

Nitrogen: A Limiting Factor in Sunflower Production on Non-fallow Soils

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Sunflower seed yields can be increased by applying nitrogen fertilizer on many non-fallow soils. The amount of nitrogen fertilizer required depends on the yield goal and amount of soil test nitrate-N in the soil at planting time. Information is presented on response data of oil-type sunflower seed yield, oil concentration and oil yield to applied fertilizer and soil nitrogen at 23 locations.

INTRODUCTION

Sunflower is adapted to a wide variety of soil and climatic conditions and produces optimum yields when accompanied with sound management practices. Non-fallow soils in North Dakota are often deficient in available nitrogen and without supplemental fertilizer nitrogen, yields of sunflower and other crops may be small. Other limiting factors that contribute toward small sunflower seed yields are: inadequate supply of phosphorus or potassium, incorrect plant population, inadequate or excess moisture, late planting, weed competition, disease, insect damage, herbicide damage, bird depredation, lodging and harvesting losses.

Field trials have been conducted annually since 1971 on dryland and irrigated soils to evaluate the effects of soil fertility, moisture, and plant population on sunflower seed yield and quality of seed. Results obtained from these field experiments have been discussed in earlier publications (1, 2, 3, 5, 6, 7). This report will discuss only the effects of rate of fertilizer nitrogen applied to non-fallow dryland soils on seed yield, oil concentration and yield of oil produced by oil-type sunflower.

MATERIALS AND METHODS

A total of 23 dryland field trials that contained comparisons of rates of nitrogen fertilizer were conducted since 1971. Rates of nitrogen in 10 trials conducted in 1971 through 1976 were 0, 50 and 100 lbs of N/acre as ammonium nitrate. Nitrogen in these trials was banded 2 inches to the side and 2 inches below the seed at planting time. Nitrogen rates in 13 trials conducted in 1978 were 0, 40, 80, 120 and 160 lbs of N/acre as either ammonium nitrate or urea^{1/}. This nitrogen was broadcast pre-plant at several locations and post emergence on the remaining sites. Fertilizer was incorporated into the soil by tillage or rototilling. Phosphorus fertilizers were applied at most sites and potassium was tested at one site.

Open pollinated varieties were used as the test crop prior to 1975 with hybrids utilized in succeeding years.

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Plant populations in trials prior to 1976 were 14,520, 19,360 and 29,040 plant/acre at each site. Results presented in this report are averaged over the three populations tested. In the 1976 and 1978 trials, plant population ranged from 7,800 to 19,100 plant/acre.

Weeds were controlled by use of appropriate herbicides, hand hoeing, and cultivation. Weeds were not a problem in any of the trials.

Seed yield data in six trials in 1978 were calculated from threshed heads that were hand harvested from two center rows each 10 feet long. Data from the remaining 1978 trials were obtained from hand harvesting heads from row segments without missing plants from the two center rows that totaled 20 feet. Twenty heads were collected for yield determinations in the earlier trials. Equivalent seed yields, oil concentrations, and yields of oil at 40, 80 and 120 lb N rates were estimated from response curves for trials having the 50 and 100 pound N rates. Data from the 160 pound N rate in the 13 trials in 1978 are not presented because these data were not significantly different from the 120 lb N rate. Oil concentration was determined on a 38 cubic centimeter sample by the nuclear magnetic resonance procedure. Oil yield was determined by multiplying oil concentration by seed yield at zero per cent moisture.

Bird depredation, disease, insect damage and lodging were minimal and presumed to have affected yields only to a small degree.

RESULTS AND DISCUSSION

Site location, soil type and selected chemical properties of soils are presented in Table 1.

Average seed yield, oil concentration and yield of oil of 23 field experiments and the 16 responding sites as affected by rate of nitrogen fertilizer are presented in Table 2.

^{1/} Trials conducted in 1978 were supported in part with grant funds provided by the North Dakota Sunflower Council, Capitol Building, Bismarck, North Dakota 58505.

Table 1. Location, year of trial, soil type and some chemical properties of soils.

| Location and year | Soil type ^{1/} | Soil pH | Chemical Soil Properties ^{2/} | | |
|----------------------|----------------------------|------------|--|-------------|-------------|
| | | | NO ₃ -N lbs/A/2 ft | P, lbs/A | K, lbs/A |
| Clifford, 1971 | Svea I | 6.2 | 53 | 34 | 550 |
| Embden, 1972 | Hecla sl | 6.7 | 16 | 9 | 250 |
| Page, 1972 | Svea I | 7.9 | 45 | 34 | 260 |
| Amenia, 1972 | Bearden sil | 8.0 | 30 | 15 | 190 |
| Argusville, 1973 | Bearden sil | 7.0 | 36 | 29 | 260 |
| Buffalo 1, 1973 | Hamerly I | 8.0 | 34 | 25 | 850 |
| Buffalo 2, 1973 | Hamerly I | 8.0 | 34 | 25 | 850 |
| Argusville, 1974 | Bearden sil | 8.1 | 57 | 13 | 180 |
| Buffalo, 1975 | Svea I | 7.5 | 26 | 12 | 280 |
| Buffalo, 1976 | Glyndon I | 7.9 | 41 | 32 | 285 |
| Lisbon 1, 1978 | Hecla Ifs | 6.8 | 41 | 17 | 260 |
| Lisbon 2, 1978 | Svea I | 7.3 | 100 | 16 | 465 |
| Valley City, 1978 | Barnes I | 7.1 | 90 | 15 | 565 |
| Menoken, 1978 | Roseglen- | | | | |
| | Makoti I | 6.9 | 43 | 37 | 535 |
| Jamestown, 1978 | Barnes-Svea I | 6.6 | 42 | 20 | 360 |
| Galesburg, 1978 | Gardena- | | | | |
| | Echman I | 7.4 | 51 | 15 | 350 |
| Forman, 1978 | Forman cl | 7.8 | 48 | 25 | 550 |
| Starkweather, 1978 | Great Bend- | | | | |
| | Beotia sil | 8.0 | 104 | 12 | 465 |
| Dunseith, 1978 | Overly sil- | | | | |
| | Gardena I | 7.6 | 42 | 15 | 495 |
| Perth, 1978 | Barnes I | 7.4 | 26 | 11 | 405 |
| Webster, 1978 | Barnes- | | | | |
| | Hamerly I | 7.8 | 32 | 11 | 420 |
| Williston, 1978 | Williams I | 7.3 | 22 | 10 | 289 |
| Hettinger, 1978 | Grail sil | 6.5 | 73 | 17 | 609 |

^{1/} Soil type was determined by Michael Sweeney, associate professor of soils, NDSU, Fargo, ND 58105. I = loam, sl = sandy loam, sil = silt loam, cl = clay loam, Ifs = loamy fine sand.

^{2/} Chemical properties of soils were determined by the NDSU Soil Testing Laboratory, Fargo, ND 58105.

Table 2. Average sunflower seed yields, oil concentrations and yields of oil as affected by rates of nitrogen fertilizer.

| Fertilizer N, lbs/A | Average Seed Yield, lbs/A ^{1/} | Average Oil Conc., % ^{2/} | Average Yield, Oil lbs/A ^{3/} |
|------------------------|---|--|--|
| 0 | 1845 (1892) | 45.1 (46.1) | 749 (785) |
| 40 | 2170 (2286) | 44.2 (45.2) | 863 (930) |
| 80 | 2310 (2470) | 43.6 (44.3) | 906 (985) |
| 120 | 2330 (2497) | 43.3 (43.9) | 908 (987) |

^{1/} Seed yields are expressed on a 10% moisture basis. Numbers without parentheses are averages of all trials and numbers within parentheses are averages of the 16 responding sites.

^{2/} Oil concentration is expressed on dry basis. Numbers without and within parentheses are for all trials and the 16 responding trials, respectively.

^{3/} Yield calculated as product of oil concentration and seed yield at zero moisture content. Numbers without and within parentheses are for all trials and the 16 responding trials, respectively.

Nitrogen fertilizer significantly increased seed yields at 16 of the 23 sites. A significant response was not obtained at Buffalo, 1976 due to poor emergence and variable plant populations; at Lisbon #1, 1978 due to high perched water table and probable horizontal soil water movement within rooting depth; at Lisbon #2, 1978 due to high soil nitrate at planting; at Starkweather, 1978 due to hail damage and high soil nitrate; at Dunseith, 1978 due to variable plant population for each nitrogen rate; at Williston, 1978 due to high plot variability; and at Hettinger, 1978 due to late planting and high soil nitrate levels below 2 feet. For all trials 40 pounds of fertilizer nitrogen per acre increased average seed yields by 325 lbs seed/acre. The 80 pound rate increased seed yields by 465 pounds over non-fertilizer yields. The 120 pound rate caused small but non-significant yield increases over that produced by the 80 pound rate. For the responding sites the 40 and 80 pound N rates increased seed yields by 394 and 578 lbs seed/acre, respectively.

The regression equations describing average response of sunflower seed yield to applied fertilizer nitrogen for all trials and the 16 responding sites are:

$$Y = 1848 + 9.71X - 0.048X^2 \text{ (all trials)}$$

$$Y = 1895 + 11.89X - 0.057X^2 \text{ (16 responding sites)}$$

where Y = estimated seed yield in pounds of seed per acre and X = rate of fertilizer nitrogen in lbs/acre.

The relationship between average sunflower seed yield and amount of soil nitrate-nitrogen and fertilizer nitrogen applied is presented in Table 3. The average soil nitrate nitrogen present in the soil at planting was 47 lbs N/acre/2 foot depth for all trials and 43 lbs N/acre/2 feet for the 16 responding sites. This quantity is considered low for a seed yield goal of 2000 lbs/seed/acre (4). The nitrogen recommendation for a 2000 lb seed yield is 100 lbs of soil plus fertilizer nitrogen (4). The data in Table 3 show that about 87 and 83 lbs of N (soil plus fertilizer) was required for a yield of about 2200 lbs of seed for all trials and the 16 responding sites, respectively.

Table 3. Relationship between average sunflower seed yield and amount of soil plus fertilizer nitrogen.

| Average seed yield, lbs/acre | Average soil nitrate-N, lbs N/A 2 ft. | Fertilizer N added, lbs/acre | Soil + fertilizer N, lbs N/A/2 ft. |
|------------------------------|---------------------------------------|------------------------------|------------------------------------|
| 1845 (1892) ^{1/} | 47 (43) ^{1/} | 0 | 47 (43) ^{1/} |
| 2170 (2286) | 47 (43) | 40 | 87 (83) |
| 2310 (2470) | 47 (43) | 80 | 127 (123) |
| 2330 (2497) | 47 (43) | 120 | 167 (163) |

^{1/} Numbers in parentheses are averages of 16 sites producing significant responses to nitrogen fertilizer.

The regression equation relating seed yield to fertilizer nitrogen plus soil nitrogen to a 2-foot depth at planting time for the 16 sites producing a significant response to nitrogen fertilizer is:

$$Y = 1277 + 16.8X - 0.057X^2$$

where Y = seed yield in pounds/acre and X = pounds/acre/2 feet of soil nitrate N plus fertilizer N at planting time.

When a value of 100 pounds of soil plus fertilizer N is substituted in this equation, the predicted yield is 2387 lbs seed/acre. The predicted yield is somewhat higher than what present fertilizer recommendations circular (4) shows for 100 pounds of soil plus fertilizer N. This discrepancy is due, at least in part, to yields being calculated on a 100 per cent stand basis for about one-half of the trials, which results in larger yields than actual field yields, and to hand harvesting and careful threshing of seeds, which also tends to produce larger seed yields than would be obtained from field combining where loss of heads and seeds often occurs. Additional trials must be conducted to more fully evaluate the relationship between seed yield and soil test nitrogen plus fertilizer nitrogen values.

Nitrogen fertilizers significantly reduced oil concentration at all locations. The 40, 80 and 120 pound N rates caused an average of 0.9, 1.5 and 1.8 percentage units decline in oil concentration for all trials, respectively. The decline in oil concentration for the 16 responding sites was 0.9 and 1.8 percentage units for the 40 and 80 pound nitrogen rate, respectively.

The regression equations describing response of sunflower oil concentration to applied fertilizer nitrogen for all trials and 16 responding sites are:

$$Y = 45.1 - 0.026X + 0.000094X^2 \text{ (all trials)}$$

$$Y = 46.1 - 0.028X + 0.000078X^2 \text{ (16 responding sites)}$$

where Y = per cent oil in seeds and X = rate of fertilizer nitrogen in lbs/acre.

Even though nitrogen fertilizer decreased oil concentrations, average yields of oil were not decreased by nitrogen fertilizer. Seed yield increases offset the decreased oil concentration due to nitrogen fertilizer. The 40, 80 and 120 pound N rates increased yields of oil by 114, 157 and 159 lbs oil/acre over non-treated plots for all trials and by 145, 200 and 202 pounds oil for the 16 responding sites, respectively. The 120 pound N rate did not produce a significantly greater yield of oil than the 80 pound rate.

The regression equations describing average response of sunflower oil yield to applied fertilizer nitrogen for all trials and the 16 responding sites are:

$$Y = 750 + 3.4X - 0.0175X^2 \text{ (all trials)}$$

$$Y = 787 + 4.3X - 0.022X^2 \text{ (16 responding sites)}$$

where Y = yield of oil in lbs oil/acre and X = rate of fertilizer nitrogen in pounds/acre.

CONCLUSIONS

Nitrogen fertilizer increased sunflower seed yields significantly in 70 per cent of the field experiments conducted since 1971. The average increases in yield for responding sites were 394 and 578 lbs seed per acre for 40 and 80 lbs N/acre, respectively, as either ammonium nitrate or urea. Oil concentrations for responding sites were reduced by 0.9 and 1.8 percentage units for the 40 and 80 lb nitrogen rates, respectively. However, oil yields were increased by an average of 145 and 200 lbs oil/acre for the 40 and 80 pound nitrogen rates, respectively at sites responding to nitrogen fertilizer.

Data obtained in these experiments support the hypothesis that nitrogen is a limiting factor in sunflower production on many non-fallow soils, and that soil tests measure the nitrate status.

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