

## ACQUISITION, PARTITIONING AND REMOBILIZATION OF NITROGEN AND THEIR RELATIONSHIP TO SEED YIELD IN MEDITERRANEAN SUNFLOWER

---

J. Alberto Escalante E.<sup>1</sup>, Ma.Teresa Rodríguez<sup>1</sup>, A. De Haro<sup>2</sup> and  
Elías Fereres C.<sup>2</sup>

---

<sup>1</sup> *Especialidad de Botánica, Instituto de Recursos Naturales, Colegio de Postgraduados, Chapingo, Méx. 56230, México*

<sup>2</sup> *Consejo Superior de Investigaciones Científicas, Córdoba, España*

Received: October 24, 1997

Accepted: December 7, 1998

### SUMMARY

A field study was conducted in Córdoba, Spain, to assess the effect of N fertilizer on the N content, N accumulation, N partitioning, N remobilization and their relationship with seed yield. Two sunflower hybrids, early (AB-E353) and late (Sungro 380) season types, were grown in sandy loam soil (Typic xerofluvent). Nitrogen at rates of 150 kg ha<sup>-1</sup> (1987) and 300 kg ha<sup>-1</sup> (1988) was applied before planting. In both years, the N content (%) and N accumulation (g m<sup>-2</sup>) in the organs of sunflower increased with N fertilization. The highest N concentrations were observed during early growth stages; N concentrations subsequently decreased until physiological maturity. Nitrogen uptake ceased earlier in N-fertilized sunflower than in unfertilized sunflower and this was reflected in a lower nitrogen harvest index (NHI). In N+ a greater percentage of N accumulated in the seeds was supplied by the vegetative organs. This redistribution increased in relation to the N and genotype growth cycle. The leaf was the organ which accumulated most N and which made the greatest contribution to the seeds. The amount of N supplied by the shoot to the seeds and N accumulation in the leaf (g m<sup>-2</sup>) 66 days after emergence showed a higher correlation with the seed yield.

**Key words:** Nitrogen fertilization, nitrogen partitioning, uptake, remobilization, sunflower, water-limited

### INTRODUCTION

Studies on sunflower (*Helianthus annuus* L.) grown under conditions where water is not a limiting factor have reported increases in yield in response to nitrogen fertilization (Steer *et al.*, 1984; Blanchet *et al.*, 1986; Alvarez, 1987). Moreover, the distribution of N in the sunflower plant with irrigation have been documented by Hocking and Steer (1983), Steer and Hocking (1984) and Blanchet *et al.* (1986). In Mediterranean climate conditions, several studies in wheat have indicated that N

accumulation increases with N fertilization and that grain N primarily originates as a result of translocation from vegetative parts after anthesis (Papakosta and Gagianas, 1991). This translocation depends on environmental conditions (Spiertz, 1977) and is also under genetic control (Van Sanford and Mackown, 1987). Under rainfed conditions, however, little is known about N acquisition by sunflower in response to nitrogen fertilization in a Mediterranean type climate where the weather after anthesis is usually hot and dry. In these conditions photosynthesis is limited and, consequently, yield can depend mainly on the translocation of pre-anthesis assimilates to grain. The aim of this study was to assess, under rainfed conditions, the effect of N fertilization on the N content (%), N accumulation in the leaf ( $\text{g m}^{-2}$ ), N partitioning during crop growth and N remobilization, and the relationship of these with seed yield in two cultivars of sunflower.

## MATERIALS AND METHODS

### Treatments, experimental design and plant establishment

The experiments were carried out in Córdoba, Spain ( $37^{\circ}51'N$ ,  $4^{\circ}51'W$  and 110 m altitude). The climate is Mediterranean-type with high temperatures in the summer and rainfall concentrated between late autumn and spring. The sunflower hybrids AB-E353 and Sungro 380 (early and late season types, respectively) were sown in a sandy loam soil (Typic xerofluvent, bulk density 1.4 and pH 8.3) on March 18, 1987 and 1988. The plant population was 100,000 plants  $\text{ha}^{-1}$  with spacing of 50 x 20 cm per plant. The conditions of temperature and rainfall are shown in Table 1. In both years, the experimental design was split-plot with four replicates. The genotypes were the main principals. Nitrogen levels were the sub-plots (5 x 10 m). N as urea was applied at a rate of 150  $\text{kg ha}^{-1}$  in 1987 and 300  $\text{kg ha}^{-1}$  in 1988. The latter rate was higher because it was assumed that the lower crop growth in 1987 was due to insufficient N. Phosphorus fertilization was applied at a rate of 100  $\text{kg ha}^{-1}$  in both years.,

Table 1: Mean maximum and minimum temperature and rainfall<sup>a</sup> monthly for Córdoba, Spain, in 1987-1988

Month	1987			1988		
	Temperature °C		Rainfall mm	Temperature °C		Rainfall mm
	max	min		max	min	
March	21.5	7.5	11.7	22.4	5.2	10.5
April	23.6	9.9	65.0	22.4	9.7	15.4
May	27.8	11.5	4.7	25.2	12.5	37.1
June	32.9	15.8	0.3	28.0	15.9	28.4
July	36.4	18.4	43.2	36.1	18.3	1.1
August	35.5	17.5	31.3	37.2	19.4	0

<sup>a</sup>The rainfall season (September-August) was 446 mm (1986-1987) and 680 mm (1987-1988). About 70% of rainfall occurred before planting.

### Plant measurements

During the 1987 experiment, two plants were analyzed 37 and 65 days after emergence (DAE), and at physiological maturity (108 N0 and 100 N+ DAE in AB-E353 and 130 N0 and 121 N+ in Sungro 380). In the 1988 experiment two plants were analyzed 33, 66, 102 DAE and at physiological maturity (120 N0 and 114 N+ in AB-E353; and 130 N0 and 116 N+ in Sungro 380). Plants were separated into stem plus petioles, laminae, capitulum and seeds. They were oven-dried at 80°C for 72 hours and ground so as to pass through a 1 mm mesh-screen. The nitrogen content was determined by near infrared, previously calibrated by Kjeldhal method. Calibration was done for each organ:  $r^2$  was 0.96 for stem, 0.98 for leaf, 0.96 for capitulum and 0.88 for seed (details of this will be presented in another paper). The leaf nitrogen content per unit of leaf area (specific leaf N, SLN,  $g\ N\ m^{-2}$ ), which is closely correlated with leaf C exchange rate (Sinclair and Horie, 1989), was also calculated. The N acquisition ( $kg\ ha^{-1}$ ) was calculated from dry weight and N concentration per organ. The total acquisition is the addition of the N acquisition in each organ. The N harvest index is the ratio seed N/plant N. Remobilization (R) was obtained from the following equation:

$$R = ((N_{\text{maximum}} - N_{\text{harvest}}) / N_{\text{maximum}}) * 100$$

where:  $N_{\text{maximum}}$  is the maximum N accumulation and  $N_{\text{harvest}}$  is the N in the final harvest in each organ. Standard statistical procedures were used for analysis of variance and calculation of simple correlation coefficients between yield seed and N content in vegetative organs.

Table 2:  $NO_3$ -N content in the loam sand soil 24 days after sowing (Córdoba, 1988)

Depth (m)	$NO_3$ -N (ppm)*	
	N+	N0
0-1	14±4	6±2
1-2	5±6	2±0.8
2-3	10±3	5±1.5

\*Means of 4 replicates.

## RESULTS AND DISCUSSION

### Nitrogen accumulation

Figures 1 and 2 show that N accumulation for plants rose with N fertilization in both genotypes for 1987 and 1988, respectively. The variety AB-E353 reached full anthesis 61 DAE and Sungro 380 75 DAE. The data for 1988 (Figure 2) shows that the greatest N accumulation occurred between 33 and 66 DAE at a rate of  $3.6\ kg\ m^{-2}\ day^{-1}$  N+ and  $0.98\ kg\ m^{-2}\ day^{-1}$  for N0 in AB-E353;  $3.8\ kg\ m^{-2}\ day^{-1}$  for N+ and  $1.8\ kg\ m^{-2}\ day^{-1}$  for N0 in Sungro 380. The higher N accumulation in N+ was related to: 1) N availability in the soil (Table 2), and 2) more abundant growth (LAI, biomass) of the crop (Escalante, 1992).

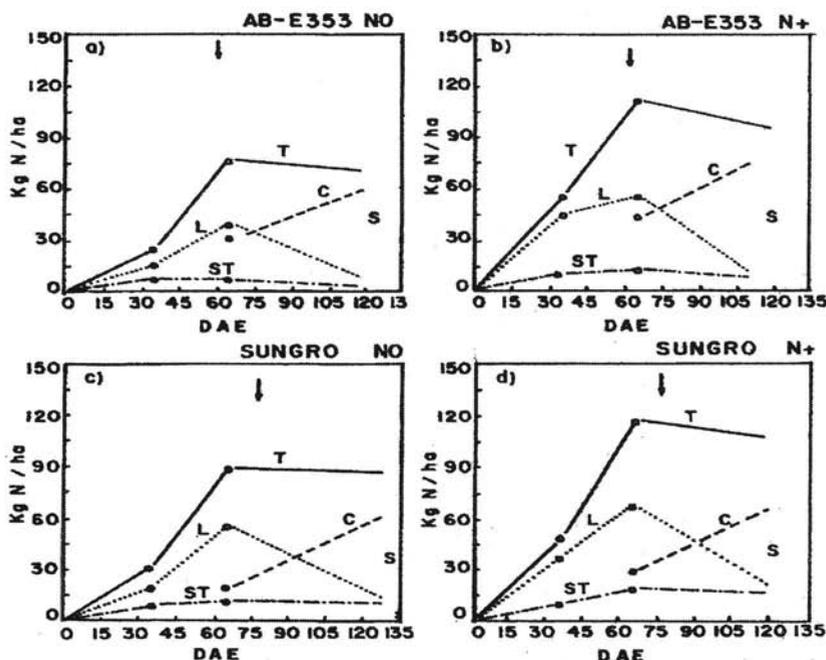


Figure 1: Accumulation and distribution of nitrogen during growth of plants of *H. annuus* L. cv: AB-E353 (a,b) and Sungro 380 (c,d) in relation to the nitrogen supply. The vertical straight line is DMS ( $p=0.05$ ) for total accumulation between N levels. NO=without N applied; N+=300 kg ha<sup>-1</sup>. The arrow (↓) indicate flowering date. T=total; L=leaf; C=capitulum; ST=stem; S=seed; DAE=days after emergence

Table 3: Total N accumulation by the crop (kg N ha<sup>-1</sup>) at final harvest, seed N accumulation, N harvest index (NH<sub>1</sub>) and yield as affected by N supply

Genotype	N	Kg N ha <sup>-1</sup>							
		Total		Seed		NH <sub>1</sub>		Yield kg ha <sup>-1</sup>	
		1987	1988	1987	1988	1987	1988	1987	1988
AB-E353	NO	71	73	49	53	0.68	0.73	1800	1950
	N+	94	166	60	118	0.64	0.71	2030	3970
SUNGRO	NO	86	102	45	56	0.51	0.55	1680	2100
	N+	108	172	49	90	0.45	0.52	1800	3300
DMS (P=0.05)	N	4.8	4.5	1.8	10.7	-	0.02	80	320
PROB.F.	G	NS	NS	NS	NS	**	**	NS	NS
	N	**	**	**	**	NS *	**	**	**
	G*N	NS	NS	**	**	NS	NS	NS	NS

\* P<0.05, \*\* P<0.01, NS=non-significant at P<0.05

In both genotypes, the differences in N accumulation between N+ and NO remained to the final harvest. However, after 66 DAE the N accumulation rate decreased and stopped after 102 DAE. This was particularly evident in N+. These

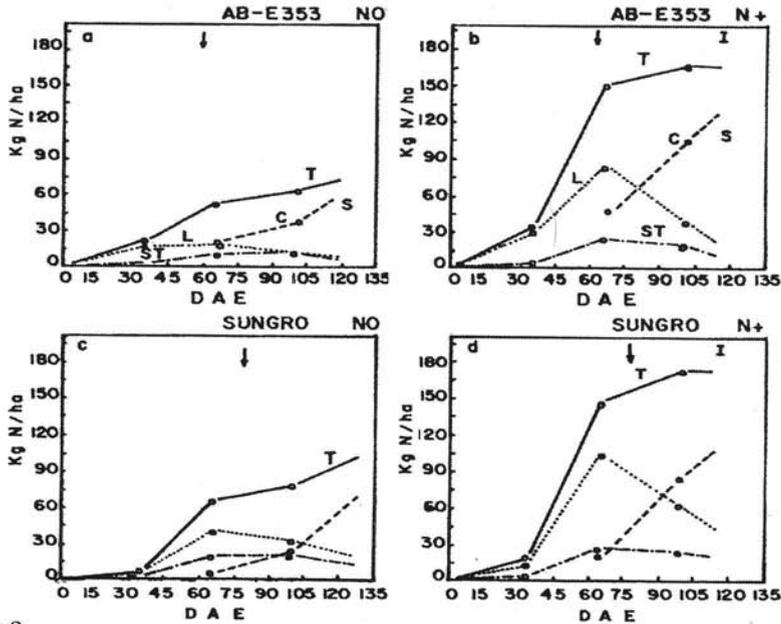


Figure 2:

Accumulation and distribution of nitrogen during growth of plants of *H. annuus* L. cv: AB-E353 (a,b) and Sungro 380 (c,d) in relation to the nitrogen supply. The vertical straight line is DMS ( $p=0.05$ ) for total accumulation between N levels. NO=without N applied; N+=150 kg ha<sup>-1</sup>. The arrow (↓) indicate flowering date.

results are explained by a reduction in leaf area due to a high senescence rate caused by early exhaustion of soil moisture (Escalante, 1992) and less available N in the soil between 1 to 2 m (Table 2). This perhaps impeded N uptake. Patterns of N accumulation similar to NO were found by Steer and Hocking (1984) in sunflower that had been irrigated and grown at different N levels. In N+ the decrease in N accumulation after 102 days may also be due to N remobilization from root to soil (Hale *et al.*, 1971), removal of N leaf by atmospheric factors and volatilization (Wetelaar and Farquhar, 1990).

Patterns of N accumulation similar to N+ were reported for sunflower with non-limiting water conditions by Vrebalov *et al.* (1980); Blanchet *et al.* (1986); Hocking and Steer (1983); Steer *et al.* (1985).

In 1987 (a drier year), the N accumulation pattern was similar to that in 1988 (Figure 1) although N accumulation ceased earlier (after 65 DAE). This may be due to the earlier depletion of the soil moisture by more limiting water conditions (Escalante, unpublished data). However, the trend between the 65<sup>th</sup> DAE and final harvest could not be seen because of the lack of samples. The two genotypes showed differences in N accumulation in response to N fertilization in both years. In 1988, in AB-E353 the nitrogen content was 127% higher in N+ than NO, while in Sungro 380 it was 68% higher (Table 3). This difference in varieties may be due to the fact

that in AB-E353 water stress was less severe because of its early physiological maturity. However, in the absence of N fertilization, Sungro 380 accumulates more N. This may be due to its longer vegetative cycle, which would provide a greater opportunity for exploration for and depletion of soil nitrogen.

### Partitioning and remobilization of nitrogen in the plant

In both years, the N accumulation in leaf, stem, receptacle and seeds of the genotypes increased with the N fertilization (Figures 1 and 2). In stem and leaf the maximum N accumulation occurred 66 DAE. N accumulation in leaf was higher than in stem; for example, in 1988 the leaf N accumulation was 56% of the total N accumulation in AB-E353 and 70% in Sungro 380. After 66 DAE, the N accumulation in stem and leaf decreased because of remobilization to the seed. In contrast, the N accumulation in capitulum (receptacle+seeds) increased until the final harvest. Similar results were reported by Hocking and Steer (1983) in sunflowers grown under greenhouse conditions with irrigation. The leaf was the principal organ of N redistribution to the seed (Table 3). Similar tendencies were reported also by Steer *et al.* (1984).

Table 4: Apparent N remobilization (%) from stem and leaf and proportion that represent the N remobilization in relation to the N accumulated in the seed to the final harvest

Genotype	N	Remobilization (%)				(N seed/N shoot)*100	
		Stem		Leaf		1987	1988
AB-E353	NO	53	37	81	50	74	27
	N+	41	59	80	73	82	66
SUNGRO	NO	13	42	78	55	100	57
	N+	13	27	68	59	100	78
DMS (P=0.05)	N	-	-	14.1	-	10.2	
PROB.F.	Genotype	NC	NS	NS	NC	NS	
	N		NS	*		**	
	G*N		NS	NS		NS	

\* P<0.05, \*\* P<0.01, NS=non-significant at P<0.05, NC=non-calculated

$$\text{Remobilization (\%)} = \frac{(\text{amount at anthesis} - \text{amount at maturity}) * 100}{\text{amount at anthesis}}$$

Regarding the effect of N fertilization on N remobilization, the data in Table 4 show that, with the exception of Sungro 380 in 1987, the remobilization of N from shoot to seeds was higher in sunflower N+ than in NO. This was probably due to the larger number of seeds generated by the nitrogen fertilized sunflower (Escalante, 1992), which appeared to modulate assimilate remobilization (Connor and Sadras, 1992).

In both years for the fertilized sunflower, remobilization was 66% and 82% of the N accumulated in the seed for AB-E353 and 78% and 100% for Sungro 380; the

higher values correspond to the dry year (1987). The greater redistribution in Sungro suggests that the N uptake after flowering ceased earlier in Sungro than in AB-E353 or that the larger number of leaves of Sungro indicated a larger pool of N. The lower shoot redistribution shown by NO (Table 4) and the pattern of N after flowering (Figure 1), appear to be indicative of the N uptake in the late stage of growth. It may be that the water was held longer in the soil by the sunflower without N fertilization due to its lower uptake before flowering (Escalante, unpublished data). In agreement with Steer *et al.* (1985), these results suggest that the N redistribution occurs even in good conditions of water and nutrients. This suggests that in sunflower, as in other species (for example, soybean) (Sinclair and de Wit, 1976), this process is controlled genetically.

In relation to genotypes, N remobilization was higher in Sungro 380 than AB-E353, because Sungro, due to its longer vegetative growth, exhausted soil water more rapidly than AB-E353. These results suggest that N extraction after flowering is limited more by water availability than by the N in the soil. The results of Alvarez (1987), who found increased N extraction in Sungro 380 with irrigation after flowering, confirm this.

#### **N harvest index and N accumulation in seeds**

The nitrogen harvest index is a measure of N partitioning in plants which provides an indication of how efficiently the plant utilizes acquired N for grain protein production. In this study, the N harvest index of the genotypes significantly decreased with N fertilization (Table 3). This decrease was more severe in 1987 because the water conditions were more limiting (Table 1), preventing N extraction after flowering. In this year seed N came from N stored in the shoot.

However, as in the other studies with irrigation (Hocking and Steer, 1983; Blanchet *et al.*, 1986; Alvarez, 1987), the N accumulated in the seeds was lower in the NO treatment (Table 3). In AB-E353, the N accumulated in the seeds was 55% less in NO than N+; while for Sungro 380 it was 38% less. Moreover, this increase occurred even though there were variations in the soil water content. Also, the total N accumulated by the NO crop indicates that N fertilization is necessary to maintain a minimum production level and that high yields require the absorption of large quantities of N. For example, in 1988, AB-E353 crop extracted 170 kg N ha<sup>-1</sup> to produce nearly 4 t ha<sup>-1</sup> of seed, whereas the N extracted by AB-E353 and Sungro 380 NO was 70 kg N ha<sup>-1</sup> and 90 kg N ha<sup>-1</sup>, respectively.

#### **N concentration (%) in organs and its evolution**

The % N in the stem, leaf, capitulum (receptacle+seeds) of both AB-E353 and Sungro increased with N fertilization (Table 5). Both genotypes and treatments showed the highest leaf and stem N concentrations 33 DAE, and these were higher in leaf than in stem. After this date the % N declined sharply (Figure 3). This is because as plants grow they have increasing proportions of structural and storage

Table 5: N concentration (%  $\text{gN/g}^{-1}$  dry weight\* 100) in the plant organs of the sunflower genotypes affected by N supply at diferent DAE

A. Stem		1987				1988			
		DAE		Harvest*		DAE		Harvest	
Genotype	N	37	65	33	66	102	Harvest		
AB-E353	NO	0.87	0.34	0.21	1.26	0.43	0.33	0.33	
	N+	0.99	0.36	0.31	1.34	0.57	0.44	0.22	
SUNGRO	NO	0.94	0.43	0.26	0.98	0.44	0.37	0.31	
	N+	1.16	0.45	0.32	1.10	0.54	0.24	0.32	
DMS N(P=0.05)		0.08	-	0.07	0.10	0.08	-	0.08	
PROB. F.	Genotypes	NS	NS	NS	NS	*	NS	NS	
	N	**	NS	*	**	**	NS	NS	
	G*N	*	NS	NS	NS	NS	NS	NS	
B. Leaf		1987				1988			
		DAE		Harvest		DAE		Harvest	
Genotype	N	37	65	33	66	102	Harvest		
AB-E353	NO	3.66	3.54	1.14	4.50	2.17	1.84	1.35	
	N+	4.71	3.62	1.37	5.44	3.94	1.93	1.46	
SUNGRO	NO	3.65	3.43	1.46	4.53	2.49	2.30	1.38	
	N+	4.51	3.51	1.55	5.07	4.14	2.98	1.77	
DMS N(P=0.05)		0.12	-	0.06	0.12	0.21	0.41	0.17	
PROB. F.	Genotypes	NS	NS	*	NS	*	*	NS	
	N	**	NS	**	**	**	*	*	
	G*N	NS	NS	*	NS	*	NS	NS	
C. Head+Seed		1987				1988			
		Harvest		Harvest		Harvest		Harvest	
Genotype	N	65	Receptacle	Seed	66	102	Receptacle	Seed	
AB-E353	NO	2.52	0.96	2.72	0.55	2.53	0.79	1.77	
	N+	2.55	1.13	2.99	0.71	2.98	0.77	2.95	
SUNGRO	NO	2.54	1.30	2.67	0.56	2.15	0.87	2.11	
	N+	2.69	1.36	2.74	0.60	2.80	0.71	2.73	
DMS N(P=0.05)		-	-	0.09	-	0.12	-	0.24	
PROB. F.	Genotypes	NS	*	*	NS	*	NS	NS	
	N	NS	NS	*	NS	**	NS	**	
	G*N	NS	**	NS	NS	NS	NS	NS	

\* P&lt;0.05, \*\* P&lt;0.01, NS=non-significant, DAE = days after emergence

Table 6: Specific leaf nitrogen (SLN, g m<sup>-2</sup> of leaf area) during the growth of the sunflower genotypes as affected by nitrogen supply

Genotype	N	DAE					
		33		66		102	
		1987	1988	1987	1988	1987	1988
AB-E353	N0	2.1	2.8	2.6	2.4	-	1.7
	N+	2.7	3.0	3.4	3.4	-	2.0
SUNGRO	N0	1.7	2.4	3.5	1.9	-	1.7
	N+	2.6	2.5	3.8	3.9	-	2.3
DMS (P=0.05)	N	0.45	0.19	0.37	0.18	NC	0.13
PROB. F.	Genotype	NS	NS	NS	NS	NC	NS
	N	**	*	*	**	-	**
	G*N	NS	NS	NS	NS	-	NS

\*P<0.05, \*\* P<0.01, NS=non-significant at P<0.05, DAE = days after emergence

materials that contain little nitrogen (Greenwood *et al.*, 1990). In contrast with the report of Greenwood (1982) for C3 vegetable crops, the data shown in Figure 3 indicate curves for stem and leaf N which differed for each treatment. Moreover, the results of specific leaf N (SLN, g N m<sup>-2</sup> of leaf area) reported in Table 6, show a SLN pattern similar to the leaf N concentration which increased with N fertilization. This is important because the SLN has been linked to metabolic activity, particularly photosynthesis (Sinclair and Horie, 1989). The maximum SLN occurred 66 DAE, but after that it decreased due to N remobilization to seed since seed growth demands large amounts of assimilates (Connor and Sadras, 1992), and consequently senescence and leaf fall occur as in maize (Wolfe *et al.*, 1988).

Table 7: Simple correlation coefficients (r) between seed yield and N content in leaf (%) and specific leaf nitrogen (g N m<sup>-2</sup> leaf area) 66 days after emergence for sunflower. 1987-1988 (n=8)

Genotype	Year	N leaf (%)		SLN (g N m <sup>-2</sup> )	
AB-E353	1987	0.71	*	0.89	**
	1988	0.96	**	0.87	**
SUNGRO	1987	0.87	**	0.70	*
	1988	0.76	*	0.84	**

\*,\*\* Significant at the 0.05 and 0.01 probability levels, respectively

In contrast to the stem and leaf, the capitulum (receptacle+seeds) showed a constant increase from 66 DAE until the final harvest. With the N fertilization the seeds of both genotypes had a higher N content.

#### Relationship of seed yield and N in vegetative organs

The results indicate that in both years the seed yield of AB-E353 and Sungro is correlated with the leaf N content (%) and leaf N per unit of leaf area (Table 7).

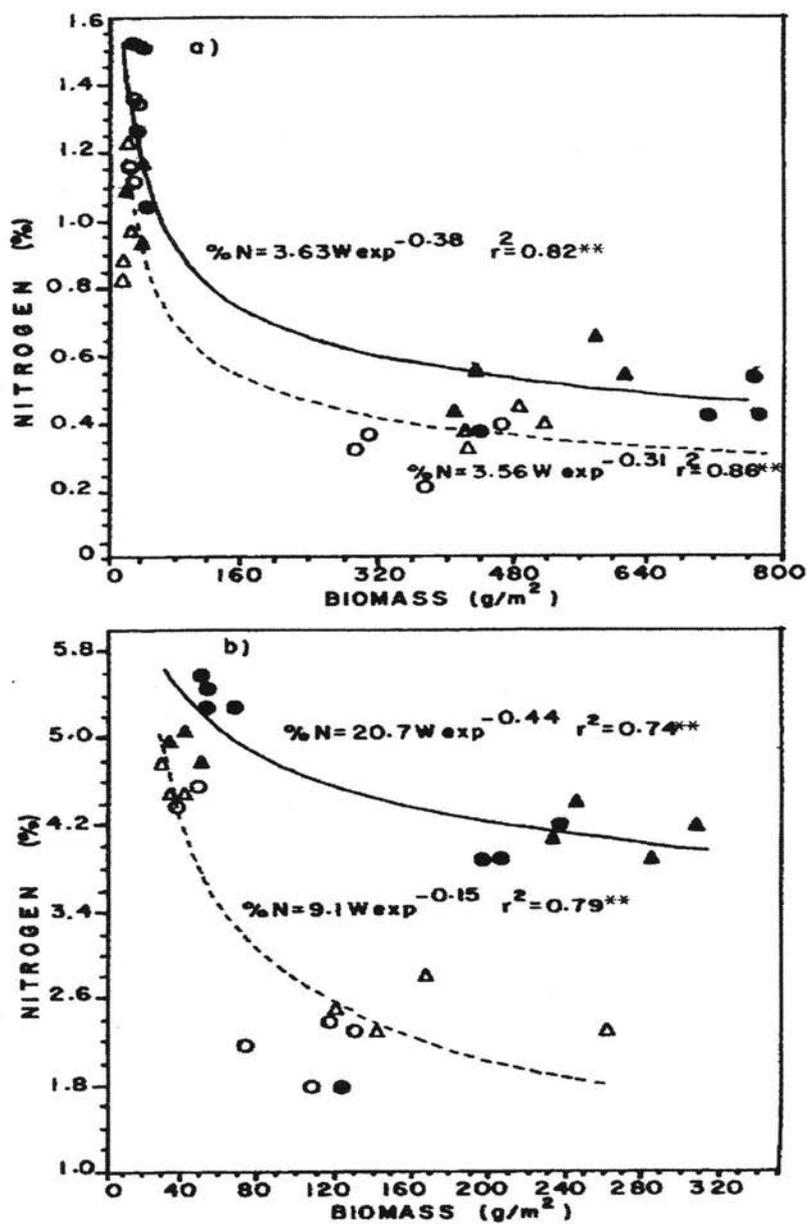


Figure 3: Measured % N and biomass ( $g\ m^{-2}$ ) of steam (a) and leaf (b) to the 66 days after emergence for AB-E353 NO (○) and N+ (●) and Sungro NO (△) and N+ (▲). NO=without nitrogen, N+=300 kg N  $ha^{-1}$ .

## CONCLUSIONS

Under rainfed Mediterranean conditions, fertilizations with N increased the N content (%) and N accumulation ( $\text{g m}^{-2}$ ) in the organs of sunflower AB-E353 and Sungro 380 (early and late season types, respectively). In both N treatments and genotypes the highest N accumulation in stem and leaf occurred 66 DAE (and was higher in leaf than in stem), after which it decreased. In contrast, the increase in N accumulation in capitulum began 66 DAE. The N content and biomass of stem and leaf showed a negative exponential relationship. The remobilization of N from shoot to seed was greater in the crop with N fertilization, and in Sungro 380, but the N harvest index was lower. Finally, these results show that the increase in the seed yield obtained with N fertilization is linked to greater N extraction by the crop.

## ACKNOWLEDGEMENTS

*J. Alberto Escalante gratefully acknowledges a grant from Consejo Nacional de Ciencia y Tecnología (CONACYT) México.*

## REFERENCES

- Alvarez del Toro, J.A., 1987. Respuesta del girasol (*Helianthus annuus* L.) a un suministro variable de agua de riego y de nitrógeno. Tesis Doctoral. ETSIA. Universidad de Córdoba. 384 pág.
- Blanchet, R., Cavalie, G., Piquemial, M., Gelfi, N., Duprat, Y. and Martínez, E., 1986. Influence de la nutrition azotée sur l'assimilation nette et la formation du rendement du tournesol. *Helia*. 9: 39-45.
- Connor, D.J. and V.O. Sadras., 1992. Physiology of yield expression in sunflower. *Field Crops Research*. 30: 339-389.
- Escalante Estrada, J.A., 1992. Interacciones entre el nitrógeno y la densidad de siembra en el cultivo de girasol (*Helianthus annuus* L.) bajo suministro limitado de agua. Tesis Doctoral. ETSIA. Universidad de Córdoba España. 230 págs.
- Greenwood, D.J., Lemaire, G., Grasse, G., Grux, P., Draycott, A. and Neeteson, J.J., 1990. Decline in percentage N of C3 and C4 crops with increasing plant mass. *Annals of Botany*. 66: 425-436.
- Greenwood, D.J., 1982. Modelling of crop response to nitrogen fertilizer. *Philosophical Transactions of the Royal Society of London*. B296: 351-362.
- Hale, M.G., Foy, C.L. and Shay, F.J., 1971. Factors affecting root exudation. *Adv. Agron.* 23: 89-109.
- Hocking, P.J. and Steer, B.T., 1983. Distribution of nitrogen during growth of sunflower (*Helianthus annuus* L.). *Ann. Bot.* 51: 787-799.
- Papakosta, D.H. and Gagianas, A.A., 1991. Nitrogen and dry matter accumulation, remobilization and losses for Mediterranean wheat during grain filling. *Agron. J.* 83: 864-870.
- Sinclair, T.R. and De Wit, D.T., 1976. Analysis of the carbon and nitrogen limitations to soybean yield. *Agron. J.* 68: 319-324.
- Sinclair, T.R. and Horie, T., 1989. Leaf nitrogen photosynthesis and crop radiation use efficiency: A review. *Crop Sci.* 29: 90-98.
- Spiertz, J.H.J., 1977. The influence of temperature and light intensity on grain growth in relation to the carbohydrate and nitrogen economy of the wheat plant. *Neth. J. Agric. Sci.* 25: 182-197.

- Steer, B.T. and Hocking, P.J., 1984. Nitrogen nutrition of sunflower (*Helianthus annuus* L.): Acquisition and partitioning of dry matter and nitrogen by vegetative organs and their relationship to seed yield. *Field Crops Res.* 9: 237-251.
- Steer, B.T., Hocking, P.J., Kortt, A.A. and Roxburgh, C.M., 1984. Nitrogen nutrition of sunflower (*Helianthus annuus* L.) yield components, the timing of the establishment and seed characteristics in response to nitrogen supply. *Field Crops Research.* 9: 219-236.
- Steer, B.T., Hocking, P.J. and Low, A., 1985. Nitrogen nutrition of sunflower (*Helianthus annuus* L.): concentrations, partitioning between organs and redistribution of N in seven lines in response to N supply. *Field Crops. Res.* 12: 17-32.
- Van Sanford, D.A. and Mackown, C.T., 1987. Cultivar differences in nitrogen remobilization during grain fill in soft red winter wheat. *Crop Sci.* 27: 295-300.
- Vrebalov, T., Rajković, Z. and Bogdanović, D., 1980. Dry matter accumulation and nitrogen phosphorus and potassium assimilation by sunflower hybrid NS-H-26-RM. pág. 182-191. IX Conferencia Internacional del girasol. Torremolinos (Málaga, España). 8-13 junio 1980.
- Wetselaar, R. and Farquhar, G.D., 1990. Nitrogen losses from tops of plants. *Adv. Agron.* 33: 263-302.
- Wolfe, D.W., Henderson, D.W., Hsiao, T.C. and Alvino, A., 1988. Interactive water and nitrogen effects on senescence of maize. II. Photosynthetic decline and longevity of individual leaves. *Agron. J.* 80: 865-870.

## ABSORCIÓN, PARTICIÓN Y REMOVILIZACIÓN DE NITRÓGENO Y SU RELACIÓN CON EL RENDIMIENTO DEL GIRASOL MEDITERRANEO

### RESUMEN

Este estudio realizado bajo condiciones de campo en Córdoba España, fué con el objeto de determinar el efecto de la fertilización nitrogenada sobre el contenido, acumulación y removilización de nitrógeno y su relación con el rendimiento de semilla. Los híbridos de girasol AB-E353 y Sungro 380 (precoz y tardío, respectivamente) fueron sembrados en un suelo franco-arenoso (Typic xerofluvents) en 1987 y 1988. El nitrógeno fue aplicado antes de la siembra a dosis de 150 kg ha<sup>-1</sup> (1987) and 300 kg ha<sup>-1</sup> (1988). Los resultados indican que en ambos años, el contenido (%) y acumulación (g m<sup>-2</sup>) de nitrógeno en los órganos de la planta se incrementó con la fertilización nitrogenada. Las concentraciones de nitrógeno más altas se encontraron en las primeras etapas de crecimiento, posteriormente ésta disminuyó conforme la planta avanzó en su crecimiento. En N+, la mayor parte del N acumulado en la semilla, provino del N almacenado en órganos vegetativos. La removilización de N fue mayor en N+ y en el genotipo tardío. En N+, la absorción de N cesó antes que en N0 y se reflejó en un índice de cosecha de N más bajo. La hoja fué el órgano de mayor acumulación de N y el que más contribuye con N a la semilla. La cantidad de N removilizado desde el vástago a la semilla y la de N almacenado en hojas a los 66 días después de la emergencia, mostró una relación más alta con el rendimiento de semilla.

**ABSORPTION, PARTAGE ET LE MOBILISATION DU NITROGÈNE ET SA RELATION AVEC LE RENDEMENT DE TOURNESOL MEDITERRANÉE**

## RÉSUMÉ

L'objectif de cette étude, menée en conditions de champ à Córdoba, en Espagne, était de déterminer l'effet de la fertilisation nitrogenisée sur le contenu, l'accumulation, et le mouvement du nitrogène et sa relation avec le rendement de la graine. Les hybrides de tournesol AB-E353 et Sungro 380 (hybride précoce et hybride tardif, respectivement) ont été semés dans un sol franco-sablonneux (xerofluents typiques) en 1987 et 1988. Le nitrogène a été appliqué avant la semence, en quantités de  $150 \text{ kg ha}^{-1}$  (1987) et  $300 \text{ kg ha}^{-1}$  (1988). Dans les deux cas, tant le contenu (%) comme l'accumulation ( $\text{g m}^{-2}$ ) de nitrogène dans les organes de la plante avaient augmenté avec la fertilisation nitrogenisée. Les concentrations les plus élevées de nitrogène ont été constatées durant la première étape de croissance, suite à laquelle (celles-ci) ont diminué à mesure que la plante développait. En  $N+$ , la majorité du N accumulé dans la graine provenait du N qui avait été stocké dans les organes végétatifs. Le mouvement du N a été plus élevé dans le cas du  $N+$  et du génotype tardif. Dans le cas du  $N+$ , l'absorption du N a cessé avant celle du  $N0$ , ce qui a été reflété par un indice de récolte moins élevé. La feuille fut l'organe qui montrait l'indice le plus élevé d'accumulation tandis que la graine montrait l'indice de contribution du N le plus élevé. Aux 66 jours après le brottage, la quantité de N remué du feuillage jusqu'à la graine, et la quantité de N stocké dans les feuilles a montré une relation plus élevée avec le rendement de la graine.

