EFFECTS OF PLANT GEOMETRY AND PLANT POPULATION ON SOME YIELD CHARACTERS AND WATER USE IN SUNFLOWER (Helianthus Annuus L.).

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Abstract

The trials were carried out at the Experimental Station of Pisa University, during three years (1988-1990) in a clay soil of a typical Mediterranean area. A sunflower hybrid (Flamme) was sowed following a split-plot experimental design with four replications and with two plant densities, 4 and 8 plants·m^{-2} in the main plot and two inter-row distances, 40 and 80 cm in the sub-plot. The most important yield characteristics were measured and moreover hydrologic balance and the percentage of PAR adsorbed by the crop was calculated. The highest yield was obtained with 8 plants·m^{-2} and the main characters responsible were shown to be LAI at flowering time and seed number per unit area. The crop with the lowest inter-row distance showed greater interception of PAR compared to the other treatment; moreover the best utilization of available water (WUE) proved to correspond to the treatment of 40 cm inter-row, and 8 plants·m^{-2}. Therefore complete soil covering obtained by a reduction of row spacings could be very useful to reduce soil evaporation, especially in environments with high photon flux density and limited water availability in the soil.

Introduction

Competition (Clemens, 1929) is very common in agroecosystems, particularly in sunflower in which commercial hybrids are widely spread troughout the world, with light and water as the main factors implied. Light competition may be evaluated by plant population, a parameter very close to yield. Many authors involved in this research (Davidson and Donald 1958; Jadanova 1967; Remussi et al., 1976; Robinson 1975; Pacucci and Martignano 1975; Laureti 1981; Da Silva and Schmidt 1985; Zubriski and Zimmerman 1974; Prunty 1981; Prunty 1983; Kirton 1985;

Mathers and Stewart 1982; Alessi et al., 1977; Cuocolo 1986; Stanojevic 1985; Tarantino and Alba 1978; Monotti et al., 1982; Gubbels and Dedio 1986;Baldini et al., 1988; Benvenuti et al., 1987; Fick et al. 1985; Guiducci and Bianchi 1989; Piquemal et al., 1985; Rao et al. , 1991 Zaffaroni et al., 1991) have shown a very notable adaptability of sunflower to different and various plant densities with acceptable achene yield ranging from 3 to 10 plants$\cdot m^{-2}$. Optimal densities are from 5 to 7 plants$\cdot m^{-2}$. Although the existence of these data show the importance of low row spacing, the influence of plant density and row spacing on achene yield is not known. Moreover, water is frequently an important factor because of water shortage in many soils, leading to competition among plants (Prunty 1981; Unger 1982; Zaffaroni et al., 1989). Sunflower achieves considerable water stress tolerance with ETM (Maximum Evapotranspiration) near to 650 mm (Merrien 1986) and ETE (Real Evapotranspiration) 571-605 mm (Costantini 1985), 686-734 mm (Rizzo et al., 1989). If one takes into account WUE (water use efficiency), it is 2.5 $g\cdot l^{-1}$ (total dry matter) (Merrien 1986) and 1.9 $g\cdot l^{-1}$ (total dry matter), 0.54 $g\cdot l^{-1}$ (achene dry matter). Although several authors state that WUE is not influenced by plant density, others claim that WUE is increased by water availability in the previous stages of the crop such as the pre-emergence period. Considerable plant density may permit reduction of transpiration of each single plant and inter-row soil evaporation. The aim of this trial is to evaluate influence of several different plant densities on achene yield, also considering the water consumption and light interception in a near coastal pedoclimatic environment of northern Tuscany.

Materials and Methods

This trial was conducted in dry cultivation during 1988, 1989, 1990 years at the Experimental Station "Rottaia" belonging to the Agronomy Department of Pisa University. The principal treatments were two plant densities of 4 and 8 plants$\cdot m^{-2}$ respectively, whereas the secondary treatments were two different sowing schemes with rows spaced 40 cm or 80 cm apart. The experimental scheme adopted was a split-plot with four replications. The most recent and well adapted agronomic techniques (weed control, fertilization ecc.) were adopted. The phenological, biometrical and productive characters examined were the following:

-emergence-flowering period (days)

-flowering-ripening period (days)
-plant height (cm)
-head diameter (cm)
-stem diameter (cm)
-LAI at flowering
-achene number per plant·unit area^{-1}
-achene weight per plant (g)
-1000 achene weight (g)
-achene oil %
-leaves, stem and head weight at two different phenological times, namely the flowering and physiological ripening periods (g)
-biomass yield.unit area-1 (leaves, stems and head) at flowering, and physiological ripening respectively (t·ha^{-1})
-achene yield per unit area (t·ha^{-1});
-oil yield per unit area (t·ha^{-1}).

The hydrologic balance equation referring to the emergence-physiological ripening period was adopted to evaluate crop water consumption (ETE), and the WUE (total and grain). Moreover the Harvest Index was calculated to evaluate yield efficiency of a individual plants. Finally, a linear sensor was used to evaluate Photosynthetically Active Radiation (PAR) at soil level, with the sensor between crop rows (Steiner 1986). The difference between the PAR over the crop and the PAR at the soil was the PAR intercepted by the crop, compared to the outer PAR (%).

Results and discussion

Examination of the characters showed that during the three years of the trial, mean plant height was higher at plant densities of 8 plants·m^{-2} (175.3 cm) compared to 4 plants·m^{-2} (147.6 cm)(table 1). Detailed analysis of the interaction effect between treatments has highlighted excessive plant closeness on the same row at 8 plants·m^{-2} x 80 cm, with excessive height (181 cm) compared to 4 plants·m^{-2} x 80 cm (143.1 cm) probably determined by light competition.

Head diameter was significantly higher at 4 plants·m^{-2} (16.7 cm) compared to 8 plants·m^{-2}(13.3 cm)(table 1).

Achene number per plant was better at lower plant density (1437), compared to higher plant population (1176), and likewise achene weight per plant (84.9 g compared to 54.9 g) and also 1000 achene weight (57.1 and 43.1 respectively)(table 1).

Effect of the two treatments on the Harvest Index (HI) was influenced by the individual trial year. While in 1989 treatments showed no significant effect on the Harvest

Index, in 1988 plants on rows spaced at 80 cm had greater mean efficiency (0.363) compared to plants on rows spaced at 40 cm (0.352)(table 1). The interaction effect between treatments highlighted that 4 plants·m^{-2} x 80 cm was more efficient (0.378). In 1990, the HI was higher at lower plant density (0.428) compared to higher density (0.407).

Biomass yield per unit area at flowering was higher at 8 plants·m^{-2} (11.6 t·ha^{-1}) compared to 4 plants·m^{-2} (8.8 t·ha^{-1})(table 2). At physiological ripening this trend was confirmed, with 11.6 and 9.01 t·ha^{-1} respectely (table 2).

The Leaf Area Index (LAI) at flowering was higher at 8 plants·m^{-2} (4.2) compared 4 plants·m^{-2} (3.2) (table 2).

In the same manner achene number per unit area was better at higher plant density (94080 compared 57500) (table 2). Probably as was convincingly demonstrated by (Merrien, 1988), these two characters influenced achene yield, which reached a maxima at 8 plants·m^{-2} density (4.37 t·ha^{-1}) and was about a ton higher compared to 4 plants·m^{-2} (3.39 t·ha^{-1}) (table 2).

Water use efficiency (WUE) referred to biomass yield was better at higher plant density (2.52 Kg·m^{-3}) than lower density (1.88 Kg·m^{-3}) (table 3). WUE referred to achene yield in interaction 8 plants·m^{-2} x 40 cm was the most efficient (1.04 Kg·m^{-3}) (table 3).

Photosynthetically Active Radiation (PAR) as indicated in fig. 1 was representative of the possibility of covering the soil with the crop. Study of this feature revealed that close to 30-37 days after emergence, the higher plant density was better and covered the soil more fully compared to lower density. From 73 days after emergence,on the other hand at the phenological phase corresponding to the end of flowering, progressive decrease in crop-cover on the 80 cm spaced row was observed, due probably to progressive loss of photosynthetic surface.

Conclusions

The following trial-dependent conclusions can be drawn:

-8 plants·m^{-2} is the best plant density (better than 4) for achene yield, as already confirmed by a several authors (Benvenuti et al., 1987) in the same environment.

-the LAI (whose levels were high at flowering), as confirmed by several authors (Rawson, 1980), and the greater achene number per unit area (Merrien, 1988) were the characters which mainly contributed to the highest achene yield. Therefore, these factors are to be considered

Table 1 - Mean of individual plants for biometric-yield characters. (1988-89-90)

	Plant height (cm)	Head Diameter (cm)	Plant achene number	Plant achene yield (g)	1000 achene yield (g)	Harvest Index (1988)	Harvest Index (1990)
Plant Population							
8 plants·m-2	175.5 a	13.3 b	1176 a	54.9 b	43.1 b	0.354	0.407 b
4 plants·m-2	147.6 b	16.7 a	1437 a	84.8 a	57.1 a	0.361	0.428 a
Rows apart							
80 cm	162.0	14.7	1276	67.0	49.3	0.363 a	0.411
40 cm	161.0	15.3	1354	72.6	51.0	0.352 b	0.427
Interaction							
8 plants·m-2 x 80 cm	180.9 a	13.2	1154	52.9	42.5	0.350 b	0.395
8 plants·m-2 x 40 cm	170.1 b	13.4	1198	56.9	43.8	0.362 ab	0.419
4 plants·m-2 x 80 cm	143.1 d	16.2	1388	81.2	56.1	0.378 a	0.423
4 plants·m-2 x 40 cm	152.1 c	17.2	1487	88.3	58.3	0.340 b	0.432

The values having different letter are significantly different at 5 % level of significant (DMRT)

Table 2 - Mean of individual plants for biometric-yield characters (1988-89-90)

	Biomass total ($t \cdot ha^{-1}$) (flowering)	Biomass total ($t \cdot ha^{-1}$) (ripening)	LAI (flowering)	Achene number·ha-1 (x1000)	Achene yield (t·ha-1)
Plant Population					
8 plants·m-2	11.60 a	11.60 a	4.2 a	94060 a	4.37 a
4 plants·m-2	8.60 b	9.01 b	3.2 b	57500 b	3.39 b
Rows apart					
80 cm	9.94	9.97	3.5 b	73890	3.75
40 cm	10.55	10.64	3.9 a	77670	4.05
Interaction					
8 plants·m-2 x 80 cm	11.60	11.42	4.0	92320	4.25
8 plants·m-2 x 40 cm	11.62	11.79	4.4	95680	4.55
4 plants·m-2 x 80 cm	8.29	8.52	3.1	55460	3.25
4 plants·m-2 x 40 cm	8.48	9.50	3.3	59480	3.55

The values having different letter are significantly different at 5 % level of significant (DMRT)

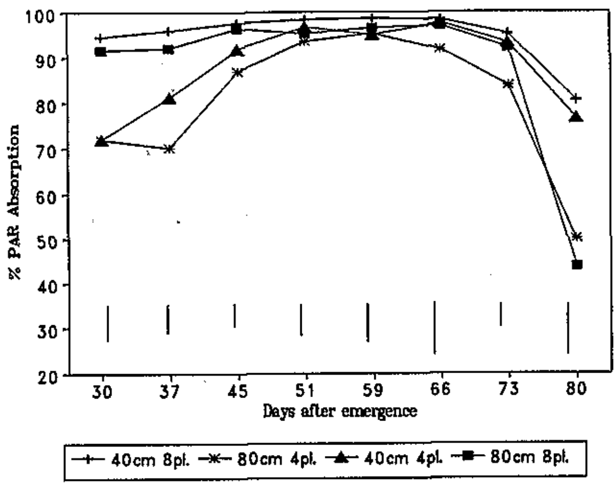
Table 3 - Total ETE and Water Use Efficiency (1988-89-90).

	Total ETE (mm)	Total Biomass WUE (kg dry matter·m⁻³water)	Achene WUE (kg dry matter·m⁻³water)
Plant Population			
8 plants·m⁻²	459	2.52 a	0.95
4 plants·m⁻²	478	1.88 b	0.70
Rows apart			
80 cm	459	2.17	0.81
40 cm	478	2.22	0.84
Interaction			
8 plants·m⁻² x 80 cm	482	2.36	0.88 b
8 plants·m⁻² x 40 cm	436	2.70	1.04 a
4 plants·m⁻² x 80 cm	436	1.95	0.74 b
4 plants·m⁻² x 40 cm	495	1.91	0.71 b

The values having different letter are significantly different at 5 % level of significant (DMRT)

Fig. 1 - Crop PAR Absorption.

The bars represent the L.S.D. at 1 % level of significant



very important for crop intensification in the examined environment.

-With regard to WUE, it can be argue that this factor is higher with 8 plants·m^{-2}. Particularly as regards achene yield , a 40 cm row spacing could permit a better efficiency than 80 cm.

-PAR absorption is greater at 8 plants·m^{-2} and 40 cm and shows that very little incident light reach the soil level, so that a reduction of row spacing could be extended to low soil water content environments. This could lead to more complete soil covering by plants, less water evaporation from the soil and better utilization of water stocks (reserves) by plants. Plants could thus more effectively carry out the most important physiological activities such as photosynthesis and transpiration, with marked positive consequences on the achene yield component.

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