Irrigation And Nitrogen For Sunflower and Fieldbean On Sandy Soil

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IRRIGATION AND NITROGEN FOR SUNFLOWER AND FIELDBEAN ON SANDY SOIL

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Minnesota has about 8 million acres of sandy soil, and about 1 million acres have potential for irrigation[2]. Irrigated land amounted to over 500,000 acres in 1985. Irrigation research on sunflower and fieldbean was conducted at Elk River and Becker in Minnesota's central sand plain. The soil textures were coarse sands, loamy coarse sands, loamy sands, and sandy loams. These soils can store about 1 inch of water available to crops in the surface 12 inches and not quite 2 inches in the top 30 inches of soil. In dry weather, water is removed from these soils by evaporation and transpiration. Average evapotranspiration is equal to about 40 percent of the evaporation from an exposed pan of water in the spring and to about 80 percent of evaporation from an exposed water surface in midsummer. Consequently, soils dry rapidly, and water must be added every 2 to 7 days in drought periods to avoid crop stress.

Frequent irrigation and coarse textured soil results in leaching of soluble materials like nitrate nitrogen. This may lead to nitrogen (N) deficiency in the crop even though adequate amounts of N were present at planting time.

Previous research showed that irrigation increased yields of fieldbean and sunflower in 5 of 6 years and that highest yields were obtained with both irrigation and N fertilization.[3] However, in trials where irrigation increased yield, fieldbean seed from irrigated plots was low in protein.

Ground water depletion has not been a frequent problem in Minnesota's central sand plain, so ample amounts of water are applied to irrigated crops. However, water pumping costs have increased, and unneeded water should not be pumped. Consequently, losses from less than adequate amounts of water should be determined.

Four major objectives of this research were to: 1) determine if irrigation during various growth periods of sunflower and fieldbean could replace full-season irrigation; 2) measure the effect of irrigation and nitrogen on oil and protein concentrations in sunflower seed; 3) compare organic and inorganic sources of N in maintaining acceptable levels of protein in fieldbean seed; and 4) measure effects of reducing sunflower plant population at heading and of removing lower sunflower leaves after anthesis.

EXPERIMENTAL DETAILS

Sunflower and fieldbean were planted in cultivated rows 30 inches apart, and herbicides and hand weeding kept plots weed free. Experimental designs were randomized complete blocks using splitplot and split-splitplot layouts. Data for treatments not included in all trials averaged within a table were adjusted so that averages within a table are comparable. Yield, protein, and oil data in the tables were converted to a 10 percent moisture basis.

Irrigation which supplemented rainfall was accomplished with full- and half-circle overhead sprinklers set in pipe surrounding each irrigated plot. Alleyways and splash boards kept water off the dryland plots which received rainfall. Irrigation water was applied 0.5 to 1 inch per irrigation. Rainfall in June, July, and August ranged from 6 to 14 inches each year. Evaporation and rainfall data were obtained from an official weather station within 0.25 miles of the plots. Irrigation water was applied during various growth periods prior to crop maturity. Sunflower maturity is when the color of the backs of the heads becomes banana yellow regardless of whether or not leaves remain green.[4] UI-114 pinto fieldbean has a viny, indeterminate growth habit, but seeds are mature when red or brown stripes appear on the fading green pods.

The soil in Elk River trials is underlined with coarse gravel about 14 inches below the surface, and roots did not penetrate into the gravel. Tensiometer tubes were placed about 12 inches deep on the dryland check and full-season irrigation treatments. A tensiometer tube is placed vertically in the soil with the top at the surface. The tube is closed at the bottom with a ceramic tip and closed at the top with a

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[2]Bergsrud, F. G. 1976. Potential irrigated acreage. In The potential for irrigated crop production. Minnesota Agric. Exp. Sta. Misc. Rep. 138:18.

[3]Robinson, R. G. 1976. Dry edible beans or fieldbeans and sunflower. In The potential for irrigated crop production. Minnesota Agric. Exp. Sta. Misc. Rep. 138:26-34.

[4]Robinson, R. G. 1983. Maturation of sunflower and sector sampling of heads to monitor maturation. Field Crops Research 7:31-39.

dial graduated in centibars. The tube is filled with water which in dry soil passes through the ceramic tip into the soil. The water loss creates a vacuum in the tube causing the needle on the dial to show more centibars. After rainfall or irrigation, water moves back through the ceramic tip into the tube, and the centibar reading declines. A 10-centibar reading is field capacity (ideal moisture for crop roots) on sandy soil and an 80-centibar reading indicates that very little water available to crops remains in the soil. Readings of 55 to 60 centibars indicate that about 50 percent of the moisture available at field capacity is gone. Irrigators often start irrigating when sandy soil is about 50 percent of field capacity.

Varieties planted were Sputnik sunflower and UI-114 pinto fieldbean at Elk River and USDA 894 sunflower, UI-114 pinto fieldbean, and Seafarer navy fieldbean at Becker. Clay or Evans soybean with and without N fertilization was included in the fieldbean trials for crop comparisons. Sunflower plant populations were 25,000 plants per acre except on dryland plots in 1977 and 1978 where populations were 15,000 plants per acre. Fieldbean and soybean were planted at rates of 100,000 and 157,000 seeds per acre, respectively.

Soil phosphorous levels were very high and potassium levels were medium-high in all trials. Fieldbean was not inoculated except for the inoculated treatment where a commercial (Nitragin) soil injection type rather than a moist seed treatment was used.

The compost was of good physical quality (brown, no disagreeable odor, and an easily pulverized structure) and originated from livestock manure that had been stored for at least 1 year. Rate applied was 10 tons (2.5 to 4.5 tons dry matter) per acre and contained 75 to 150 pounds of N.

Ammonium nitrate, inorganic form of N fertilizer, was applied at 300 pounds per acre at planting time on all treatments in the trials at Elk River. Split applications of ammonium nitrate varying with treatment were used at Becker: 100 pounds per acre at planting plus 200 pounds per acre in mid-June for the 100 pounds of N per acre treatments. Additional applications at approximately 10 day intervals for the high N treatments amounted to a total of 250 to 300 pounds of N per acre.

RESULTS AND DISCUSSION

Restricted and Full-Season Irrigation of Sunflower.

Most sunflower is grown without irrigation, but it is a potential alternative to corn, soybean, fieldbean, and potato which occupy nearly 90 percent of Minnesota's irrigated cropland. Prior to initiation of heading, sunflower rarely shows stress from drought because its densely branched tap root efficiently extracts water from the soil. Sunflower leaves often remain turgid in June when corn leaves in adjacent plots roll and wilt. However, after heading, sunflower leaves readily wilt in dry weather. Consequently, full-season sunflower irrigation in Minnesota is generally confined to the 0.5 inch head to maturity period of about 2 months.

The full-season irrigation treatment at Elk River was irrigated whenever the soil tensiometer readings exceeded 50 centibars and required 16.5 inches of water (Table 1). When irrigation was limited to the 2-inch heads through pollination period (20 to 26 days), irrigation amounted to only 5 inches of water. Yields did not differ significantly among these growth periods in 1974. But restricting irrigation to the small head through pollination period in 1975 resulted in much lower yields than those on plots irrigated to maturity. Dif-

Table 1. Response of sunflower at Elk River to irrigation at various stages of growth, 1974-75

Irrigation interval	Water (inches)	Yield/acre (pounds) 1974	1975	1974-75	Oil (percent)	Protein (percent)[1]	Test weight/ bushel (pounds)	Weight/ 100 seeds (grams)	Height (inches)	Lodging (percent)
No irrigation	0.0	696	81	388	44.3	24.2	35.6	4.8	54	23
2-inch heads through pollination	5.0	2343	576	1459	44.1	18.1	30.9	6.3	74	4
1.5-inch heads through pollination	6.0	2288	862	1575	42.8	18.1	30.8	6.0	76	3
Full head to maturity	7.0	--	1920	--	48.8	14.0	33.7	6.1	64	15
2-inch heads to maturity	8.5	2668	2028	2348	48.0	15.1	32.9	6.2	72	14
1.5-inch heads to maturity	9.5	2593	2179	2386	48.3	14.3	32.6	6.2	77	10
0.5-inch heads to maturity	16.5	--	2634	--	49.4	12.9	33.5	6.6	77	0
LSD 5%		505	866	501	1.4	1.7	0.8	0.5	7	8

[1] 1975.

ferences in yield among the heading to maturity treatments were not statistically significant. However in 1975, the 0.5-inch heads to maturity treatment averaged 455 to 714 pounds per acre more than the other heading to maturity treatments at an additional cost of 7.0 to 9.5 inches of water.

Although percentage yield increases from irrigation over dryland were much greater in 1975, total rainfall during June, July, and August amounted to 10.9 inches in 1974 and 15.13 inches in 1975. However, distribution of rainfall was more uniform in 1974 as indicated by 1.94 inches in July 1974 compared with only 0.72 inches in July, 1975. The cumulative excess of evaporation over rainfall since planting was higher in June and July but lower in August, 1974 than in 1975, and this is associated with the lesser total summer but greater July rainfall in 1974 (Figure 1). Tensiometer readings on the dryland plots show that moisture stress was greater from July 6 to August 22 in 1975 than in 1974 (Figure 1). These weather, soil tensiometer, and yield data indicate that rainfall distribution is more important than total summer rainfall in determining irrigation needs of sunflower on sandy soil.

Irrigation had consistent and important effects on seed composition and quality (Table 1). Increasing amounts of irrigation water increased oil percentage and decreased protein percentage of sunflower seed. Termination of irrigation at the end of pollination instead of at maturity resulted in significantly lower oil percentages both years. Although increasing amounts of irrigation water increased test weight per bushel, dryland sunflower had the highest test weight and lowest weight per 100 seeds.

Irrigation increased plant height. The increase was manifested solely by internode elongation during July and August, because irrigation was started after heading when it was too late to affect numbers of nodes and internodes. Lodging is the major noticeable effect of extreme drought stress on sunflower prior to bloom. Some stalks break from 4 to 24 inches above the soil at heading time. This is the sunflower crop's way of reducing an excess population and accounts for the significantly

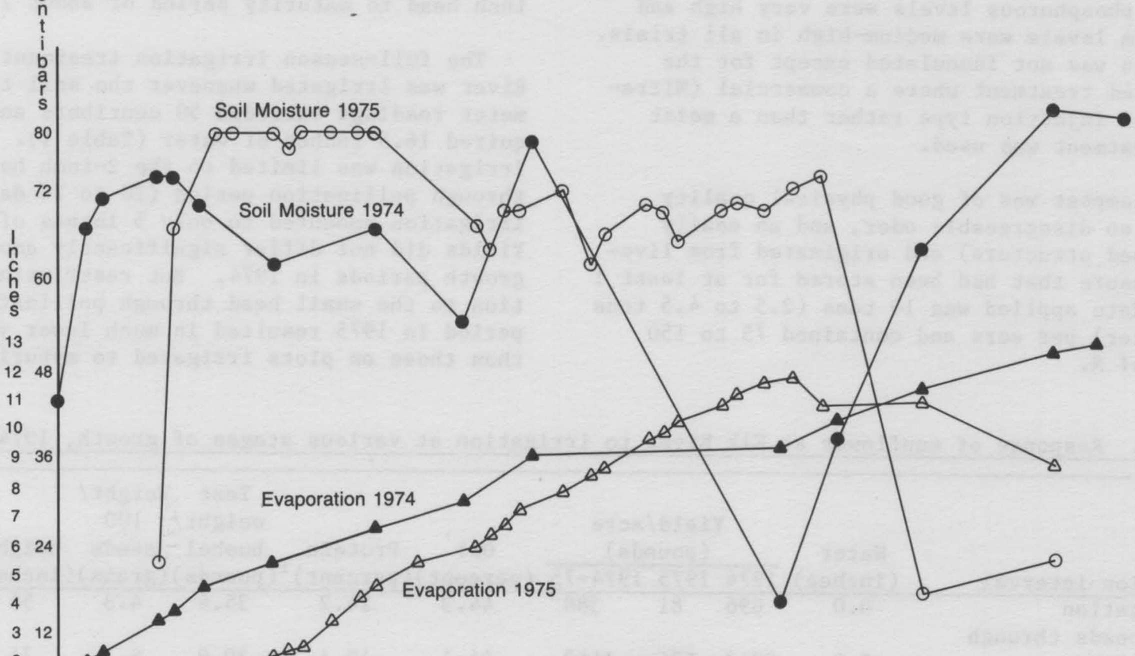

Figure 1. Soil tensiometer readings (centibars) under dryland sunflower and cumulative excess (inches) of evaporation over rainfall since planting at Elk River in 1974 and 1975.

greater lodging in dryland plots (Table 1). The no moisture-stress treatment (16.5 inches of water) had no lodging compared to the dryland check with 23 percent broken stalks. Drought did not increase lodging after pollination when stalks were maturing, but continued irrigation of previously stressed stalks tended to increase lodging.

Restricted and Full-Season Irrigation of Fieldbean

Fieldbean had the same irrigation schedule as sunflower since both crops were planted in the same plot areas. Irrigation greatly increased fieldbean yield both years (Table 2). About 9 inches of water between full bloom and maturity gave maximum yields. Stopping irrigation when stripes appeared on a few pods did not significantly reduce yield in 1974 or on the average and saved over 3 inches of water. The usual management decision from these data, however, would be to supply an inch of water up to three more times in order to gain another 300 to 500 pounds of seed per acre.

All irrigation treatments reduced protein percentages of fieldbean seed to less than the 22 percent value that is used by many nutritionists in formulating diets.[5]

Irrigation and Nitrogen Effects on Seed Yield and Quality.

Irrigation of sunflower and fieldbean on sandy soil resulted in decreased protein concentrations in the seed. Use of compost rather than inorganic N fertilizer and inoculation of legumes with rhizobia are important practices of organic farming. It is often claimed that crops fertilized organically have better nutritive value than those fertilized with inorganic fertilizer. In trials at Becker from 1976 through 1978, effects of organic, inorganic, and excessive rates of N on protein levels and yields of sunflower and fieldbean were compared in irrigated and dryland environments.

SUNFLOWER

Irrigation increased yield, oil percentage, and test weight but decreased protein percentage of sunflower seed harvested from all treatments in Table 3. Yields from untreated, compost, and N treatments did not differ on dryland, but with irrigation, yields from compost and/or N treatments greatly exceeded those from untreated plots. Inorganic N treatments gave significantly higher yields than those from compost alone. N treatments and the compost plus N treatment produced seed that was lower in oil but higher in protein than seed from untreated plots. The compost plus N treatment produced seed of lowest oil percentage but of highest protein and test weight among irrigated treatments. The 100-pound N treatment was the most profitable treatment for irrigated sunflower considering yield, seed composition, seed quality, and treatment cost. Neither N nor compost affected yield of dryland sunflower because water not N was the limiting factor. However low rates of N provide reasonable insurance against yield-limiting N shortages in years of good rainfall distribution on these sandy soils; 20 to 60 pounds per acre are suggested.[6]

FIELDBEAN

Irrigation increased yields but decreased protein percentages of fieldbean seed (Table 4). Treatments did not affect yield on dryland because water not nitrogen was the limiting factor. With irrigation, the compost plus N treatment gave highest yields followed by the high inorganic N treatment. The compost and 100-pound N treatments were almost identical in

Table 2. Response of fieldbean at Elk River to irrigation at various stages of growth, 1974-75

Irrigation interval	Water (inches)	Yield/acre (pounds) 1974	1975	1974-75	Protein (percent) 1974	1975	1974-75
No irrigation	0.0	529	444	486	25.6	29.3	27.4
Full bloom to few striped pods	5.0	2519	1921	2220	20.8	21.3	21.1
Full bloom to few striped pods	6.0	2772	2133	2452	20.5	22.4	21.4
Podding to maturity	7.0	--	1827	--	--	21.0	--
Full bloom to maturity	8.5	3016	2405	2710	20.5	21.3	20.9
Full bloom to maturity	9.5	2834	2422	2628	20.9	21.6	21.3
Full bloom to maturity	16.5	--	2287	--	--	20.8	--
LSD 5%		977	429	533	1.1	2.1	1.2

[5]Watt, B. K. and A. L. Merrill. 1963. Composition of foods. USDA Handbook 8. U.S. Government Printing Office, Washington, D.C.

[6]Robinson, R. G. 1976. Sunflower. In The potential for irrigated crop production. Minnesota Agric. Exp. Sta. Misc. Rep. 138:31-34.

Table 3. Response of sunflower to irrigation, compost, and inorganic nitrogen fertilizer on sandy soil at Becker, 1977-78

Treatment	N/acre (pounds)	Yield/acre (pounds) dryland	Yield/acre (pounds) irrigated	Oil (percent) dryland	Oil (percent) irrigated	Protein (percent) dryland	Protein (percent) irrigated	Test weight/ bushel (pounds) dryland	Test weight/ bushel (pounds) irrigated
Untreated	0	1469	2138	43.2	45.4	14.2	12.8	31.7	34.7
Compost	0	1544	3043	42.1	45.6	15.5	13.2	32.9	34.8
Compost[1]	300	1549	3410	42.0	43.4	16.9	16.3	34.4	35.8
Nitrogen	300	1476	3571	39.6	44.7	18.4	14.4	32.7	33.7
Nitrogen	100	1413	3403	41.5	44.6	18.5	13.3	30.8	33.4
Alternate plants removed[2]	100	1619	3118	39.3	44.4	15.7	13.6	30.4	35.1
Alternate rows removed[3]	100	1662	3083	39.7	45.7	15.5	12.8	29.2	34.8
Lower leaves excised[4]	100	1295	2175	44.1	45.9	14.2	12.5	28.6	29.2
LSD 5%		296	296	1.8	1.8	1.8	1.8	1.3	1.3

[1]1977 data adjusted to be comparable with 2-year data. [2]Planted at double rate in rows 30-inches apart and alternate plants removed July 5, 1978, when head diameter averaged 1-inch. [3]Planted at double rate in rows 15-inches apart and alternate rows destroyed July 5, 1978, when head diameter averaged 1-inch. [4]All but the upper seven leaves excised August 1, 1978, when anthesis was completed.

Table 4. Response of fieldbean to irrigation, rhizobia, compost, and inorganic nitrogen fertilizer on sandy soil at Becker, 1976-78

Treatment	N/acre (pounds)	Yield/acre (pounds) dryland	Yield/acre (pounds) irrigated	Protein (percent) dryland	Protein (percent) irrigated
Untreated	0	970	1838	24.4	20.0
Rhizobia	0	910	2074	25.1	20.6
Compost[1]	0	1134	2258	24.8	20.1
Compost	250	1119	3005	27.7	21.6
Nitrogen	250	1088	2661	28.2	22.4
Nitrogen[1]	100	1080	2255	25.9	20.3
LSD 5%		289	289	1.1	1.1

[1]2-year data adjusted to be comparable with 3-year data.

Table 5. Response of soybean to irrigation and inorganic nitrogen fertilizer on sandy soil at Elk River and Becker, 1972-77

Treatment	N/acre (pounds)	Yield/acre (pounds) dryland	Yield/acre (pounds) irrigated	Protein (percent) dryland	Protein (percent) irrigated
Untreated	0	1186	2407	35.3	35.3
Nitrogen	66-100	1198	2524	36.3	35.0

fieldbean yields and protein percentages, while the rhizobia treatment was slightly lower in yield. None of the irrigated treatments except the compost plus N and high N treatments produced fieldbean seed that met the arbitrary minimum of 22 percent protein.

Although soybean and fieldbean are both large-seeded annual legume crops, their response to irrigation and N fertilizer was vastly different in these trials. Soybean yields were not increased significantly by N fertilizer, and seed protein percentages were not reduced by irrigation (Table 5).

Stand Reduction and Leaf Removal Effects on Sunflower Yield

The two stand reduction treatments reported in Table 3 were experimental techniques to conserve water and increase yields of dryland sunflower. High plant populations and/or closely spaced rows intercept more sunlight than do low populations and/or widely spaced rows which allow more sunlight to reach the soil (Figure 2). Consequently, water loss from transpiration is higher and from evaporation lower for high-population, narrow-row than from low-population, wide-row environments. Since sunflower is

Figure 2. Soil is shaded sooner under high than under low plant population densities and sooner under rows 15 inches apart (left) than under rows 30 inches apart (right).

drought tolerant until heading, plant populations were doubled (50,000 irrigated and 30,000 dryland) in both 30-inch and 15-inch row spacings to reduce water loss from evaporation. Populations were reduced to normal levels at the 1-inch head diameter stage by cutting alternate plants in 30-inch rows and by cutting alternate rows in 15-inch row spacings. Compared with the check treatment, 100 pounds per acre of N, these cutting treatments reduced yields of irrigated sunflower by about 300 pounds per acre but increased yields of dryland sunflower by over 200 pounds per acre. Although the yield increases were not statistically significant, they were expected from the research hypothesis so more research is warranted.

After anthesis, when sunflower heads and leaves reach maximum size, most of the lower leaves on healthy plants remain green. These lower leaves are shaded, and might increase, decrease, or not affect seed yield. The last treatment in Table 3 involved removal of all leaves but the upper seven about a month before seed maturity (Figure 3). Compared with the check treatment of 100 pounds per acre of N, leaf removal reduced seed yield, protein percentage, and test weight of both dryland and irrigated sunflower. These reductions indicated that the lower leaves were either still contributing to seed production after anthesis or that their removal reduced yield by damaging the plant.

SUMMARY

Irrigation is needed to obtain high yields of sunflower and fieldbean on sandy soil, but irrigation frequency and total water needed vary each year depending on rainfall distribution during June, July, and August. Although yield increases from nitrogen (N) on dryland sand may be small because lack of water limits yield, large increases from N may be expected on irrigated sand.

Figure 3. A dryland sunflower plot after the lower leaves were removed.

Sunflower is relatively drought-tolerant until heading. Extreme drought stress during heading results in stalk breakage and reduced plant population. Irrigation from heading through pollination is most important but later irrigation is also needed most years. Soil tensiometer data indicated that after sunflower heading, moisture loss is so rapid in periods of extreme drought that irrigation as frequently as every other day is needed to completely avoid stress. However, complete avoidance of drought stress is neither practical nor necessary.

Irrigation of sunflower increased seed yield, seed oil percentage, and test weight per bushel but decreased seed protein percentage. Yield increases from inorganic N at 100 pounds per acre exceeded those from 10 tons of compost per acre; higher rates of N gave no additional benefit. N tended to reduce oil and increase protein percentages of sunflower seed. Removal of the lower shaded leaves of sunflower plants after anthesis reduced yield of both irrigated and dryland sunflower. The hypothesis of using excess plant population to reduce evaporation prior to heading needs more research.

Irrigation of fieldbean increased seed yield but decreased protein to levels below 22 percent. Either N at 100 pounds per acre or compost at 10 tons per acre significantly increased yields of irrigated fieldbean but did not significantly increase protein percentage. N at 250 pounds per acre with or without compost increased protein of irrigated fieldbean to 22 percent and increased yields over those from 100 pounds of N. Rhizobia applied at planting time did not significantly increase yield or protein percentage.