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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LITERATURE CITED

ALLESSI, J., POWER, J.F. and ZIMMERMAN, D.C. 1977. Sunflower yield and water use as influenced by planting date, population and row spacing. *Agronomy Journal* 69, 465 — 469.

ANDERSON, W.K. 1979. Water use of sunflower crops. *Australian Journal of Experimental Agriculture and Animal Husbandry* 19, 233 — 240.

BROWNE, C.L. 1977. Effect of date of final irrigation on yield and yield components of sunflowers in a semi-arid environment. *Australian Journal of Experimental Agriculture and Animal Husbandry* 17, 482 — 488.

CULL, P.O. 1979. Irrigation scheduling of cotton by computer. Unpublished Ph.D. thesis, University of New England, Armidale. N.S.W.

HARRIS, HAZEL C., DUBBELDE, E.A. and McWILLIAM, J.R. 1982. Growth and development of sunflower in a semi-arid environment. *Proceedings 10th International Sunflower Conference,* Surfers Paradise, Australia (In Press).

JESSOP, R.S. 1977. Influence of time of sowing and plant density on the yield and oil content of dryland sunflowers. *Australian Journal of Experimental Agriculture and Animal Husbandry* 17, 664 — 668.

MASON, W.K. 1979. The irrigation scheduling of soyabeans. Unpublished Ph.D. thesis, University of New England, Armidale, N.S.W.

MURIEL, J.L., GIMENEZ, R and BERENGENA, J. 1974. Yield of sunflower in field plots in response to various watering regimes and to irrigation during critical phases of growth. *Proceedings 6th International Sunflower Conference,* Bucharest, Romania, 577 — 581.

PATINEANU, RODICA and SIPOS, G.H. 1974. Evapotranspiration of the irrigated sunflower. *Proceedings 6th International Sunflower Conference,* Bucharest, Romania, 145 — 151.

RITCHIE, JOE T. 1981. Water dynamics in the soil-plant-atmosphere system. In *'Soil Water and Nitrogen in Mediterranean-type Environments.'* (Eds.) J. Monteith and C. Webb, Martinus Nijhoff/Dr. W. Junk Publishers, The Hague (1981), pp. 81 — 96.

STANHILL, G. 1962. The control of field irrigation practice from measurements of evaporation. *Israel Journal of Agricultural Science* 12(2), 51 — 62.

TALHA, M. and OSMAN, F. 1975. Effect of soil water stress on water economy and oil composition in sunflower (*Helianthus annuus* L.). *Journal of Agricultural Science,* Cambridge 84, 49 — 56.

TURNER, NEIL C. 1981. Designing crops for dryland Australia: Can the deserts help us? *Journal of the Australian Institute of Agricultural Science* 47, 29 — 34.

UNGER, P.W. 1978. Effect of irrigation frequency and timing on sunflower growth and yield. *Proceedings 8th International Sunflower Conference,* Minneapolis, U.S.A., 117 — 129.

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

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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 outside the sunflower growing season and field water capacity of the soil.

Irrigated sunflower crops however, do not extract water as well from deeper soil layers. This change should be taken into account when calculating water balance and irrigation water requirements.

MATERIALS AND METHODS

In field trials with sunflower irrigated according to soil moisture, water balance to the depth of 2 meters was calculated at the end the growing season. In the first year, large differences were observed between the irrigated and non-irrigated treatments regarding the water uptake from deeper soil layers. This phenomenon prompted us to try to determine the soil moisture extraction pattern of sunflower along the depth of soil profile and the changes in the pattern caused by irrigation.

Experiments were conducted on calcareous chernozem soil developed on a loess terrace. This soil type has favorable physical properties, and loamy texture. The irrigation calculated for the soil layer to 60 cm, was 60 mm applied by sprinkling. Soil moisture was determined by the gravimetric method in three reapplications, in 20 cm layers.

RESEARCH RESULTS AND DISCUSSION

Although it had been expected that the irrigation to the depth of 60 cm would reduce the activity of the sunflower root system in deeper soil layers, the results obtained in the first year surpassed our expectations. Depending on the pre-irrigation soil moisture levels, the irrigated sunflower took up 2 — 3 times less water from deeper soil layers than the non-irrigated sunflower (Table 1). The above figures include the total water expenditure through evapotranspiration i.e., one portion stands for water which evaporated from the soil, primarily from the upper soil layers. However, the figures for water expenditure in deeper soil layers stand mostly for transpiration which depends on root activity. There is no doubt that water movement in soil, especially of capillary water, affects water expenditure. However, when soil moisture reaches the level of lentocapillary water in the soil. Film water moves very slowly so that further reductions of water content below the level of lentocapillary moisture signify an intensified activity of root system.

Soil moisture in some layers in the plots under non-irrigated sunflower reached the wilting point while in the plots under irrigated sunflower it mostly stayed at the level of lentocapillary moisture (Table 2).

Water expenditure in irrigated treatments was lower because soil moisture would decrease to the level representing the point of transition to slow moving water forms while the root activity is low. The differences are pronounced in soil layers from 60 to 160 (Tables 1 and 2).

It is obvious that non-irrigated sunflower used large quantities of water from deeper soil layers. In our case, the average amount was over 1,700 m^3 ha^{-1} to the depth of two meters. This amount is more than a half of total requirements of sunflower grown in Vojvodina Province (Yugoslavia). The remaining portion should be provided from the rainfall during the growing season. If the rainfall is insufficient, irrigation is applied wherever it is possible. It is thus possible to forecast reliably the yields of sunflower grown in certain climatic conditions (a stable rainfall during the growing season) on the basis of soil moisture at the beginning of the growing season.

In irrigation, however, sunflower plants are less active regarding the uptake of water from deeper soil layers. This is normal because sufficient quantities of readily available water are continually present in the soil layer to 60 cm. The quantities of water taken up from deeper soil layers are reduced by half, amounting to 700 — 1,000 m^3 ha^{-1} depending on the irrigation schedule. The higher the pre-irrigation soil moisture, the lower the uptake from deeper soil layers and vice versa.

At this point there comes a practical question: which quantities of water taken up from deeper soil layers should be taken into account when considering and calculating water balance. It is certain that lower values should be used when considering irrigation meaning that the irrigation water requirements will be larger. On the other hand, if we consider the amount of reserve soil moisture available to sunflowers in order to estimate the availability of water in conditions without irrigation, higher values should be used.

This question is doubtlessly equally interesting for theory and practice. It is certain that sunflower is not an exception in this respect but it is also quite probable that the pattern of use of water from deeper soil layers of sunflower differs from the patterns of other crops which also differ from sunflower in root systems and their characters. The soil, its texture and properties may also affect the soil moisture extraction pattern.

Table 1. Water Consumption (m^3 ha^{-1}) by sunflower plants dependent on irrigation treatments.

Irrigation Treatments	Year	soil depth, cm 0 — 10	10 — 20	20 — 40	40 — 60	60 — 80	80 — 100	100 — 120	120 — 140	140 — 160	160 — 180	180 — 200	Total
Irrigated at 70%of Field Water Capacity (FWC)	1976	−29	−9	−29	125	0	145	59	11	22	166	227	688
	1977	16	16	111	60	76	68	67	64	74	81	193	826
	1978	12	15	20	60	113	100	125	72	5	168	3	693
	Average	0	7	34	82	63	104	84	49	34	138	141	736
Irrigated at 60% of FWC	1976	1	6	7	119	39	118	56	25	−11	101	305	766
	1977	28	28	138	68	139	170	113	42	111	62	46	945
	1978	13	18	20	87	149	144	145	105	25	192	50	947
	Average	14	17	55	91	109	144	104	57	42	118	134	886
Irrigated According to the Critical Phases	1976	49	−3	24	272	254	265	191	99	142	151	318	1762
	1977	42	42	42	8	16	16	37	58	54	59	148	522
	1978	21	9	26	138	165	111	104	94	−4	40	37	741
	Average	37	16	31	139	145	131	111	84	64	83	168	1008
Check — non Irrigated	1976	45	22	174	244	283	254	198	174	115	178	275	1962
	1977	39	39	177	207	194	176	231	205	167	90	116	1641
	1978	13	13	138	164	178	258	273	231	204	109	63	1645
	Average	32	25	163	205	218	229	234	203	162	126	151	1749

Table 2. Soil Moisture (% by mass) at the End of Sunflower Vegetation Period.

Irrigation Treatments	Year	soil depth, cm 0 — 10	10 — 20	20 — 40	40 — 60	60 — 80	80 — 100	100 — 120	120 — 140	140 — 160	160 — 180	180 — 200
Irrigated at 70% of FWC	1976	24.6	26.2	25.8	20.9	24.1	16.6	18.0	18.2	17.0	12.1	13.0
	1977	21.9	21.9	20.9	21.9	20.9	19.7	18.3	17.2	16.2	14.1	11.0
	1978	24.5	24.9	24.5	23.5	20.9	18.4	17.7	17.4	17.1	13.5	14.0
	Average	23.6	24.3	23.8	22.1	22.0	18.3	18.0	17.6	16.8	13.1	12.7
Irrigated at 60% of FWC	1976	21.9	24.8	24.4	21.1	22.5	17.6	18.0	17.7	18.1	14.3	10.5
	1977	20.8	20.8	19.9	21.6	18.5	15.8	16.7	17.9	14.9	14.7	15.7
	1978	24.4	24.8	24.7	22.9	19.6	16.7	16.5	16.3	16.4	12.4	12.5
	Average	22.4	23.5	22.9	21.7	20.2	16.7	17.1	17.3	16.5	13.8	12.9
Irrigated according to the Critical Phases	1976	17.6	25.7	23.6	15.4	14.3	20.0	13.2	15.4	13.0	12.7	10.1
	1977	19.5	19.5	23.7	23.8	24.5	22.7	19.4	17.4	16.9	14.8	12.5
	1978	23.7	24.4	22.7	19.3	19.0	18.0	17.9	16.7	17.4	17.4	12.9
	Average	20.0	23.2	23.3	19.4	19.3	20.3	16.6	16.4	15.8	15.0	12.0
Check — non Irrigated	1976	17.9	23.4	17.4	16.5	13.2	12.4	12.9	12.7	13.9	11.7	11.5
	1977	19.8	19.8	18.1	16.5	16.4	15.6	12.5	12.5	13.1	13.8	13.5
	1978	23.5	23.0	18.1	16.3	15.9	13.7	13.1	14.3	15.5	15.7	17.9
	Average	20.4	21.1	17.9	16.4	15.2	13.9	12.8	13.2	14.2	13.7	14.3
Field Water Capacity		26.7	26.7	26.7	26.2	24.8	24.8	24.8	23.1	23.1	23.1	20.7
Wilting Moisture		10.9	10.9	10.9	11.2	11.3	11.3	11.3	8.7	8.7	8.7	8.9
Lentocapillary Moist. (all % by mass)		15.6	15.6	15.6	16.8	17.1	17.1	17.1	12.0	12.0	12.0	12.7

CONCLUSION

Sunflower grown without irrigation takes up considerable quantities of reserve water from deeper soil layers. On calcareous chernozem on loess terrace in Yugoslavia, sunflower takes up 1,600 — 1,900 m^3 ha^{-1} of water from soil layers to the depth of two meters. This quantity amounts to one half of total water requirements of sunflower. The remaining portion is provided by rainfall during the growing season.

In conditions of irrigation, however, the sunflower root system is less active, taking only a half of the normally taken quantities of water (700 — 1,000 m^3 ha^{-1}, or even less than a half in some years.

This phenomenon bears both theoretical and practical importance because it affects the calculation of water balance and the irrigation practice. The phenomenon has been neglected until recently because the soil moisture extraction pattern of a certain crop had been considered immutable regardless of the variation in other factors.

INFLUENCE OF PLANT POPULATION ON PHASIC DEVELOPMENT, GROWTH, YIELD AND WATER USE OF IRRIGATED SUNFLOWER IN A SEMI-ARID ENVIRONMENT.

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ABSTRACT

Sunflowers are an established irrigated crop in Australia but recommendations for optimum plant population are widely divergent. To assist in clarification, populations of 50, 80, 110 and 140 thousand plants ha^{-1} were grown in hilled rows 75 cm apart. Soil type was a heavy grey clay (60% clay). Furrow irrigation was applied at an interval of 70 mm of estimated evapotranspiration. Irrigation water was metered onto the plots and a water balance approach was used to calculate water use. Crop development, ground cover and plant height development with time, seed yield, yield components, total dry matter production and oil content were also measured. Population had no effect on phasic development with bud appearance, peak flowering and physiological maturity occurring 35, 55 and 89 days after emergence, respectively. There was a significant difference in percent ground cover at 19 and 26 days after emergence but all populations achieved a similar ground cover by day 35 (80%). Seed yield was significantly highest from 50 and 80 thousand plants ha^{-1} but differences between populations would be of little practical significance. The data presented indicate the ability of the sunflower plant to compensate for large differences in plant numbers. Water use at 695 mm was not greatly influenced by population, and represented 85% of pan evaporation.

INTRODUCTION

Sunflowers (*Helianthus annuus*) are an established irrigated summer crop in Australia but recommendations for optimum plant population under irrigation are widely divergent. Schuppan and Thomas (1976) recommend a plant population of 100,000 plants ha^{-1} for northern Victoria, while 60,000 plants ha^{-1} (Matheson, 1976) and 100 — 110,000 plants ha^{-1} (Anon. 1972) are both recommended for New South Wales.

This paper reports an experiment conducted to examine the influence of plant population on phasic development, growth, yield and water use of sunflowers in the semi-arid environment of southern New South Wales.

MATERIALS AND METHODS

The experimental site was on the Leeton Agricultural Research Station (lat. 34°28'S, long. 146°25'E) in the Murrumbidgee Irrigation Area. The soil type was a grey, texturally undifferentiated heavy clay soil (van Dijk, 1961) with an available water content of the top 120 cm of 185 mm. As hydraulic conductivity of the subsoil is low, drainage beyond the root zone would have been minimal. There was no effective water table.

During the period of growth, rainfall was 133 mm, evaporation (U.S. Class A pan) averaged 8.5 mm per day, mean maximum temperature was 31°C and mean minimum temperature was 17°C. All components were average except minimum temperature which was 1.6°C above the long-term mean.