African Journal of Biotechnology Vol. 11(102), pp. 16688-16696, 20 December, 2012
Available online at http://www.academicjournals.org/AJB
DOI: 10.5897/AJB12.387
ISSN 1684–5315 ©2012 Academic Journals

Full Length Research Paper

The effect of plant density with different row spacing on quality of the fatty acid composition and grain yield of sunflower

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Accepted 10 October, 2012

This research was aimed to assess the influence of density with different row spacing on sunflower crop in two different locations in southern Italy. The experiment was laid out in a randomized block design with four replicates. It involved the comparison of sunflower grown in the field on 25 m^2 (5 x 5 m) plots at three plant densities (7.5, 5.0 and 3.75 plants m^{-2}), obtained by keeping a constant number of plants within the row (3 plants m^{-1}) and varying the spacing between rows (0.4, 0.6 and 0.8 m). In the crops grown at the density of 7.5 plants m^{-2} (0.4 m row spacing) achene and oil yields were significantly lower as compared to the other treatments. Therefore, the mean values of the two trials did not show any statistical difference between the two densities of 3.75 and 5 plants m^{-2} (0.8 and 0.6 m row spacing, respectively). However, the superiority in the quality of the fatty acid composition was observed in the crops grown at lower density. Therefore, the row spacing of 0.8 m seems to be a good compromise between achene production and good acid composition of oil.

Key words: *Helianthus annuus* L, plant distribution, plant density, achene yield, oil fatty acid composition.

INTRODUCTION

Sunflower (*Helianthus annuus* L.) is one of the most important oil crops in the world. In 2006, it reached the acreage of 23.1 million hectares and a production of 30.5 million tons of seeds (FAO, 2010). Among edible vegetable oils, sunflower oil is the third after soybean (*Glicine max* L. Merr.) and rapeseed (*Brassica napus* L. and *Brassica campestris* L.) oils, in terms of production (10.6 million tons). In addition to traditional cultivars, genetic engineering has developed hybrids capable to produce oils with oleic acid content up to 85 to 90% of total fatty acids. Actually, high-oleic oils are suitable for food uses and biodiesel production (Fuller et al., 1967); they have a better oxidative stability than high-linoleic conventional oils, so they are suitable for cooking and frying (Monotti, 2002).

Vegetable fats are receiving growing attention for their possible applications in the industry to replace petrochemical materials. The use of vegetable oils and fats for different industrial purposes depends on the specific physical and chemical properties of the fat components, mostly on their fatty acid composition.

Oleic acid is one of the most important for the preparation of technical oils and oleochemicals (Monotti, 2002). Within the strategy aimed to streamline environmental resources and enhance renewable energies, the use of sunflower oil in the production of biofuels has recently received considerable attention. Since 1992, the institutions of the European Union have been promoting the production of biodiesel, which reached 5.7 million tons (EBB, 2008) in 2007.

Achene production and the fatty acid composition of

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Table 1. Main properties of the soils being tested.

Property/analysis	Valenzano	Policoro
Chemical properties		
Total Nitrogen (Kjeldahl method) (g kg^{-1})	1.28	1.77
Available phosphorus (Olsen method) (mg kg^{-1})	19.00	21.08
Exchangeable potassium ($BaCl_2$ method) (mg kg^{-1})	170.00	303.00
Organic matter (Walkley Black method) (g 100 g^{-1})	2.75	2.65
Total limestone (g 100 g^{-1})	11.75	7.14
Active limestone (g 100 g^{-1})	4.60	3.40
pH (pH in H_2O)	7.76	7.95
ECe (dS m^{-1})	0.56	0.68
ESP	0.54	0.62
CEC ($BaCl_2$ method) (meq 100 g^{-1} of dry soil)	28.16	32.14
Particle-size analysis		
Total sand 2 > ∅ > 0.02 mm (g 100 g^{-1})	38.24	20.30
Silt (%) 0.02 > ∅ > 0.002 mm (g 100 g^{-1})	33.69	41.63
Clay (%) ∅< 0.002 mm (g 100 g^{-1})	28.07	38.07
Hydrologic properties		
Field capacity (field determ.) (g 100 g^{-1} of soil dry mass)	26.09	32.80
Wilting point (-1.5 MPa) (g 100 g^{-1} of soil dry mass)	18.44	15.48
Bulk density (t m^{-3})	1.20	1.25

oils are strongly influenced by the pedo-climatic and agronomic techniques. As to the oleic acid content and the oleic/linoleic acid ratio, nitrogen fertilization is reported to have a minor effect (Pritoni et al., 1999), whereas temperature (Anastasi, 2000), sowing date (Pritoni et al., 1999; Anastasi et al., 2000), cultivars (Monotti et al., 2005), water availability (Calviño et al., 2004), salt stress (Flagella et al., 2002) are shown to have a more significant effect.

In addition to these factors, plant density and row spacing can also be influential for light capture (Calviño et al., 2004), water and mineral uptake (Gubbels et al., 1988) and the subsequent plant growth and achene production. In plants grown without any water deficit, low row spacing increases production (Alessi et al., 1977; Andrate et al., 2002). In other studies, instead, no effect has been observed (Zaffaroni and Schneiter, 1991; Blamey et al., 1997). On the contrary, in sunflower plants grown under dry conditions, narrow rows cause a yield reduction due to an increase in the water demand resulting from early plant coverage of soil (Zaffaroni and Schneiter, 1989). In fact, sunflower plants are submitted to a severe water stress during the achene development stage (Fulton, 1970). Metz et al. (1984) suggest that optimum seed yield could be achieved when the distance between rows and within rows is equal at any plant density. Several studies showed that the optimum planting density depends on the cultivar used and the specific environment (Diepenbrock et al., 2001; Blamey et al., 1997; Prunty, 1981). Unluckily, there are insufficient data on the effects of plant density and row spacing on achene production and fatty acid composition of oil in the Mediterranean region. Therefore, in 2006 to 2007, a research was carried out to evaluate the effect of row spacing on a high-oleic sunflower hybrid (*Helianthus annuus* L.) grown in two different environments of Southern Italy.

MATERIALS AND METHODS

The research was carried out for two years in field trials at the University of Bari. In 2006, the trial was run at the experimental farm "Martucci", near Valenzano Southern Italy (Bari) on shallow silty clay soil (about 0.3 m deep, with low nutrient levels and poor available moisture, on underlying fissured rock) previously cultivated with durum wheat; in 2007 the test was conducted at the farm E. Pantanelli, near Policoro Southern Italy (MT) on deep silty clay soil (deeper than 1m, rich in nutrients and in plant available moisture). The main characteristics of the two soils are presented in Table 1.

In both years, the randomized block design with 4 replicates was adopted. Sunflower crops, grown in the field on 25 m^2 (5 × 5 m) plots were compared at three plant densities (7.5, 5.0 and 3.75 plants m^{-2}) obtained by keeping a constant number of plants in the row (3 plants m^{-1}) while varying the distance between rows (0.4, 0.6 and 0.8 m).

"Olsavil" sunflower cultivar, with medium-to-late cycle, was grown in the field of Valenzano (crop A), while the "PR64H61" sunflower cultivar, with mid-late cycle was grown in the field of Policoro, (crop B) as the cultivar Olsavil, with similar morphological and production

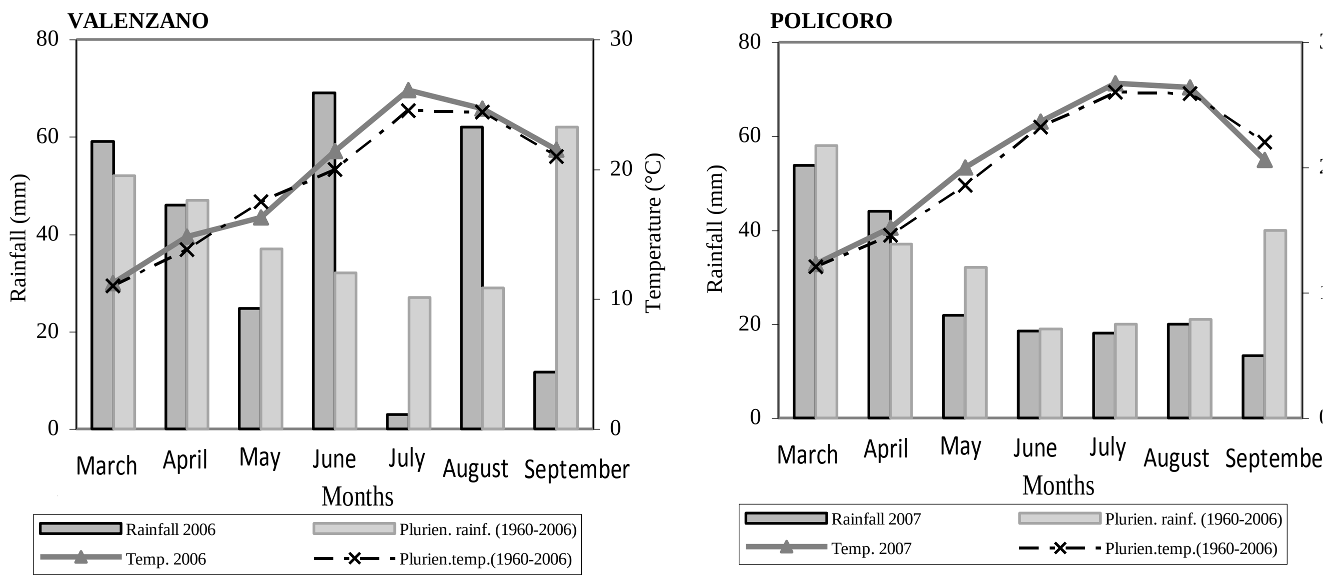

Figure 1. Monthly mean temperatures and total monthly rainfall in the period concerned with the crop in the areas of Valenzano and Policoro.

traits, was not available.

Just after sowing (on April 6, 2006, and on March 15, 2007, respectively), supplemental irrigation was applied to favour seed germination and seedling emergence. Afterwards, crops were cultivated under rainfed conditions.

At harvesting, on September 14, 2006 and on August 19, 2007, respectively, the biometric, yield and quality parameters (namely plant height, head diameter, weight and number of achenes per head, 1000 achene weight, oil yield and content of major fatty acids) were evaluated.

Climate pattern

In both locations, during the sunflower cropping cycle, the monthly mean temperatures did not show any significant difference from plurennial values and were always favourable for crop growth (Figure 1). For precipitation as well, no significant deviations from plurenial values were observed in the area of Policoro, whereas at Valenzano, rainfall exceeded plurennial values in June and August with deviations equal to + 37 and +23 mm, respectively (Figure 1).

Analysis of fatty acids

The achenes were ground in a blender (Waring Laboratory Blender, 06055 New Hartford, Connecticut, USA) and kept dry until oil extraction. The oil was extracted from seed meal by using a CEM model MDS 2100 microwave extractor (CEM Corporation, 28106-0200 Matthews, North, Carolina, USA) under the following conditions: the extraction vessels were loaded with about 1 g of seed meal and 50 mL of diethyl ether.

The microwave oil extraction method was proved to be as accurate and precise as the traditional extraction method (Saxhlet), but also faster since it required about 40 min at 105°C vs 6 to 8 h for the Soxhlet extraction. The recovery data obtained from the two extraction methods were statistically not different when compared by linear regression procedure (the regression equation was $y = -0.001 + 1.012 \cdot x$, $R^2 = 0.999$) and intercept and slope were not different from 0 and 1, respectively, at $P < 0.05$.

After removal of the meal from the liquid phase by filtration, the oil was recovered by solvent evaporation, and submitted to the methylation treatment using the official method (E. E. C., 1991).

The fatty acid composition was determined by using a Fisons model GC-8160 gas chromatograph (Italian Fisons, I — 20100 Milan, Italy) equipped with a split-splitless injector, a ZB Wax fused silica column (30 m, 0.53 mm, i.d, 0.50 µm film thickness; Zebron, Phenomenex, Torrance, CA, USA) and a flame ionization detector (FID) connected to a Chromquest signal acquisition and data reporting (Thermoquest, Milan, Italy). The carrier gas was helium at a linear gas velocity of 250 mm/s. The operating temperatures of injector and FID were respectively 250 and 280°C. The sample injection (1/µl) was split at a ratio of 1:100. The oven temperature programme was 165°C for 3 min, raised to 220°C by increments of 1.5 deg C/min. A commercial standard mixture (Larodan Fine Chemicals, Malmo, Sweden) of fatty acid methyl esters was used for calibration and for obtaining the correction factors to compensate for the different sensitivity values of FID to each fatty acid (Gargano et al., 1981).

The results were statistically analyzed using the general linear model (GLM) procedure, SAS / STAT, and the differences between the means were compared using the SNK and Tukey's test.

RESULTS AND DISCUSSION

The climate pattern of the first period after sowing allowed, in both locations, the regular emergence of sunflower plantlets, for neither compaction nor surface crusting occurred in the soil. The soil temperature (always above 10°C) favoured a fast and uniform emergence.

The rainfall pattern was favourable for crop production in both locations; however, at flower bud growth and seed filling stages, when the sunflower is most sensitive to water shortage, the rainfall distribution did not allow sufficient water storage in the Valenzano field, characterised by shallow soil with poor water holding capacity (available water = 9.65% of dry soil mass) and subsequent fast

Table 2. Achene and oil production, above-ground dry biomass, yield components and (morphological) traits of sunflower grown in the two locations of Southern Italy (Valenzano and Policoro) as influenced by density with different row spacing.

Source of Variation	Plant height (m)	Leaf area plant^{-1}(m^2)	Shoot dry biom. (Mg ha^{-1})	1000 seed weight(g)	Seed yield (Mg ha^{-1})	Oil yield (Mg ha^{-1})
Farm	**	**		**	**	**
Valenzano	1.40^{B}	0.68^{B}	5.15^{B}	56.51^{B}	2.81^{B}	1.50^{B}
Policoro	1.66^{A}	0.79^{A}	10.23^{A}	62.76^{A}	3.26^{A}	1.85^{A}
Distance (m)	**	**	**	**	**	**
0.4	1.61^{A}	0.51^{C}	6.63^{C}	49.82^{C}	2.66^{C}	1.43^{C}
0.6	1.54^{B}	0.72^{B}	8.66^{A}	60.06^{B}	3.41^{A}	1.88^{A}
0.8	1.43^{C}	0.96^{A}	7.78^{B}	68.32^{A}	3.02^{B}	1.71^{B}
Farm x distance	NS	NS	NS	NS	NS	NS

NS = Not significant; ** = Significant 1% probability level. For each effect considered, the values followed by the same letter are not significantly different, according to the SNK test at $p \leq 0.01$

Table 3. Oil yield, aboveground dry matter, yield components and plant characteristics as influenced by sunflower row spacing. Mean data of trials carried out in 2006 to 2007 in the two southern Italy environments (Valenzano and Policoro).

Yield/ parameter	Distance between rows (m)					
	0.4	0.6	0.8	0.4	0.6	0.8
	Valenzano			Policoro		
Plant height (m)	1.47^{A}	1.42^{A}	1.31^{B}	1.75^{A}	1.67^{B}	1.54^{C}
Leaf area plant^{-1} (m^2)	0.47^{C}	0.63^{B}	0.93^{A}	0.56^{C}	0.81^{B}	0.99^{A}
Shoot dry biom. (Mg ha^{-1})	4.38^{B}	5.74^{A}	5.31^{A}	8.8^{B}	11.6^{A}	10.2^{A}
Head diameter (m)	0.11^{C}	0.13^{B}	0.15^{A}	0.12^{C}	0.14^{B}	0.16^{A}
1000 seed weight (g)	47.05^{B}	54.82^{B}	66.27^{A}	52.6^{B}	65.3^{A}	70.4^{A}
Oil yield (%)	53.40^{C}	54.46^{B}	55.82^{C}	54.76^{C}	55.96^{B}	57.3^{A}

For each effect considered, the values followed by the same letter are not significantly different, according to the SNK test at $p \leq 0.01$.

depletion of stored water. Hence the yield efficiency of sunflower crop grown in the field of Policoro (on a soil exceeding 1 m depth and with available moisture = 17.32% of dry soil mass) was statistically higher than the crop grown at Valenzano. No differences were observed between the 2 locations in the response of crop plant density with different row spacing (Table 2).

Effects on the plant

Crop A

The plant height increased progressively from 1.32, 1.42 to 1.47 m, with the reduction of the row spacing from 0.8, 0.6 to 0.4 m, respectively (Table 2). The number of leaves per plant (about 20) was not influenced significantly with different row spacing, whereas the leaf area per plant increased significantly with the increasing distance between rows from 0.47 to 0.93 m^2, respectively, for the plants grown at lower or higher spacing. The head diameter also increased significantly with the increasing distance between rows from 0.11, 0.13 to 0.15 m, respectively, when the crop was grown with row spacing of 0.4, 0.6 and 0.8 m, respectively (Table 3).

Crop B

The PR64H61 sunflower cultivar grown in the area of Policoro, although showing higher development – presumably due to the favorable climate conditions (deeper soil, better rainfall distribution) - had a similar response to the crop grown near Valenzano, when varying the plant density with different row spacing.

The maximum plant height (175.5 m) was reached in the crop grown at the density of 7.5 plants m^{-2}. On the contrary, the average head diameter and the leaf area per plant increased gradually with the increasing distance between rows, and they reached values of 0.16 m and 0.99 m^2, respectively, when the inter-row spacing was 0.8 m (Table 3). Moreover, the number of leaves per plant (about 20) did not vary with the plant density.

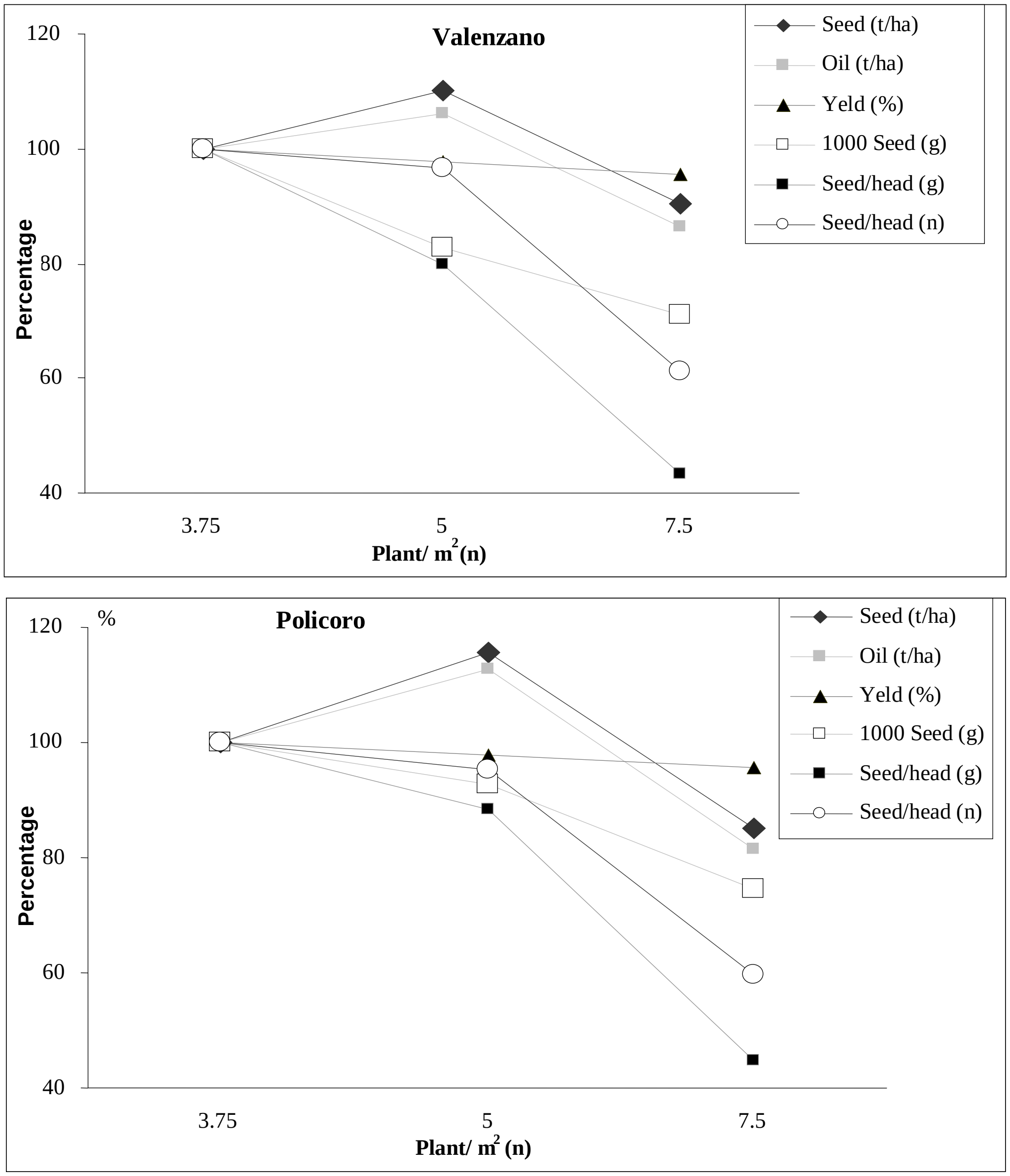

Figure 2. Effects of sunflower plant density grown in two Southern Italy environments (Valenzano and Policoro) on seed yield, seed oil content, oil yield, seed/head yield, number of seeds per head, 1000 seed weight, expressed taking 100 as the value of each trait at the density of 3.75 plants/m^2 (from Monotti, 1978: modified).

Effects on yield

Crop A

The varying plant morphology influenced by plant density resulted in a higher aboveground dry matter yield (5.74 Mg ha^{-1}) at the density of 5 plants m^{-2} and the row spacing of 0.6 m. Moreover, achene and oil yields did not increase at plant density greater than 5 plants m^{-2}, because the higher number of plants in the unit area did not compensate for the lower yield per plant. In fact, all yield components gradually decreased with the increase in plant density. Thus, the highest seed (3.06 Mg ha^{-1}) and oil (1.63 Mg ha^{-1}) yields were recorded when the crop was grown with the row spacing of 0.6 m. Instead, the two parameters decreased, respectively by 18.6, 18.4, 6.2 and 6.1% as the row spacing varied from 0.4 to 0.8 m. The weight of 1000 seeds increased respectively from 47.1 to 54.8 and 66.3 g when the row spacing increased from 0.4, to 0.6 and 0.8 m. A significantly positive result was found in the crop grown with the highest row spacing. The aboveground dry biomass yield was higher (5.7 Mg ha^{-1}) for the crop with intermediate row spacing followed by those of highest (5.3 Mg ha^{-1}) and lowest

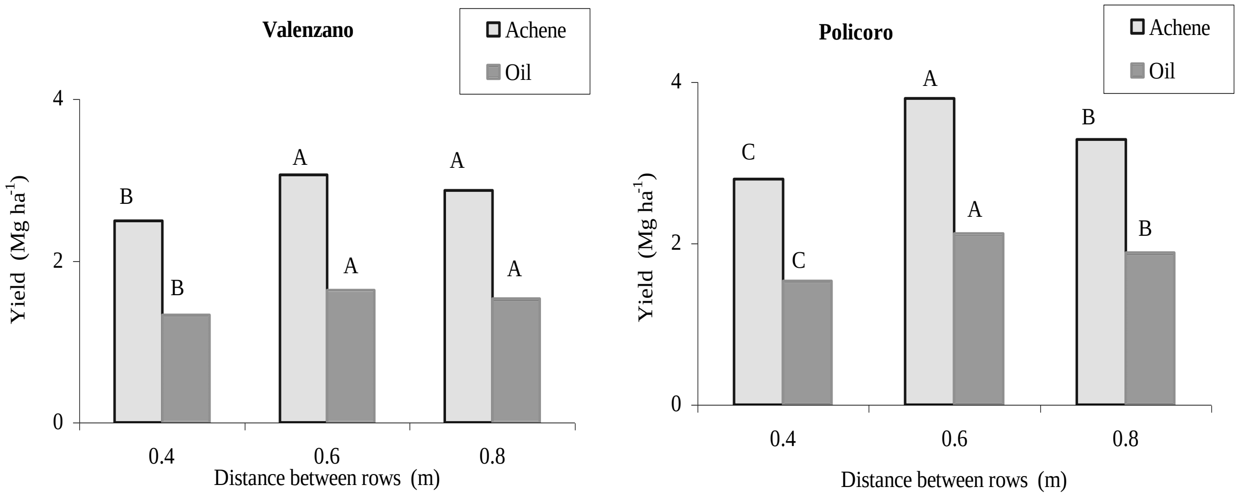

Figure 3. Effects of row spacing on seed and oil yield in sunflower grown in two Southern Italy locations (Valenzano and Policoro). For each effect considered, the values followed by the same letter are not significantly different, according to the SNK test at P ≤ 0.01

spacing (4.4 Mg ha^{-1}) (Table 3, Figures 2 and 3).

Crop B

The PR64H61 sunflower cultivar, grown in the area of Policoro, showed great vigor and a greater production of aboveground dry biomass (11.6 Mg ha^{-1}) at intermediate plant density (row spacing of 0.6 m; density of 5 plants m^{-2}) but no statistical difference as compared with the lowest density (0.8 m row spacing) (Table 2, Figures 1 and 2). A similar trend was observed for seed (3.8 Mg ha^{-1}) and oil (2.1 Mg ha^{-1}) yields, which decreased by 26.3 and 28.1%, respectively, with 0.4 m row spacing and at the density 7.5 plants m^{-2}.

Despite, the different cultivars and locations, the highest number of plants per unit area did not compensate for the lower yield per plant. Actually, all yield components decreased with increasing density.

The varying row spacing influenced the whole development of plants since the early vegetative stages. Plants grown in plots with 0.4 m row spacing showed thinner stem and lower expansion of individual leaves than those grown in plots with higher row spacing.

At the end of the production cycle, the sunflower crops grown at higher plant density (7.5 plants m^{-2}) and 0.4 m row spacing showed greater height but lower head diameter than those grown in plots characterized by lower density and higher row spacing (0.6 and 0.8 m) (Table 3, Figures 2 and 3).

The higher development in height observed in plants grown with minimum row spacing was due to the effect of competition for the use of production factors such as light radiation, nutrient and water supply. This competition resulted in a reduced leaf expansion, less biomass per plant, lower seed and oil yields per plant and a deterioration in oil quality, because of the lower percentage of oleic acid compared to plants grown in plots with greater spacing. The trial results are in agreement with other similar research works conducted in different areas of Italy (Monotti, 1978).

Although these results have been obtained experimentally with varieties characterized by high plant size and heterogeneous and late pollination, it seems that they do not need to be updated for the new available hybrids, which are earlier, smaller in size and marked by a high bio-morphological uniformity.

In fact, Curotti et al. (1977) did not find any difference in behaviour with regard to density between the tested varieties and the Romsum HS90 hybrid.

In other countries, studies on the effects of plant density and row spacing on seed yield provided contrast-ing results, suggesting that the optimum planting density depends on the cultivar and the environment (Blamey et al., 1997; Prunty, 1981). For example, Wade and Foreman (1988) found that seed production increased up to the maximum level with the optimal plant density, and then it remained constant at higher density when conditions were quite favourable. However, under adverse environmental conditions, the optimum density was lower. In Central Europe, the applied plant densities ranged between 6 and 8.5 plants m^{-2} (Hammann et al., 1995; Stock and Diepenbrok, 1999). In southern regions, shallow soils are prevailing, so the stored water is rapidly depleted. In these countries, the subsequent reduced availability of water can affect seed filling in the crop raised in narrow rows (Andrade et al. 2002).

In the traditional sunflower producing areas of Central Italy, research identified 5 plants m^{-2} as the optimal density (Monotti et al., 1999).

Table 4. Effects of row spacing on fatty acid composition of oil in sunflower crop grown in two Southern Italy locations (Valenzano and Policoro).

Fatty acid (%)	Distance between row (m)					
	0.4	0.6	0.8	0.4	0.6	0.8
	Valenzano			Policoro		
Palmitic acid (C16:0)	4.53^{A}	4.46^{B}	4.35^{C}	4.69^{A}	4.39^{B}	4.20^{C}
Stearic acid (C18:0)	2.50^{A}	2.49^{A}	2.45^{A}	2.42^{A}	2.47^{A}	2.48^{A}
Oleic acid (C18:1)	89.38^{C}	89.93^{B}	90.28^{A}	88.25^{C}	89.04^{B}	89.96^{A}
Linoleic acid (C18:2)	3.28^{A}	3.09^{B}	2.95^{C}	3.47^{A}	3.21^{B}	2.94^{C}
Linolenic acid (C18:3)	0.14^{A}	0.16^{A}	0.13^{A}	0.13^{A}	0.12^{A}	0.13^{A}
Arachic acid (C20:0)	0.20^{A}	0.20^{A}	0.20^{A}	0.20^{A}	0.20^{A}	0.20^{A}
Eicosenoic acid (C20:1)	0.18^{B}	0.23^{A}	0.23^{A}	0.19^{B}	0.2^{AB}	0.21^{A}
Beehnic acid (C22:0)	0.28^{A}	0.28^{A}	0.24^{B}	0.25^{A}	0.24^{A}	0.23^{A}
Lignoceric acid (C24:0)	0.13^{A}	0.11^{B}	0.11^{B}	0.14^{A}	0.13^{AB}	0.12^{B}
C18:1/C18:2	27.25^{C}	29.10^{B}	30.60^{A}	25.43^{C}	27.73^{B}	30.59^{A}
(18:1+18:0)/16:0	20.28^{C}	20.72^{B}	21.31^{A}	19.33^{C}	20.84^{B}	22.00^{A}

For each effect considered, the values followed by the same letter are not significantly different, according to the SNK test at P ≤ 0.01.

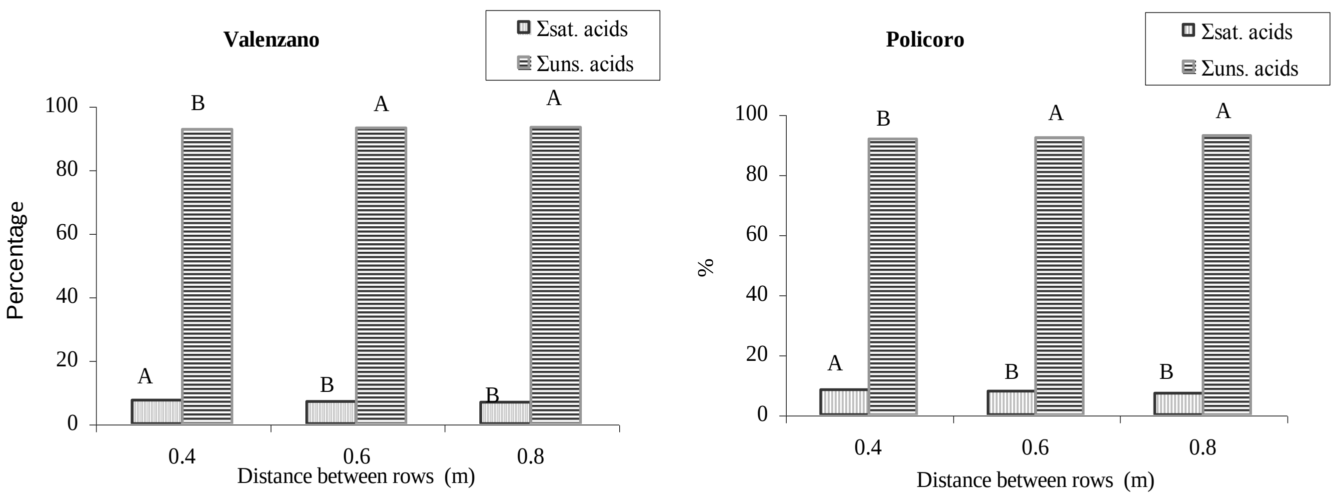

Figure 4. Effects of row spacing on saturated and unsaturated fatty acids of oil in sunflower crop grown in two Southern Italy locations (Valenzano and Policoro). For each effect considered, the values followed by the same letter are not significantly different, according to the SNK test at P ≤ 0.01.

Effects on yield and oil quality

Crop A

Oil yield and fatty acid composition were significantly affected by plant density. In particular, shifting from 0.8 m to 0.6 and 0.4 m row spacing, the oil yield decreased by 2.4 and 4.3%, respectively (Table 3, Figures 2).

Regarding the fatty acid composition, a significant effect of plant density was found on the content of oleic, linoleic and palmitic acids, on the total content of saturated and unsaturated fatty acids and oleic/linoleic and oleic acid + stearic/palmitic acid ratios (Table 4).

In particular, a progressive increase was observed in oleic acid (+1%), unsaturated fatty acids (+0.6%), oleic/ linoleic acid (+3.4%) and oleic + stearic/palmitic acid ratios (+1%) and a corresponding decrease was found in linoleic (-10.0%) and palmitic (-3.9%) acid contents, as the row spacing increased from 0.4 to 0.8 m (Table 4, Figure 4).

Crop B

The best features of seeds were found in sunflower crop grown in the area of Policoro at minimum density (row spacing of 0.8 m). In particular, shifting from 0.8 m to 0.6 and 0.4 m row spacing, the oil yield decreased by 2.3 and 4.4% respectively (Table 3, Figure 2).

Regarding the fatty acid composition, a significant effect of plant density was observed on the oleic, linoleic and palmitic acids, total content of saturated and unsaturated fatty acids and oleic – linoleic and oleic acid + stearic acid - palmitic acid ratios. In particular, a progressive increase was observed in oleic acid content (+1.9%), unsaturated fatty acids (+1.3%), oleic/linoleic (+5.2) and oleic + stearic/palmitic acid ratios (+2.7) and a corresponding decrease was found in linoleic (-15.3%) and palmitic acid (-10.4%) contents, as the row spacing increased from 0.4 to 0.8 m (Table 4, Figure 4).

The genotype characteristics, the growing environment and the agronomic practices affect not only the yield response, but also oilseed quality (Santonoceto et al., 2003).

The variability of the fatty acid composition of sunflower seeds is mostly attributed to the change in the following climate parameters: minimum temperature at "early flowering- physiological ripeness", solar radiation and water availability (Anastasi et al., 2001).

Therefore, the varying row spacing had a fairly significant effect on crop yield and on the quality response in both southern Italy environments.

Conclusion

Based on the results of the research aimed to assess the influence of row spacing on sunflower crop in 2 different locations in Southern Italy, the following concluding remarks can be made:

(i) The better yield results observed for sunflower grown in the area of Policoro (MT) are very likely due to more favourable soil and climate conditions;
(ii) The effects of different row spacing on sunflower crop did not varied according to the location;
(iii) sunflower seed and oil yields did not increase at a density greater than 5 plants m^{-2} (0.6 m row spacing), because the higher number of plants per unit area did not compensate for the lower yield per plant: all yield components decreased gradually with increasing density;
(iv) seed and oil yields are significantly lower than the maximum possible values obtained from the plants grown at the density of 7.5 plants m^{-2} (0.4 m row spacing);
(v) small significant increases in oleic acid and unsaturated fatty acid contents, oleic/linoleic, oleic + stearic/ palmitic acid ratios and a corresponding decrease in linoleic and palmitic acid contents were obtained by increasing the row spacing.

Therefore, the mean crop yields in the two experiments did not show any significant difference at the densities of 3.75 and 5 plants m^{-2} (0.8 and 0.6 m row spacing, respectively).

However, the superiority in the quality of the fatty acid composition was observed in crops grown at lower density. Therefore, 0.8 m row spacing is a good compromise as it allows both higher seed production and better acid composition of oil.

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