SUGARBEET PRODUCTION UNDER REDUCED TILLAGE — PROSPECTS AND PROBLEMS

R. E. Sojka, E. J. Deibert, F. B. Arnold, and J. Enz

A study was initiated in the fall of 1977 to obtain base line data on the applicability of reduced tillage sugarbeet production in the Red River Valley. Three reduced tillage systems were compared to a conventional system which consisted of fall plow plus secondary tillage. Results indicated warmer early spring soil temperatures, better seedling emergence, lower ground-level wind speed and no significant yield loss under reduced tillage as compared to the conventional system.

INTRODUCTION

The 1970's have seen changes in agricultural production systems, energy utilization, and environmental legislation that would make no-till crop production highly attractive provided the practice can be accomplished successfully. The concept of no-till production in North Dakota has, until recently, only been applied to small grain production (2). No-till and other reduced tillage sugarbeet production systems have not been studied in depth. Certain preliminary data (3,4) have been encouraging.

The 1980's will see even more significant reductions in the availability of petroleum fuel for agricultural production. Conventional sugarbeet culture in the Red River Valley is highly energy intensive in its present form. In the near future, agricultural operations may be governed by fuel availability per se, with price of fuel no longer the relevant limiting factor. This situation already occurred in some midwest farming areas during the spring of 1979.

Faced with the energy crisis and a national commitment to erosion control and elimination of non-point pollution from agricultural sources, agricultural systems less dependent on extensive tillage practices must be examined.

EXPERIMENTAL PROCEDURE

Tillage Operations

The experiment was conducted on a Fargo clay loam soil located on the NDSU main experiment station (NW22 annexed land) at Fargo. The area was planted to hard red spring wheat in 1977. After harvest approximately 1 metric ton per hectare (approximately 1 ton/acre) straw remained on the field. The primary tillage treatments described below were implemented in a randomized complete design with two replications.

Fall tillage operations performed in late September were as follows:

Plow	Conventional Method — A four bottom, 40 cm (16 inch), plow share two-way (reversible) plow was utilized (residue covered).
Sweep*	A 2.4 m chisel plow, with 30 cm spacing (8 feet @ 12 inch spacing) and 35 cm (14 inch) sweeps was utilized (residue flattened).
Inter-till*	A six-row inter-tiller with 56 cm spacing (22 inch) was utilized. This implement roto-tills a 20 cm (8 inch) wide band down the center of each row (⅔ residue standing and ⅓ residue incorporated).
No-till*	No tillage operations performed (residue standing).

**Reduced tillage systems*

The plow treatment was the only plot receiving any secondary tillage. Operations consisted of two tandem disk operations followed by one operation prior to planting with a field cultivator with attached harrow.

Planting Operations

All plots were planted with a 6-row double disk flex planter with 2.5 cm (1 inch) depth bands. A 72-cell plate was used with sprocket ratio set to deliver 6 seeds/30 cm of row (6 seeds/foot). Flex planter units were attached to the rear bar of a double tool-bar (60 cm or 2 ft spacing between tool bars). A 45 cm (18 inch) notched (serrated) rolling coulter was attached to the front tool-bar in line with the double-disk planter openers to assist with slicing through the stubble and/or trash (Figure 1). Plots were planted on 15 May with American Crystal ACH-17 sugarbeet seed. Each primary tillage plot contained 24 rows @ 56 cm (22 inch) spacing. Later each plot was divided into subplots with 12 rows cultivated and 12

Sojka is former assistant professor, Deibert is assistant professor, Arnold is former research assistant and Enz is assistant professor (climatology), Department of Soils.

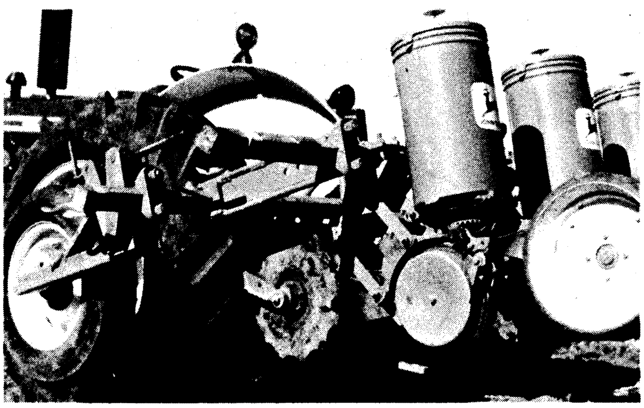

Figure 1. Notched rolling coulter attached in front of flex planter units to cut through surface residue when planting no-till sugarbeet.

rows non-cultivated. Plot length was 30.5 m (100 feet). An additional study area of the same size was dedicated to reduced tillage wheat with identical primary tillage treatments used to rotate beets and wheat in alternate years of the study.

Soil Tests and Fertilizer Application

Initial soil samples were collected in the fall of 1977 for analysis. Phosphorus tested 41.5 kg/ha (37 lb/acre) — very high, potassium 624 kg/ha (557 lb/acre) — very high. Nitrate in the top 60 cm (2 feet) was 49 kg/ha (44 lb/acre). The plot area was fertilized for a yield goal of 40.3 T/ha (18 T/acre) from standard recommendations (derived from field tests in conventional systems). Both phosphorus and potassium were adequate so none was applied. Nitrogen as ammonium nitrate was broadcast @ 112 kg/ha (100 lb/acre) on the surface in early May to supply the nitrogen requirements. The N fertilizer was incorporated during the spring tillage operations in only the Plow treatment.

Weed Control — Herbicides and Cultivation

Early established weeds on the reduced tillage plots were controlled by spraying with glyphosate (Roundup). The glyphosate was applied with a ground sprayer at 2.9 bar (40 psi) with a delivery of 46 l/ha (40 gal/acre) of water, at the rate of 0.84 kg AI/ha (¾ lb AI/acre of 1 qt/acre material). Only partial weed control was achieved, thus a second application at the same rate was applied preemergence six days after planting. All weeds were controlled by the second application. Three weeks after emergence, both broadleaf and grassy weeds appeared on all plots. Broadleaf weeds, except for the Kochia, were controlled with a postemergence application of 1.12 kg AI/ha (1 lb AI/acre) each phenmedipham (Betanol) + desmedipham (Betanex) on 12 June. A postemergence application of diclofop (Hoelon) at 1.12 kg AI/ha (1 lb AI/acre) was sprayed on 22 June with good control on small grassy weeds. Subsequently the plots were split and half of the plots received two cultivations, two weeks apart. Some areas of the noncultivated plots had excessive growth of grassy weeds. These grassy weed spots were hand sprayed with dalapon (Dowpon) at approximately 3.36 kg AI/ha (3 lb AI/acre). Only fair control was achieved with the spot treatment. Generally, weeds were not a problem in the cultivated plots, but Kochia was a problem in all noncultivated tillage treatments.

Data Collection

Parameters observed or measured periodically during the growing season included soil temperature, ground level wind speed, soil moisture, bulk density, soil strength, emergence rate, stand establishment and vigor, dry weight, weight of tops and roots, and leaf area.

Individual soil thermometers were used to record soil temperature in the plots at 10 cm (4 inch) depth for one month prior to spring tillage and planting. After planting these thermometers were replaced with banks of thermocouples at 7.5, 15.0 and 30.0 cm (3, 6, and 12 inch) depth increments, and soil temperatures were again observed periodically through the remainder of the growing season.

Wind speed was measured at the 5 cm (2 inch) elevation with precision cup anemometers. Sugarbeet plants were collected throughout the season for determination of leaf area and dry matter of roots and tops. Data on these variables are reported on a per plant basis. Bulk density was determined using standard procedures. Soil strength (resistance) was measured with a direct-reading pocket penetrometer.

On 19 October, the center two rows of a 6-row section in each plot were lifted with a 2-row three-point hitch beet lifter after removing the beet tops by flailing. Two samples were collected from each subplot, each having a total of 12.2 row m (40 row feet) harvested. Tare samples were collected and processed. Brei samples were sent to American Crystal Research Center for quality analysis.

Data collected were statistically analyzed and Duncan's multiple range test at the .05 level was utilized to test for treatment mean differences.

RESULTS AND DISCUSSION

Soil Temperature

Contrary to expectations 10 cm-depth temperatures in the month preceding planting were warmer in reduced tillage plots (Table 1). This was probably related to the increased amount of snow retained on reduced tillage plots which resulted in a substantial insulating effect. Postplant soil temperatures were significantly warmer under the no-till treatment at all three depths observed (Table 2).

Soil temperature observations indicated that limited tillage in North Dakota can be expected to conserve heat from the preceding growing season when sufficient snow accumulates to insulate the soil against low ambient winter temperatures. Temperature differences were particularly pronounced in the lower profile from late May until late June in this study. These data were similar to those observed by Schneider *et al.* in western North Dakota (5). The early growth period is particularly critical to stand establishment and early crop vigor, and may impact strongly on weed competition.

Table 1. Pre-plant spring soil temperatures at the 10-centimeter depth as influenced by fall tillage system — Fargo, 1978.

Fall Tillage System	Soil Temperature[1] Minimum	Maximum	Mean
	°C		
Plow	3.2 a[2]	6.0 a	4.6 a
Sweep	3.9 b	6.9 b	5.4 b
Inter-till	3.8 b	7.8 c	5.8 c
No-till	5.4 c	9.8 d	7.6 d

[1]*Data are the average of 18 observations collected during the period 10 April to 9 May.*
[2]*Values in same column followed by the same letter are not significantly different at the .05 level of significance.*

Table 2. Postplant soil temperatures at three depths under sugarbeet plants as influenced by fall tillage system — Fargo, 1978.[1]

Fall Tillage System	Soil Depth (cm) 7.5	15.0	30.0	Mean
	°C			
Plow	17.0 a[2]	15.8 a	14.4 a	15.6 a
Sweep	17.4 a	16.3 b	15.9 b	16.6 a
Inter-till	17.6 a	16.6 bc	15.9 b	16.7 a
No-till	17.9 b	17.0 c	16.2 b	17.0 b

[1]*Data are the average of 6 observations collected during the period 16 May to 27 July.*
[2]*Values in same column followed by the same letter are not significantly different at the .05 level of significance.*

Wind Speed

Measurements of wind speed at 5 cm (2 inches) above the soil surface were made shortly after planting in the various tillage (cover) treatments. In eight days of comparisons, wind speeds in the Plow treatment averaged 7.1 km/hr (4.4 mph) while those in the No-till treatment averaged only 3.5 km/hr (2.2 mph) (Table 3). Average wind velocities generally decreased with increased standing stubble and/or trash accumulation on the soil surface. In addition, maximum or gust wind speeds were reduced by nearly 50% in the reduced tillage treatments when compared to the Plow. For example, the maximum speed observed was 20.9 km/hr (13 mph) on the Plow treatment while at the same time the maximum on the No-till treatment was only 11.3 km/hr (7 mph).

Reduction in wind speed due to standing stubble and trash on the soil surface is an important benefit of no-till sugarbeet production. Beet seedlings, because of their large leaves and fragile hypocotyl, are very susceptible to twisting caused by the wind. The amount of damage caused by twisting is extremely variable, but in 1977, one of the worst years, about 15% of the Red River Valley beet acreage was replanted, with most of the damage caused by the wind. In addition, stand reduction was common in many other fields. Thus any reduction in wind speeds near the soil surface would be highly desirable.

Stand Establishment — Early Plant Growth

Stand counts were significantly improved in reduced tillage plots (Table 4). Of the 600 seeds/30.5 m (100 feet) planted, fewer emerged in the conventional fall-plowed treatment than in any of the reduced tillage treatments. There was also a trend by 22 June for top weight, root weight, and leaf area to be greater in limited tillage treatments (Table 5). The Plow treatment produced only half the plant growth as measured by any of these parameters compared to any of the limited tillage treatments. By 18 July the effect of cultivation on plant dry matter production was pronounced.

Table 3. Wind speed above the soil surface in a sugarbeet crop shortly after planting as influenced by tillage system — Fargo, 1978.

Fall Tillage System	Wind Speed[1] Minimum	Maximum	Mean
	km/hr		
Plow	2.0 a[2]	12.1 a	7.1 a
No-till	1.4 b	8.3 b	4.5 b

[1]*Wind speed measured at 5 centimeters above the soil surface. Average of eight days during the period 16 May to 11 June.*
[2]*Values in the same column followed by the same letter are not significantly different at the .05 level of significance.*

Table 4. Sugarbeet seedling emergence and moisture bulk density and strength in the soil surface as influenced by fall tillage system — Fargo, 1978.

Fall Tillage System	Seedling Emergence[1]	Soil Moisture[2]	Bulk Density[3]	Soil Strength[4]
	plants/30 m	%	gram/cm³	kg/cm³
Plow	172 a[5]	22.0 a	1.00 a	.97 a
Sweep	230 b	28.8 bc	1.07 a	.93 a
Inter-till	230 b	27.4 b	1.07 a	.56 a
No-till	205 b	30.6 c	1.02 a	.56 a

[1]*Data are the average of 4 observations per treatment.*
[2]*Soil moisture in the surface 7.5 centimeters. Data are the average of 4 observations from the period 16 May to 29 June.*
[3]*Bulk density measured in the surface 5 cm (2 inches) on 16 May.*
[4]*Soil strength measured at the surface on 30 May. Values not corrected for soil moisture.*
[5]*Values in the same column followed by the same letter are not significantly different at the .05 level of significance.*

Table 5. Plant dry matter and leaf area of sugarbeet plants as influenced by fall tillage or cultivation system — Fargo, 1978.

Fall Tillage System	Cultivation	Leaf Area	Plant Dry Matter Top	Root	Total
		cm^2/plant	grams/plant		
		June 22[1]			
Plow		74	.31	.03	.34
Sweep		168	.76	.08	.84
Inter-till		156	.71	.08	.79
No-till		148	.63	.07	.70
		July 18			
Plow	Yes	3760	30	33	63
	No	2858	23	21	44
	Average	3309 a[2]	27 a	27 a	54 a
Sweep	Yes	2654	28	29	57
	No	1995	22	27	49
	Average	2324 a	25 a	28 a	53 a
Inter-till	Yes	3076	27	38	65
	No	1620	13	16	29
	Average	2348 a	20 a	27 a	47 a
No-till	Yes	4099	37	49	86
	No	2094	19	20	39
	Average	3096 a	28 a	35 a	63 a
Average	Yes	3397 a	30 a	37 a	67 a
	No	2142 b	19 b	21 b	40 b

[1]*Data collected prior to cultivation thus values are the average over subplot (cultivation) samples.*
[2]*Average values in the same column followed by the same letter are not significantly different at the .05 level of significance.*

Soil Moisture, Bulk Density and Resistance

Soil in the germination zone (surface 8 cm or 3 inches) was considerably drier in the fall plowed conventionally tilled plots throughout the period of stand establishment (Table 4). In nearly all cases the no-tilled plots had the greatest seed-zone soil moisture percentages. Soil profile moisture measured periodically throughout the season indicated two consistent trends: 1) fall plowed, conventionally tilled plots were drier than reduced tillage systems, and 2) cultivated plots were drier than noncultivated. Observations varied with date of sampling as to individual statistical significance, but the greatest differences occurred most frequently in the surface 0-15 cm and 15-30 cm (0-6 inches and 6-12 inches)-depth increments.

There was no statistical difference between treatments in surface bulk density or soil surface strength (Table 4). These observations are similar to others obtained in a previous seedbed study conducted at Casselton (6). The assumption is that pore geometry changes, while total soil pore volume remains relatively static over a range of cultural practices.

Yield and Quality

Harvest results indicated no significant differences among tillage treatments for impurity analysis (Table 6), yield, sugar content or recoverable sugar (Table 7). Yields were significantly higher on cultivated than noncultivated plots.

There was no evidence in this study of insect or plant pathogenic problems in either conventional or reduced tillage systems.

CONCLUSIONS

Most importantly, there was no observable reduction in yield by reduced tillage systems. Overall yield levels are recognized as being low. Contributing factors may be related to increased levels of broadcast herbicide application to achieve adequate weed control or unidentified chemical and physical soil problems associated with the soils in the study area.

The importance of adequate weed control is underscored by the 9 metric ton/ha (4 ton/acre) difference in yield between cultivated and non-cultivated treatments. Herbicide application technology for no-till farming in the North Central region, particularly for use with sugarbeet, is still in the research stage. Studies are being conducted on the use of directed postemergence herbicide sprays or various types of recirculating or limited contact herbicide application methods. These methods

Table 6. Impurity analysis of sugarbeet roots as influenced by fall tillage and cultivation system — Fargo, 1978.

Fall Tillage System	Cultivation	Impurity analysis NO_3	Na	K	Amino-N
		ppm			
Plow	Yes	31	303	2446	1091
	No	29	326	2135	980
	Average	30 a[1]	315 a	2291 a	1035 a
Sweep	Yes	26	192	2148	882
	No	26	212	2252	772
	Average	26 a	202 a	2200 a	827 a
Inter-till	Yes	16	181	2135	689
	No	28	171	2032	736
	Average	22 a	176 a	2084 a	712 a
No-till	Yes	32	201	2174	778
	No	14	152	2019	674
	Average	23 a	177 a	2097 a	726 a
Average	Yes	26 a	220 a	2226 a	860 a
	No	24 a	216 a	2110 a	791 a

[1]*Average values in the same column followed by the same letter are not significantly different at the .05 level of significance.*

Table 7. Yield, sugar content, and recoverable sugar of sugarbeet roots as influenced by fall tillage and cultivation system — Fargo, 1978.

Fall Tillage System	Cultivation	Yield	Sugar Content	Recoverable Sugar[1]
		T/ha	%	kg/T
Plow	Yes	33.9	15.7	130
	No	21.7	15.5	131
	Average	27.8 a[2]	15.6 a	130 a
Sweep	Yes	33.2	15.6	134
	No	23.2	15.2	131
	Average	28.2 a	15.4 a	133 a
Inter-till	Yes	30.1	16.1	142
	No	24.0	15.5	135
	Average	27.1 a	15.8 a	139 a
No-till	Yes	32.6	15.5	134
	No	25.1	15.5	137
	Average	28.8 a	15.5 a	135 a
Average	Yes	32.4 a	15.7 a	135 a
	No	23.5 b	15.4 a	134 a

[1]*Total sugar minus the amount of sugar lost to molasses during processing which is determined by the amount of impurities (Na, K, Amino-N). The higher the impurities the greater the loss to molasses and the lower the recoverable sugar.*

[2]*Average values in the same column followed by the same letter are not significantly different at the .05 level of significance.*

are in current use in other types of no-till row-crop culture (1,7). Use of between-row ground-level wick applicators or recirculating sprayers for application of such "hot" herbicides as glyphosate and paraquat have provided an effective weed control method for very modest material costs. The introduction of successful granular herbicide materials presently under investigation should also assist in alleviation of weed problems encountered in reduced tillage sugarbeet systems.

Reduced tillage or no-till practices can reduce fuel inputs, reduce erosion potential, and conserve soil heat and moisture for spring planting. Presence of small grain stubble and other crop residue provide desirable soil surface conditions that decrease crusting potential. Since seedbed moisture is preserved, more uniform and complete emergence of seedlings takes place and stand establishment is enhanced by increased seedling vigor. Planting to stand, with the subsequent elimination of thinning by hand or mechanical methods, may be a successful management practice under these reduced tillage conditions. Additional research needs to be conducted in this area.

Two other important management areas for successful no-till beet production beyond chemical weed control are fertilizer application and residue management. By its nature, a no-till beet production system encounters some tillage at the time of and following beet harvesting. Required levels of phosphorus and potassium may conceivably be applied via the preceding small grain or other crop cover. Further research may be needed to explore the role of banding, side dressing, or liquid injection of fertilizer during midseason. In other no-till cropping systems, between-row sidedressing of liquid fertilizer sprays is often combined with herbicide application.

In this study only minor problems with trash "plugging" occurred during mechanical cultivation. If mechanical cultivation is to be preserved as a weed control option, it is likely that minor trash control problems could be alleviated by the addition of cutting coulters ahead of the cultivator sweeps. There is a substantial advantage to keeping residue at the soil surface to reduce wind speed and seedling loss by wind damage and abrasion.

These data point the way to an alternate program for beet culture in which some of the problems and potentials have already been identified. It should be emphasized, however, that any no-till system must be regarded as a more management-intensive system of production than conventional production, and should not be regarded as a shortcut approach. We look forward to further study and interest in the years ahead.

ACKNOWLEDGEMENT

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