

THE RESPONSE OF IRRIGATED SUNFLOWER CULTIVARS TO NITROGEN FERTILIZER.

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ABSTRACT

The adaptability of a range of sunflower cultivars to a high nitrogen environment was studied in an irrigated field experiment. Three types of response to increasing fertiliser rates were apparent. The yield of the first group increased to an N rate of 30 kg N ha⁻¹ with no increase in yield or a yield decline, at higher rates. In the second group the yield reached a maximum at 90 kg N ha⁻¹ and then declined. In the final group, the yield continued to increase to 150 kg N ha⁻¹. The highest oil yield (1.9 t ha⁻¹) was produced by a cultivar in the second group which had a high yield with no fertiliser but produced a large response to N fertiliser. The variation which exists in sunflower germplasm should be exploited in developing cultivars better suited to a high nitrogen environment under irrigated conditions. Current overseas recommendations for fertiliser N based on nitrate-N in the soil underestimated the yield without fertiliser, because this test did not adequately predict the mineral N released from organic matter during the growth of this crop.

INTRODUCTION

Sunflower yields in excess of 3 tonnes seed per hectare are produced under irrigation in temperate areas of Australia. These crops remove about 150 kg ha⁻¹ from the soil and 85 kg N ha⁻¹ is harvested in the seed (Muirhead unpublished data). Consequently, large inputs of fertiliser nitrogen are required for high sunflower yields with intensive cropping systems under irrigation. Rao *et al.* (1976) demonstrated the advantage of split application of N fertiliser, and techniques are now available for relieving nitrogen stress during crop growth by applying urea in the irrigation water (Muirhead *et al.*, 1980).

Cultivars of many crops have been shown to differ in their response to nitrogen fertiliser; for example, rice (Evans and De Datta, 1979), maize (Pollmer *et al.*, 1979) and sunflowers (Shabana, 1979). Differences between cultivars in their response to N are usually small, but commercially important because a change in the cultivar grown could produce an increase in yield without additional expense. Thompson and Fenton (1979) reported that a large difference in harvest index (HI) existed between commercial cultivars of sunflowers with the short-statured, early maturing Hysun 10 producing a higher HI (0.42) than the taller and later maturing Hysun 30 (0.34). They did not measure N uptake but cultivars with a large HI are likely to use N fertilizer more efficiently. Although increasing N rates can reduce oil concentration in the seed, the total oil yield is generally increased (Cheng and Zubriski, 1978). High N rates applied to some cultivars can reduce seed set in sunflowers (Jain *et al.*, 1978). However, little information is available on the changes in yield and yield components of different cultivars of sunflower exposed to N stress.

The objective of this experiment was to study the adaptability of a range of sunflower cultivars grown under irrigation, to a high N environment.

MATERIALS AND METHODS

The growth and yield of 9 cultivars receiving 4 rates of N was studied in a field experiment. The four N treatments were 0, 30, 90 and 150 kg N ha⁻¹. Cultivars were Hysun 30, Eureka, Dekalb 500, Suncross 150, Suncross 52, Sunking, Sunbred 707, Sungirl and Hysun 21. The experimental design was a split plot, with N rates as the main treatments and cultivars as the sub-treatments. Each treatment was replicated in six blocks with each subplot (cultivar) 4 rows wide (91 cm spacing) and 12 m long. Three subplots were located along the furrow in each plot.

The experiment was conducted on a grey cracking clay soil (vertisol), located near Griffith in the Murrumbidgee Irrigation Areas in New South Wales. The site had grown summer crops for more than 10 years with maize being grown in the 3 previous seasons. Characteristics of the surface 30 cm soil were: pH 7.7; nitrate-N 13 ppm; and bicarbonate-P 31 ppm. Nitrate-N in the 30–60 cm depth was 1.8 ppm. The average bulk density was 1.2 in the top 30 cm and 1.4 in the 30 to 60 cm interval.

Trifluralin, 840 g active ingredient ha⁻¹ was applied and incorporated, before hilling, to control grass weeds. Half of the N was banded below the hill, as anhydrous ammonia two weeks before sowing and the remainder applied as urea in equal amounts in the first 3 irrigations after the crop emerged. Superphosphate (9.4% P) at 30 kg P ha⁻¹ was banded below the hill on 8 December 1980. Seed was sown into dry soil at 10.5 cm spacing (10.5 seeds m⁻²) with a vacuum-plate planter on 16 December 1980, and plots were furrow irrigated to initiate germination on 19 December, 50% emergence occurred on 24 December. Irrigations occurred on 15 and 28 January and on 23 February 1981, with the third irrigation being delayed by 71 mm rain received between 6 and 13 February. A final irrigation was applied on 9 March.

Seedling establishment was estimated from counts of plants in 5 m length of row on 40 plots, 7 days after 50% of the seedlings had emerged.

Fifteen plants were harvested from each cultivar receiving 0 and 150 kg N ha⁻¹ when 50% of the plants in that cultivar had reached anthesis, and again at physiological maturity. Seed yield was determined when seeds contained less than 9% moisture by counting and harvesting all heads producing seed in 10 m lengths of row from the two centre rows of each plot. The total number of plants in the sample area were counted on all plots in two replicates. The harvested heads were threshed in a stationary thresher, weighed and a subsample taken for cleaning. The weight of 1000 seeds and oil percentage was determined on this sample.

RESULTS

Morphological Development. Despite a range of maturity types, cultivars reached 50% anthesis with a period of 4 days of each other and about 50 days after emergence (Table 1). Visual observations showed no effect of the N treatments on time to 50% anthesis. Physiological maturity was reached about 90 days after emergence.

Table 1. Mean effect of nitrogen rates and cultivars on plant development, dry matter production and harvest index.

N Rate (kg N ha ⁻¹)	Time to 50% Anthesis (Days after emergence)	Dry Matter		Harvest Index
		Anthesis (g m ⁻²)	Physiological Maturity (g m ⁻¹)	%
0	n.a.	483	856	36.2
150	n.a.	553	1060	36.9
L.S.D. (5%)		50	113	n.s.
Cultivar				
Sungirl	49	513	922	38.3
Suncross 150	50	464	846	39.0
Sunking	51	556	1026	37.0
Suncross 52	50	533	1009	35.7
Eureka	51	555	995	34.2
Dekalb 500	51	574	1014	33.6
Hysun 30	51	524	959	38.2
Sunbred 707	50	493	975	36.8
Hysun 21	47	450	872	36.4
L.S.D. (5%)	n.a.	53	78	1.2
n.a. not available				

Dry Matter Production. N rates (0 and 150 kg N ha⁻¹) and cultivars significantly influenced dry matter production at anthesis and physiological maturity but these factors did not interact in their effect on dry matter production (Table 2). 150 kg N ha⁻¹ increased dry matter production at anthesis by 14% ($P < 0.05$) and this difference increased to 24% at physiological maturity (Table 1). All cultivars showed a

similar increase in dry matter between anthesis and physiological maturity but the increase was 36% higher when 150 kg N ha⁻¹ was applied. The HI was not influenced by the N rate but large differences existed between the cultivars which varied from 0.34 (Dekalb 500) to 0.39 (Suncross 150).

Table 2. Analysis of variance (F values) of nitrogen and cultivar effects on dry matter production and harvest index.

Attribute	Source			
	N Rate	Cultivar	N Rate*	Cultivar
Dry Matter (Anthesis)	12.83**	5.09***	0.98	n.s.
Dry Matter (Physiological Maturity)	21.50**	5.41***	1.64	n.s.
Increase in Dry Matter (Anthesis to Physiological Maturity)	12.90*	0.84 n.s.	1.41	n.s.
Harvest Index	0.63 n.s.	19.71***	0.31	n.s.
n.s. not significant; * $P < 0.05$; ** $P < 0.01$; *** $P < 0.001$				

Oil Yield. Nitrogen rate and cultivar treatments interacted in their effect on oil yield (Table 3) which produced three types of response to N fertiliser in the cultivars (Table 4).

Table 3. Analysis of variance (F values) of nitrogen and cultivar effects on oil yield and yield components.

Attribute	Source		
	N Rate	Cultivar	N Rate*
Oil Yield #	10.25 ***	44.71 ***	2.96 ***
Plant density	2.40 n.s.	43.10 ***	1.58 n.s.
Unproductive plants (% of harvested)	0.70 n.s.	5.14 ***	1.76 n.s.
Seed/capitulum #	40.14 ***	130.60 ***	2.30 **
1000 Seed Weight	9.94 ***	335.91 ***	1.05 n.s.
Oil percentage	40.18 ***	102.16 ***	2.80 ***
# Yield gradient in the buffer used as a covariate.			

Table 4. Effect of the nitrogen rates on oil yield (t ha⁻¹) of nine sunflower cultivars.

Cultivar	Response Type	N Rates (kg N ha ⁻¹)				Mean
		0	30	90	150	
Sungirl	A	1.43	1.64	1.57	1.51	1.54
Suncross 150	1	1.32	1.53	1.47	1.41	1.43
Sunking	B1	1.63	1.75	1.88	1.82	1.77
Suncross 52	B1	1.65	1.79	1.83	1.70	1.74
Eureka	B2	1.51	1.64	1.66	1.60	1.60
Dekalb 500	B2	1.33	1.50	1.65	1.60	1.52
Hysun 30	B2	1.47	1.54	1.63	1.60	1.56
Sunbred 707	B2	1.40	1.55	1.57	1.48	1.50
Hysun 21	C	1.35	1.39	1.50	1.64	1.47
Mean		1.45	1.59	1.64	1.59	1.57

L.S.D. (5%) cultivars within N rate 0.10 L.S.D. (5%) any other cultivar * N rate pairing 0.12

In the first response type (A-Suncross 150 and Sungirl), there was a significant increase in yield to 30 kg N ha⁻¹ and then a decline at higher rates with the yield at 150 kg N ha⁻¹ not significantly higher than the yield with no N fertiliser. Most of the cultivars (Group B) produced a significant increase in yield to 90 kg N ha⁻¹ with a decline in yield at 150

kg N ha⁻¹. The yield at 90 kg N ha⁻¹ with Suncross 52 and Sunking (B1) was significantly higher than with Hysun 30, Eureka, Dekalb 500 and Sunbred 707 (B2). There was a linear increase in oil yield from nil to 150 kg ha⁻¹ with Hysun 21 (Group C).

Yield Components. The N treatments had no effect on plant density (harvested plants) but the number of heads harvested varied between cultivars (Table 5). The plant density varied from 6.56 (Eureka) to 9.06 plants m⁻² (Hysun 21). The proportion of unproductive plants was relatively

high at 20% (expressed as a percentage of those harvested) but was not significantly influenced by N treatment. Unproductive plants were significantly higher in some cultivars (eg. Sunbred 707 — 32%) than others (eg. Sunking 15%).

Table 5. Mean effects of nitrogen rates and cultivar on plant density and seed weight of nine sunflower cultivars.

Treatment	Plant Density (plants m ⁻²)	Unproductive Plants (% of harvested)	Seed Weight (g/1000 seed)
N Rate (kg N ha ⁻¹)			
0	8.1	18.8	46.7
30	7.9	20.8	47.4
90	7.7	22.4	48.5
150	7.9	20.0	50.6
L.S.D. 5%	n.s.	n.s.	1.6
Cultivar			
Sungirl	7.24	26.1	41.0
Suncross 150	7.9	22.1	43.8
Sunking	8.7	15.2	44.7
Suncross 52	8.3	19.3	45.6
Eureka	6.6	16.5	65.6
Dekalb 500	8.4	20.6	53.8
Hysun 30	8.1	17.1	42.1
Sunbred 707	7.1	31.7	46.2
Hysun 21	9.1	15.8	52.1
L.S.D. 5%	0.34	7.0	1.2

There was an interaction with the N rate and cultivars on the number of seed per capitulum (Table 6). Some cultivars (eg. Hysun 30) showed no significant change in the number of seeds as the N rates increased whereas other cultivars (eg. Dekalb 500) produced 30% more seeds in each capitulum at

the 90 kg N ha⁻¹ rate. All cultivars showed a decrease in the number of seeds per capitulum at 150 kg N ha⁻¹ when compared with 90 kg N ha⁻¹ but this decline was significant ($P \leq 0.05$) in only half of the cultivars.

Table 6. Effect of nitrogen rates on the number of seed per capitulum of nine sunflower cultivars.

Cultivar	N Rates (kg N ha ⁻¹)				Mean
	0	30	90	150	
Sungirl	956	1160	1163	1083	1090
Suncross 150	797	907	911	827	861
Sunking	833	928	937	891	897
Suncross 52	839	926	967	864	899
Eureka	676	767	813	753	752
Dekalb 500	573	688	746	741	687
Hysun 30	909	892	941	939	920
Sunbred 707	830	955	1093	960	959
Hysun 21	594	636	692	656	644
Mean	778	873	918	857	857
L.S.D. (5%) cultivars within N Rate = 69					
L.S.D. (5%) any other cultivars *N rate paring = 70					

Increasing the nitrogen rate from 0 to 150 kg N ha⁻¹ produced an 8% increase in seed weight, with each fertiliser increment producing slightly larger seed. Significant differences in seed weight occurred between the cultivars which varied from 41.0 (Sungirl) to 65.6 (Eureka).

Oil percentage varied from 47.8% (Sungirl) to 51.7% (Suncross 52) (Table 7), with a general decline in oil percentage as the N rate increased from 0 to 150 kg N ha⁻¹. The interaction of nitrogen rates and cultivars on oil percentage was associated with a smaller decline as the N rate increased in some cultivars (eg. Hysun 21, Hysun 30 —1.5% units) than in others (eg. Eureka —4.3% units).

Table 7. Effect of the N rates on the oil percentage in the seed of the 9 cultivars.

Cultivar	N Rates (kg N ha ⁻¹)				Mean
	0	30	90	150	
Sungirl	48.57	48.48	47.68	46.30	47.76
Suncross 150	49.55	49.27	48.07	47.15	48.51
Sunking	52.30	51.50	50.93	50.23	51.24
Suncross 52	53.07	52.80	50.85	50.27	51.75
Eureka	51.60	50.87	49.37	47.33	49.79
Dekalb 500	50.35	49.45	49.02	49.98	49.20
Hysun 30	50.37	50.67	49.58	48.88	49.87
Sunbred 707	50.07	49.30	47.77	46.58	48.43
Hysun 21	49.27	48.87	48.17	47.72	48.50
Mean	50.57	50.13	49.05	48.05	49.45

L.S.D. (5%) cultivars within N rate = 0.74

L.S.D. (5%) any other cultivar *N rate pairing = 0.86

DISCUSSION

Oil yield of the cultivars studied varied in response to N fertiliser and could be separated into three groups. The relative performance of cultivars depended on the amount of N fertiliser applied, and the responsiveness of a cultivar to N may partly contribute to the variation in performance of cultivars in national trials (Frame, 1981). The response pattern observed was for one season only and may vary from year to year depending on environmental conditions. However, it may be possible to exploit this variability by developing cultivars with a high yield under moderate fertility, but able to respond to high rates of N fertiliser under irrigation and high rainfall conditions.

In this experiment N fertiliser mainly increased dry matter production after anthesis. Furthermore the high N rate did not affect the distribution of dry matter within the plant as the HI was similar at both N rates. Cheng and Zubriski (1978) also reported little effect of N rates on HI but generally their HI of 0.29 was much lower than the 0.37 recorded in this experiment.

The N treatments affected oil yield by influencing the number of seed in the capitulum, seed weight and oil percentage. Seed weight showed a small increase for each increase in N rate and the response was similar for all cultivars. However, the effect of N on the number of seeds in the capitulum and oil percentage, the main factors determining the response to N, varied between cultivars. The seed number per capitulum increased for all cultivars, except Hysun 30, as the N rate increased from 0 to 90 kg N ha⁻¹. The decline in seed numbers between 90 and 150 kg N ha⁻¹ varied between cultivars and may have been associated with either fewer flowers formed or a higher proportion of aborted seed (Jain *et al.*, 1978). Increasing the N rates decreased the oil percentage in the seed which decreased. The highest oil yield was produced by two cultivars with high oil concentration and plant density, a relatively large number of seeds in the capitulum but seed of average size.

Over 90% of the seed sown emerged and were present at physiological maturity. However, about 20% of the plants at harvest were unproductive with considerable variation between cultivars. The data of Robinson *et al.*, (1980) showed a similar proportion of unproductive plants which were not influenced by plant population. An early *Heliothis* attack was responsible for producing some sterile plants while the growth of others was reduced by competition from neighbours. It is unlikely that the range in plant densities between cultivars influenced yield because Thompson and Fenton (1979) have shown over several seasons that plant densities between 25,000 and 140,000 plants per hectare had little effect on yield.

Soil nitrate-N tests are often used to predict the amount of N fertiliser required to minimise N stress in a sunflower crop. Cobia and Zimmer (1978) recommend that the amount of fertiliser N required to produce a particular yield goal can be related to the amount of nitrate-N in the top 60 cm of soil before the crop is sown. The nitrate-N in this experiment was 55 kg N ha⁻¹ which would be expected to produce 1.1 t seed ha⁻¹. However, the average seed yield on the nil N treatments was 2.9 t ha⁻¹ which would require a total of 175 kg N ha⁻¹ as nitrate-N and N fertiliser. The additional N used by the crop was probably released through mineralisation of organic matter. Cheng and Zubriski (1978) also reported higher yields

on nil N treatments than would be expected from the predictions by Cobia and Zimmer (1978). They measured an apparent mineralisation of 130 kg N ha⁻¹ during the growth of a sunflower crop. These results suggest that current overseas recommendations for fertiliser N based on presowing soil nitrate levels are not well suited for irrigated conditions in Australia because they do not adequately predict the potential mineral N release from organic matter during the growth of the sunflower crop.

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