

# NITROGEN NUTRITION OF SUNFLOWER WITH SPECIAL REFERENCE TO NITROGEN STRESS.

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## ABSTRACT

This paper is a review of the N nutrition of sunflower based largely on glasshouse and field research on the effects of N supply on development and yield of irrigated sunflowers, especially in relation to application of urea in irrigation water during growth of the crop. Sunflower grows best on nitrate-N and poorest on urea-N. However, urea applied in the field is transformed in clay soils to nitrate which is taken up by sunflower. Over 75% of nitrate taken up is reduced in leaves. As supplied-nitrate increases so the level of nitrate in vegetative parts rises. Further, relationships between levels of reduced-N and nitrate-N, and between reduced-N and dry matter change as nitrate supply increases. Mature seeds have 38% of total plant dry weight but 68% of the N. Apparent redistribution, particularly from leaves, can supply 43% of the N in mature seeds, despite continued supply of N to roots. Low N supply decreases the number of leaves and florets, hence potential seed number. N supply has no effect on timing of floret initiation, anthesis or seed maturity. Low N decreases oil yield per plant mainly by decreasing seed number. We believe it worthwhile to develop a simple test for N sufficiency for irrigated sunflowers so that growers can quickly assess the N status of their plants and avoid yield losses.

## INTRODUCTION

The recent development of applying nitrogen fertiliser, especially urea, to sunflower in the irrigation water allows the

application of N at frequent intervals during growth of the crop and provides flexibility in management strategies. Maximising the benefit of nitrogen inputs is important if high yields are to be attained and profitability increased, because N fertiliser represents up to 20% of the production costs. Sunflower can utilize a number of forms of nitrogen fertiliser and from these produce a wide range of nitrogenous compounds such as amino acids, many of which are transported to developing seeds and incorporated into protein. Sunflower has a direct N requirement for adequate growth of its tissues and organs, but nitrogen has many indirect effects which control plant development. For example, N supply may determine the size and photosynthetic activity of the plant's leaf canopy, and consequently control the production of carbon compounds needed for growth as well as for oil and protein synthesis. The nitrogen status of the plant can also regulate levels of plant hormones (Salama and Wareing, 1979) and therefore indirectly affect developmental processes such as leaf expansion and floret production.

### Uptake of nitrogen.

Sunflower can utilize either nitrate or ammonium forms of N, but grows best on nitrate-N (Kirkby and Mengel, 1978). However, irrigated sunflower responds to N fertiliser regardless of whether the source is nitrate, ammonium or urea (Cheng and Zubriski, 1978). This is due to changes which urea and ammonium-N undergo in the soil. When urea is applied either as a preplant dressing or in irrigation water, it is hydrolysed rapidly to ammonium-N in the soil. Most of the ammonium-N is then nitrified by soil micro-organisms, and uptake of N by sunflower occurs largely as nitrate (Table 1).

Table 1. Levels of nitrogenous compounds in root xylem sap from field-grown Hysun 21 sunflower at two stages of development. Values are means of all sap samples taken hourly over 9 h; 95% confidence limits in parentheses. The soil was a fine-textured cracking clay.

N solute in sap	Stage of plant development			
	One Week Before Bud Burst		One Third Seed Fill	
	Water + Urea	Water Only	Water + Urea	Water Only
Urea ( $\mu\text{g/ml}$ )	0.69 (0.26)	0.51 (0.24) NS	0.76 (0.30)	0.48 (0.36) NS
Amino compounds ( $\mu\text{ mole/ml}$ )	1.67 (0.19)	1.52 (0.25) NS	2.50 (0.27)	2.80 (0.32) NS
Nitrate ( $\mu\text{g/ml}$ )	40.4 (4.3)	31.5 (0.23)*	114.1 (7.6)	87.6 (8.6)*

Comparison of water only and urea + water; NS: not significant; \*:  $P < 0.05$

When sunflower is grown in sand culture at high levels of supplied urea, some urea enters the plant and is transported in the xylem. However, most of the urea which enters the plant is either hydrolysed in the roots or withdrawn as it ascends the stem in xylem sap (Table 2).

Table 2. Levels of urea and amino compounds in xylem sap of Hysun 21. (A) sap from stem stumps of plants fed different levels of urea; (B) sap from various internodes of plants fed 25mM urea. (95% confidence limits in parentheses). Plants grown in sand culture.

(A) Levels of urea supplied (mM)	Level in xylem sap ( $\mu\text{ mole/ml}$ )	
	Urea	Total Amino Compounds
0.25	0	0.77 (0.05)
5.0	1.50 (0.13)	4.96 (0.30)
25.0	17.25 (0.66)	5.82 (0.30)
(B) Sap Collected from Internode:		
1	17.25 (0.66)	5.82 (0.30)
14	4.08 (0.14)	3.60 (0.12)
28	1.00 (0.09)	2.46 (0.11)

Urea can cause a large reduction in the growth of sunflower if plants are forced to rely solely on this form of N (Table 3).

It has been suggested that the uptake and metabolism of urea requires more energy than nitrate (Kirkby and Mengel, 1970).

**Table 3. Effect of the form and level of N fertiliser on dry matter production, N uptake and N levels in 4 week-old sunflower plants (adapted from Kirkby and Mengel, 1970).**

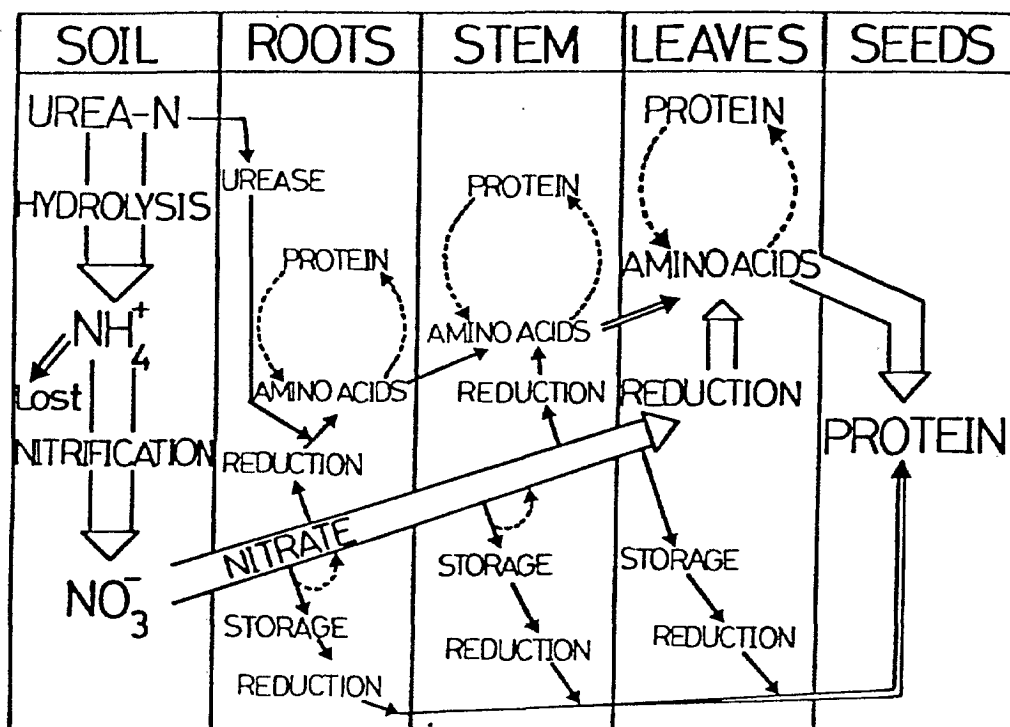
N Form	Level Applied (mM)	Dry Matter (g/plant)	N Uptake (mg/plant)	% N in Plant Tissue
Nitrate	2	1.06	61.4	5.8
Urea	2	0.48	16.0	3.3
Urea	4	0.62	29.0	5.7
Urea	8	0.71	41.1	5.8

#### Nitrate reduction.

The fate of nitrogen accumulated by the plant is outlined in Fig. 1. Nitrate is the main form of N taken up by roots. When sunflower is fed nitrate-N, 77 — 94% of the N transported in xylem sap from the roots to the leaves is as nitrate (Kaiser and Lewis, 1980). The small amount of organic N in xylem sap is mainly as amino acids. Nitrate-N has to be reduced to the ammonium form before it can be utilised, and leaves are

the major site of nitrate reductase activity in sunflower. Nitrate reduced in the leaves is incorporated initially into glutamine and glutamic acid and subsequently into other amino acids (Kaiser and Lewis, 1980). These amino compounds are transported from leaves by the phloem to young vegetative organs or developing seeds where they are utilised for protein synthesis.

**Figure 1. Summary diagram of the fate of Urea-N applied to sunflower in irrigation water on a fine-textured clay soil. The size of the arrows indicates approximately the magnitude of the nitrogen fluxes.**



#### N supply, dry matter production, N accumulation and N uptake efficiency.

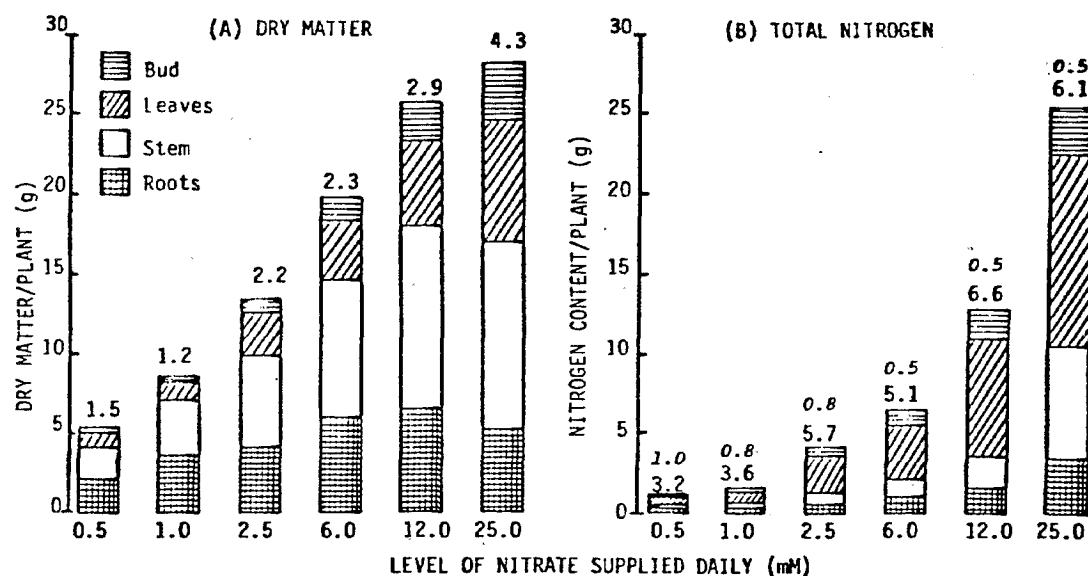
Dry matter production in sunflower increases with increased N supply (Fig. 2A), although there is only a marginal gain in dry weight between high (12 mM) and luxurious (25 mM) N applications. N supply also has a marked effect on the shoot to root dry weight ratio (Fig. 2A). At deficient N levels (0.5 and 1.0 mM) plants allocate more of their photosynthate to roots, whereas at high N levels they allocate proportionately more to the shoot. Root dry weight declines at luxury N supply and results in a very high shoot:root ratio.

Increasing N supply has a large effect on the amount of N accumulated by sunflower (Fig. 2B). Similar, but less marked changes to those for dry matter occur in the shoot:root ratio for total N content because the proportion of total plant N in roots declines with increased N supply. The distribution of N among shoot parts is fairly constant for a wide range of N application rates, except at luxury levels when the stem

accumulates a greater proportion of the plant's N at the expense of leaves. Leaves are the main depository for N despite the fact that the stem has by far the largest proportion of the plant's dry matter (Fig. 2).

N uptake efficiency (values in italics in Fig. 2B, defined as the amount of N taken up per plant divided by the total amount of N supplied to the plant during growth) is highest for plants which receive very low N (0.5 mM) and declines by 50% in plants which receive adequate to luxurious amounts of N.

Figure 2. Effect of increased N supply on the accumulation and distribution of dry matter (A) and total nitrogen (B) contents of Hysun 21 sunflower at bud burst. Shoot:root ratios are shown immediately above each histogram. Nitrogen uptake efficiency values are shown in italics (Fig. 2B), and are normalised to the lowest N treatment. Plants grown in sand culture.



#### Effect of Nitrate supply on levels of reduced-N and nitrate-N in sunflower.

As the level of supplied nitrate-N increases, so the level of reduced-N and nitrate-N increases in all vegetative parts (Table 4). For a 50-fold rise in supplied nitrate, there is only a 3–4 fold increase in the level of reduced-N in all organs except buds and roots which are buffered against large changes in the external N supply. The increase in nitrate-N in all organs except buds is much greater than the increase in supplied nitrate, especially in petioles which accumulate more nitrate-N than reduced-N at luxury nitrate supply.

The relationships between reduced-N levels and free nitrate levels in roots, stems + petioles and leaves follow the same pattern as supplied nitrate increases (Fig. 3). Little free nitrate accumulates until supplied nitrate reaches a high level. Nitrate reduction appears to be saturated at very high rates of applied nitrate so that reduced-N levels plateau and high levels of free nitrate accumulate; this is especially pronounced

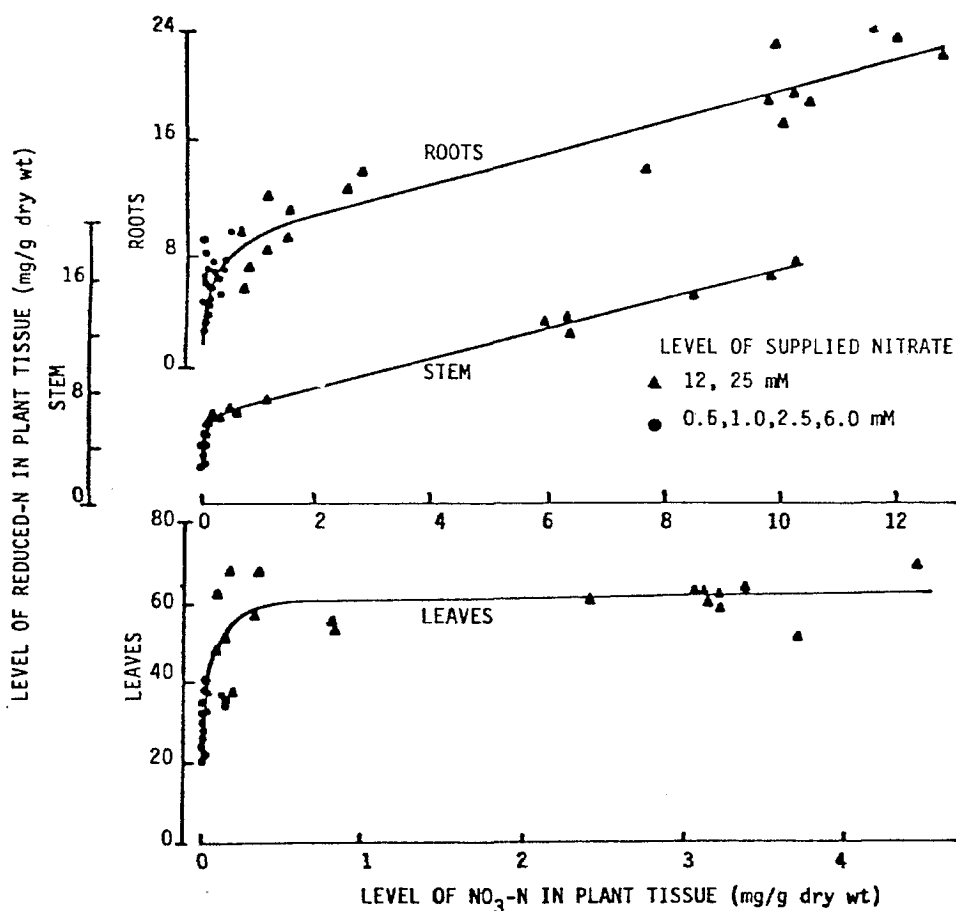
in leaves (Fig. 3).

At levels of supplied nitrate of 6 mM and higher, not only does free nitrate accumulate rapidly, but also there are changes in the external N supply. The increase in nitrate-N in N contents of each organ (Fig. 4). This is most noticeable in roots where very high levels of applied nitrate result in a high content of reduced-N but a decrease in root dry weight. In stems, the content of reduced-N rises sharply between 12 to 25 mM applied nitrate, but stem dry weight does not increase. Leaf dry matter rises with increasing N application although increments in leaf dry weight become progressively smaller per unit of reduced nitrogen, suggesting that much of the reduced-N accumulated by leaves of plants grown on high to luxury N supply is stored. The extent to which this stored N is utilized has obvious practical implications when large amounts of N fertiliser are applied to sunflower in irrigation water.

Table 4. Concentrations of reduced-N and nitrate-N in Hysun 21 sunflower grown on a range of nitrate levels in sand culture. Plants harvested at bud-burst. (All values as mg/g dry wt).

mM Nitrate supplied	Roots	Stem	Petioles	Leaves	Buds
Reduced Nitrogen					
0.5	6.10	3.53	6.68	22.23	20.80
1.0	3.63	2.99	5.23	27.66	24.11
2.5	6.10	4.58	6.23	34.33	26.83
6.0	7.04	4.54	6.05	38.27	27.60
12.0	9.83	5.98	10.11	55.30	31.03
25.0	10.07	14.06	18.97	60.13	32.37
Nitrate Nitrogen					
0.5	0.080	0.016	0.011	0.014	0.045
1.0	0.061	0.015	0.009	0.010	0.012
2.5	0.112	0.030	0.027	0.022	0.051
6.0	0.271	0.117	0.053	0.067	0.086
12.0	1.404	0.339	2.673	0.375	0.379
25.0	10.464	7.972	19.482	3.211	0.959

Figure 3. The relationships between the levels of reduced nitrogen and free nitrate in roots, stem and leaves of Hysun 21 sunflower grown on a range of supplied nitrate in sand culture.



#### Partitioning of N in mature plants and redistribution of N to seeds.

The distribution of N in mature Hysun 21 sunflower is shown below. (The plants were grown under glass to avoid N losses by leaching from senescent organs). Seeds accumulate 68% of the total plant N but only 38% of the total plant dry matter. Apparent redistribution from vegetative parts can provide 43% of the N in seeds, despite the daily application of adequate nitrate-N (6 mM). Leaves are the most important organs in N redistribution; they contribute 36% of the N in seeds, and N was withdrawn from them with an efficiency of 56%. Redistributed N from the stem makes only a small contribution (7.5%) to the seeds, as also found by Vrebalov (1974). Nitrogen uptake from the rooting medium

during seed development can provide over 50% of the N accumulated by seeds, suggesting that roots and N assimilatory processes in sunflower are functional well into seed filling. However, limited N availability in the field during seed filling may severely restrict N uptake by roots and force the plants to rely on previously-stored N. For example, Vrebalov (1974) found that N uptake from the soil ceased at about full anthesis, and over 75% of the N accumulated by seeds was redistributed from vegetative parts. We are investigating the importance of N redistribution in seed nutrition over a wide range of applied N levels and at different stages of the plant's development using  $^{15}\text{N}$ . This information is important for the efficient use of N fertiliser applied to sunflower during growth of the crop.

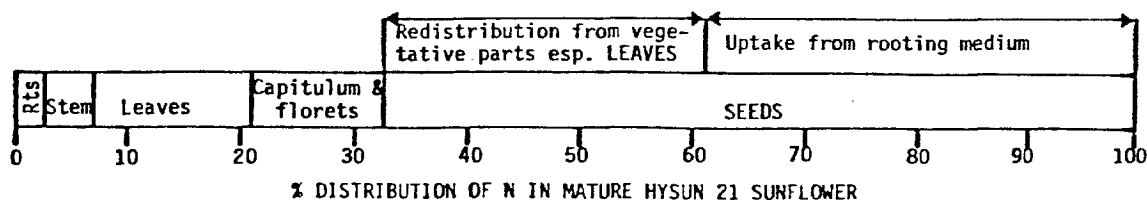
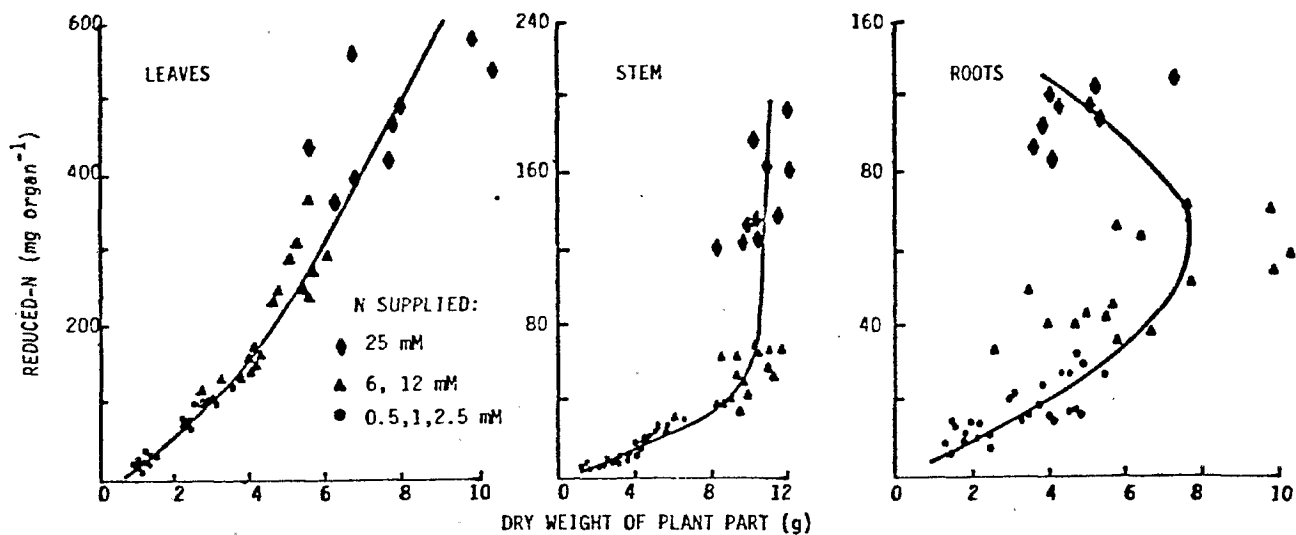


Figure 4. Relationships between the amounts of reduced nitrogen and dry matter accumulated by leaves, stems and roots of Hysun 21 sunflowers grown on a range of supplied nitrate in sand culture.



**N stress and phenological development.**

Cultivated sunflower has a determinant growth habit with a rigid sequence of phenological development which is outlined below for Hysun 21 sown in midsummer. Some important aspects of sunflower development are: 1. Floret initiation occurs when the plants are very small (only 8–9 leaves visible). 2. Once the apical dome becomes reproductive no more leaves are formed. 3. Floret initiation lasts only 12–14 days and sets the maximum potential yield of the crop. Once floret initiation is finished no more florets (potential seeds)

can be produced, irrespective of improvements in husbandry. Good management after floret initiation can only maximise the number of existing florets which produce sound seeds. There are no published quantitative data on the effects of N stress either on vegetative or floret development, and little on seed characteristics (Cheng and Zubriski, 1978). Preliminary results of our research in this area using a range of N levels shows that N deficiency has profound effects on many aspects of vegetative and reproductive development in sunflower (Fig. 5 and Table 5).

Figure 5. Effects of N supply on vegetative (A) and reproductive (B) characters of Hysun 21 grown in sand culture. Data are normalised to the maximum value for each character (in parenthesis).

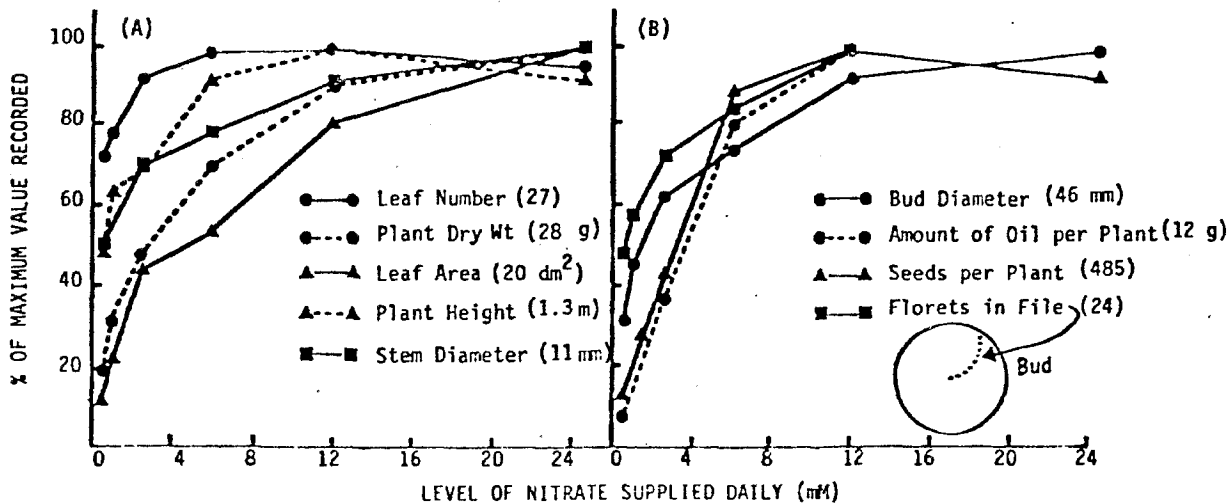
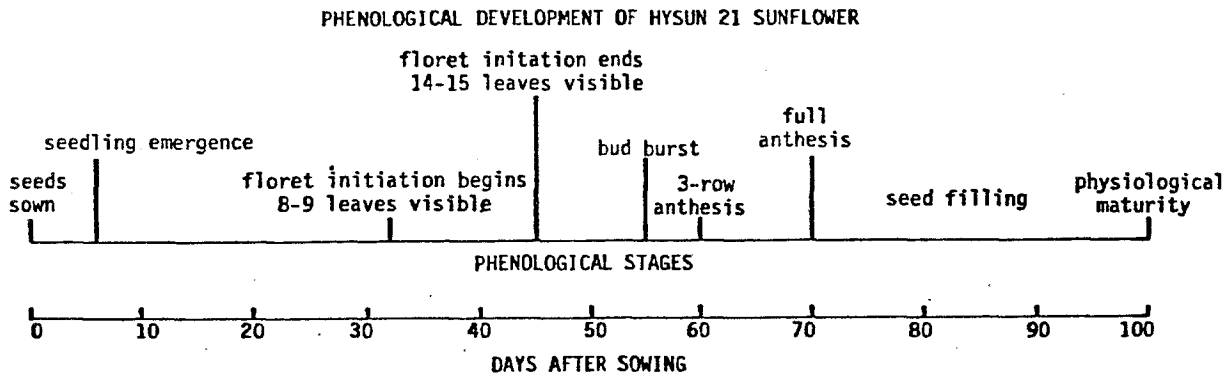


Table 5. Effects of N stress on various stages of phenological development in sunflower (see also Fig. 5).



**N Stress Reduces:** (a) Plant height, stem diam., leaf number and area (b) Rate of floret initiation (c) Total number of florets (d) Seed number and seed weight per plant (e) Protein per seed and per plant (f) Oil yield per plant.

**N Stress does not alter:** (a) Onset of floret initiation (b) Duration of floret initiation (c) Timing of bud burst (d) Timing of 3-row or full anthesis (e) Timing of seed maturity.

**N Stress Increases (marginally):** (a) Oil as % of seed dry wt.

Increasing N supply after the completion of floret initiation has no effect on leaf number or floret number because these have been determined already. As yet we have no information on the effects of N stress on embryo development during seed filling.

#### A field test for N sufficiency in sunflower?

In view of the stunted vegetative growth, depressed floret production and poor oil yields of N-deficient sunflowers, we believe that it is worthwhile to develop a test or index of N sufficiency for the crop. We feel that criteria for the test should be as simple as possible and allow for farm use. The test could be based on petiolar nitrate levels as these seem to be the most responsive to increasing nitrate in the rooting medium (see Table 4), possibly in conjunction with vegetative characters such as stem diameter, leaf number and leaf size. The test would need to be calibrated for changes in nitrate levels and vegetative characters as the plants age. In addition it would also need to take into account differences between cultivars. A rapid test for N sufficiency would be especially attractive where sunflowers are grown under irrigation and N fertiliser is applied in the irrigation water.

#### LITERATURE CITED

- CHENG, S.F. and ZUBRISKI, J.S. 1978. Effects of nitrogen fertiliser on production of irrigated sunflower, plant uptake of nitrogen, and on water use. *Proceedings 8th International Sunflower Conference* pp. 400 — 409.
- KAISER, J.J. and LEWIS, O.A.M. 1980. Nitrate-nitrogen assimilation in the leaves of *Helianthus annuus* L. *New Phytologist* 85:235 — 241.
- KIRKBY, E.A. and MENGEL, K. 1970. Preliminary observations on the effect of urea nutrition on the growth and nitrogen metabolism of sunflower plants. In *'Nitrogen Nutrition of the Plant'* ed. E.A. Kirkby, Leeds, pp 35 — 38.
- SALAMA, A.M.S.EI-D.A. and WAREING, P.F. 1979. Effects of mineral nutrition on endogenous cytokinins in plants of sunflower (*Helianthus annuus* L.) *Journal of Experimental Botany* 30:971 — 981.
- VREBALOV, T. 1974. Rate of NPK assimilative uptake of sunflower variety VNIMK 8931. *Proceedings 6th International Sunflower Conference* pp. 205 — 212.

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## EFFECT OF NUTRITIONAL AND CULTURAL TREATMENTS ON SEED PRODUCTION OF WINTER GROWN SUNFLOWER.

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#### ABSTRACT

An experiment on sunflower to study the effect of soil and foliar application of N and K (60 kg N and 40 kg K<sub>2</sub>O ha<sup>-1</sup>) and cultural treatments (inter cultivation, mulching and herbicide application) was carried out in a split plot design with three replications in the University farm during 1978 — 79 and 1979 — 80 winter seasons. Application of N and N with K significantly increased seed yield, stalk yield and oil yield over the control. Application of K either to soil or foliage also significantly increased seed and oil yield. Highest seed and oil yield was found with soil application of N with K. Thousand seed weight, number of filled seeds and head diameter was increased due to application of N and N with K. Intercultivation significantly increased seed, stalk and oil yield and influenced yield attributes over other cultural treatments, followed by mulching and herbicide application.

#### INTRODUCTION

Oilseed crops play an important role in the agricultural economy in India. To meet the acute shortage of oilseeds in this country, sunflower has been introduced as a potential oilseed crop. Commercial cultivation of sunflower in India has not yet become possible because of problems with the crop including the production of a sterile zone in the centre of the head, large yield fluctuation, poor seed setting, production of hollow or partly filled seeds and bird damage.

Several workers have reported the beneficial effect soil and foliar application of N on yield and yield-contributing characters of sunflower (Simanskii, 1961; Singh *et al.*, 1975). Fabian-Galan, 1971 and Sobachkin (1974) agreed that K deficiency caused disturbances in N and carbohydrate metabolism and also delayed the translocation of assimilate in sunflower. Application of N, P, K led to an increased seed

yield in sunflower (Galgoczi, 1968, 1969). Johnson (1972) reported the favourable effect of intercultivation and herbicide application on the seed yield of sunflower.

Information on desirable agronomic practices for sunflower under conditions in West Bengal is scanty. This investigation was carried out to study the effect of nutritional and cultural treatments on yield and yield components of sunflower.

#### MATERIALS AND METHODS

The experiment was conducted in split plot design with three replications at the University farm during winter seasons of 1978 — 79 and 1979 — 80. Plot size was 4 m x 3 m. The variety E.C.68414 (Peredovik) was sown at the end of November and was harvested by the 3rd week of March during both the years. Seed rate was 10 kg ha<sup>-1</sup> and the seeds were treated with Brassicol, Brestanol and BHC before sowing. There were 7 main plot treatments combinations — control (without N and K), Nitrogen at 60 kg/ha as urea, potassium at 40 kg ha<sup>-1</sup> as K<sub>2</sub>SO<sub>4</sub> and their combinations (Nitrogen + Potassium) were applied both to the soil and foliage of sunflower. In case of the soil application, half of the dose of nutrients was applied at the time of sowing and the remaining half was applied one month after sowing. In the foliar treatments, nutrients were applied in 4 equal parts at 45, 60, 75 and 90 days after sowing. The concentrations of spray solutions were 1.85 percent urea, 1.23 percent potassium sulphate and in the case of combined application it was 3.0 percent. Lime was used to neutralize free acidity of the spray solution during spraying of nutrients. Subplot treatments were control, intercultivation (3 times at 2, 4 and 6 weeks after sowing), mulching with paddy straw (at 2 tonnes ha<sup>-1</sup>) and herbicide application (twice at 3 and 5 weeks after