T1978AGRO31

EFFECTS OF NITROGEN FERTILIZER ON PRODUCTION OF IRRIGATED SUNFLOWER, PLANT UPTAKE OF NITROGEN, AND ON WATER USE[1]

by

S.F. Cheng and J.S. Zubriski[2]

Summary (Abstract)

Irrigated sunflower was grown to test effects of three sources of nitrogen, each at four rates, on seed yield, oil concentration and yield, nitrogen concentration and yield at three stages of growth, soil nitrogen at harvest and on water use.

Nitrogen sources caused similar responses for all measurements.

Fertilizer N increased average seed yields from 2734 for 0-N to 4195 kg/ha for 112 kg N/ha. Oil concentration was decreased from 50.0% oil at 0-N to 48.5% oil at 112 kg N/ha. However, yield of oil was increased from 1367 at 0-N to 2034 kg/ha at 112 kg N/ha. Nitrogen concentrations of whole plants at 90 percent yield were 5.20, 1.63, and 1.13 percent for samplings at 30 cm height, ray flower and physiological maturity stages, respectively. Mature leaves at ray flower and maturity contained 2.79 and 1.62 percent N, respectively. At harvest soil profiles contained similar amounts of N in all plots. Crop water use efficiencies were 39.10 and 50.49 kg/ha/cm for the 0 and 56 kg N plots.

Results of this study show that irrigated sunflower responds to applied N regardless of source tested, when grown on soils deficient in N and when irrigation water increases potential yield. Fertilized sunflower removed water to a 244 cm depth and produced more seeds per unit of water used than non-fertilized sunflower. At this site 112 kg N/ha did not produce maximum yield.

Introduction

Sunflower (Helianthus annuus L.) production has increased to the extent that it is now the second leading oilseed crop in the world. As markets improved and growers gained experience, the acreage of this relatively new crop has increased rapidly and become a promising crop in the U.S., especially in North Dakota. In 1977 about 500,000 hectares were planted to sunflower in North Dakota (1).

Sunflower is adapted to a wide variety of soils and climatic conditions, but fertile soils, warm temperature and adequate water usually produce the largest yields and best quality seed (5). In North Dakota, most soils cannot supply enough of all nutrient elements, particularly nitrogen, and water for large sun-

---

[1] Contribution from the Department of Soils, North Dakota State University, Fargo, North Dakota 58102.

[2] Associate Professor, Department of Chemistry, Taiwan Provincial Pingtung Institute of Agriculture, Pingtung, Taiwan, R.O.C., formerly graduate student, North Dakota State University, and Professor of Soils, North Dakota State University, Fargo, North Dakota 58102.

flower yields (11,5). In the production of sunflower for oil and non-oil uses, growers want to use both irrigation water and fertilizers in the most efficient manner. However, before growers can make intelligent decisions on quantities of these variables to apply, researchers must provide data that show the responsiveness of sunflower to applied water and fertilizer.

At the present time there is insufficient data for many soils on quantities of fertilizer nitrogen to apply for production of irrigated sunflower. The objectives of this research were to determine the effects of ammonium nitrate, ammonium sulfate and urea, each at 0, 28, 56 and 112 kg N/ha on: (a) seed yield, oil concentration, oil yield, dry matter yield of plant parts at three growth stages, nitrogen concentration in plant tissues and nitrogen yield by "hybrid 894" oil sunflower at three stages of plant development, (b) soil nitrate nitrogen at harvest, and (c) water use efficiency of sunflower under near optimum irrigation.

Materials and Methods

A field trial was conducted on Maddock sandy loam soil (Aeric Calciaquoll) at Oakes, North Dakota. Soil analyses (6) before fertilization indicated: 0.5 M sodium bicarbonate soluble P = 55 kg/ha/30 cm; 1.0 M ammonium acetate soluble K = 273 kg/ha/30 cm; soil nitrate = 10 kg N/ha/61 cm.

The experimental design was a split plot arrangement in randomized complete block design with four replications. Three nitrogen sources; NH_4NO_3(34-0-0), $(NH_4)_2SO_4$ (21-0-0) and $CO(NH_2)_2$ (46-0-0 were used as the whole plots. Four nitrogen rates; 0, 28, 56 and 112 kg/ha were used as subplots. The size of each whole plot was 25.6 by 3.7 m. Each subplot was 6.4 by 3.7 m. A rate of 112 kg P_2O_5/ha as 0-46-0 and 56 kg K_2O/ha as 0-0-60 were broadcast over the entire plot area before spring plowing. Nitrogen fertilizers were banded 5x5 cm to side and below seed at planting time.

Sunflower "hybrid 894", an oil-type cultivar, was planted on May 17, 1977. Each plot contained four rows 92 cm apart. Before emergence of the third pair of leaves, each row was thinned to an average space of 18 cm between plants. final plant population was approximately 59,300 plants per hectare. Weeds were controlled by preplant application of trifluralin, cultivation and hand hoeing. duirng seed ripening stage malathion was sprayed to control sunflower moth.

Irrigation water was applied with sprinklers and scheduling was based on the daily readings of tensiometers which were installed at soil depths of 30 and 60 cm. Before July 1, water was added when the tension at 30 cm reached 550 mb. After July 1, water was added when the average tension at 30 and 60 cm reached 550 mb. This plot was irrigated to a level considered near optimum.

To monitor soil water with a neutron probe, eight access tubes were installed in the subplots that received 0 and 56 kg N/ha as NH_4NO_3.

Plant samples for dry matter determination and chemical analyses were taken from every subplot three times during the growing season. Four plants from the first samplings (30 cm stage) were cut at soil surface and kept whole. At ray flower and maturity stages four plants were sampled from each of the two border rows. Plants from the last two samplings were cut off at the ground level and separated into leaves, stems and heads. Plant materials were dried at 70°C and

ground in a Wiley mill tp pass a 20-mesh sieve. On September 6, 20 heads from plants having neighboring plants at 18 cm were harvested by hand from the two center rows of each plot for yield determination. Harvested heads were dried at 50°C and threshed in an experimental plot combine. Before being weighed, seed was cleaned with a small fanning mill.

After harvest, soil samples in 30 cm increments were taken to a depth of 274 cm from each subplot. Nine samples were collected from each subplot. Each of the five upper samples were a composite from 2 cores of the respective depths, but each of the four lower samples came from only one core per plot. Samples were air dried before chemical analyses.

Total nitrogen in the plant samples was determined with a modified micro-Kjeldahl procedure. The plant samples were digested with the aluminum-block method described by Nelson and Sommers (8) using procedure B for the salicylic acid modification. Ammonium in the digest was determined as described by Bremner and Edwards (4). Total phosphorus in the plant samples was determined by the ammonium phosphovanadomolybdate method described by Bolin and Stamberg (3). Oil concentration was determined with nuclear magnetic resonance equipment (7).

Soil nitrate nitrogen was measured with an Orion nitrate electrode (6).

Water use efficiency was calculated on plots receiving 0 and 56 kg N/ha as NH_4NO_3 by dividing seed yield by the total amount of water used in evapotranspiration. The amount of evapotranspiration was estimated by adding amounts of irrigation water and precipitation received during the planting to harvest period to soil water depletion during the same period. Runoff and percolation were considered to be negligible.

Analysis of variance was performed at the North Dakota State University Computer Center using the statistical analysis system developed by Barr et al (2). The least significant difference test (9) was used to determine significant differences between sample means.

Results and Discussion

Source of nitrogen caused similar responses for all variables that were measured. The nitrogen source by rate interaction was also not significant for all measurements made. Therefore, the data presented are averages over all nitrogen sources.

Seed Yield, Oil Concentration and Yield

Average seed yield, oil concentration and yield of oil as affected by nitrogen fertilizer are presented in Table 1.

Average seed yields were significantly increased by nitrogen from all three sources. Nitrogen fertilizer at 28, 56, and 112 kg N/ha increased average seed yields by 644, 974 and 1,463 kg/ha, respectively. Zubriski and Zimmerman (11) indicated that nitrogen fertilizer at 56 and 112 kg N/ha, respectively, increased average oil-type sunflower seed yield by 648 and 850 kg/ha under dryland conditions. Apparently, in North Dakota yields of sunflower seed were increased more

by nitrogen fertilizer in conjunction with irrigation water than by applied nitrogen fertilizer on dryland.

TABLE 1. Effect of Nitrogen Fertilizer on Average Seed Yield, Oil Concentration and Oil Yield.

Nitrogen Rate	Seed Yield	Oil Conc.	Oil Yield
kg/ha	kg/ha	%	kg/ha
0	2734	50.0	1367
28	3378	49.7	1678
56	3708	49.1	1820
112	4197	48.5	2034
LSD (.05)	255	0.6	118

From the trend of seed yield response to rates of nitrogen tested and the data showing nitrogen rate having no significance on the soil nitrate nitrogen content (Table 3), it appears that 112 kg N/ha did not produce maximum seed yield and a larger nitrogen rate was required to achieve the production potential of irrigated sunflower.

Nitrogen fertilizer significantly reduced oil concentration. Nitrogen fertilizer at 28, 56 and 112 kg N/ha reduced average oil concentration by 0.3 (NS at P = .05), 0.9 and 1.5 percentage units, respectively, or by 0.6, 1.8 and 3.0% as compared with plots given no nitrogen. However, the increased seed yield to nitrogen offset the decreased oil concentration so that nitrogen fertilizer at 28, 56 and 112 kg N/ha increased average oil yield by 311, 453, and 667 kg/ha, respectively.

Dry Matter Yield, Nitrogen Concentration and Nitrogen Yield

Average dry matter yields, nitrogen concentrations and nitrogen yields as affected by nitrogen fertilizer are presented in Table 2.

Average dry matter yields were significantly reduced by nitrogen. Nitrogen fertilizer at 28, 56 and 112 kg N/ha, respectively, increased average dry matter yields of whole plants by 13, 20 and 21% at 30 cm height stage, by 15, 20 and 33% at ray flower stage and by 15, 29 and 34% at maturity. At maturity, nitrogen fertilizer at 28, 56 and 112 kg N/ha, respectively, increased average dry matter yield of leaves by 16, 34 and 50%, of stems by 13, 24 and 31%, of receptacles by 9, 19 and 16%, of seeds by 20, 38 and 41%. The average dry matter yield proportion at maturity of leaves, stems, receptacles and seeds over all sources and rates of nitrogen was 1:2.4:1.2:1.9. Largest yields were found in the stems and with much lower yields in the leaves.

Nitrogen concentration of plant parts tended to increase with an increase in fertilizer nitrogen. The nitrogen concentration data of whole plants indicated that nitrogen concentration of sunflower were highest at the early growth stage and then decreased as the season progressed. At maturity the highest concentration of nitrogen was found in the seeds with much lower amount in the stems. The nitrogen concentrations of whole plant at 90 percent seed yield

(assume the nitrogen concentration at 90% of seed yield is the lower limit of sufficiency) were 5.21, 1.63 and 1.13% (data not shown) for samplings at 30 cm height stage, ray flower stage and maturity, respectively. The leaves at ray flower stage and maturity contained 2.79 and 1.62% N, respectively. Nitrogen concentration changes in whole plants and leaves due to added fertilizer nitrogen suggest that plant analysis could be used to evaluate nitrogen status of sunflower.

Nitrogen yields by sunflower increased with increasing nitrogen fertilizer. Fertilizer nitrogen at 28, 56 and 112 kg N/ha, respectively, increased average nitrogen yields of whole plants by 17, 27 and 28% at 30 cm height stage, by 21 (NS at P = 0-05), 28 and 93% at ray flower stage and by 20 (NS at P = 0.05), 45 and 95% at maturity. The average nitrogen yields of leaves, stems, receptacles, seeds and whole plant at maturity over all sources and rates of nitrogen were 30, 15, 15, 73 and 132 kg/ha, respectively. This indicated that about 1/3 of the total nitrogen required by sunflower was present in vegetative organs and about 2/3 was present in reproductive organs. A comparison of the nitrogen yield of whole plant at ray flower stage with that at maturity, reveals that nitrogen uptake was practically complete at the flowering stage. After flowering some nitrogen translocated to the reproductive organs from vegetative organs. This study indicated that the irrigated sunflower removed about 130 kg of N to produce a yield of 3,500 kg/ha of seed.

Soil Nitrogen at Harvest

Average soil nitrate nitrogen data in several soil depths at harvest as affected by nitrogen source and rate are presented in Table 3.

TABLE 3. Effects of nitrogen source and rate on soil nitrate nitrogen in several soil depths.

N Rate or N Source[1]	Nitrate-N in Soil			
	0-21 cm	0-152 cm	0-274 cm	152-274 cm
	kg/ha			
0 kg/ha	23	40	59	20
28 kg/ha	23	43	66	24
56 kg/ha	24	44	67	23
112 kg/ha	27	47	72	25
NH_4NO_3	25	44	68	24
$(NH_4)_2SO_4$	23	39	59	21
$CO(NH_2)_2$	25	46	71	24

[1] For each rate, nitrate-N was averaged over all sources.
For each source, nitrate-N was averaged over all rates.
Effects of N rate, N source and N rate x N source were NS at P = .05 for all depths.

Nitrogen source and rate caused no significant differences in average nitrate nitrogen content in all soil depths. At harvest soil profile nitrate nitrogen averages were 24.3, 43.5, 66.0 and 23.0 kg/ha for the 0-61, 0-152, 0-274 and

152-274 cm depths. The soil test value for the 0-61 cm depth of all plots was very low by NDSU Soil Testing Laboratory standards (10).

The amount of nitrogen present in the above ground parts of sunflower and the content of soil nitrate nitrogen in soil profiles sampled on October 5, 1976 and on October 6, 1977 are shown in Table 4. This same table also provides data for an estimate of nitrogen mineralized from soil organic matter between 1976 and 1977 profile samplings. Based on plant uptake of nitrogen and soil content at harvest, it appears little or no nitrogen loss occurred during the year.

TABLE 4. Utilization of Nitrogen by Sunflower as Measured by Available Soil Nitrogen and Plant Analysis.

N Rate kg/ha	Soil Nitrate-N Harvest 1976[1]	Soil Nitrate-N Harvest 1977[2]	Plant N Uptake[3]	N mineralized from org. matter[4]	
	------kg/ha/274 cm---		----------kg/ha----------		
(a)	(b)	(c)	(d)		
0	25	59	97	131[5]	141[6]
28	24	66	116	130	142
56	27	67	140	124	138
112	30	72	175	105	123

[1] Date of harvest soil sampling was on Oct. 5, 1976, each value is average of 12 plots.

[2] Date of harvest soil sampling was on Oct. 6, 1977, each value is average of 12 plots.

[3] Nitrogen in above ground parts.

[4] Nitrogen from soil organic matter = (d) + (c) - (a) - (b), nitrogen from precipitation and irrigation water are considered to be negligible.

[5] Calculations based on nitrogen uptake by above ground plant parts.

[6] Calculations based on nitrogen uptake by roots plus above ground plant parts. Nitrogen uptake by root was assumed to be 10 percent of above ground plant parts.

Furthermore, the calculations from data on above ground plant parts presented in Table 4 show that approximately 131, 130, 124 and 105 kg/ha of available nitrogen were mineralized from soil organic matter at the 0, 28, 56 and 112 kg N/ha plots, respectively. However, if one assumes that roots utilized 10 percent as much nitrogen as tops, the calculated values for nitrogen mineralization from soil organic matter are 141, 142, 138 and 123 for the 0, 28, 56 and 112 kg N/ha plots, respectively.

Water Use Efficiency

Available soil moisture at planting and harvest are presented in Table 5. At harvest available soil moisutre level at the 244 cm depth of 0 and 50 kg N/ha plots are lower than of the same depth at planting. This indicated that sunflower, whether fertilized or not, removed water from at least a 244 cm depth.

Water use efficiencies as affected by nitrogen fertilizer are presented in Table 6. Total water use was 69.20 and 71.81 cm of water for the 0 and 56 kg N/ha plots. Fertilizer increased water use about 2.86%, but the average seed yield increased 33% from 2,706 to 3,594 kg/ha as a result of fertilization. Consequently, water use efficiency was increased by the use of nitrogen fertilizers from 39.10 kg/ha/cm of water where no nitrogen was applied to 50.49 kg/ha/cm where 56 kg N/ha was applied. This is equivalent to a 29% increase in seed yield per cm of water from nitrogen fertilizer. Since nitrogen at the 56 kg rate did not cause an appreciably greater soil water depletion than in no nitrogen plots, it can be assumed that the 28 and 112 kg nitrogen plots caused about the same soil water depletion as the 56 kg plots. If this assumption is valid, then water use efficiencies for the 28 and 112 kg rates can be estimated as 48.03 and 57.92 kg/ha/cm.

Literature Cited

1. ANONYMOUS, 1978. 1977 four-state sunflower production figures released. The Sunflower. The official publication of the Sunflower Association of America, Fargo, North Dakota. Jan. p. 4.

2. BARR, A.J., J.H. GOODNIGHT, J.P. SALL, and J.T. HELWIG, 1976. A user's guide to SAS, 76. N. Carolina: SAS Inst. Inc.

3. BOLIN, D.W. and O.A. STAMBERG, 1944. Rapid digestion method for determination of phosphorus. Ind. Eng. Chem. Anal. Ed. 16:345.

4. BREMNER, J.M. and A.P. EDWARDS, 1965. Determination of isotoperatio analysis of different forms of nitrogen in soils: I. Apparatus and procedure for distillation and determination of ammonium. Soil Sci. Soc. Amer. Proc. 29:504-507.

5. COBIA, D.W. and D. ZIMMER (ed.) 1975. Sunflowers production, pests and marketing. NDSU Ext. Bull. 25.

6. DAHNKE, W.C. (ed.), 1975. Recommended chemical soil test procedures for the North Central Region. N. Dak. Agr. Sta. Bull. 499.

7. GRANLUND, M. and D.C. ZIMMERMAN, 1975. Effect of drying conditions on oil content of sunflower (Helianthus annuus L.) seeds as determined by wide-line nuclear magnetic resonance (NMR). Proc. N. Dak. Acad. Sci. 27:128-132.

8. NELSON, D.W. and L.E. SOMMERS, 1973. Determination of total nitrogen in plant material. Agron. J. 65:109-112.

9. STEEL, ROBERT G.D. and J.H. TORRIE, 1960. Principles and procedures of statistics. McGraw-Hill Book Company, Inc., New York.

10. WAGNER, D.F., W.C. DAHNKE, D.E. ZIMMER, J.C. JUBRISKI and E.H. VASEY, 1975. Fertilizing sunflowers. Cooperative Extension Service Circular S & F 3 revised. North Dakota State University, Fargo, North Dakota 58102, United States Department of Agriculture Cooperative.

11. ZUBRISKI, J.C. and D.C. ZIMMERMAN, 1974. Effects of nitrogen, phosphorus and plant density on sunflower. Agron. J. 66:798-801.

TABLE 2. Effect of nitrogen fertilizer on average dry matter yield, nitrogen concentration and nitrogen yield.

Parameter	Plant part	N rate, kg/ha 0	28	56	112	LSD (.05)
30 cm stage						
Dry matter, kg/ha	Whole plant	388	439	466	468	39
N Concentration, %	Whole plant	4.91	5.10	5.21	5.21	0.16
N yeild, kg/ha	Whole plant	19.1	22.4	24.3	24.4	2.34
Ray Flower Stage						
Dry matter, kg/ha	Leaves	2186	2693	2878	3272	461
	Whole plant	6924	7979	8328	9172	941
N Concentration, %	Leaves	2.47	2.61	2.73	3.20	0.17
	Whole plant	1.38	1.47	1.60	2.02	0.14
N Yield, kg/ha	Leaves	54.5	70.1	78.4	104.1	14.0
	Whole plant	96.3	116.8	133.1	185.4	22.1
Maturity						
Dry Matter, kg/ha	Leaves	1440	1666	1925	2165	262
	Stems	3691	4177	4593	4835	298
	Receptacles	1980	2165	2357	2288	264
	Seeds	2795	3346	3864	3938	573
	Whole plant	9906	11354	12739	13226	1230
N Concentration, %	Leaves	1.46	1.56	1.60	1.87	0.15
	Stems	0.24	0.28	0.31	0.49	0.05
	Receptacles	0.68	0.66	0.67	0.75	0.05
	Seeds	1.88	1.91	2.05	2.38	0.15
	Whole plant	0.97	1.02	1.10	1.31	0.08
N Yield, kg/ha	Leaves	21.1	26.2	30.8	40.9	6.1
	Stems	8.9	11.7	14.3	23.7	3.3
	Receptacles	13.4	14.4	14.9	17.2	2.3
	Seeds	53.1	64.0	79.4	93.6	14.1
	Whole plant	96.5	116.3	140.4	175.4	21.3

TABLE 5. Available Soil Moisture at Planting and Harvest.

Date	N rate, kg/ha	Depth increments, cm 0-15	15-31	31-61	61-92	92-122	122-153	153-183	183-213	213-244	Total
		Available soil moisture, cm.[1]									
Planting[2] (May 17)		4.55	3.71	3.51	4.12	3.51	3.51	4.83	4.39	4.17	36.30
Harvest (Sept. 6)	0	3.45	3.30	3.30	3.44	3.23	3.25	4.13	3.62	4.07	31.79
	50	3.61	3.38	3.40	2.87	2.74	2.45	3.81	3.40	3.15	29.81

[1] Available soil moisture = field soil moisture determined by neutron probe minus moisture retained by soil when a positive pressure of 15 atmospheres was applied.

[2] Soil moisture was averaged over all 0 and 56 kg N/ha plots.

TABLE 6. Effect of nitrogen fertilizer on water use efficiency by oil-type sunflower.

Nitrogen rate, kg/ha	Water source, cm. Soil	Irrigation	Precipitation	Seed Yield, kg/ha	Water Use Efficiency, kg/ha/cm
0	4.51	41.78	22.91[1]	2706	39.10[2]
28	6.49[3]	41.78	22.91	3419	48.03
56	6.49	41.78	22.91	3594	50.49
112	6.49[3]	41.78	22.91	4123	57.92

[1] Precipitation from May 17 through September 6, 1977.

[2] Seed yield divided by sum of water sources.

[3] Water use efficiency calculated on the assumption that soil water depletion was the same as for the 56 kg/ha plots.