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Effect of Sowing Date on Water Use Efficiency of Sunflower Crop

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Abstract

Results of a trial carried out on sunflower in order to evaluate the most appropriate sowing date and irrigation regime for a more efficient water use are reported. Sunflower was sown in 1995-1996 at the usual date (end of April) and in advance (end of March). It was subjected to three irrigation regimes: full restoration of consumptive water use, supplementary irrigation at the bud stage and flowering and unirrigated control. During the growing cycle, the following parameters were measured: water use, the main climatic data that can affect growth and evapotranspiration, yield and its components. Despite the lower vapor pressure deficit of the air during the cropping cycle of the first sowing date caused a reduction in the average daily evapotranspiration, the colder temperature regime of this period, by making longer the growing cycle, caused almost the same total water use respect to the usual sowing dates. However, with early sowing, the crop could benefit from the spring rainfall at the initial stages of its cycle that reduced the seasonal irrigation volume, in the case of full irrigation and made available a greater amount of water in the case of unirrigated treatment or with supplementary irrigation. The greater water availability in the stressed treatments also produced higher grain yield in early sowing, so that an interesting interaction between the sowing date and the irrigation regime in terms of water use efficiency was observed. In fact, a significant higher irrigation yield water use efficiency and an interesting yield response was measured in the treatment with supplementary irrigation of the first sowing date. No effect of sowing date, both in terms of yield that of water use efficiency was measured in the treatment irrigated with the full restoration of evapotranspiration.

Key-words: Sunflower, sowing date, irrigation scheduling, irrigation yield water use efficiency, yield response.

1. Introduction

Variation in sowing date modifies the radiative and thermal conditions during crops growing cycle (Cirilo and Andreade, 1994a). Low temperatures and high air humidity that generally occur at the early sowing dates of summer crops, by lowering the vapour pressure deficit of the air, can reduce the crop evapotranspiration. Also, at the early sowing dates, spring rainfall can be effective to the crops water requirements. However, temperature also affects growing cycle duration, photosynthesis and radiation use efficiency (Cirilo and Andreade, 1994a) and, consequently, the dry matter accumulation.

Sunflower is neutral to photoperiod, so the shortening of growing cycle observed delaying the sowing date is a mere consequence of the increase in daily thermal units (Santamaria et al., 1991). Temperature also affects sunflower photosynthesis (Fock et al., 1979) and reproductive organs formation (Giannini et al., 1988).

The yield response is influenced by dry matter accumulation and its partitioning and translocation between vegetative and reproductive organs, in addition to the number and the specific weight of reproductive organs (Vannozzi et al., 1999). One study made by Cirilo and Andreade (1994b) and Quaranta et al. (1988) on maize, emphasized a significant reduction in the number of kernels per spike and the number of spikes per unit area by delaying the sowing date.

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Thus significant effects of these environmental factors on growth, productivity and water use efficiency of summer crops could be expected shifting the sowing date in temperate regions.

The aim of this study was to determine the effect of sowing dates on dry matter accumulation, yield, water use and water use efficiency of sunflower crop subjected to different irrigation regimes. The ultimate goal is to detect the most efficient use of the irrigation water in an area (southern Italy) characterized by scarce water resources.

2. Materials and methods

The trial was carried out in the two-years period 1995-96 in southern Italy (Matera, 40° N, 16° E), on a deep sandy-loam soil, rich in organic matter, with a good chemical fertility and a moisture content on weight basis of 32.8% at field capacity (-0.03 MPa) and 17.0% at the wilting point (-1.5 MPa). Commercial hybrid Romsun HS 90 was sown on March 20 and April 24 in 1995 and on March 25 and April 29 in 1996, with a plant density of 5.5 plants m^{-2}. At each sowing date, three irrigation regimes were applied: unirrigated control (Vo), supplementary irrigation (with an irrigation volume of 500 m^3ha^{-1}) at the bud stage and anthesis (Vs) and restoration of 100% of maximum crop evapotranspiration (ETc, V_{100}). In the V_{100} treatment, the ETc was estimated by multiplying the reference evapotranspiration (ETo) calculated through the FAO modified Blaney-Criddle equation by the Kc coefficients obtained in the same area (Rizzo et al., 1989). The irrigation moment in the V_{100} treatment was established by keeping constant the set point (equal to 30 mm of ETc until reaching 50% ground cover and 50 mm later on) and by changing the irrigation interval. The other cropping practices consisted in fertilization, weed and pathogen control.

The experiment was analyzed as split-plot factorial design, with, sowing dates in the main plot and irrigation regimes in the split-plot.

During the growing cycle the main climatic data (temperature, humidity and rainfall) were daily recorded; at harvest, the total aboveground dry matter, yield and its components were measured. Total water use was computed by the hydrologic balance and water use efficiency was calculated as the ratio of total aboveground dry matter respect to total water use (WUE, Kg m^{-3}) and as the ratio of yield respect to seasonal irrigation volume (IYWUE, Kg m^{-3}).

3. Results and discussion

3.1 Water use and seasonal irrigation volume

Cooler air temperature and higher relative humidity reduced the average vapor pressure deficit of the air (v.p.d.) of the early sowing date respect to the ordinary sowing date in both the experimental years (Table 1).

Total rainfall was 65 and 56 mm higher, respectively, in 1995 and 1996 at the early sowing dates and 104 and 95 mm higher in the first year, respectively at the first and the second date (Table 1).

The lower v.p.d. of the air measured during the growing cycle of the first sowing date reduced the daily maximum crop evapotranspiration respect to the second sowing date (4.7 and 5.8 mm d^{-1} as an average of the two-years of the well watered treatment, V_{100}, respectively during the first and the second sowing date, Table 2).

Average daily evapotranspiration was quite similar in the two sowing dates in the stressed treatments (V_o and V_s, Table 2) since, the lower evapotranspiration demand of the first date

Table 1. Mean temperature, relative humidity, vapour pressure deficit, total rainfall and growing cycle duration of sunflower sown at different dates in the two years.

Sowing date	Mean temp. (°C)	Rel. Humidity (%)	v.p.d. (Kpa)	Rain (mm)	Duration (d)
March 95	16.8	68.8	0.65	246	160
April 95	18.6	66.9	0.74	181	130
March 96	18.4	65.5	0.80	142	158
April 96	20.9	63.7	0.90	86	135

Table 2. Daily evapotranspiration, total water use and seasonal irrigation volume of sunflower sown at different dates and subjected to the three irrigation regimes.

Sowing data	Daily evapotranspiration			Total water use			S easonal irrig. Volume		
	V_0	V_s	V_{100}	V_0	V_s	V_{100}	V_0	V_s	V_{100}
	mm d^{-1}			m^3 ha^{-1}			m^3 ha^{-1}		
Mar. 95	1.8	2.4	4.1	2959	3801	6564	-	1024	3854
Apr. 95	1.8	2.5	5.6	2357	3290	7334	-	1048	4871
Mar. 96	1.8	2.2	5.3	2792	3462	8359	-	1140	6421
Apr. 96	1.6	2.4	6.2	2107	3241	8391	-	1096	6836

was matched by a greater reduction in the transpiration rate of the crop in the second date because of the more severe soil moisture deficit caused by the dryer rainfall regime (Perniola, 1994).

Anyway cool temperatures slowed development at the early sowing dates; the growing cycle of the first sowing dates was in fact 30 and 23 days longer than the second respectively in 1995 and 1996 (Table 1). As a consequence, notwithstanding the lower daily evapotranspiration rate measured in the first sowing date of the well watered treatment, the longer growing cycle resulted in an almost identical total maximum crop evapotranspiration (ETc) respect to the second sowing date (746 and 786 mm as an average of the two-years ETc respectively of the first and the second sowing date, Table 2).

In the water stressed treatments (V_0 and V_s), daily evapotranspiration being the same in the two sowing dates, the longer duration of the growing cycle in the first sowing date produced an higher total water use than in the second (Table 2).

The seasonal irrigation volume applied in 1995 and 1996 in the V_{100} treatment (Table 2) was respectively 102 and 41 mm lower in the first sowing date respect to the second; this is a mere consequence of the above-said higher amount of rain fallen at the beginning of first sowing date.

3.2 Yield response and water use efficiency

The total shoot dry matter accumulated by the crop at harvest was generally higher at the first sowing date, and progressively increased according to the irrigation volume (Table 3).

The average water use efficiency (WUE) calculated respect to the total shoot dry matter was equal to 2.1 Kg m^{-3} and did not show significant variation among the years, the sowing dates and the irrigation regimes.

Therefore the total epigeous dry matter production obtained in the different sowing dates and irrigation regimes is exclusively dependant on the water availability resulting from the rainfall and irrigation volume of each experimental treatment; this is evident from the linear relationship reported in figure 1, showing a proportional increase of the total shoot dry matter

Table 3. Total shoot dry matter, grain yield and irrigation yield water use efficiency of sunflower grown at different dates and subjected to the three irrigation regimes. The values reported at the bottom of the table represent the least significant differences calculated according to the Tukey test for P = 0.05.

Sowing Data	Total shoot dry matter			Grain yield			Irrig. yield water use eff.		
	V_0	V_s	V_{100}	V_0	V_s	V_{100}	V_0	V_s	V_{100}
	g m^{-2}			t ha^{-1}			kg m^{-3}		
Mar. 95	746	826	1450	1.97	2.23	3.77	-	2.2	1.0
Apr. 95	574	623	1237	1.55	1.82	3.35	-	1.7	0.7
Mar. 96	541	742	1644	1.77	2.56	4.37	-	2.2	0.7
Apr. 96	437	705	1493	1.57	2.10	4.48	-	1.9	0.6
Sow. D.			*131*			*0.50*			*0.12*
Irr. R.			*156*			*0.64*			*1.16*
S.DxI.R			*n.s.*			*n.s.*			*0.23*

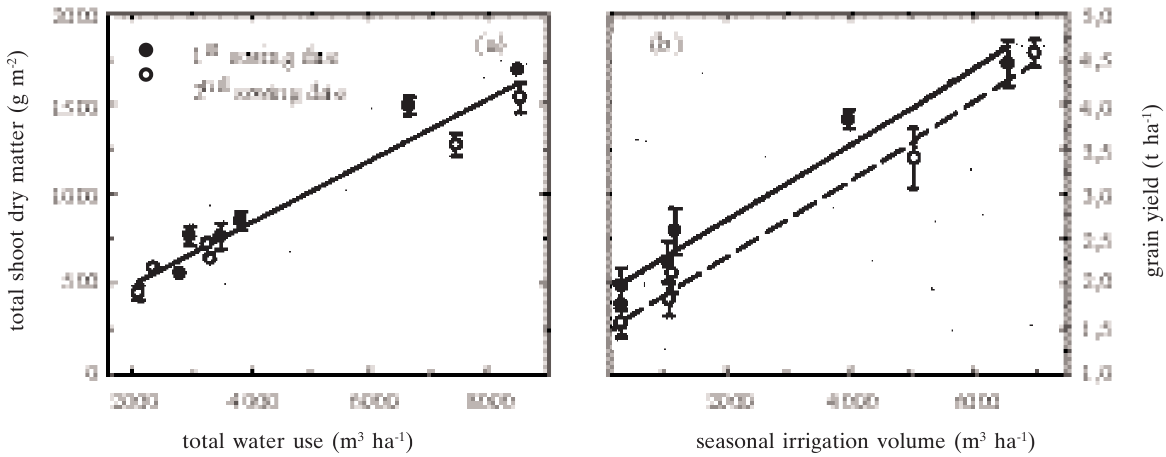

Figure 1. Relation between total water use and total shoot dry matter (a) and between sesonal irrigation volume and grain yield (b) for sunflower in the two sowing dates. Vertical lines are standard error of the means.

with the increase of the total water use of each experimental treatment ($r^2 = 0.98$, $p = 0{,}001$).

The sowing date, as well the irrigation regime, did not significantly affect the partitioning of assimilates between the vegetative and the reproductive organs, with an average harvest index equal to 0.29. This values and its stability in relation to the water regime is confirmed by Baldini and Vannozzi (1999) in large pots and field experiment. Therefore, the sowing date and the irrigation regime influenced the crop yield in the same way observed for the total dry matter, i.e. yield was higher at the first date than at the second (with an average seed production respectively of 2.8 and 2.5 t ha^{-1}, Table 3) and progressively increased according to the water regime (ranging from an average value of 1.7 to 4.0 t ha^{-1} respectively in V_0 and V_{100}, Table 3).

In particular, the irrigation regime affected all the yield components (causing an increase in the head diameter and in the specific seed weight and a drop in the percentage of the infertile area of the head, Table 4). The sowing date interacted with irrigation regime causing an increase in the specific seed weight for earlier sowing dates in the stressed treatments and an increase in the head diameter in the unirrigated treatment (Table 4). These data fully agree with those obtained by Santamaria et al. (1991) in a similar experiment.

As already shown, the higher amount of rainfall associated to the earlier sowing date caused a reduction in the seasonal irrigation volume in the treatment with full irrigation, and an increase in the soil water availability in the treatments with supplementary irrigation and in

Table 4. Head diameter, percentage of infertile area and 1000 seed weight of sunflower sown at different dates and subjected to the three irrigation regimes. The values reported at the bottom of the table represent the least significant differences calculated according to the Tukey test for P = 0.05.

	Head diameter			Infertile area			1000 seed weight		
Sowing	V_0	V_s	V_{100}	V_0	V_s	V_{100}	V_0	V_s	V_{100}
Data		cm			%			g	
Mar. 95	11.1	12.5	14.6	19.8	10.1	2.5	48.0	54.4	66.2
Apr. 95	8.9	12.9	14.9	35.9	10.1	2.2	47.1	48.4	68.3
Mar. 96	14.1	16.1	17.7	4.3	1.0	4.1	54.7	52.2	66.7
Apr. 96	12.4	14.1	18.1	10.3	4.2	4.4	47.7	37.6	67.9
Sow. D.			*n.s*			*n.s*			*2.55*
Irr. R.			*1.55*			*9.8*			*2.14*
S.DxI.R			*2.25*			*n.s.*			*3.05*

the unirrigated control. On the base also of the yield response, an interesting interaction did result between the sowing date and the irrigation regime in terms of irrigation water use efficiency (Table 3, Figure 1). Irrigation water use efficiency calculated respect to the seed yield (IYWUE) increased from 0.6 kg m^{-3} of the more irrigated treatment sown at the usual date to 2.2 kg m^{-3} in the treatments sown earlier and subjected to supplementary irrigation (Table 3). A significant increase in irrigation yield water use efficiency was measured in the first sowing date of the treatment with supplementary irrigation that, in the environment of the trial, also gave interesting yield levels (2.2 t ha^{-1}). A general reduction in the irrigation yield water use efficiency was measured in the treatments irrigated with the full restoration of evapotranspiration, even though they gave the best yield results (in average 4.0 t ha^{-1}). Anyway in these last treatments no significant variation in the IYWUE was measured as a consequence of sowing date. It results that, the early sowing date, by interacting with the irrigation scheduling, can improve the use of rainfall water and the efficiency of the irrigation water; infact, in the experimental area, the anticipation of sunflower sowing date respect to the ordinary (meddle-end of April), gave as result an increase in grain yield and in the irrigation yield water use efficiency in the water stressed treatments and a reduction in the irrigation volume in the treatment irrigated with the full restoration of evapotranspiration. These result fully agree with those already obtained in the same environment by Ruggiero et al. (1981) and Quaranta et al. (1988) on maize and by Barbieri (1988) on sunflower.

Anyway, for an ordinary application of this technique, breeding programs should be direct to get sunflower varieties more tolerant to the relative low temperatures characterizing the beginning of the spring. The shortening of growing cycle and the avoidance of the low temperature damages that can occur at the beginning of spring could further improve the agronomic performance of this tecnique.

4. Conclusions

From a two-years study on the interaction between the sowing date and the irrigation regime in sunflower, in order to investigate the more efficient use of irrigation water in an area (southern Italy) characterized by scarce water resources, the following conclusions can be drawn.

Despite the lower v.p.d. of the air, that generally occurs at the early sowing dates, causes a reduction in the maximum daily evapotranspiration, the colder temperature regime of this period, by making longer the growing cycle, leads to a total water use almost identical to that of the usual sowing dates.

However, the earlier sowing dates, reduces the seasonal irrigation volume under full irrigation and increase the soil water availability in the case of unirrigated treatment or with supplementary irrigation since the crop can benefits of spring rainfall at its early stages.

The greater water availability in the stressed treatments, also produces higher grain yield at earlier sowing date, so that an interesting interaction was observed between the sowing date and the irrigation regime in terms of water use efficiency. In fact, a significant increase in irrigation yield water use efficiency (IYWUE) was measured in the first sowing date of the treatment with supplementary irrigation that, in the environment of the trial, also gave interesting yield levels (2.2 t ha^{-1}). A general reduction in the irrigation yield water use efficiency was measured in the treatments irrigated with the full restoration of evapotranspiration, even though they gave the best yield results (4.0 t ha^{-1}). Anyway in these treatments no significant variation in the IYWUE was measured as a consequence of sowing date. It results that earlier sowing dates, by interacting with the irrigation scheduling criteria, can lead to a better use of rain water and improve the efficiency of the irrigation water. Infact, in the experimental area, the anticipation of sunflower sowing date respect to the ordinary (meddle-end of April), gave as result an increase in grain yield and in the irrigation yield water use efficiency in the water stressed treatments and a reduction in the irrigation volume in the treatment irrigated with the full restoration of evapotranspiration.

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