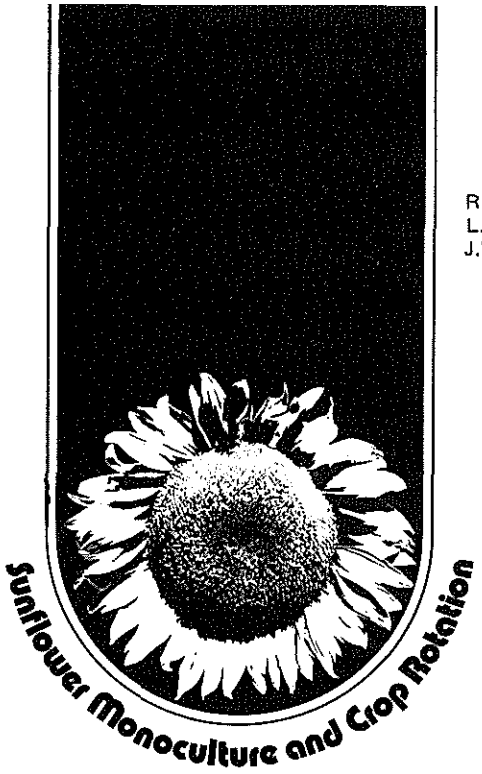
Sunflower Monoculture and Crop Rotation

Miscellaneous Report 166—1979
Agricultural Experiment Station
University of Minnesota



R.G. ROBINSON
L.J. SMITH
J.V. WIERSMA

Preface

Crop rotations of 4 to 6 years have been commonly recommended for sunflower. Some authorities suggest shorter rotations when disease-resistant hybrids are used. Many sunflower producers use a 3-year rotation, some use a 2-year rotation, and some are considering monoculture.

Monoculture is the antithesis of crop rotation. It consists of growing the same species of crop for two or more years on the same field. Crop rotation is a recurring succession of crops on the same field. Rotations vary in length from 2 to 6 years or longer. The shortest rotation, 2 years, is called crop alternation.

Crop rotation provides diversification of risk and labor for the individual farmer. Farmers often change rotations or crop sequence in the rotation to meet federal farm program requirements or in response to anticipated changes in prices of crops. The objective of a good crop rotation or sequence for sunflower is weed, insect, and disease control.

Monoculture and Alternation Research

Monoculture of sunflower and alternation of sunflower and other crops have been researched for nearly 25 years at Crookston in northwestern and at Rosemount in southeastern Minnesota.

EXPERIMENTAL DETAILS

Primary tillage involved *moldboard plowing* each fall. Small grains were planted early with a grain drill in rows 6 inches apart. Sunflower, corn, soybean, potato, and sugarbeet were planted at recommended times and rates in cultivated rows 22, 30, or 40 inches apart. Weeds did not affect yields because they were controlled with effective herbicides. Seed of all crops, potato tubers, and beet roots were removed from the field, but straw and stover were left except where indicated differently in the tables. Good varieties of each crop were used, but all sunflower varieties are susceptible to *Sclerotinia.*

Experimental designs were randomized complete blocks in split-plot layouts. Crops were planted in plots 40 to 60 feet by 40 to 70 feet the first year and replicated three times except for trial 3 with six replicates. Sunflower was planted on all plots the second year in trials 2 and 4. In trials 1 and 3 all crops were planted in both the first and second year. These 2-year cycles were repeated twice in trial 4 and three times in the other trials. Half of each plot in trials 2 and 4 was fertilized each year with high rates of nitrogen (N), phosphorus (P), and potassium (K). Trials 1 and 3 were not fertilized.

RESULTS

Trial 1. Crookston 1954-59. Fargo clay soil.

Sunflower in monoculture maintained yields equal to sunflower following other crops from 1955 to 1957 (table 1). In the fifth (1958) and sixth (1959) years of monoculture, sunflower yields were significantly lower than those of sunflower following soybean. Continuous sunflower maintained yields equal to those of sunflower in rotation with corn. Despite inoculation, soybean nodulation was poor. Other research at Crookston indicated that many soybean nodules in this soil were not effective in fixating atmospheric N. Consequently, the increase in yield and oil percentage following soybean can prob-

R.G. Robinson is professor, Department of Agronomy and Plant Genetics L.J. Smith and J.V. Wiersma are associate professor and assistant professor respectively, at the Northwest Experiment Station at Crookston.

ably be attributed to improved soil tilth from soybean on this heavy clay soil. Soil fertility and weather were the major factors affecting sunflower yield. Diseases and insects were not of major importance even though the Arrowhead and Arrowhead High-oil varieties used were susceptible.

Trial 2. Crookston 1972-78. Wheatville loam.

Sunflower in alternation with other crops yielded significantly more than in monoculture as an average of three cycles of alternation (table 2). Wheat was the best previous crop for high sunflower yield. The 1978 crop was second-year (seventh on monoculture plots) sunflower on the 1977 plots, and the yields indicate that the beneficial effects of alternation lasted only 1 year except for the sugarbeet alternation.

Previous crop also affected oil percentage, test weight, lodging, height, and vigor (table 3). Sunflower after pinto bean tended to be low in oil but differences were significant in only 1 year. Sunflower after potato or pinto bean was consistently

Table 1. Average yields, oil percentages, and test weights of sunflower grown in monoculture and in alternation with soybean, corn, oat, flax, and oat (alfalfa green manure) at Crookston, 1955-59

	Seed yield/acre (pounds)						Oil (percent)	Test weight/ bushel (pounds)
Previous crop	1955	1956	1957	1958	1959	Average	1955, 57-59	1956-58
Sunflower	834	1519	890	593	853	938	31.6	30.0
Soybean	932	1801	993	762	1075	1113	33.9	30.1
Corn	1010	1558	862	608	888	985	31.7	29.7
Oat	908	---	---	---	---	---	---	---
Flax	946	---	---	---	---	---	---	---
Oat-alfalfa	845	---	---	---	---	---	---	---
LSD 5%	201	732	153	111[1]	97[2]	158		

[1,2]Average yields significantly different at the 5 percent and 1 percent levels, respectively.

Table 2. Average yields of sunflower grown in monoculture and in alternation with potato, sugarbeet, pinto bean, and wheat at Crookston, 1972-78

	Seed yield/acre (pounds)							
Previous crop	1972	1973	1974	1975	1976	1977	Average 1973, 75, 77	1978
Sunflower	2824	852	1434	1338	1293	1852	1347	1781
Potato	---	908	---	1279	---	2348	1512	1605
Sugarbeet	---	770	---	1683	---	2358	1604	2168
Pinto bean	---	946	---	1410	---	2282	1546	1674
Wheat	---	1284	---	1549	---	2339	1724	1655
LSD 5%	---	240[2]	---	121[2]	---	292[2]	132[2]	368[1]

[1,2]Average yields significantly different at the 5 percent and 1 percent levels, respectively.

Table 3. Average oil percentages, test weights, lodging, heights, and vigor (July 1-7) of sunflower grown in monoculture and in alternation with potato, sugarbeet, pinto bean, and wheat at Crookston, 1972-78

	Oil	Test weight/bushel	Lodging	Height	Vigor
Previous crop	1973, 75, 77 (percent)	1973, 75, 77 (pounds)	1977-78 (score)[1]	1973, 77 (inches)	1973, 75 (rank)[2]
Sunflower	45.6	29.9	2.5	60	1.9
Potato	45.3	28.8	2.7	65	3.9
Sugarbeet	45.3	29.9	2.5	58	4.3
Pinto bean	44.7	28.8	3.6	65	1.9
Wheat	45.2	30.0	2.4	65	2.2
LSD 5%	0.9	1.0	0.8	6	1.3

[1] 1 erect, 9 flat. [2] 1 most, 5 least.

Table 11. Yields of crops the first year following sunflower on land that had not been cropped recently to sunflower

	Crop yields/acre					
	Crookston			Rosemount		
Crop	1955	1956	1974	1958	1973	1974
Sunflower (pounds)	834	1519	1434[1]	869	2354[1]	1637
Soybean (bushels)	14	18	---	28	51	16
Corn (bushels)	47	59	---	---	122	---
Flax (bushels)	10	---	---	---	---	---
Oat (bushels)	28	---	---	---	109	---
Potato (hundredweights)	---	---	206	---	---	---
Sugarbeet (tons)	---	---	16	---	---	---
Pinto bean (pounds)	---	---	2123	---	---	---
Wheat (bushels)	---	---	46	---	---	---
Kidney bean (pounds)	---	---	---	---	---	1119

[1]Third year sunflower.

The only practical controls for volunteer sunflower in sunflower are cultivation and delayed planting. About 90 percent of the volunteer sunflower emerged before June 1 and about 50 percent by May 21 at Rosemount. Planting should not be delayed at Rosemount after May 20, because late planting is more likely to reduce yield than is the presence of volunteer sunflower. But, later planting might be considered if future research indicates that late planting is effective in avoiding damage from sunflower head moth.

Herbicides will give good annual weed control in sunflower monoculture. A postemergence herbicide of wide-spectrum weed control and low toxicity to sunflower would be another great advance for sunflower monoculture, but such herbicide is not yet available. Rotation is still needed for practical control of serious infestations of quackgrass, thistles, and other perennial weeds.

Diseases are the greatest deterrent to adoption of sunflower monoculture. Sunflower and other crops susceptible to the same pathogen should, ideally, be separated in the crop sequence by resistant crops until the pathogen disappears. But this takes a long time—over 10 years for *Verticillium*, 5 years for *Sclerotinia* (sclerotia near the soil surface disintegrate rapidly), and over 6 years for downy mildew. Consequently, crop rotations of practical length can only be expected to reduce the amount of inoculum carryover, not eliminate it. A minimum time between sunflower crops should allow all sunflower stalk, root, and head residues to decompose. This took 1 year in our trials using moldboard plowing for primary tillage. Thus crop alternation will help control rust and other pathogens that require sunflower for survival.

But many of the serious pathogens attacking sunflower live on other crops and dicot weeds. Rotating among susceptible crops will not help control the disease. *Sclerotinia* infects sunflower, field bean, soybean, rape, pea, fababean, lentil, flax, mustard, sugarbeet, potato, alfalfa, sweetclover, wild mustard, thistles, lambsquarters, and black nightshade. *Fusarium* infects sunflower and many weeds and crops such as corn and wheat. *Verticillium* attacks sunflower, safflower, rape, sugarbeet, potato, alfalfa, red clover, and lambsquarters. These fungi, however, include many physiologic races. The races that injure sunflower may not injure all the other crops and vice versa. Some races of *Verticillium* attack both sunflower and potato, and some races of *Sclerotinia* attack sunflower, mustard, rape, and field bean.

Hybrids tolerant or resistant to rust, *Verticillium*, and downy mildew have made crop rotation unnecessary for control of these diseases[1]. All hybrids are susceptible to *Sclerotinia* and that is the major present barrier to successful monoculture, alternation, and 3-year rotations. Rotations of 4 to 6 years are the best present control, but they do not insure against loss from *Sclerotinia.* Rotation and clean seed control the root rot and wilt phases of the disease and reduce the incidence of head and stalk rot. Airborne spores and mycelium carried by birds can produce *Sclerotinia* head and stalk rot on otherwise healthy plants during the long period from flowering to maturity. Consequently resistant hybrids and/or fungicides remain as a hope for the control of this disease in the future.

Summary

Monoculture is an old practice. Rice has been grown in monoculture in parts of southeast Asia for 1000 years. Monoculture of soybean, tobacco, cotton, and corn is common in parts of the USA. A combination of monoculture and alternation of corn and soybean is common in southern Minnesota.

Monoculture and alternation of sunflower are feasible, but they increase the risk of sunflower production. Disease-resistant hybrids, herbicides, and adequate fertilizer should be used. Management of the volunteer sunflower population should be considered each year based on the amount of seed lost in harvesting. Planting methods that produce evenly-spaced plants in medium to low rather than high populations will delay contact between roots of *Sclerotinia*-infected and healthy sunflower plants. Fields should be observed frequently, so that insecticides can be applied when necessary.

Monoculture is justified only when second-year sunflower is expected to give a greater net return per acre than that of other crops requiring similar equipment. Significant losses from *Sclerotinia* or other soilborne pathogens are a warning that monoculture on that field should cease.

[1]Sunflower breeders have the responsibility of providing new hybrids resistant to any new races of these pathogens that may evolve.

low in test weight. Lodging differences were not consistent among years. Sunflower following sugarbeet was noticeably low in vigor compared with sunflower after the other crops until July when recovery was complete. Effects on soil structure of sugarbeet harvest machinery may account for the low vigor.

The fertilizer spread on half of each plot amounted to 120 pounds N - 35 pounds P - 33 pounds K per acre each year from 1972 to 1977. The NPK treatment did not affect yield significantly but it decreased oil percentage and increased test weight and height. Statistical interactions between previous crop and NPK were generally not significant so the average data are shown in table 4. Soil tests each fall indicated that the five cropping systems did not differ in their effect on the NPK status of the soil. The high amount of K remaining after sugarbeet is the only exception (table 5). Despite the large amount of fertilizer applied in April or early May, P and K soil tests were not significantly increased over unfertilized plots (table 6). More fertilizer was added to the soil than was removed in the harvested seed. This and the lack of response to fertilizer in these trials indicate that soil fertility was adequate for sunflower.

Sunflower budworm(*Suleima helianthana*, Riley), sunflower moth (*Homoeosoma electellum*, Hulst), and sunflower beetle (*Zygogramma exclamationis*, Fab.) caused slight damage 1 or 2 years but did not increase with monoculture.

Verticillium wilt (*Verticillium dahliae* Klebahn) and *Sclerotinia* wilt, stem, and head rots (*Sclerotinia sclerotiorum* [Lib.], de Bary) were the most serious diseases in these trials, but they did not cause extreme reductions in sunflower yield. Use of disease-tolerant varieties in some years probably prevented serious losses from diseases. Hybrid 894, resistant to *Verticillium*, downy mildew (*Plasmopara halstedii* [Farl.] Berl. & de Toni), and rust (*Puccinia helianthi* Schw.), was grown in 1976 and 1977. Hybrid 896, resistant to rust and *Verticillium*, was grown in 1974. P-21 ms X HA60 hybrid, resistant to rust, was grown in 1972. Varieties or hybrids susceptible to the above disease organisms were grown in the other years. *Verticillium* was found in the Kenebec potato tubers harvested in 1974 and 1976. Sputnik sunflower variety, susceptible to rust, mildew, *Verticillium*, and *Sclerotinia*, was grown in 1978, but only *Sclerotinia* caused appreciable damage.

Trial 3. Rosemount 1957-62. Waukegan silt loam soil.

Sunflower in monoculture maintained yields equal to sunflower following soybean for 2 years, but from 1960 to 1962 yields and oil percentage following soybean were significantly higher than monoculture (table 7). No fertilizer was used in these trials, so sunflower alternated with soybean probably had access to more soil N than did monoculture sunflower. Arrowhead variety, susceptible to *Verticillium*, was used in these trials, and *Verticillium* increased each year until the crop was

Table 4. Average yields, oil percentages, test weights, lodging, heights, and vigor (July 1-7) of unfertilized and fertilized sunflower at Crookston, 1972-78

	Years	None	NPK	LSD 5%
Yield/acre (pounds)	1972-78	1647	1772	157
Oil (percent)	1973-78	46.1	44.8	0.6
Test weight/bushel (pounds)	1972-77	29.6	30.4	0.5
Lodging (1 erect, 9 flat)	1977-78	2.1	3.4	2.3
Height (inches)	1973, 77	61.0	64.0	2.0
Vigor (rank)	1973, 75	2.9	2.8	0.2

Table 5. Average NPK soil tests in the fall following sunflower monoculture and alternation with potato, sugarbeet, pinto bean, and wheat at Crookston, 1972-77

	N	P	K
Previous crop		(pounds/acre)	
Sunflower	59	16	162
Potato - sunflower	77	17	157
Sugarbeet - sunflower	58	16	203
Pinto bean - sunflower	63	17	160
Wheat - sunflower	59	18	170
LSD 5%	27	4	34

Table 6. Average NPK soil tests of unfertilized and fertilized soil in October compared with NPK removal in harvested sunflower seed and NPK additions in fertilizer at Crookston, 1972-77

	None	NPK	Removed in seed	Added in fertilizer
Elements			(pounds/acre)	
N	42	84[1]	273	720
P	13	21	40	211
K	165	176	63	199

[1]Significantly higher than None treatment.

Table 7. Average yields and oil percentages of sunflower grown in monoculture and in alternation with soybean at Rosemount, 1958-62

	Seed yield/acre (pounds)						Oil (percent)
Previous crop	1958	1959	1960	1961	1962	Average	1959-62
Sunflower	869	1481	874[1]	601[1]	116[2]	788	28.0[1]
Soybean	1022	1431	1055	1158	344	1002	29.9

[1,2] Monoculture significantly lower than alternation at the 5 percent and 1 percent levels, respectively.

devastated in 1962. *Verticillium* increased more slowly in the sunflower following soybean, and this difference may account for the higher oil percentage (table 7).

The reduction in P and K soil tests between 1957 and 1962 is in good agreement with the removal of these elements by the sunflower crop (table 8). Soil pH decreased from 6.0 to 5.8. Removal of calcium and magnesium by sunflower amounted to 49 pounds/acre.

Trial 4. Rosemount 1971-74. Waukegan silt loam soil of high fertility from manure applications prior to 1965.

Sunflower in alternation with oat and soybean yielded more than in monoculture, but in alternation with corn, yields were about the same as in monoculture (table 9).

NPK fertilizer applications had no effect on crop yields on this highly fertile soil, but the decline in P and K soil tests from 1971 to 1974 and removal of P and K by sunflower are shown in table 10. Soil pH decreased from 6.0 to 5.8. Removal of calcium and magnesium by sunflower amounted to 130 pounds per acre.

Varieties and hybrids used in this trial were susceptible to both downy mildew and *Verticillium*, but in contrast to trial 3, *Verticillium* injury was small and did not increase from 1971 to 1974. Downy mildew in the 1972 and 1973 crops was sufficiently serious to reduce both stand and yield but was not a problem in 1974. *Sclerotinia* head and stalk rot was the major disease in both 1973 and 1974. Birds can spread the pathogen with their talons. This may account for the prevalence of head rot because only a few plants showed the early wilt symptom of soilborne infection. *Fusarium*, not recognized as a sunflower pathogen at the time, also caused lodging in the 1973 and 1974 crops.

Trials 1 to 4. Crop comparisons

These trials provide statistically valid crop comparisons because the yields are from replicated plots in the same fields. The yield data of second-year sunflower and the yields of other crops following sunflower in table 11 can be used to calculate *relative* gross return per acre from each of the crops at any chosen price levels. These data are pertinent to farmers' decisions on whether to plant sunflower or some other crop on sunflower land. The yield comparisons in table 11 are not affected by the 2-year rotation used because only data from the end of the first cycle or start of the second cycle are given.

Table 8. Average P and K soil tests before and after 5 years of sunflower monoculture at Rosemount compared with removal of P and K in the harvested sunflower

	In soil (pounds/acre)		In sunflower[1] (pounds/acre)
Elements	1957	1962	1958-62
Phosphorus	39	20	15
Potassium	185	110	55

[1]Seed 1958-62 plus stover 1958 and 1961 were removed from the field.

Table 9. Average yields of sunflower grown in monoculture and in alternation with corn, oat, and soybean at Rosemount, 1971-74

	Seed yield/acre (pounds)				
Previous crop	1971	1972[1]	1973	1974	Average, 2 years
Sunflower	3107	1333	2354	1476	1405
Corn	---	1165	---	1609	1387
Oat	---	1387	---	1887	1637
Soybean	---	---	---	1770	---
LSD 5%	---	244	---	235[2]	169

[1]Yields are low and variability high because sunflower was destroyed by error and had to be replanted. [2]Average yields significantly different at the 5 percent level.

Discussion

When sunflower was a new crop in Minnesota, some people indicated that it was "hard on the soil" because of soil fertility depletion or release of toxic chemicals which injure the following crop (allelopathy). Research has shown that sunflower is usually less soil depleting than high yielding grain crops. However, allelopathic research shows that sunflower residues in the soil do have inhibitory effects on sunflower and other plants. Our monoculture and crop sequence research indicates that these effects, if any, are not major considerations in field crop production.

Volunteer sunflower is usually a serious problem for 2 years after a sunflower crop. However, over 95 percent emerge the first year. Nonetheless, farmers should plan to spray for 2 years after sunflower. The following herbicides used *postemergence* at *rates recommended* in various crops killed volunteer sunflower in trials at Rosemount: 2,4-D, MCPA, 2,4-DB, MCPB, bromoxynil (Brominal, Buctril), dicamba (Banvel), bentazon (Basagran) at 1 pound/acre, cyanazine (Bladex), or atrazine + oil (Aatrex + oil), and dinoseb (DNBP). Metribuzin (Sencor, Lexone) at 0.75 pounds/acre preemergence killed sunflower.

Table 10. Average P and K soil tests in April before and after 3 years of sunflower monoculture at Rosemount compared with removal of P and K by sunflower

	In soil (pounds/acre)				In sunflower (pounds/acre)		
Elements	1971	1972	1973	1974	seed[1] 1971-73	stalks[1] 1971-72	total
Phosphorus	170	112	112	110	22	4	26
Potassium	430	350	340	210	35	100	135

[1]Removed from field.