESW at sowing (mm)	Total Class A pan (mm)	Rainfed	1	2	3	4	5
Suncross 150 (early)	1	217	1172	358				692	
	2	213	1241	305				593	
	4	180	911	261				564	
Suncross 51 (mid)	1	237	1266	361	534	670	764		834
Suncross 52 (late)	1	230	1340	419	551	709	830		957
	2	220	1373	314				799	
	3	191	988	246			555		
	4	191	999	251				677	

The values of total water use are in agreement with Paltineanu and Sipos (1974), Talha and Osman (1975), Alessi *et al.*, (1977), Browne (1977), Jessop (1977) and Anderson (1979) for both irrigated and rainfed crops with the totals for irrigated and early sown rainfed crops at the upper end of their respective ranges. The higher total water use by the early sówn crops (Sowings 1 and 2) is consistent with the higher values measured for early sown rainfed crops by Alessi *et al.*, (1977) and Jessop (1977) and is in accord with the higher total pan evaporation measured for these crops (Table 2). Under the high evaporative conditions of a semi-arid region, total water use by a sunflower crop will be high were the supply of water does not fall below critical levels until an advanced stage of growth.

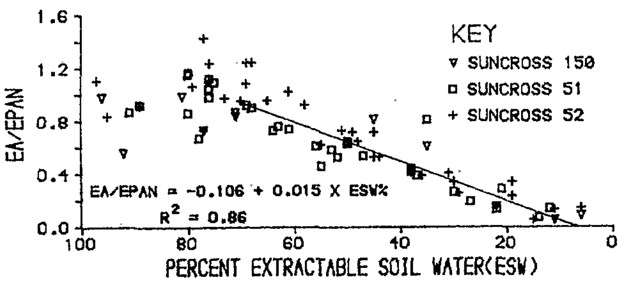
Daily water use for the rainfed and irrigated treatments of Suncross 150 (early) and Suncross 52 (late) are illustrated for Sowing 1 in Figure 1. The rate of use was the same for all treatments to approximately the buds visible stage of growth, after which usage by rainfed crops was limited by reduced soil water levels (Harris *et al.*, 1982). Maximum daily usage by irrigated crops was 18 mm per day or 1.2 time corrected pan evaporation. Suncross 150 required approximately 2 mm per day less water than the late maturing cultivar at maximum usage which accounts for approximately 50 percent of the difference in total water use between the early and late maturing cultivars. The remaining difference resulted from reduced crop duration of the early cultivar. Patterns of daily water use observed in this study are consistent with those previously published (Muriel *et al.*, 1974; Talha and Osman, 1975; Anderson, 1979) except that the maximum daily rates are several millimeters per day higher than those previously reported.

Figure 1. Daily water use (mm) as a function of time from sowing for Sowing 1, 1979/80.



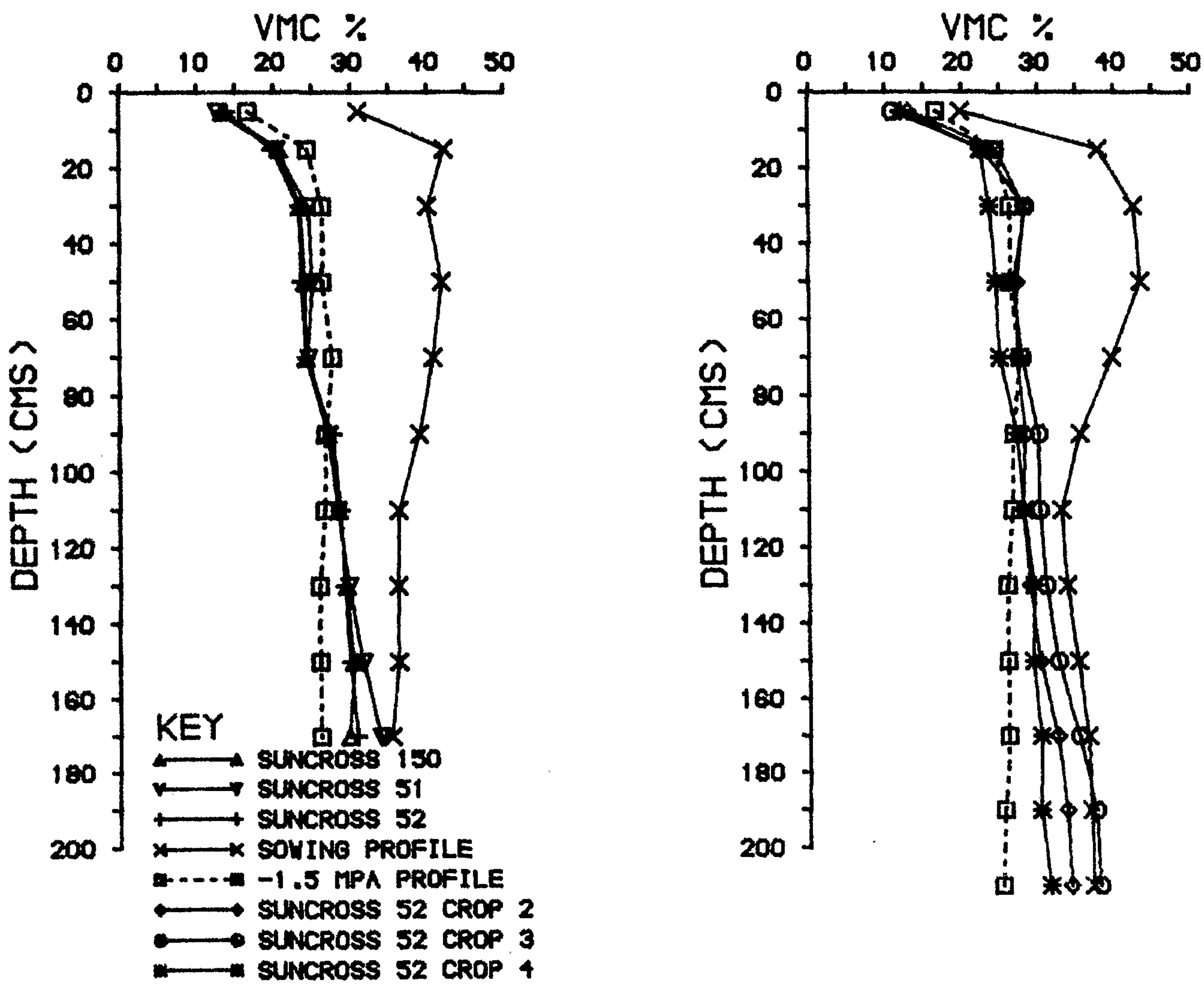
The daily water use at maximum LAI for Sowing 1 was apparently not limited by ESW in the range of 70 — 100 percent ESW_{max} but below approximately 70 percent the crop factor (Ea/Epan) declined linearly to close to zero at zero ESW (Figure 2). There was no clear difference between cultivars. Data from Sowings 2 and 4 (unpublished data) verified this relationship, suggesting that the time of sowing (evaporative demand) had no effect. These data suggest that the value of 40 percent of ESW_{max} remaining in the soil, used in this study to schedule irrigations, would have resulted in some reduction in the rate of water use between irrigations and hence the measured total water use would not have been at its maximum. Work on cotton (Cull, 1979) and soyabeans (Mason, 1979) had shown that water use was not limited until about 40 percent of ESW_{max} remained in the profile on the Narrabri grey clays. However, Anderson (1979) also found that the value of Ea/Epan of sunflower began to decline at approximately 70 percent of ESW_{max}, although the very rapid rate of decline when ESW decreased below 70 percent shown by that study is difficult to accept and is not supported by the consistent findings of the current study. The early modification of daily water use as soil water declines suggests that sunflower has good adaption to conditions of limited moisture supply. However, many of the potential benefits of this early reduction in the rate of usage may be offset by the high initial rates of water use.

Figure 2. The relationship of the crop factor (Ea/Epan) to Extractable Soil Water (ESW) for Sowing 1.



All cultivars extracted water to depths in excess of 1.8 m in Sowing 1 (Figure 3a). Whilst the data suggests that Suncross 51 may be slightly less efficient than the other cultivars in extraction of water at depth, there is essentially no effect of cultivar on the profile drying pattern. The −1.5 MPa profile is illustrated for comparison. The absence of differences between cultivars in their ability to extract soil water shows that decreasing maturity time has not reduced the sunflower's ability to exploit its soil environment.

Figure 3. (a) Driest soil moisture profiles measured for 3 cultivars of sunflower, Sowing 1 spring 1979.
b) Driest soil moisture profiles measured for Suncross 52 sown during spring, early summer and late summer 1980/81.



Soil water extraction by the rainfed Suncross 52 was influenced by time of sowing in the second season (Figure 3b). The crop sown in early summer (Sowing 3) extracted less water from much of the profile than the spring sown crop (Sowing 2) which, in turn, was less efficient at depths below 1.5 m than the crop sown in late summer (Sowing 4). It is of note that there was some movement from depths greater than 2.1 m (the sampling depth) for the latter two crops. Apparent differences in water extraction in the first meter of the profile were due to rain late in crop development of Sowings 2 and 3. The reduced growth period of Sowing 3 (Harris *et al.*, 1982) may have meant that the plant had insufficient time to develop a root system capable of drying the lower profile to the moisture contents reached by Sowings 1, 2 and 4. This suggests that crops sown in early summer will make less efficient use of stored soil water and will therefore be more reliant on rainfall during crop growth.

CONCLUSION

Sunflower has a high total water requirement when grown in a semi-arid environment. Where total pan evaporation during crop growth exceeds 900 mm, water use by irrigated crops will total 50 — 70 percent of free water evaporation. The maximum total usage (mm) by an irrigated crop can be expected with spring sowing and/or use of late maturing cultivars. The lower total requirement of early maturing cultivars under irrigation is due to lower maximum rates of daily water use and a shortened crop duration. Under conditions of limited moisture supply early maturing cultivars are able to extract the same quantity of water from the soil as late maturing ones. The sunflower's ability to reduce rates of daily water use at high (≅ 70%) values of ESW could be regarded as a beneficial mechanism to conserve water for later growth. However, its value may be offset by rates greater than Epan when soil water levels are above 70 percent ESW. Spring sowings have a higher total water requirement than later sown crops due to increased crop duration and high evaporative demand during the period of maximum daily water usage. These findings have implications for the efficient use of water in yield development which are discussed by Harris *et al.*, (1982). They also emphasize the importance of fallow water storage for rainfed crop production in an area of unreliable rainfall.

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EFFECT OF IRRIGATION ON WATER USE PATTERN IN SUNFLOWER ROOT ZONE.

NOVICA VUCIC and DJURO BOSNJAK
Faculty of Agriculture, Novi Sad, Yugoslavia.

ABSTRACT

The establishment of a deep root system in sunflower allows the crop to extract water and nutrients from deeper soil layers. Thus sunflower can grow more successfully than many other field crops under conditions of low rainfall. It was found that on calcareous chernozem soil in Yugoslavia sunflower used 1,600 — 1,900 m^3 ha^{-1} of water stored in the profile at beginning of crop growth and extracted from soil down to 2 m. This represents one half on the total crop requirement. The remainder should be provided by rainfall or by irrigation during the growth of the crop. Irrigation, however, makes sunflower plants less able to extract water from deeper layers and, depending on the irrigation schedule, they take only 700 — 1,000 m^3 ha^{-1} of the initial water stored, or one half of the amount extracted from the profile if irrigation is not applied. These considerable differences are important not only from a theoretical aspect but also from practical considerations because they affect the calculation of water balance and irrigation water requirements.

INTRODUCTION

Sunflower plants have a root system capable of taking up water and nutrients from deep soil layers. This is why sunflowers may be grown with more success than other field crops in conditions of unfavorable soil moisture. Several factors determine the amounts of water that sunflower plants may take up from deep soil layers. These include the quantity of reserve water in soil which, in turn, is related to the rainfall