Sunflower Nutrient Uptake, Growth, and Yield as Affected by Nitrogen or Manure, and Plant Population[1]

A. C. Mathers and B. A. Stewart[2]

ABSTRACT

Sunflower (*Helianthus annuus* L.) is a new crop in the Southern High Plains. It was grown on Pullman clay loam (Torrertic Paleustoll) in an experiment designed to determine the effects of N, plant population, and row spacing on growth, yield, and nutrient uptake. Fertility treatments were 0, 84, and 168 kg N/ha and residue from three annual applications of 22 and 67 metric tons of manure/ha (wet wt.). Populations of 37, 62, and 99 thousand plants/ha were grown in a bed-furrow irrigation system in two row spacings (one and two rows 30 cm apart) per bed. Beds were spaced 1 m apart. The crop was irrigated to provide adequate water. Beginning about 7 weeks after planting, samples were taken at 2-week intervals for dry matter yields and chemical analyses. Seed and oil yields were taken at maturity.

In 1975, the seed yield on the unfertilized treatment was 1,950 kg/ha, whereas all other treatments produced similar yields averaging 2,850 kg/ha. In 1976, yields were similar on the unfertilized and inorganic N treatments (avg. 2,000 kg/ha) and similar on the manure treatments (avg. 2,330 kg/ha). Lower sunflower yield in 1976 than in 1975 is attributed to higher temperatures during the seed filling period in 1976. Both N fertilizer and manure reduced oil percentage in seed. Even though statistically significant effects were found in 1975, yields were not affected to a large degree by differential row spacings and plant population treatments. Dry matter and nutrient yield curves showed that adequately fertilized sunflower produced about 10 metric tons of dry matter/ha containing 200 kg N, 35 kg P, 450 kg K, 180 kg Ca, and 45 kg Mg/ha.

The 84 kg N/ha rate supplied sufficient N for maximum sunflower yields. Apparently, manure supplied some needed element or condition not supplied by inorganic N. That factor was not identified. Plant populations from 37 to 99 thousand/ha gave satisfactory yields.

Additional index words: Oil yield, Irrigation, Manure.

SUNFLOWER (*Helianthus annuus* L.) has become a major crop in the United States in the last decade. In the last few years, sunflower has been grown on the Southern High Plains. Optimum sunflower plant populations, fertilizer requirements, and seed and oil yields vary with location, rainfall or irrigation, and hybrid. Best fertilization and cultural practices have not been established for this area.

Most researchers have found that 50 to 100 kg of N/ha are adequate for sunflower. Reporting locations, and fertilizer recommendations are as follows: Georgia, 56 kg N/ha (10); Southeast Bulgaria, 100–100–50 kg/ha N-P-K (2); Northeast Bulgaria, 90-90-90 kg/ha N-P-K (3); and North Dakota, 56 kg N/ha (17).

Recommended plant populations vary from 25,000 to 86,000 plants/ha depending on soil type, plant type and moisture conditions. Massey (10) reported highest yields from 66,700 plants/ha. Zubriski and Zimmerman (17) found that increasing plant density from 36,000 to 72,000 plants/ha increased seed and oil yield. In Minnesota, Robinson et al. (16) suggested plant populations of 37,000 to 49,000 on sandy soil, 49,000 to

[1] Contribution from USDA, ARS, in cooperation with the Texas Agric. Exp. Stn., Texas A&M Univ., College Station, TX 77843. Received 12 Jan. 1982.

[2] Soil scientist and laboratory director, USDA-ARS, USDA Conservation and Production Research Laboratory, Bushland, TX 79012.

Table 1. Sunflower seed yield and analysis as affected by plant population and fertilizers on the Southern High Plains.

	1975					1976				
	Yield					Yield				
	Seed†	Oil	Oil	N	P	Seed	Oil	Oil	N	P
	kg/ha		%			kg/ha		%		
Fertility treatments										
Check	1,950	860	48.5	2.4	0.66	1,940	800	45.5	2.5	0.69
N 84 kg/ha	2,850	1,140	43.8	3.3	0.60	2,030	770	41.9	3.3	0.62
N 168 kg/ha	2,760	1,080	42.9	3.5	0.59	2,020	760	41.2	3.5	0.60
22 t/ha‡	2,800	1,100	42.9	3.4	0.77	2,310	860	41.0	3.4	0.78
67 t/ha	2,980	1,140	42.1	3.8	0.90	2,350	830	38.9	3.8	0.86
L.S.D.	285	132	1.0	0.14	0.055	177	70	1.04	0.13	0.047
Plants, thousand/ha										
37	2,610	1,030	43.4	3.3	0.72	2,270	850	41.2	3.4	0.74
62	2,770	1,100	43.8	3.2	0.69	2,140	810	42.0	3.2	0.69
99	2,630	1,060	44.1	3.2	0.70	1,990	750	41.4	3.3	0.69
L.S.D.	87	41	0.5	0.07	0.019	92	34	0.44	0.10	0.022
Row spacing§										
1	2,660	1,060	43.5	3.3	0.71	2,220	830	41.0	3.4	0.74
2	2,670	1,070	44.0	3.2	0.69	2,040	780	42.1	3.2	0.68
L.S.D.	180	75	0.30	0.05	0.032	96	37	0.54	0.11	0.041

† Seed yield at 9% water content.
‡ Residual manure treatments.
§ One or two rows (30 cm apart) on beds spaced 1 m apart.

62,000 on silt loam or clay soil and 62,000 to 86,000 plants/ha on fields where seed yields are expected to exceed 3,000 kg/ha. Variation in row width from 56 to 97 cm was not important. In North Dakota, Alessi et al. (1) found that sunflower seed and oil yields were usually higher from 25,000 plants/ha than from higher populations. Production was generally higher with 30-cm row spacing than with 90-cm row spacing. In Italy, Pacucci and Martignano (13) reported that sunflower seed and oil yields were not affected as much by plant density in tall as in short varieties. They suggested plant densities of 42,000 plants/ha in 60 or 80-cm rows for tall varieties and 82,000 plants/ha in 60-cm rows for short varieties.

Several authors have reported that chemical composition of sunflower varies with planting date, fertilizer, available water, and temperature. Scientists have found that N fertilizer reduces oil percentage of sunflower seed (2, 17). Alessi et al. (1) showed that 80% of the total variation in oil concentration was accounted for by variation in water use and temperature. In Minnesota, sunflower oil percentages were highest from early May plantings (15). Near Tambov, USSR, Makarov and Frolova (9) showed that application of N, P, and K increased the percent and uptake of these elements in sunflower plants. Applications of P gave the highest increase in seed yield. Gachon (4) in field experiments in France, found that most of the nutrients in sunflower were absorbed during the month before and the month after the beginning of flowering. The N and Ca requirements of 'Peredovik' sunflower were similar to corn but the P and K requirements were lower than corn. Robinson et al. (16) showed that concentrations of elements in sunflower leaves and stems decreased with plant age.

The objective of this experiment was to determine the effect of N, plant population, and row spacing on nutrient uptake, growth, and yield of sunflower on the Southern High Plains.

MATERIALS AND METHODS

The experiment was conducted on Pullman clay loam (fine mixed thermic Torrertic Paleustoll) at the USDA Conservation and Production Research Laboratory, Bushland, Tex. The soil had about 1% slope. During the 3 years before this study grain sorghum, fertilized with various rates of feedlot manure, was grown on this site (12).

In this experiment, sunflower ('Hybrid 896') was grown in a randomized block split plot design with three replications, five fertility treatments, three plant populations, and two row spacings. Fertility treatments consisted of N rates of 0, 84, and 168 kg N/ha applied as ammonium nitrate and disked in, and residue from three annual applications of 22 and 67 metric tons of manure/ha. Plant populations were 37, 62, and 99 thousand/ha. Row spacings were single and double rows (30 cm apart) on beds spaced 1 m apart. The N rate treatments were placed on plots that were not fertilized in the previous experiment.

The sunflower crop was planted on 16 May 1975 and 2 June 1976 in a 1-m spaced furrow-bed system. Plant populations were established by hand-thinning when the plants were 8 to 12 cm high. The crop was irrigated in a graded furrow system to provide adequate soil water to prevent severe water stress (severe wilting).

Plant samples were taken every 2 weeks, beginning about 7 weeks after planting and ending at observed, physiologic maturity. Samples were taken from 1 m^2 on three replications of the check, 84 kg N/ha, 168 kg N/ha, and 22 and 67 metric tons/ha residual manure treatments on the 62,000 plants/ha plots. These samples were divided into leaves, stems and heads and dried at 65 C to determine dry matter yields. Samples were ground to pass a 1-mm screen and were analyzed for N, P, K, Ca, and Mg. Total N was determined by the Kjeldahl method (7). A nitric, perchloric, and sulfuric acid digest was used for K, Ca, Mg, and P. Potassium, Ca, and Mg were determined by atomic absorption spectrophotometry (6) and P by the amino-naphtholsulfonic acid method on the Auto Analyzer (Technicon Auto Analyzer methodology 1968, Industrial Method INDL-8 Technicon Corporation. Tarrytown, NY 10591).

Samples were taken on 3 Sept. 1975 and 20 Sept. 1976 from 9.3 m^2 to determine seed yield. Oil percentage in the

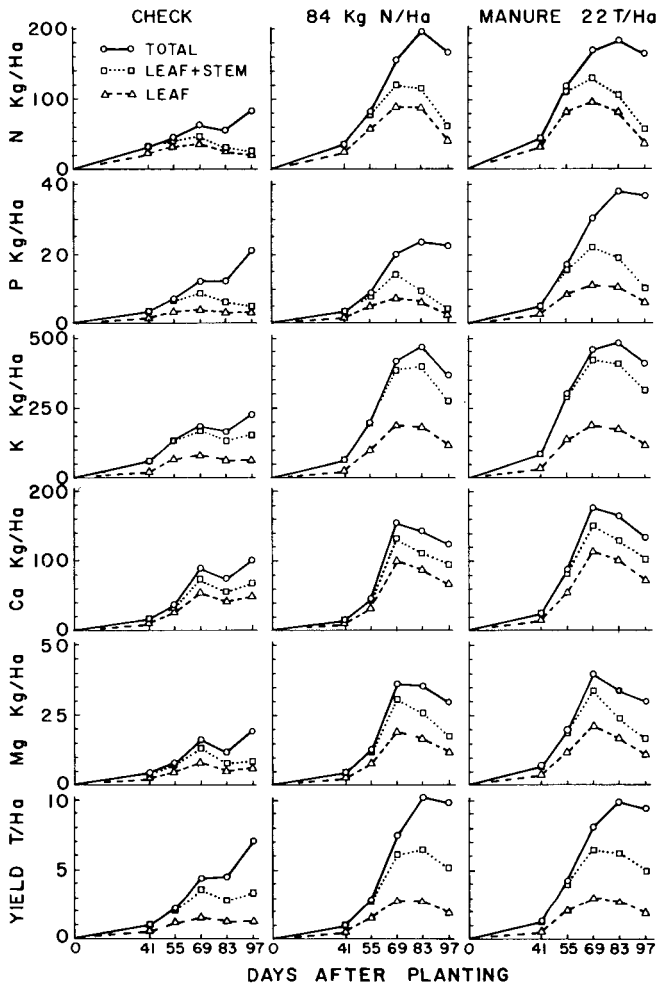

Fig. 1. Dry matter yield and uptake of N, P, K, Ca, and Mg by sunflower as affected by fertilizer treatments in 1975.

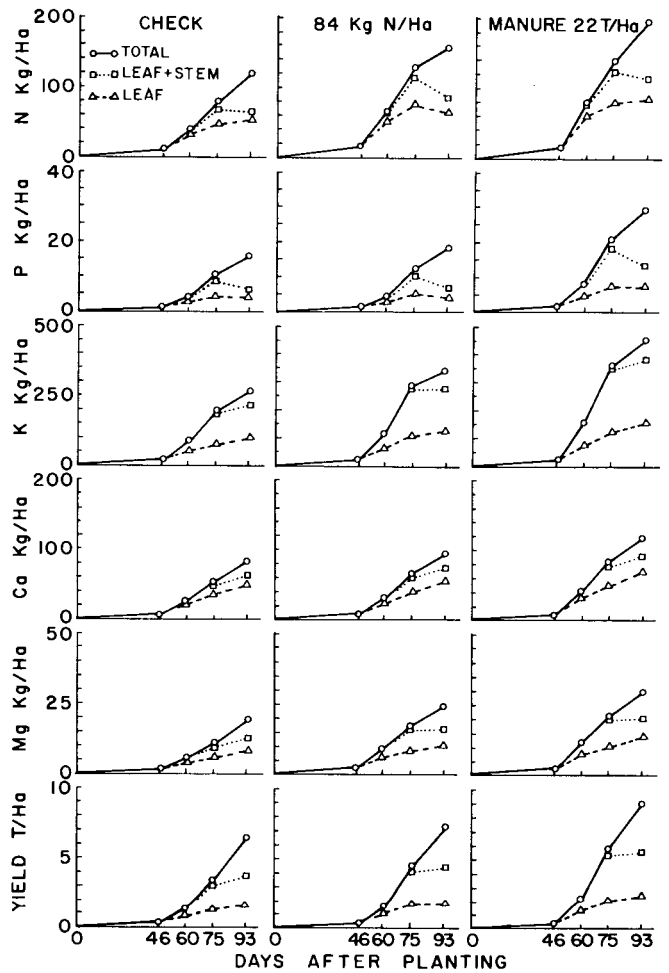

Fig. 2. Dry matter yield and uptake of N, P, K, Ca, and Mg by sunflower as affected by fertilizer treatments in 1976.

seed was determined by nuclear magnetic resonance (5). Nitrogen, P, and K in the seed were determined by the method described above for plant samples.

RESULTS AND DISCUSSION

Yield and Quality of Seeds

Fertilizer Effects

In 1975, sunflower responded to applied N on soil on which unfertilized irrigated grain sorghum had been grown for the previous 3 years (Table 1). The 84-kg/ha N rate was sufficient to produce yields equivalent to those produced by the 168 kg/ha N rate and to those produced on plots previously fertilized with feedlot manure. In 1976, on the same plots, sunflower did not respond to applied N; however, yields on the previously manured plots were higher than those on unmanured plots. Conditions that may have contributed to reduced N response are: 1) Yield levels were lower in 1976 than in 1975, thus less N was required for attained yields; 2) In 1975, the previous crop was grain sorghum, and in 1976, it was sunflower. Sunflower residues may have been more completely decomposed, releasing more available N for the 1976 crop. Comparison of Fig. 1 and 2 shows that N uptake on the unfertilized treatment was considerably greater in 1976 than in 1975. The higher yields on the previously manured plots and the absence of a response to applied N indicate that some element, other than N, may have been limiting. Uptake of all elements was greater on the manured than on the unmanured plots; however, there was a greater difference in P uptake than in uptake of other elements. In addition, P concentrations were higher on manured than on unmanured plots (data not shown). These indications point to a possible response to P, but other field crops have not responded to P on Pullman soil (8, 11, 14) and it is well known that "luxury consumption" of P occurs when adequate supplies are available. Thus, a P deficiency is not likely. It is possible that the differential response to manure in the 2 years resulted from interactions with planting dates or with climatic conditions which differed in the 2 years.

Lower yield levels in 1976 than in 1975 may be attributed to the higher maximum daily temperatures and higher than average wind velocity during the seed filling period. In 1975, the maximum daily temperatures were below average but in 1976 the maximum daily temperatures were above average much of the

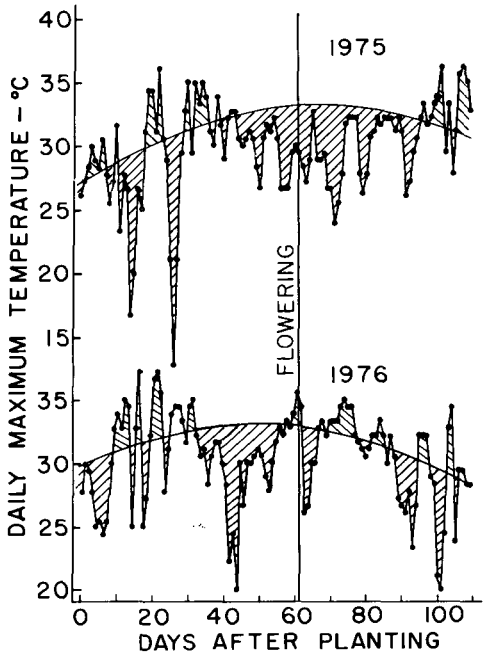

Fig. 3. Maximum daily temperature at Bushland, Texas during the sunflower growing period in 1975 and 1976. Curved lines indicate a 38-year average.

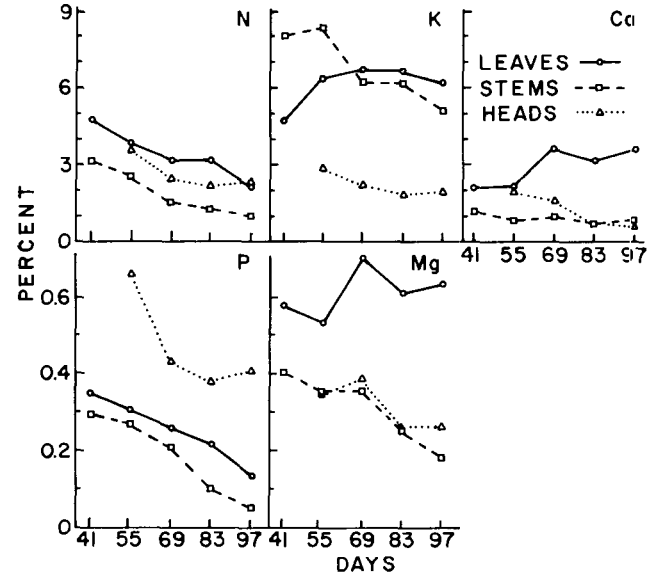

Fig. 4. Concentration of N, P, K, Ca, and Mg in leaves, stems, and heads of sunflower on plots fertilized with 84 kg N/ha in 1975.

period (Fig. 3). Frequent showers in July 1975, totaling 113 mm, kept the temperature down. June, July, and August winds were much above normal in 1976. Therefore, hot dry winds contributed to plant water stress even though the crop received four seasonal irrigations totaling 510 mm.

Oil, N, and P concentrations are shown in Table 1. Oil concentrations in seeds were higher on the unfertilized plots than on those fertilized with N or manure. The first increment of N reduced percent oil more than the second. Concentrations in seeds grown on the residual manure plots were generally similar to those in seeds grown on the 168-kg/ha N plots.

Nitrogen concentrations in seeds increased as N rates increased. The largest increase occurred between the 0 and 84-kg/ha N treatments. Seed N concentrations on the residual manure plots were generally similar to those on the 168-kg/ha N treatment.

Seed P concentrations decreased with increasing rates of inorganic N application and were higher on manured than on unmanured plots. First increments of N caused larger decreases than second increments.

Plant Population and Row Spacing Effects

Effects of plant population and row spacing are shown in Table 1. In 1975, 62,000 plants/ha produced the highest yields, whereas in 1976, 37,000 plants/ha produced the highest yields. Yields from 99,000 plants/ha plots were intermediate in 1975 and lowest in 1976. Head size increased when stand decreased so a small change in stand had little effect on yield. Good yields of sunflower seed and oil were produced with 37,000 and 62,000 plants/ha when plants were fully irrigated in 1-m rows. Row spacing did not have a significant effect on yield.

Although some statistically significant differences in seed yield, oil, N, and P concentrations in seeds resulted from differences in plant populations and row spacings, actual differences were small and of little consequence.

Growth and Nutrient Uptake

Growth and nutrient uptake curves for sunflower grown on unfertilized, N fertilized (84 kg N/ha), and manure fertilized (22 T/ha) soil are shown in Fig. 1 and 2. Growth was slow during the first 6 weeks and very rapid during the 4 weeks preceding physiological maturity. Variations in sampling dates between the 2 years make direct comparisons difficult; however, it appears that maximum growth on the fertilized treatments was attained earlier in 1975 than in 1976.

In 1975, leaf and stem weights decreased and head weights increased as the crop approached maturity. The shift in dry weight is attributed to translocation into the heads, senescence, and loss of lower leaves. The increase in dry weight of leaves and stems was not observed in 1976. Differences in planting dates and sampling schedules may be partially responsible for the differences between years, but the greatest factor probably was the high temperature and high wind velocity in July and August 1976.

In 1975, N fertilizer increased growth rate and dry matter production. The response to the residual manure treatment was similar to that from the N treatment. In 1976, the N treatment increased growth and total dry matter production but to a lesser extent than in 1975, whereas the residual manure treatment produced more total growth than the N treatment.

The uptake of N, P, K, Ca, and Mg is shown in Fig. 1 and 2 and concentration for the 84 kg/ha N treatment is shown in Fig. 4. This N treatment represents the concentration data quite well, except the concentration of N in plants was lower on unfertilized plots and the concentration of P was increased by manure. There was little difference in concentration of the other elements between treatments. Uptake of these elements increased as growth increased; how-

ever, the concentration of N, P, and K decreased. Concentration of Ca increased slightly in the leaves, decreased in the heads, and remained about the same in the stems. Magnesium concentration decreased in the heads and stems but did not change appreciably in the leaves. In 1976, yields and the uptake of elements were lower than in 1975. On fertilized plots total N uptake was directly proportional to dry matter production throughout the growth period. Nitrogen accumulation in leaves and stems increased until seed filling and then decreased as it was translocated into heads. At physiological maturity, heads contained about 40% of the 200 kg/ha of N found in plant tops. On check plots, N uptake increased with dry matter production but N concentration in the plant tissue declined.

On the manure-treated plots, P uptake followed trends similar to those of N uptake and dry matter production. Translocation into heads also followed patterns similar to those of N. At maturity, heads contained about 60% of the 35 kg/ha of P found in plant tops. On check and N fertilized plots, P uptake continued throughout the growing period but it was not directly proportional to dry matter production. As dry matter increased, P concentration in the plant tissue decreased. At maturity, plants on these plots had accumulated about 20 kg of P/ha, and about 70% of that P was contained in the heads.

Potassium uptake followed the same trends as that of N until the stems reached maximum weight (70 to 75 days after planting) and then slowed somewhat. However, some K uptake occurred until the plants reached maturity. The curves indicate that there was no translocation from leaves and stems to heads in 1976 and very little, if any, in 1975. Sunflower growing on the N- and manure-treated plots in 1975 and on the N-treated plots in 1976 accumulated about 450 kg of K in aboveground plant material. Uptake was lower on the N-treated plots in 1976 and on check plots in both years. The concentration of K decreased in the stems and heads but increased slightly in the leaves during the season. Except on the check plot in 1976, at maturity, 16, 42, and 44% of the K accumulated aboveground was in the heads, leaves, and stems, respectively.

In 1975, on the N and manure-treated plots, Ca uptake followed the same trends as that of K except that 69 days after planting, Ca uptake apparently ceased; then there was a net loss of Ca from the plant, presumably due to loss of Ca from leaves or loss of leaves. Amounts of Ca in stems and heads did not change after 69 days. On the check treatment in 1975 and on all three treatments in 1976, Ca uptake was not proportional to N and K uptake. As the growth period progressed, Ca concentration in the head decreased, increased slightly in the leaves, and remained about the same in the stems. Leaf Ca accounted for most of the Ca taken up late in the season. Calcium uptake ranged from about 80 kg/ha on check plots in 1975 and to 180 kg/ha on manure-fertilized plots in 1976. About 13, 17, and 70% of the Ca was in heads, stems, and leaves respectively. In 1975, Mg uptake on the N and manure-treated plots followed the same trends as Ca, K, and N uptake on those plots. During the first 69 days, Mg was taken up, and then a decrease occurred as the plants approached maturity. Leaf Mg decreased during the last 28 days, reflecting translocation into the heads or loss of leaves. At maturity, heads, stems, and leaves contained 36, 22, and 42% of the accumulated Mg, respectively. In 1976, Mg uptake was less rapid than in 1975. The curves resembled those of Ca and P. There is no apparent reason for the difference in Mg uptake curves between the two seasons.

The uptake of elements by sunflower is quite high. Fertilizer recommendations are much lower than the elements taken up in the crop. Where 84 kg N/ha was applied, 200 kg N/ha was measured in the plants. Because these plots had been cropped to grain sorghum for 3 years before the sunflower experiment, it appears that sunflower rooted deeper than sorghum and obtained N that had moved below the normal rooting zone of sorghum. These data agree with Makarov and Frolova (9) that N requirements of sunflower and corn are about the same. Sunflower roots penetrate deeper than many crops, however, and may obtain N that has moved below the normal rooting zone.

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