

FOUR-YEAR FIELD EXPERIMENT ON NITROGEN APPLICATION TO SUNFLOWER GENOTYPES GROWN IN SEMIARID CONDITIONS

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SUMMARY

A four-year field experiment was carried out to study the effects of different N levels on yield, yield components, N uptake and seed quality of sunflower genotypes grown in semiarid Mediterranean conditions. Five genotypes (four commercial hybrids and one newly selected genotype) and three N fertilization levels (0, 50 and 100 kg N ha⁻¹) were compared over four years (1996, 1997, 1998 and 1999).

Sunflower plants were taken at flowering time and their dry weight, leaf area index and total N content were determined. At maturity stage, yield, yield components, oil content, protein content, N uptake and seed quality were determined.

The obtained results indicated significant differences in yield performance (seed, oil and protein production) throughout the years (from 2.52 t ha⁻¹ in 1996 to 3.81 in 1999), confirming the need to use recommended genotypes and adjust fertilizer rates to crops requirements, especially in the Mediterranean environment where weather conditions are unpredictable and inconsistent. In fact, the genotypes showed different behavior in all years regarding total N uptake, seed, oil and protein production, indicating that the sunflower crop is responsive to agronomic management. The highest level of N fertilizer resulted in the best sunflower performance although, due to variations in year and genotype, fertilizer N could be applied according to total annual N uptake. Finally, the N uptake and the diameter of head were the most important parameters that influenced sunflower yield performance.

Key words: nitrogen fertilization, N uptake, seed quality, sunflower, yield components

INTRODUCTION

Sunflower (*Helianthus annuus* L.) is one of the most important oil crops and, due to favorable agricultural policies, its acreage has been expanding in recent

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years, also in Mediterranean countries because of its importance in many dryland farming systems (López-Bellido *et al.*, 2003). In this area, selection of genotypes with high performance and good adaptation to the specific environmental conditions could be an important goal, especially when low input is adopted (Leto *et al.*, 1997). In fact, in semi arid climates characterized by high variability of rainfall distribution, the main factors limiting growth and production are water and nitrogen (N) supplies. Therefore, a particular amount of N fertilizer added to a sunflower crop could result in a depletion or accumulation of soil mineral N, depending on rainfall, plant growth and genotype utilized.

Effects of N fertilization on sunflower yield and quality have come under scientific scrutiny (Hocking and Steer, 1995; Thavaprakash *et al.*, 2002), because N is a major nutrient for plants and it increases total biomass production, yield and its components. Furthermore, under Mediterranean conditions, N fertilization increases total N uptake in several crops (Delogu *et al.*, 1998; Montemurro *et al.*, 2002) and in sunflowers in other environments (Steer *et al.*, 1985; Hocking and Steer, 1995) and, due to high correlations with yield, also crop performance. Conversely, inaccurate distribution of N fertilizer induces N dissipation in the environment due to high N mobility in the soil (Magdoff *et al.*, 1997; Janzen *et al.*, 2003), therefore, the choice of an N-efficient cropping system (genotype and rotation) and an adequate level of N fertilizer require methods and knowledge to evaluate N effects on plant yield and its environmental risks. Consequently, appropriate genotypes and N fertilization levels are important features for farmers, especially in Mediterranean conditions where dry growing seasons and water deficit in the soil influence yield, growth and plant development (Botella Miralles *et al.*, 1997; Corbeels *et al.*, 1998). The aim of this work was to study the behavior of different sunflower hybrids cropped under different N levels in Mediterranean conditions. The evaluation of yield reduction and its interaction with different genotypes, quality performance and yield components under N constraints were further investigated.

MATERIALS AND METHODS

This research was carried out at Istituto Sperimentale Agronomico, the experimental farm in Foggia (Southern Italy), an area with a typical Mediterranean environment ("accentuated thermo Mediterranean" as classified by UNESCO-FAO). It is characterized by temperatures that can range below 0°C in winter and up to 40°C in summer, with uneven rainfall distribution during the year, the precipitation occurring mainly in the winter season. The soil, typical of the flat land of Apulia Tavoliere (South Italy), has a clay-loamy texture and is classified by Soil Taxonomy-USDA as a fine, mesic, Typic Chromoxerert. Its main characteristics are as follows: total N=1.34 g kg⁻¹; available P=27 mg kg⁻¹; exchangeable K=1018 mg kg⁻¹; organic matter=20.7 g kg⁻¹; pH = 8.83.

The research was conducted during 4 years (1996, 1997, 1998 and 1999) on four sunflower hybrids (Isoleic, Sanbro, Akiles, Select) and one new genotype (Printa AGD) selected by INTA (Argentina). Three N fertilization levels (0, 50 and 100 kg N ha⁻¹, indicated as N0, N50 and N100, respectively) were also compared in this research. Printa AGD was included in the trials from 1997. The experimental design was a split-plot with three replications; the main plot was assigned to the nitrogen level and the sub plot to the genotype. The elementary plot consisted of 45 m² with about 7 plant m⁻². The N fertilizer, as ammonium nitrate, was distributed in two equal amounts during sunflower growth (at 3-4 and 11-12 leaves) for N50 (25 kg ha⁻¹ in each distribution) and N100 (50 kg ha⁻¹). Irrigation was performed only once during the sunflower cycle, at the early flowering stage (80 mm).

At flowering time, 1 m² of sunflower plants were taken and leaf area index (LAI), dry weight and total N content from different parts of the plant were determined by a CHN elemental analyzer (Fison EA 1108). The last two parameters allowed the calculation of N uptake (N content per dry weight). At maturity, a sample of 10 m² was collected from each plot and the following parameters were determined: seed yield (at 10% moisture level), yield components (plant height, diameter of the fertile and infertile head), seed quality (1000-seed weight, hectoliter weight, ash and crude fiber), seed and stem N uptake, protein content and oil content (extraction with diethyl ether in Soxhlet for 36 h). To better understand the yield performance of the treatments, oil production (oil yield), protein production (protein yield) and harvest index (ratio of seed yield and total plant biomass at harvest) were also calculated.

Statistical analyses were made using the SAS software package (SAS Institute, 1990), considering years as random and genotype and N fertilization levels as fixed effects. Differences among treatments were evaluated using Duncan's range multiple test (DMRT), whereas Pearson correlation coefficients were used to compare yield performance with yield components, seed quality and N uptake.

RESULTS AND DISCUSSION

Figure 1 shows the long-term (45 years) mean, annual and seasonal rainfalls during the four-year field experiment in Foggia. No large difference was found among the years in respect to the long-term mean total rainfall, but marked variations were recorded in spring and summer, which are most important periods for sunflower growth. In particular, the sums of rainfall in these two seasons were 282, 156, 245, 254 and 226 for 1996, 1997, 1998, 1999 and the long-term period, respectively. Therefore, although the sunflower plants received a single irrigation during early flowering time (about 80 mm), 1997 presented a greater lack of rainfall during the cropping cycle (70 mm and about 100 mm, in respect to the long-term period and other experimental years, respectively), which can strongly influence the sunflower response to fertilizers. In fact, Lòpez-Bellido *et al.* (2003) reported that sunflower N uptake, and consequently its yield performance, are likely to increase if there is adequate soil water. No substantial difference in mean temperature was

found either in spring (17.8, 17.3, 19.1, 19.5 and 17.3°C for 1996, 1997, 1998, 1999 and the long-term period, respectively) or summer (22.6, 24.2, 25.7, 24.7°C and 23.7°C) through the experimental years.

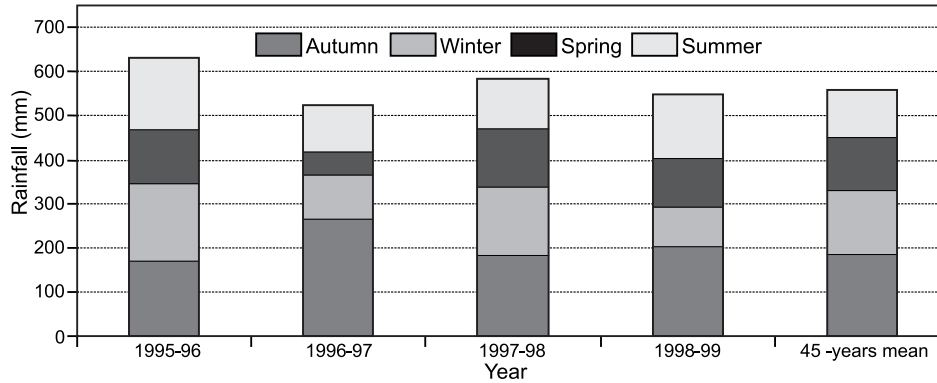


Figure 1: Long-term (45 years) mean, annual and seasonal rainfalls during the field experiment period in Foggia

Significant differences in seed yield were found for years, genotypes, N fertilization levels, year x genotype and years x N fertilization level interactions. The interaction genotype x N fertilization showed no significant difference, which indicated that the genotypes responded similarly to N increase regarding their yield performance (Table 1). The variation of climatic conditions significantly influenced yield, yield components, quality and N uptake, but not the oil content, while significant differences were found among the genotype and the interaction year x genotypes in all parameters considered. The level of N fertilization influenced yields (seed, oil and protein production) and N uptake, but not seed quality (oil percentage and protein content). Significant differences in N uptake (seed and total) were found for year, genotype, N fertilization level and year x N level interaction (Table 1). Also for these parameters, year x N level and genotype x N level were insignificant, indicating that the genotypes responded similarly to an increase in N.

Table 1: Significance of F values from the analysis of variance for the main parameters measured

	d.f.	Yield (t ha ⁻¹)	Oil content (%)	Protein content (%)	Oil yield (t ha ⁻¹)	Protein yield (t ha ⁻¹)	1000 seed weight (g)	LAI max	N uptake seed (kg ha ⁻¹)	Total N uptake (kg ha ⁻¹)	HI
Year (Y)	3	***	n.s.	***	***	***	***	***	***	***	***
Genotype (G)	4	***	*	***	***	***	***	***	***	**	***
N level (N)	2	**	n.s.	n.s.	**	*	n.s.	**	*	***	n.s.
Y x G	12	***	***	***	***	***	***	**	***	***	***
Y x N	6	*	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.
G x N	8	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.
Y x G x N	24	n.s.	n.s.	*	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.

*, **, *** = Significant at the P<0.05, 0.01 and 0.001 levels, respectively; n.s.=not significant

Table 2 shows the genotype and year interactions for seed yield. Significant differences were found among the years (3.05, 2.52, 3.47 and 3.81 t ha⁻¹ for 1996, 1997, 1998 and 1999, respectively) and the genotypes (2.89, 3.44, 3.26, 3.23 and 3.30 t ha⁻¹ for Isoleic, Sanbro, Akiles, Select and Printa AGD, respectively).

Table 2: Genotype × year interaction for seed yield (t ha⁻¹)

Genotype	Year				Mean
	1996	1997	1998	1999	
Isoleic	2.29f	2.50ef	3.26cd	3.50bd	2.89b
Sanbro	3.44cd	2.42ef	3.46cd	4.42a	3.44a
Akiles	3.16d	2.77e	3.43cd	3.67bc	3.26a
Select	3.31cd	2.59ef	3.49bd	3.55bd	3.23a
Printa AGD	-	2.30f	3.69bc	3.92b	3.30a
Mean	3.05c	2.52d	3.47b	3.81a	

The values of the interaction, mean of year and genotype followed by different letters are significantly different according to DMRT at P≤0.05

The low amount of rainfall observed in 1996 determined a lower amount of water available for grain filling, increasing the detrimental effects of water stress on the formation of achenes and, consequently, reducing grain yield, according to the results found by Botella Miralles *et al.* (1997). The highest seed yield was observed for Sanbro in 1999 (4.42 t ha⁻¹), which exhibited good performance throughout the entire trial, while the hybrid Isoleic achieved a lower yield even with favorable environmental conditions as in 1996.

Table 3: Genotype × N fertilization level interaction for seed yield (t ha⁻¹)

Genotype	N fertilization			Mean
	N0	N50	N100	
Isoleic	2.97cd	2.69d	3.00bd	2.89b
Sanbro	3.31ac	3.51a	3.49a	3.44a
Akiles	3.17ac	3.20ac	3.40a	3.26a
Select	3.13ac	3.14ac	3.43a	3.23a
Printa AGD	3.37ab	3.12ac	3.41a	3.30a
Mean	3.18b	3.13b	3.34a	

The values of the interaction, mean of N fertilization and genotype followed by different letters are significantly different according to DMRT at P≤0.05

Table 4: Year × N fertilization level interaction for seed yield (t ha⁻¹)

Year	N fertilization			Mean
	N0	N50	N100	
1996	2.79de	2.95d	3.41c	3.05c
1997	2.55e	2.46e	2.53e	2.52d
1998	3.44c	3.42c	3.54bc	3.47b
1999	3.86ab	3.68ac	3.90a	3.81a
Mean	3.18b	3.13b	3.34a	

The values of the interaction, mean of N fertilization and year followed by different letters are significantly different according to DMRT at P≤0.05

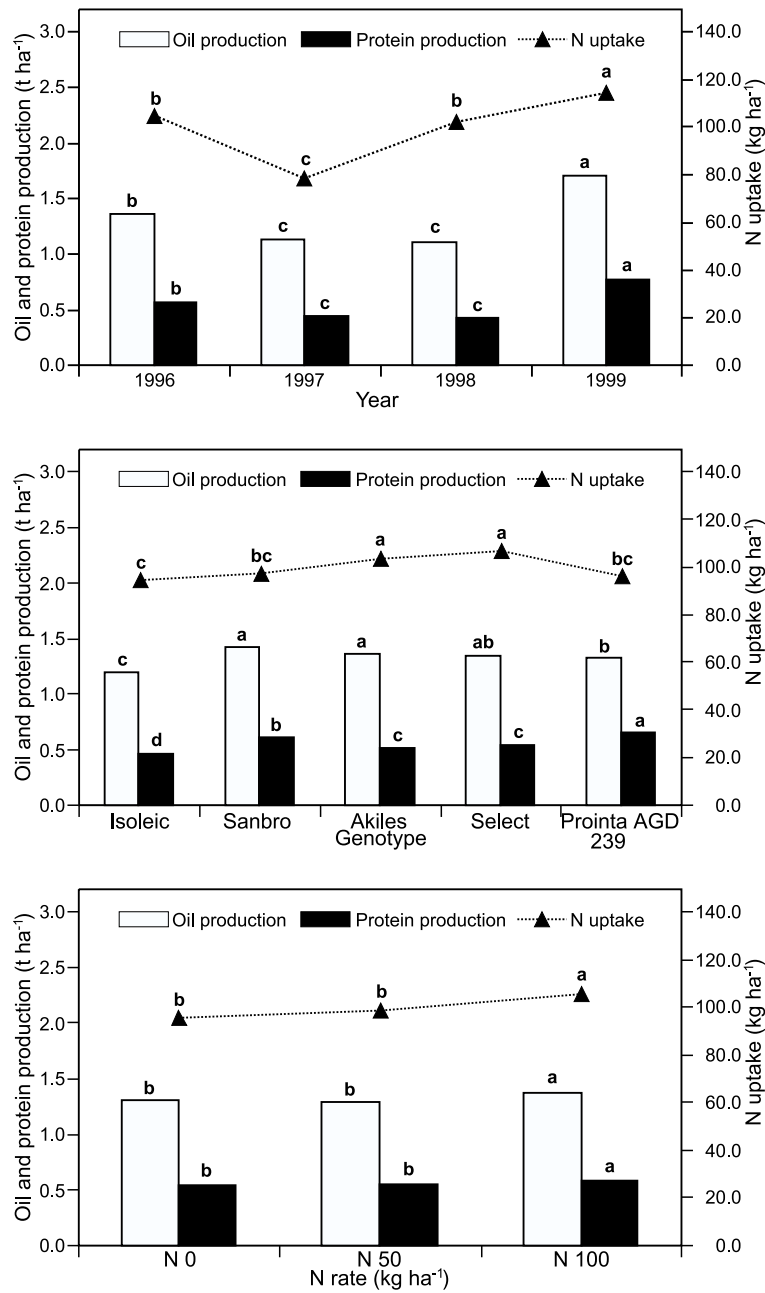


Figure 2: Sunflower total N uptake, oil and protein production in the experimental treatments (Within treatments (year, genotype and N fertilization) and parameters (grain yield, oil and protein production) means followed by different letters are significantly different according to DMRT at $P \leq 0.05$).

The high N application rates used by farmers are justified because they increase plant growth, but in general, N fertilization of sunflowers grown in semiarid climates is a controversial practice, since N availability is governed by rainfall pattern (López-Bellido *et al.*, 2003). In our study, the N100 treatment had a higher seed yield than the N50 and N0 treatments (3.34, 3.13 and 3.18 t ha⁻¹, respectively) (Table 3). Furthermore, it is well known that the reduction of seed oil due to the addition of N is relatively small and it is compensated for by the increase of seed yield (Scheiner *et al.*, 2002). Therefore, the results of our four-year field experiment with five genotypes indicated that the annual rate of N fertilizer could be around 100 kg ha⁻¹, according to the level of N uptake (Figure 2). Conversely, the yield of the hybrid Isoleic was significantly lower in respect to the other genotypes with all levels of N fertilization, confirming that yield performance of the genotypes is independent from N fertilizer application, as shown by no significant interaction between genotypes and N levels (Table 1).

Table 4 shows the effect of year and N fertilization interaction on seed yield. Significant differences were found throughout the field experiment (3.05, 2.52, 3.47 and 3.81 t ha⁻¹ for 1996, 1997, 1998 and 1999, respectively), indicating that the weather conditions strongly influenced the performance of sunflowers in a Mediterranean environment (Botella Miralles *et al.*, 1997). Furthermore, the interaction year × N fertilization was significant (Table 1), and therefore, at the same N fertilization level (N100), the seed yield reached the highest value (3.90 t ha⁻¹ for 1999) and one of the lowest (2.53 t ha⁻¹ for 1997).

Figure 2 shows the total N uptake, oil and protein production in the experimental treatments. Significantly higher values of these parameters were found in 1999 compared with the other experiment years. The total N uptake in 1997 (78.4 kg ha⁻¹) was extremely low confirming that this parameter is limited by drought, thus consequently affecting sunflower yield performance (Table 2). Similar results were obtained by Corbeels *et al.* (1998). In our study, the genotypes tested showed different behavior in total N uptake, oil and protein production, indicating that sunflower crops are particularly susceptible to different agronomic management (Owen, 1983; Ujjanaiah *et al.*, 1995; Murillo *et al.*, 1998). In particular, Prointa AGD showed the highest value of protein production (0.66 t ha⁻¹), Sanbro and Akiles of oil production (1.42 and 1.36 t ha⁻¹, respectively) and Akiles and Select of total N uptake (103.4 and 106.8 kg ha⁻¹, respectively). The highest performance in seed yield (Table 2), total N uptake, oil and protein production (Figure 2) was obtained with 100 kg ha⁻¹ of N fertilizer (N100 treatment), confirming the results of other researches (Ujjanaiah *et al.*, 1995; Dalla Costa and Giovanardi, 1996). Therefore, considering that sunflowers can absorb a high amount of residual N from the soil (Leto *et al.*, 1997) and that they produce satisfactory yield with low N input (Sinsawat and Steer, 1993), fertilizer N should be applied only when required, according to total annual N uptake.

Table 5: Yield components of the sunflower divided by year, genotype and level of N fertilization

Treatment	Parameter					
	1000 seed weight (g)	Hectoliter weight (g)	Plant height (cm)	Diameter fertile head (cm)	Diameter infertile head (cm)	LAI at flowering
Year						
1996	51.1c	40.7c	135.1b	16.7b	2.81a	3.91a
1997	50.8c	41.8b	106.9c	14.7d	2.95a	3.29b
1998	55.0a	44.6a	140.9a	15.9c	1.47b	3.39b
1999	53.6b	37.9d	142.9a	17.7a	1.62b	3.43b
Genotype						
Isoleic	52.2b	39.2c	133.3b	15.9b	2.05b	3.83a
Sanbro	54.1a	43.6a	138.4a	16.9a	1.83b	3.19b
Akiles	48.8c	42.2b	120.9d	16.1b	2.56a	3.22b
Select	54.7a	39.4c	125.9c	16.2b	2.75a	3.48ab
Prointa AGD	54.1a	42.3b	140.1a	16.1b	1.54c	3.77a
Level of N						
N0	52.7	41.7	130.5	16.2	2.04	3.25b
N50	53.0	41.1	131.9	16.1	2.23	3.56a
N100	52.4	41.1	131.5	16.3	2.26	3.64a

Within years, genotypes and N fertilization levels, the values in each column followed by a different letters are significantly different according to DMRT at $P \leq 0.05$

Table 5 shows the sunflower yield components. Significant differences were found for all parameters in all years and genotypes tested, whereas increased values for N50 and N100 were found only for LAI at flowering time. The diameter of fertile achenes per head was higher in 1999 (17.7 cm) and for Sanbro (16.9 cm). There were positive and significant correlations between the diameter of fertile achenes per head and seed yield, oil and protein production (0.6405, 0.6289 and 0.6427 for $P < 0.0001$, respectively) (Table 7), indicating that this yield component is the most important parameter that influences yield performance in a Mediterranean environment, as reported by Zaffaroni and Schneiter (1991) and Botella Miralles *et al.* (1997). Similar behavior, but with lower absolute correlation values, was observed for 1000-seed weight (Tables 5 and 7).

Finally, Table 6 shows the seed quality and N uptake (seed and stem) of the sunflowers. The highest value of HI was obtained in 1997, but this parameter was not in correlation with yield performance (Table 7). The highest values of ash, seed and stem N content were obtained for N100 treatment (Table 6) and these parameters were significantly correlated with seed, oil and protein production (Table 7). The high and positive correlations between N uptake and yield performance confirm that N nutrition is extremely important for sunflower yield performance (Hocking and Steer, 1995; López-Bellido *et al.*, 2003).

Table 6: Seed quality and N uptake (seed and stem) of the sunflower divided by year, genotype and level of N fertilization

Treatment	Parameter				
	HI	Ash	Crude fiber	Seed N uptake	Stem N uptake
	(%)	(%)		(kg ha ⁻¹)	(kg ha ⁻¹)
Year					
1996	38.0b	2.71a	15.5c	86.4a	18.4c
1997	44.3a	2.36c	22.0a	66.6b	11.9d
1998	34.3c	2.60b	19.5b	63.3b	23.8b
1999	37.9b	2.58b	15.6c	89.1a	25.4a
Genotype					
Isoleic	35.9c	2.59b	16.4c	69.9b	18.3c
Sanbro	40.3ab	2.47cd	19.1ab	75.9ab	21.2b
Akiles	38.2bc	2.44d	19.6a	78.6a	18.8c
Select	38.2bc	2.73a	18.2b	82.0a	18.3c
Prointa AGD	41.4a	2.55bc	18.3b	71.9b	24.2a
Level of N					
N0	39.1	2.50b	18.3	73.4b	18.1c
N50	38.2	2.54ab	18.3	74.7ab	19.8b
N100	39.6	2.62a	18.2	79.5a	21.9a

Within years, genotypes and N fertilization levels, the values in each column followed by a different letters are significantly different according to DMRT at $P \leq 0.05$

Table 7: Correlation coefficients among yields (seed, oil and protein production) \times yield components, seed quality and N uptake

	Yield (t ha ⁻¹)	Oil yield (t ha ⁻¹)	Protein yield (t ha ⁻¹)
HI (%)	0.0539 n.s.	0.0593 n.s.	0.0346 n.s.
Oil content (%)	-0.0707 n.s.	-0.0005 n.s.	-0.1005 n.s.
Protein content (%)	0.2631 ***	0.2567 ***	0.7203 ***
1000-seed weight (g)	0.3693 ***	0.3737 ***	0.3667 ***
Hectoliter weight (g)	0.0176 n.s.	0.0262 n.s.	-0.1213 n.s.
Plant height (cm)	0.5797 ***	0.5697 ***	0.5486 ***
Diameter fertile head (cm)	0.6405 ***	0.6289 ***	0.6427 ***
Diameter infertile head (cm)	-0.4560 ***	-0.4476 ***	-0.4679 ***
LAI at flowering	-0.1258 n.s.	-0.1295 n.s.	0.0098 n.s.
Ash (%)	0.1832 *	0.1786 *	0.2889 ***
Crude fiber	-0.3468 ***	-0.3193 ***	-0.3116 ***
Seed N uptake (kg ha ⁻¹)	0.5873 ***	0.5819 ***	0.5114 ***
Stem N uptake (kg ha ⁻¹)	0.6171 ***	0.6146 ***	0.6096 ***
Total N uptake (kg ha ⁻¹)	0.6995 ***	0.6941 ***	0.6327 ***

*, **, *** = Significant at the $P < 0.05$, 0.01 and 0.001 levels, respectively; n.s. = not significant

CONCLUSIONS

The results of this research indicate that weather conditions strongly influence sunflower response when different N fertilizer levels and genotypes are used. In fact, the year with the worst environmental conditions (1996) reached only 66.1% of the seed yield obtained in the best year (1999). The hybrids behaved differently with regard to total N uptake and yield production, confirming that sunflowers are responsive to different agronomic practices. The highest level of N fertilizer ensured better yield performance (seed, oil and protein production) in most of the tested hybrids although, for optimal financial profit, N fertilizer could be applied according to the calculation of crop needs for total annual N uptake. Therefore, in order to avoid a negative environmental impact, it is necessary to use recommended genotypes and adjust fertilizer rates to crop requirements, since excessive N fertilization is one of the main causes of groundwater contamination with nitrates. The N uptake (seed, stem and total) and head diameter (sterile and fertile) were the most important parameters that influenced the sunflower yield performance in semiarid conditions, in light of the high and positive correlations found among them.

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EXPERIMENTO DE CUATRO AÑOS DE DURACIÓN SOBRE LA APLICACIÓN DE NITROGENO EN LOS GENOTIPOS DE GIRASOL EN UNA ÁREA EN CONDICIONES SEMIARIDAS

RESUMEN

Se ha llevado a cabo un experimento durante cuatro años para estudiar los efectos de diferentes cantidades de N en las cosechas, los componentes, la absorción de N y la calidad de las semillas de los genotipos del girasol cultivados en condiciones semiarias de la zona Mediterránea.

Cinco genotipos (cuatro híbridos comerciales y un genotipo nuevo seleccionado) y tres niveles de fertilización con N (0, 50 y 100 kg N ha⁻¹) han sido comparados durante cuatro años (1966, 1997, 1998 y 1999).

Se han recogido las plantas en el tiempo de floración y el peso en seco, el índice de superficie de la hoja y el contenido total de N han sido determinados; en cuanto a la fase de maduración, se han determinado la cosecha, los componentes, el contenido de aceite, el contenido de proteína, la absorción de N y la calidad de la semilla.

Los resultados indican una diferencia significativa en la actuación del cultivo (producción de semillas, aceite y proteínas) durante todos los años (de 2.52 t ha⁻¹ en 1996 a 3.81 t ha⁻¹ en 1999), lo que confirma la necesidad de seleccionar los genotipos recomendados y adaptar las percentuales de fertilizantes a las necesidades de las cosechas especialmente en ambiente Mediterráneo donde las condiciones atmosféricas son imprevedibles y variables. De hecho, los genotipos han mostrado diferente comportamiento durante todos estos años en la absorción total de N, en la producción de semillas, aceite y proteínas, demostrando que la cosecha de girasol es susceptible de gestión agronómica.

El más alto nivel de fertilizante de N ha demostrado la mayor actuación del girasol aunque, debido a un cambio de años y genotipos, el fertilizante N podría ser aplicado sobre una base anual de acuerdo con la total absorción de N. Por último, la absorción de N y el diámetro de la cabeza han sido los parámetros más importantes que han influenciado la actuación del cultivo del girasol.

QUATRE ANNÉES D'EXPÉRIMENTATION SUR L'APPLICATION D'AZOTE SUR DES GÉNOTYPES DE TOURNESOL EN CONDITIONS SEMI ARIDE

RÉSUMÉ

L'objectif de l'expérimentation, menée en conditions de plein champ sur quatre années, était d'étudier l'effet de différentes doses d'azote sur le rendement et ces composantes, l'azote total absorbé et la qualité de graines des génotypes du tournesol cultivés en conditions semi aride.

Cinq génotypes (quatre hybrides commerciaux et un nouveau sélectionné) et trois niveaux de fertilisation azotée (0, 50 et 100 kg N ha⁻¹) ont été comparé durant quatre années (1996, 1997, 1998 et 1999).

Au stade floraison, sur des plantes prélevées, la matière sèche, indice de la superficie foliaire et le contenu total d'azote ont été déterminé. Alors que, au stade maturité, le rendement et ces composantes, contenu d'huile, contenu de protéine, azote total absorbé et qualité des graines ont été évalué

Les résultats obtenues ont indiqué une différence significative concernant la performance en rendement (production en graine, huile et protéine) au cours des années (de 2.52 t ha⁻¹ en 1996 à 3.81 t ha⁻¹ en 1999), confirmant la nécessité de sélectionner des génotypes recommandés et d'ajuster la dose de fertilisation selon les besoins de la plante, spécialement dans l'environnement Méditerranéen où les conditions du temps sont imprévisibles et variables.

En réalité, les génotypes étudiés ont montré un comportement différent au cours des années en ce qui concerne l'azote total absorbé, la production en graine, huile et protéine, en indiquant que la plante du tournesol est susceptible à la gestion des techniques agronomiques. En outre, le niveau de fertilisation azotée plus élevé a montré aussi la meilleure performance du tournesol, bien que due aussi à la variation des années et des génotypes, la fertilisation azotée doit être appliquée sur la base annuelle, selon l'azote total absorbé. En fin, l'azote total absorbé et le diamètre des capitules sont les plus importants paramètres qui ont influencé la performance en rendement du tournesol.