DYNAMICS OF GROWTH, RADIATION USE EFFICIENCY AND YIELD COMPONENTS OF SUNFLOWER, SUBMITTED TO DIFFERENT TILLAGE SYSTEMS AND N FERTILIZING LEVELS UNDER SEMIARID CONDITIONS IN SOUTHERN ITALY

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Abstract
Four tillage systems (traditional mouldboard ploughing, ripper subsoiling, surface disc-harrowing and minimum tillage with rotary hoeing) combined with three nitrogen levels (50, 100 and 150 kg N ha^{-1}) were compared on a sunflower crop under water limited conditions, after six years of durum wheat continuous cropping. submitted to traditional tillage The trial was carried out in Foggia, a typical area in Southern Italy, characterized by a "chromic vertisol" and a "mesomediterranean accentuated climate".
The split plot design with three blocks was used. On the basis of the leaf area index, the total intercepted radiation and the dry matter accumulation, measured during the c ropping cycle, the radiation use efficiency pattern was obtained. At harvest, the most important yield components were measured. Considering the dry growing season, particularly during the reproductive phase, the three N doses did not influence the biomass accumulation and final yield of sunflower significantly. As to the tillage systems, the analysis of the above parameters showed significant differences. The minimum tillage reduced the rate of growth and the yield of sunflower as compared with the other tillage systems.

Key words: *Helianthus annus* L., growth cycle, soil tillage.

Introduction

The twofold utilization of sunflower, for food and energy purposes, as well as its being one of the few crop alternatives for the set aside, have led this species to occupy increasingly larger spaces especially over the last few years and particularly in Southern Italy.
Its increasing extension even to marginal areas suggests the reconsideration of the technical routes followed to achieve high yields at low costs and having respect for the environment. A great deal of research has been conducted on the improvement of traditional agrotechnique (Pacucci and Martignano, 1975; Laureti, 1981; Kirton, 1985; Cuocolo, 1987; De Giorgio et al., 1988; Ferri et al., 1989; Ferri et al., 1994; Vannini, 1995), much less on the innovative and recently introduced technique which involves either a reduction of technical factors, such as tillage, fertilization, irrigation or their appropriate combination taking account of their action on plant development processes (Aguera et al., 1994; Bona et al., 1995). This is a topical subject that necessitates, however, a careful analysis to identify the limits, within which the agrotechnical means may be modified, while still safeguarding the inexpensiveness of the crop.
With this in mind, the "Istituto Sperimentale Agronomico" has undertaken this research on sunflower submitted to varying levels of agrotechnical inputs in the Apulian Tavoliere, an agronomically relevant area in Southern Italy.

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(1) The three authors equally contributed in the praparation of the paper.

Materials and Methods

The research was conducted on a split plot experimental design , by comparing four tillage systems (A-traditional mouldboard ploughing, B-ripper subsoiling, C-surface disc-harrowing, D-minimum tillage with rotary hoeing) in large plots (300 m^2) and three nitrogen fertilization levels (50, 100, 150) in plots (100 m^2). All treatments were kept under limiting water conditions and were grown after six years of durum wheat continuous cropping, submitted to traditional tillage. At the main tillage works, performed in autumn, phosphatic and nitrogen fertilizers (100 kg ha^{-1} of P_2O_5 and K_2O, respectively) were applied. Rotary tillage, provided in all treatments, was performed in spring. Sunflower was sown on 14 April, 1989 at a density of 7 plants per m^2, using cv. Romsun HS 90. Nitrogen was applied by top dressing as ammonium nitrate: half dose between the 3rd and 4th leaf and half between the 14th and the 15th leaf . After sowing, 1100 m^3 ha^{-1} of water were applied in three irrigations, to favour emergence. Three additional irrigations were provided later on with limited water applications at the 4th-6th leaf, at the 10th-12th and at flower buds stages with about 500 m^3 ha^{-1} for each .

Throughout the cropping cycle the study of growth analysis was conducted using the leaf area meter Li-coor 3000. On a weekly basis and starting from the 7th-8th leaf , two plants were taken from each elementary plot and oven-dried at 105°C for 48 h for the dry matter determination. Throughout the cropping cycle the radiation was measured using a pyranometer "Eppley", located in the agrometeorological station of the farm, at 1 m above the ground. The photosynthetically active radiation (PAR_o) was calculated by the equation proposed by Varlet Grancher et al. (1982). and the intercepted radiation was obtained from the relation:

$$PAR_i = PAR_o\,(1-e^{(-kLAI)})$$

where k is the extinction coefficient equal to 0.9 (Rinaldi et al., 1991).

The total dry matter, measured at each determination, was correlated with the cumulative PAR_i from emergence until the maximum dry matter values were reached; the regression line was then calculated assuming the intercept value equal to 0:

$$SS = RUE\ \Sigma\, PAR_i$$

where RUE is the intercepted radiation use efficiency (g MJ^{-1}).

The pedoclimatic area is characterized by a "Typic chromoxerert" silty clay soil (according to the USDA Soil Taxonomy Classification) and a climate with rainy winter and hot dry summer, defined as "accentuated thermomediterranean" (FAO/UNESCO). In the test year (Fig. 1) total rainfall was 471 mm, whereas from April to August, the period of sunflower cycle, the recorded rainfall was 218 mm, of which only 80 in June, and the remainder distributed as poor and ineffective rainfall events. The annual rainfall deficit compared to the annual "average" of the 37 previous years (1952-88) was 105 mm. The Fig. 1 clearly shows that the crop has been mostly under water deficit compared with the evaporation rate, particularly from the second half of June onwards.

Results

The limiting water conditions, occurring from the second half of June and at the active growth stage, have seriously jeopardized sunflower growth and yield which have been, however, affected only by "tillage" treatment. The effects relating nitrogen fertilization and the "tillage x nitrogen" interaction have not proved to be significant hence they will not be taken into account.

Within the treatments being tested, minimum tillage showed the lowest biomass accumulation of sunflower, compared to the other systems (Fig. 2). Such a differentiation was evident starting from early June and increased progressively till the beginning of flowering (29 June), when the biomass produced was 707 and 951 g m^{-2} respectively for minimum tillage and for the other tillage systems. The difference dropped around mid-July (milk ripeness), when only the dry matter of "ripper subsoiling" differentiated sharply with a value above 1200 g m^{-2}, it increased again in the two last determinations, between the end of milk ripeness and full ripeness, with minimum tillage being markedly lower. From the analysis of the major plant components (Fig. 3) it results that the above variations are due to the amount of dry matter primarily accumulated in the stem and leaves and secondly in the rooting system. As to the heads' weight the differences between different tillage systems seemed to be smaller, presumably as a consequence of the water deficit that made the variations, observed in the other organs, less accentuated in the last vegetative stages.

Differences even greater were observed between the LAI patterns (Fig. 4); till the first half of June it increased for all treatments quite linearly although the peak value was 1.9 in minimum tillage, against 3.3, the mean observed in the other systems. Afterwards, as the water deficit became severe, the LAI of tillage systems B, C, D stabilized and dropped sharply starting from the second week of July. In minimum tillage, instead, after the maximum value (2.4) being reached on 22 June. the reduction of values was lower as compared to the other treatments. Despite this partial recovery, the LAD (Tab. 1) in minimum tillage was sharply lower than in the other tillage systems (98 against 141 days). the same as the photosynthetically active radiation intercepted during the cropping cycle (535 against 579 MJ m^{-2}).

No statistically significant differences were observed between the treatments in terms of radiation use efficiency (RUE). The limiting water conditions caused a slowing down in growth in the second half of June - that was more evident in minimum tillage - and a fast senescence, that was more accentuated for the other tillage systems, starting from the second week of July.

Plant height (Fig. 5) was also influenced by tillage:minimum tillage, in particular, showed a more appreciable reduction starting from June; the height peaked 119 cm at the end of the cycle against 160, the mean of the other treatments.

The mean seed yield (1.7 t ha^{-1}) was by far lower than the value (3 t ha^{-1} on average) observed on irrigated sunflower in the same environment. The yield responses (Tab. 2) to soil tillage systems have confirmed those obtained in the growth analysis already mentioned, with minimum tillage showing a yield 0.3 t ha^{-1} lower, compared to the mean of the other tillage systems. This effect may be both attributable to the lower number of heads per m^{-2} (5.6 against 6.6) and to the higher incidence of mildewed plants per m^2 (1.4 against 0.7). These two factors seem to be more influential than the 1000 seeds' weight, that was higher in minimum tillage than in the other systems (46.3 against 43.8) but not enough as to induce yield increases. Other tested parameters including the head diameter were not affected by tillage.

Conclusions

The research has highlighted that in the test environment, characterized by low rainfall in the spring-summer period, sunflower grown with low agrotechnical inputs and under low supplemental irrigation conditions, provides results that are not very satisfactory. Under these conditions minimum tillage, among tillage methodologies, showed the worst results in the parameters being tested, including seed yield. This was a consequence of the canopy reduction that in turn limited the amount of intercepted radiation, whereas no similar effects were observed in terms of radiation use efficiency.

Nitrogen fertilization and the "nitrogen x tillage" interaction did not induce any significant effect on sunflower growth or on yield, thus confirming what had been already observed in the test environment on other crops as well. These results are, however, closely related to the conditions of poor water supply but could change under optimal water conditions.

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Tab. 1 - Leaf area duration (LAD), intercepted radiation (PAR_i) and radiation use efficiency (RUE) of sunflower.

Tillage	LAD (days)	PAR_i ($MJ\ m^{-2}$)	RUE ($g\ s.s.\ MJ^{-1}$)
1:Tradit. Mouldboard ploughing	133	589	2.29
2: Ripper subsoling	151	607	2.47
3: Surface disc-harrowing	139	594	2.39
4: Minimum tillage	98	535	2.26
Mean	130	581	2.35
Contrast:			
4 vs. (1,2, 3)	**	**	n.s.
1 vs. (2,3)	n.s.	n.s.	n.s.
2 vs. 3	n.s.	n.s.	n.s.

Tab. 2- Main effects of tillage on some productive characters of sunflower.

Tillage	Achens Yield ($t\ ha^{-1}$)	1000 Seeds weight (g)	Heads density ($plant\ m^{-2}$)	Mildewed plants density ($n\ m^{-2}$)
1:Tradit. Mouldboard ploughing	1.59	43.40	7.07	0.68
2: Ripper subsoling	1.89	43.97	6.14	0.69
3: Surface disc-harrowing	1.82	43.96	6.71	0.72
4: Minimum tillage	1.45	51.92	5.65	1.37
Mean	1.69	45.81	6.39	0.86
Contrast:				
4 vs. (1,2, 3)	*	**	*	*
1 vs. (2,3)	n.s.	n.s.	n.s.	n.s.
2 vs. 3	n.s.	n.s.	n.s.	n.s.

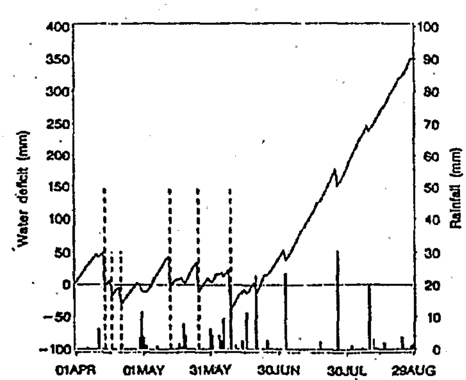

Fig. 1 - Trend of water deficit (ETo-P), rainfall (solid lines) and irrigation (dashed lines).

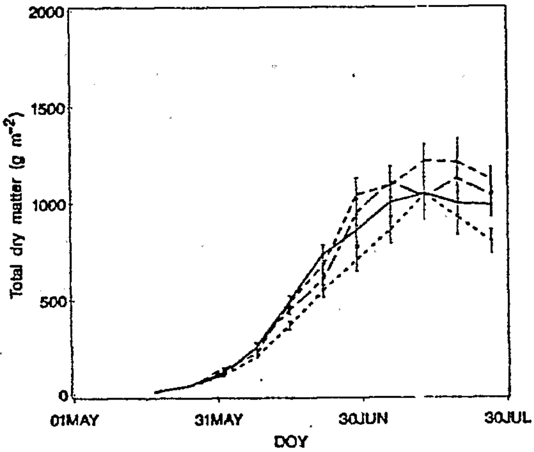

Fig. 2 - Trends of total dry matter cumulation in sunflower submitted to 4 soil tillage methods (__ traditional mouldboard; _ _ ripper subsoiling; _ __ surface disc-harrowing; .... minimum tillage).

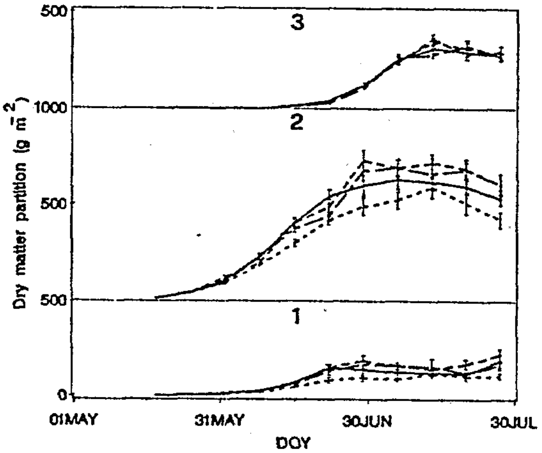

Fig. 3 - Trend of dry matter partitioning in root (1), stem and leaves (2) and heads (3) in sunflower submitted to 4 soil tillage methods (__ traditional mouldboard; _ _ ripper subsoiling; _ __ surface disc-harrowing; .... minimum tillage).

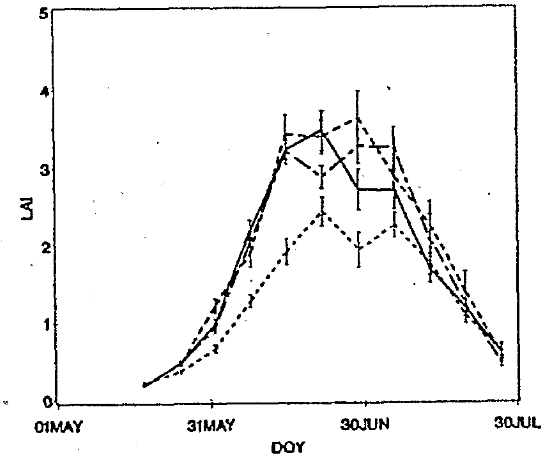

Fig. 4 - Trend of LAI in sunflower submitted to 4 soil tillage methods (__ traditional mouldboard; _ _ ripper subsoiling; _ __ surface disc-harrowing; .... minimum tillage).

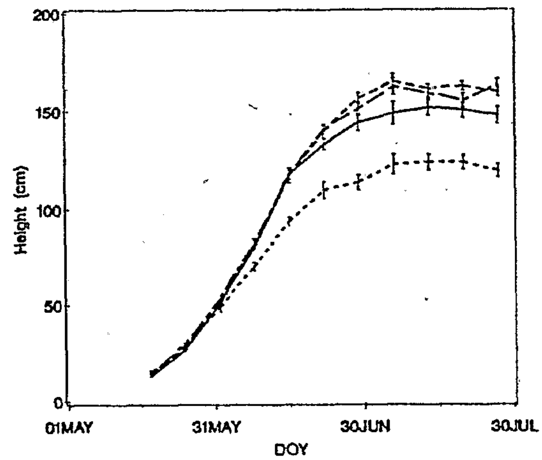

Fig. 5 - Trend of total height in sunflower submitted to 4 soil tillage methods (__ traditional mouldboard; _ _ ripper subsoiling; _ __ surface disc-harrowing; .... minimum tillage).