# Relationship between different water and nitrogen supplies on yield and nitrogen utilisation and partitioning in sunflower.

Mario BALDINI[a], GianPaolo VANNOZZI[a], Mario MACCHIA[b] and Maurizio TURI[b]
[a] Crop Production Department, Udine University, via delle Scienze, 208, 33100 Udine (Italy)
b Agronomy Department, Pisa University, via San Michele, 2, 56100 Pisa (Italy)

**Abstract**

The experiment was carried out during the 1993 growing season at the Pisa University Experimental Farm to evaluate the effects of different water and nitrogen supplies on the main sunflower characteristics and evaluate the utilisation and partitioning pattern of nitrogen in plants. Three treatments were adopted, E1N1, with high water and nitrogen supply, E1N0, with high water supply but without nitrogen fertilisation and E0N0, without any additional water and nitrogen, on two cultivars (Viki and Euroflor) following a split-plot design with four replicates. The nitrogen content of plants at maturity was positively correlated with yield and the main yield characteristic i.e. LAI at flowering. The high N fertilisation increased the active late N absorption during grain-filling by about 10% and consequently led to a 15% reduction of N mobilisation from the vegetative tissues during the same period. In the presence of adequate water availability, the natural soil nitrogen content contributed 74% of the total N absorbed by the crop, while the E1N0 treatment took up 92 kg/ha N more than was available as inorganic N at a soil depth of 1 m, confirming that the sunflower is an excellent utiliser of deep soil N residues.

## Introduction

The economic justification of fertilisation is determined, apart from economic factors, by crop response and the utilisation of the applied fertiliser. It is known that nitrogen nutrition plays a decisive role in sunflower growth and yield especially during the first phases of sunflower cycle (Coic *et al.*, 1972; Steer and Hocking, 1984). The importance of this period is linked to leaf expansion, the intensity of various physiological processes (Radin and Boyer, 1982; Rawson and Turner, 1982, 1983) and is consequently linked to the formation of an adequate number of achenes per plant (Steer and Hoching, 1984; Blanchet *et al.*, 1987). However, high nitrogen availability during the early stages could lead to over-luxuriant vegetative growth, with the ensuing risk of self-shedding, lodging and greater susceptibility to disease and water stress. Previous studies showed that the sunflower can take up nitrogen from deep soil reserves (Decau *et al.*, 1984; Blanchet *et al.*, 1987) and this determines a very low real utilisation coefficient of applied fertiliser compared to other crops such as wheat (Merrien *et al.*, 1988). Moreover, high nitrogen fertilisation may have negative results with a weak response whenever water is a limiting factor (Blanchet *et al.*, 1987). For this reason, this study was carried out to examine the effects of different nitrogen and water supplies on the main sunflower characteristics and to evaluate the utilisation and partitioning pattern of nitrogen in the plant.

## Material and Methods

The experiment was conducted in 1993 at the Pisa University Experimental Farm at S. Piero a Grado, 15 km from Pisa, Italy. This region has a Mediterranean climate with mild, rainy winters and hot, dry summers with high evaporation rates. The soil was a deep and fertile Vertisol, with a sandy clay loam texture.
Three treatments were adopted for the experiment, with different levels of water and nitrogen availability and in particular: E1N1, with high water and nitrogen availability; E1N0, with

high water availability and a low level of nitrogen; E0N0, with low water and nitrogen availability.

The high water availability treatment was provided by overhead sprinkler irrigation during the crop cycle, maintaining the available soil water above approximately 80% of field capacity. The total amount of the water used by the crop during its cycle was determined by the water balance method: water use = soil water at time of sowing + rainfall + irrigation - soil water remaining at the end of the experiment. Soil internal drainage and surface water runoff were considered negligible.

The treatment with high nitrogen availability were obtained by the application at planting of 60 Kg N/ha and at covering of 120 Kg N/ha, giving a total of 180 Kg/ha, while nitrogen fertiliser (urea) was not applied for the treatments with low nitrogen level.

Two commercial sunflower (*Helianthus annuus* L.) hybrids (Viki and Euroflor) were used.

The experimental scheme adopted was a split-plot design, with water and nitrogen levels as main treatments and genotypes as sub-treatments in 4 replicates. Each experimental unit consisted of four rows 7 m long at a spacing of 0.5 m (final planting density of about 8 plants $m^{-2}$). In all plots at pre-planting time, 180 kg/ha $P_2O_5$ and 80 Kg/ha $K_2O$ were applied. The main pedo-climatic conditions at the experimental site and the levels of the treatments are reported in tab. 1. From the beginning of flowering to maturity, three plants were taken manually at random from the central two rows of each plot once every ten days on 4 occasions. At each harvest, samples were divided into leaves, stems, head and achenes, and oven-dried. LAI and dry matter accumulation were calculated.

At final harvest, the characteristics examined were the following:

1000 achenes weight (g); achene number per plant; seed density (kg/hl); oil seed content (%), measured by nuclear magnetic resonance (N.M.R.); achene yield (t $ha^{-1}$).

The concentration of nitrogen in plant fractions was determined by micro-Kjeldahl analysis in samples from the first (beginning of flowering) and final (maturity) harvests. The amount of N accumulated by the crop during grain-filling was calculated as the difference between the N content at maturity and the N content at flowering time. Mobilisation of N from vegetative parts was estimated by the difference between the total aboveground plant N content at flowering time and the final N content of all non grain parts.

Leaf water potential was measured to evaluate the presence of drought conditions in the treatment with low water availability (E0N0), at noon during flowering time, with a Scholander pressure chamber.

All the data obtained were submitted to the analysis of variance which tested the effects of treatments, genotypes and their interactions. Simple correlations were calculated for some variable means.

**Results and Discussion**

Temperatures at Pisa during 1993 were above normal in July and August and normal for the rest of the growing season while rainfall was below normal for the entire growing season. The plants subjected to irrigation (E1N1 and E1N0) had a leaf water potential of -0.89 Mpa, lower than the -1.23 Mpa of the plants without irrigation (E0N0 treatment), indicating, in the latter treatment, the presence of a moderate stress condition.

In tab. 2, the treatment with high nitrogen and water supply (E1N1) had significantly higher values for all characteristics than E0N0 (low nitrogen and water supply), except for achene number per plant and achene oil content, where the highest values were obtained by treatment E0N0 (49.8%) and the lowest by the E1N1 treatment (45.7%). In fact, increasing soil nitrogen supply, especially after anthesis and in the presence of a terminal drought, determined a decrease of achene oil content and, due to the general inverse relationship, well known to exist in sunflower, an increase in protein concentration (Coic *et al.*, 1972; Blanchet and Merrien 1982; Steer *et al.*, 1984). The effect of different nitrogen supplies, under non-limiting water availability conditions, can be evaluated by analysing the difference between the two treatments E1N1 and E1N0. In this case, significant differences appeared only for 1000

achene weight, with values of 63.5 and 55.6 g for E1N1 and E1N0 respectively, and seed yield, in which 180 kg/ha of nitrogen supplied as fertiliser led to an increase of about 19.9%.
Marked differences were caused by the two levels of water supply, in the absence of nitrogen fertilisation (E1N0 and E0N0), for all the characteristics examined except for number of achenes per plant and achene oil content. The higher achene nitrogen content in the E1N0 treatment (17.1%) than E0N0 (13.7%) proves that, in the presence of a limited nitrogen supply, nitrogen uptake can be increased sharply by providing sufficient water availability (Blanchet *et al.*, 1987; Merrien, 1992). This result is confirmed in tab. 2, where the nitrogen content per plant at harvest was about 52% higher in treatment E1N0 than E0N0.
Moreover, from Fig. 1 it can be calculated that both crops without irrigation (E0N0 treatment) and with irrigation (E1N0 treatment) took up 38 and 92 kg/ha respectively more nitrogen than was available as inorganic at a soil depth of 1 m (Tab. 1). This means that at least part of the above amount of nitrogen became available through mineralisation and rain water during the growing season (Loubser and Human, 1992), but the main part came from the deep soil nitrogen reserves, to which the sunflower can gain access without great difficulty because of its very deep and exploratory root system (Decou *et al.*, 1984; Blanchet *et al.*, 1986; Connor and Sadras, 1992; Schneiter *et al.*, 1992). Fig. 1 also shows that the maximum nitrogen uptake by the crop generally occurred during the flowering period, with only E1N1 treatment plants showing a more prolonged N absorption than the other treatments, for few days after flowering.
In fig. 2, the time course of LAI from the beginning of flowering to maturity is reported. All three treatments had the maximum LAI during the flowering period, with leaf senescence starting almost simultaneously 86 days after sowing, but it declined more rapidly in E1N1 and E1N0 than E0N0. The excessive nitrogen and water availability during the vegetative stage led to too high an LAI, with indices of 5 and 4 for E1N1 and E1N0 respectively, and as reported by Merrien (1992), LAI at flowering should be no more than 3, because excessive plant development can determine early senescence during the grain-filling period, due to self-shading of the lower leaves by the upper ones.
The N use efficiency or N harvest index (tab. 3) was unchanged by different nitrogen supplies as reported by Moll *et al.* (1987) in other crops. In contrast, treatments differred significantly in the amount of N absorbed during the grain-filling period. In particular, N absorbed after flowering declined significantly from E1N1 (0.81 g/plant) to E1N0 (0.42 g/plant) and E0N0 (0.23 g/plant), while the differences between the latter two treatments were not significant. The total N uptake prior to flowering expressed as a percentage of the content at harvest (tab. 3), was higher for E1N0 and E0N0 (80 and 84% respectively) than the E1N1 treatment (71%). In fact, the main part of plant nitrogen absorption takes place early during the crop cycle (Merrien *et al.*, 1988), and the amount of nitrogen derived from large applications of fertiliser at sowing time and in covering, increased the active N absorption during grain-filling in E1N1 by only about 10%. High nitrogen and water supplies caused a marked reduction in the achene N derived from vegetative tissue during grain-filling. For instance, mobilisation was 56% in treatment E1N1, increased to 71% in E1N0 and to 75% in E0N0, due to the additional effect of limited water availability, in agreement with results reported by Hoching and Steer (1982) and Vrebalov (1974). The different water supplies led the E0N0 plants to have a higher water use efficiency (1.28) than the other two treatments (Merrien *et al.*, 1981; Jones, 1984), which showed no significant differences in WUE.
Significant correlations were observed between total N content in plants at harvest and all the characteristics analysed (Tab. 4), apart from the number of achenes per plant. These results indicate that the nitrogen supplied by the environment, during the first stage of the crop cycle, was sufficient to form an adequate number of achenes per plant (Steer and Hoching, 1984; Blanchet *et al.*, 1987). The strong positive correlation between the plant N content and achene weight and achene density was consistent and it led to an increase in yield. The high plant N content was associated with a large LAI at flowering and a high dry matter per plant at harvest, but was negatively related with WUE. High nitrogen availability during early

development phases could, in fact, lead to excessive vegetative growth determining wastage and a low water usage efficiency (Merrien, 1992).

## Conclusions

In the presence of adequate water availability, the natural soil nitrogen content of this trial contributed 74% of the total quantity of this element absorbed by the crop at harvest, in agreement with results from Merrien *et al.*, (1988) and at the same time this crop can be considered to be an excellent utiliser of deep soil nitrogen residues. Excessive water and nitrogen availability during the first phase of the crop cycle, led to luxurious development of LAI and dry matter accumulation in the sunflowers, wasting water and giving a very low WUE. In this case, a late water deficit, which is normal in the Mediterranean area, will have affected leaf area and senescence will occur very quickly and suddenly with a negative effect on yield. For the above reasons, notwithstanding the fact that the yield of achenes was positively related to the nitrogen content of the plants, large quantities of nitrogen fertiliser at early stages of crop cycle should be avoided in any case, with either non-limiting water resources or with limited water availability. In sunflower, the late nitrogen absorption, even in the presence of high fertiliser applications, appears very low, while an extension of LAI activity during the grain-filling period, especially in the presence of non-limiting water availability, could represent a main objective to improving seed yield. This practice could be followed by plant breeders with adequate breeding programmes in exploiting the variability of this character, but only with adequate crop management techniques such as the application of nitrogen fertiliser after flowering in order to improve late absorption.

## References


Blanchet, R., Merrien, A. (1982) - Influence of water supply on assimilation, yield component and oil/protein production on sunflower. Proc. EEC, Workshop on sunflower, Athens, 10.

Blanchet, R., Gelfi, D., Dufourcq, D., Hernandez, M., Decau, J. (1986) - Nutrition azoté et élaboration du rendement du tournesol (*Helianthus annuus* L.). Agrochimica, 6, 480-489.

Blanchet, R., Thomas, G., Gelfi, N. (1987) - Influence de l'alimentation azoté sur le nombre d'akenes et le rendement du tournesol (*Helianthus annuus* L., cv. Pharaon) dans differentes situations hydriques. Agric. Mediterranea, 117, 111-123.

Blanchet, R., Piquemal, M., Cavaliè, G., D., Hernandez, M., Quinones, H. (1988) - Influence de containtes hydriques sur la ripartition des assimilates entres les organes du tournesol. Proc. of 12th Int. Sun. Conf., Novisad, 124-129.

Connor, D.J., Sadras, V.O. (1992) - Physiology in yield expression in sunflower. Field Crop Res., 30, 333-389.

Coic, Y., Tendille, C., Lesaint, C. (1972) - La nutrition azotè du tournesol (*Helianthus annuus* L.): action sur le rendement et la composition biochimique de la graine. Agrochimica, 16, 254.

Decau, J., Jamet, L., Merrien, A., Pujol, B. (1984) - Influence du populement d'une colture de tournesol sur la dynamique ultérieure de l'azote mineral du sol et sa disponibilité pour la blé suivant. C.R. Acad. Agri. de France, 70, 1133.

Hocking, P.J., Steer, B.T. (1982) - Nitrogen nutrition of sunflower with special reference to nitrogen stress. Proc.of 10th Int. Sun. Conf., Surfers Paradise, Australia, 73-78.

Jones, O.R. (1984) - Yield, water-use efficiency, and oil concentration and quality of dryland sunflower grown in the southern high plains. Agronomy Journal, 76, 229-235.

Loubser, H.L., Human, J.J. (1992) - Effect of fertilization on the N utilization of sunflower. Proc. of 13th Int. Sun. Conf., 1, 246-252.

Merrien, A., Blanchet, R., Gelfi, N. (1981) - Relationships between water supply, leaf area development and survival, and production in sunflower (*Helianthus annuus* L). Agronomie, 1, 10, 917-922.

Merrien, A:, Estragnat, A., Maisonneuve, C., Pierre, M. (1988) - Coefficient reel d'utilization de l'azote chez le tournesol: consequences agronomiques. Proc.of 12th Int. Sun. Conf., Novi Sad, 247-253.

Merrien, A.(1992) - Physiologie du tournesol. Ed.CETIOM, 1-66.

Moll, R.H., Kamprath, E.J., Jackson, W.A. (1987) - Development of nitrogen-efficient prolific hybrids of maize. Crop Sci., 27, 181-186.

Radin, J.W., Boyer, T.S., (1982) - Control of leaf expansion by nitrogen nutrition in sunflower. Plant Physiol., 69, 771.

Rawson, H.M., Turner, N.C. (1982) - Recovery from water stress in five sunflower (*Helianthus annuus* L.)cultivars. I - Effects of the timing of water application on leaf area development and yield. Aust. J. Plant Physiol. ,9, 449-504.

Rawson, H.M., Turner, N.C. (1983) - Irrigation timing and relationship between leaf area ans yield in sunflower. Irrig. Sci., 4, 167.

Schneiter, A.A., Johnson, B.L., Henderson, T.L. (1992) - Rooting depth and water use of different sunflower phenotypes. Proc.of 13th Int. Sun. Conf., 1, 410-415.

Steer, B.T., Hocking, P.J. (1984) - Nitrogen nutrition on sunflower (*Helianthus annuus* L.): acquisition and partitioning of dry matter and nitrogen by vegetative organs and their relationship to seed yield. Field Crop Res., 9, 237-251.

Steer, B.T., Hocking, P.J., Kort, A.A., Roxburgh, C.M. (1984) - Nitrogen nutrition on sunflower (*Helianthus annuus* L.): yield components, the time of their establishment and seed characteristics in response to nitrogen supply. Field Crop Res., 9, 219-236.

Vrebalov, T. (1974) - Rate of N P K assimilative uptake of sunflower variety VNIMK 8931. Proc.of 6th Int. Sun. Conf., Bucharest, Romania, 205-212.

Tab. 1 - Soil reserves and water and nitrogen availability during the 1993 trial at Pisa University.

| | |
|---|---|
| ETM sunflower (mm) | 701 |
| Rainfall during crop cycle (mm) | 89 |
| Water available in the soil (mm)[a] | 130 |
| Number of irrigations | 8 |
| Amount of irrigation (mm) | 400 |
| Total Water available (mm): | |
| -Eo treatment (without irrigation) | 219 |
| -E1treatment (with irrigation) | 619 |
| Nitrogen fertilization (Kg/ha) | 180 |
| Mineral nitrogen in the soil (kg/ha)[a] :N0 | 68 |
| N fertilization + N mineral soil (Kg/ha):N1 | 248 |

[a]in the first 1 m soil deeph at sowing

Tab. 2 - Main yield components affected by the three adopted treatments. Values are means across cultivars during 1993 trial at Pisa University.

| Teatments | 1000 achene weight (g) | achenes per plant (n°) | seed density (kg/hl) | achene oil content (%) | seed yield (t/ha) | seed protein content (%) |
|---|---|---|---|---|---|---|
| E1N1 | 63.5 a | 1471 | 37.6 a | 45.7 c | 3.73 a | 19.3 a |
| E1N0 | 55.6 b | 1403 | 36.7 a | 48.6 b | 3.11 b | 17.1 a |
| E0N0 | 49.5 c | 1352 | 35.2 b | 49.8 a | 2.66 c | 13.7 b |

Within columns, means followed by the same letter are not significantly different at 0.01 probability level according to LSD.

Tab. 3 - N content, N partitionig patterns and WUE as affected by the three adopted treatments. Values are means across across cultivars during 1993 trial at Pisa University.

| Teatments | total N content at harvest (g/plant) | N use[a] efficiency | N accumulated during grain-filling period (g/plant)) | N uptake prior to flowering (%) | achene N derived from mobilization during grain-filling (%)[b] | water use efficiency (Kg/m$^3$) |
|---|---|---|---|---|---|---|
| E1N1 | 2.69 a | 0.667 | 0.81 a | 0.71 b | 0.56 b | 0.73 b |
| E1N0 | 2.06 b | 0.679 | 0.42 b | 0.80 a | 0.71 a | 0.63 b |
| E0N0 | 1.33 c | 0.691 | 0.23 b | 0.84 a | 0.76 a | 1.28 a |

Within columns, means followed by the same letter are not significantly different at 0.01 probability level according to LSD.

[a] N in achene/N in aboveground biomass

[b] Calculated by loss of N from vegetative parts during grain-filling

Tab. 4 - Correlation among the total N content in plants at harvest and the main traits observed during the 1993 trial at Pisa University.

| | plant N content |
|---|---|
| 1000 achene weight | 0.80** |
| achenes number per plant | 0.28n.s. |
| seed density | 0.78** |
| achene oil content | -0.88* |
| seed yield | 0.86** |
| seed protein content | 0.93** |
| LAI at flowering | 0.84** |
| WUE | -0.69** |
| aboveground plant dry matter | 0.95** |

**, significant at P 0.01 probability level

n.s., not significant

Fig. 1 - Nitrogen uptake from flowering to maturity period

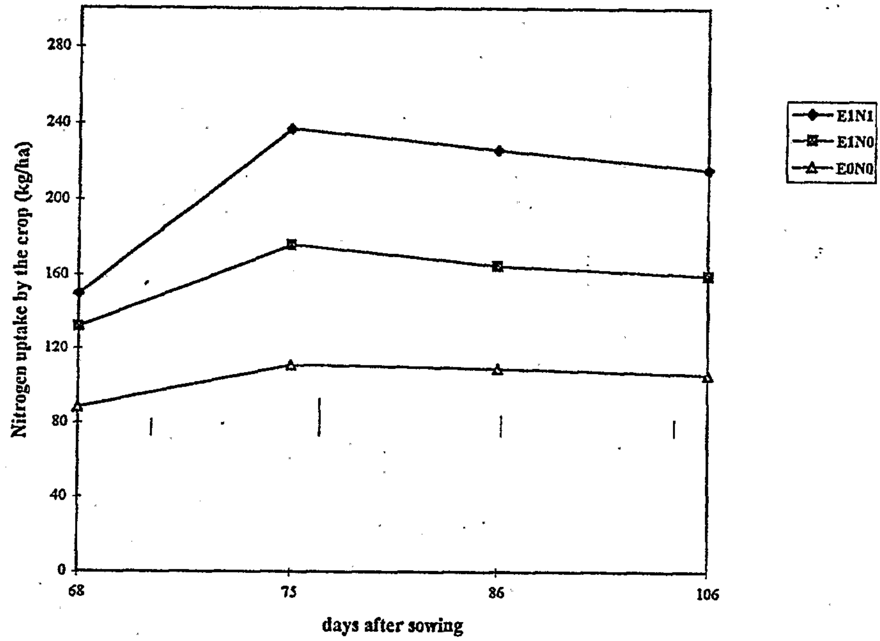


Fig. 2 - Treatment effects on LAI from flowering to maturity period