STRIP TILLAGE FOR SUGARBEET AND ITS IMPLICATIONS FOR N FERTILIZER MANAGEMENT

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ABSTRACT

Strip tillage (ST) is attractive as a means to reduce fuel and labor costs associated with sugarbeet (*Beta vulgaris* L.) production, but seedbed preparation, fertilizer management, and weed control are concerns. A field study was conducted near Sidney, MT with objectives to (i) compare the effect of tillage system [conventional tillage (CT) vs. ST] on yield and quality, and (ii) compare N uptake and availability with the two tillage systems under sprinkler irrigation. For ST, 12-inch strips spaced 24 inches apart were tilled in the fall into small grain straw residue using a modified parabolic shank strip tiller. Dry N and P fertilizers were banded about 3 inches below the seed row. The same fertilizer materials and application rates were used in both ST and CT. Results suggest that root yield and sugar production are similar with the two tillage systems under typical conditions; however, root sucrose content was higher with ST than with CT in two of three years suggesting greater end-of-season N depletion with ST. Midseason petiole nitrate concentrations show that ST sugarbeet exhibits a delay in N absorption compared to CT sugarbeet. Spatial analysis of soil NO_3-N concentrations showed that at planting fall-applied N had moved downward but remained within 24 inches of the soil surface. There was a zone of low NO_3-N between 0 and 2 inches with ST. Results suggest that seedlings may temporarily be N deficient with ST because of a N-depleted zone between the seed and fertilizer band. Starter fertilizer may be beneficial with ST to compensate for low NO_3-N in the top 2 inches of soil.

INTRODUCTION

Strip tillage has been successfully adapted to corn (*Zea mays* L.) and soybean (*Glycine max* (L.) Merr.) production (Janssen et al, 2005; Al-Kaisi and Licht, 2004) and research results with ST in sugarbeet have been favorable (Halvorson and Hartman, 1984), but questions regarding optimum fertilizer management need further research. Availability of nutrients in early growth stages (i.e., seedling and early vegetative) is critical for maximizing sugarbeet yield. Milford et al. (1985a, 1985b) showed that early leaf-area development is important for establishing yield potential and that available-N concentration in the seedling root zone is a major factor determining seedling leaf expansion. Fertilizer placement may be more important with sugarbeet production than with many other crops because of the lack of lateral root development during early growth stages. Anderson and Peterson (1978) reported that ^{32}P placed 2 inches directly under the plant row was absorbed more effectively by sugarbeet seedlings than was ^{32}P placed 2 inches below and 2 inches to the side of the seed row. Strip tillage (ST) provides a means to drastically reduce the amount of tillage while allowing fertilizer to be placed where it can be accessed by seedlings.

Observations from study at Sidney, MT suggested that, while yield and quality are similar with ST and conventional tillage (CT) sugarbeet, N uptake and utilization with ST may have been less than optimum. Early seedling growth with ST was less vigorous than with CT and N deficiency symptoms, which normally occur in mid to late August, appeared in mid July with ST. This apparent discrepancy in N availability may be due to differences in either the mineralization-immobilization balance or in fertilizer N movement within the soil profile. The latter of these two is of particular concern since fertilizer N is applied in the fall and is thus susceptible to the influence of off-season precipitation. Our objectives were to determine if (1) sugarbeet yield components and N status are affected by the tillage system and N placement, and (2) fertilizer N availability and distribution with ST differs from that with CT.

MATERIALS AND METHODS

An experiment was conducted from 2004 to 2006 in Sidney, MT where the soil is a Savage silty clay loam (fine, montmorillonitic Typic Argiborolls) with 20.9% sand, 46.3% silt, and 32.8% clay; soil, pH 7.8; organic C 0.89%, and total N 0.065% at the 0 to 8 inch depth. Growing season average monthly air temperature from April to September 2004 ranges from 45 to 70 F and total growing season rainfall is 7.5 inches.

A 2-year rotation of barley (*Hordeum vulgare* L.) and sugarbeet was implemented for the experiment so that both CT and ST sugarbeets were planted following barley. Management of barley was the same regardless of whether CT or ST was used for the subsequent sugarbeet crop. All residues remained on the field following harvest, with some lying on the soil surface and the remainder standing 6 to 8 inches in height. Individual 48 × 80-foot plots were arranged in an unbalanced stripped block design with four blocks. Each treatment combination was replicated either six (2005) or eight (2004, 2006) times according to the unbalanced design. Irrigation water was applied using an overhead linear sprinkler irrigation system.

Strip tillage was accomplished using a custom-built, six-row strip tiller (Schlagel Mfg., Torrington, WY[1]) that tills 12-inch strips and leaves 12 inches of standing stubble between tilled rows. Row spacing was 24 inches. Fertilizer is applied in a band during the tillage operation via a tube behind the tillage shank. All tillage and fertilizer application was done in the fall, except for a light tillage operation in the spring on CT plots. Urea and monoammonium phosphate were applied based on the soil test results (about 50 lb P_2O_5 acre^{-1} and 110 lb N acre^{-1} for both tillage treatments). Fertilizer with CT was broadcast and incorporated into the top 3 inches of soil while with ST, both fertilizer was banded approximately 4 inches deep directly under the seed row, except in 2004 when the fertilizer band was placed 8 inches deep.

Soil samples were collected using a hand probe at approximately monthly intervals beginning about 80 days after planting (DAP). Ten soil cores were extracted from each plot, half from within and half from between the plant rows. Each 18-inch core was divided into three 6-inch depth increments and then all 10 sub-samples were mixed. Samples were air-dried and extracted with 2 *M* KCl in preparation for NO_3-N analysis using an automated Cd-reduction instrument (Lachat Instruments, Milwaukee, WI). Petiole samples were collected at the same time as were soil samples. One recently-matured petiole was removed from each of 30 random plants within a plot. Petioles were oven-dried at 140º F, ground to pass through a 1-mm screen, extracted with deionized water, and analyzed for NO_3-N using the same instrument described for the analysis of soil extracts.

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[1] Mention of a trademark, vendor or proprietary product does not constitute a guarantee or warranty of the product by USDA and does not imply its approval to the exclusion of other products that may also be suitable. This type of information is solely provided to assist the reader in better understanding the scope of the research and its results.

In 2006, a second set of soil samples was collected from two replications of each tillage treatment on -7, 76 and 132 DAP to characterize the spatial distribution of available N. Soil cores 0.67 inches in diameter and 24 inches in length were extracted every 2 inches along a steel template perpendicular to and centered on the crop row using a hand-operated soil probe that encased the core in a plastic sleeve. Samples were processed and analyzed for NO_3-N and NH_4-N as describes previously. The means of two replicate plots were used to construct kriged graphical representations of the soil NO_3-N concentration of a vertical cross section (24 × 24 inches) of the crop row.

RESULTS AND DISCUSSION

Most sugarbeet yield parameters were nearly identical in 2004, regardless of tillage system (Table 1). The only difference was that root sucrose content was 0.5% higher for ST than for CT. This was probably the result of differences in N availability during the mid to late growing season. N deficiency chlorosis was observed much earlier in 2004 with ST than with CT. Excess N during later growth stages can reduce the production of sucrose because photosynthate is used for biomass production rather than stored as sucrose, thus the onset of chlorosis in late summer is desirable. Conversely, root yield is sacrificed if N deficiency occurs too early. Strip tilled sugarbeet may have also experienced N deficiency during the seedling stage in 2004 because fertilizer was placed 8 inches deep, increasing the time for roots to reach the fertilizer.

Table 1. Yield components for sugarbeet as affected by tillage system at Sidney, MT. Each italicized value is the p-value for comparing the two tillage means within a given year.

Tillage system	Population (plants ac^{-1})	Root mass† (lb $root^{-1}$)	Root yield† (tons ac^{-1})	Sucrose content (%)	Sucrose yield‡ (lb ac^{-1})
	------------	------------	2004	------------	------------
Conventional	33147	1.410	23.2	19.8	9223
Strip	32534	1.412	22.7	20.3	9188
	p=0.586	*P=0.953*	*p=0.370*	*p<0.001*	*p=0.898*
	------------	------------	2005	------------	------------
Conventional	30129	1.566	23.1	19.4	9018
Strip	35574	1.533	27.0	19.9	10768
	p<0.001	*p=0.133*	*p=0.002*	*p=0.009*	*p=0.001*
	------------	------------	2006	------------	------------
Conventional	32465	1.775	28.3	17.7	10098
Strip	25610	2.529	31.7	17.4	11063
	p<0.001	*p<0.001*	*p=0.001*	*p=0.061*	*p=0.010*

†Root mass and root yield are given on a fresh weight basis, according to the industry standard.
‡Sucrose yield=root yield × sucrose content with no correction for impurities.

In 2005, spring winds reduced the plant population in CT by 15% compared to ST where standing stubble protected seedlings from blowing soil (Table 1). Sugarbeets in CT plots did not compensate for lower plant population by producing roots with greater mass, and consequently root yield was 9.7 tons acre^{-1} greater for ST than for CT. As was observed in 2004, root sucrose content with ST was 0.5% higher than with CT and this corresponded to early chlorosis development with the reduced tillage treatment. Petiole NO_3-N concentration was lower in 2005 with ST than with CT from 81 to 107 DAP (Fig. 1), supporting the hypothesis that lower N availability led to higher root sucrose content with ST. Soil NO_3-N concentration confirms that there was more available N in the top 18 inches with CT than with ST at 80 DAP (Fig. 2). There was only about 5 ppm NO_3-N in each 6-inch depth increment with ST, indicating that fertilizer N may have moved below the sampling depth. With CT, there was more NO_3-N at the 6-12- and 12-18-inch depths (14 and 18 ppm, respectively) than in the surface 6 inches (9 ppm). At 101 to 141 DAP, most fertilizer N had apparently leached below 18 inches regardless of tillage (Fig 2).

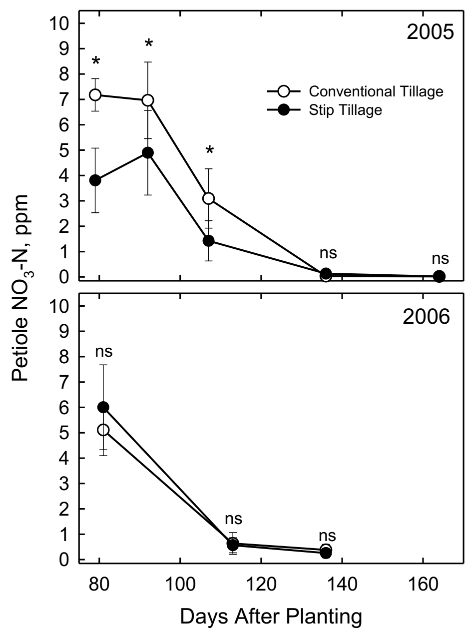

Figure 1. Petiole NO_3-N concentration for strip till and conventional till sugarbeets at Sidney, MT. Error bars show 2SE of the mean, an '*' indicates significant differences (P<0.05), and 'ns' indicates that means are not significantly different.

Wet soil conditions at planting affected emergence in 2006 with the effect being greater in ST were soil moisture was highest. As a result the plant population with ST was 21% lower than with CT (Table 1). Increased root mass compensated for the lower plant population with ST resulting in a yield advantage of 8.4 tons acre^{-1} compared to CT. The 0.4% difference in root sucrose content (ST vs. CT) was not significant (Table 1). In contrast to 2004 and 2005, there was no visual difference between ST and CT in late-summer chlorosis development or petiole NO_3-N concentration (Fig. 1) in 2006. While differences in soil NO_3-N concentration were not as great as in 2005, the same pattern was observed, with CT having higher overall concentrations than ST (Fig. 2). With CT, some fertilizer N was remaining at the 12-18 inch depth by 80 DAP, but with ST little was remaining in the top 18 inches. At subsequent sampling dates, fertilizer N had apparently moved beyond the 18-inch depth with both tillage systems.

Spatial distribution of soil NO_3-N at -7 DAP showed that fall-applied N remained within 24 inches of the soil surface, but that substantial amounts had moved to a depth of 22 inches with strip tillage and 20 inches with CT. Nitrate-N distribution in ST plots displayed the 'bullseye' pattern expected for a banded application, while the distribution in the CT plots was more uniform and less concentrated (Fig 3). Nitrate-N concentration was greater in the 0 - 2 inch depth for CT than for ST (data not shown), suggesting the potential for slower seedling growth

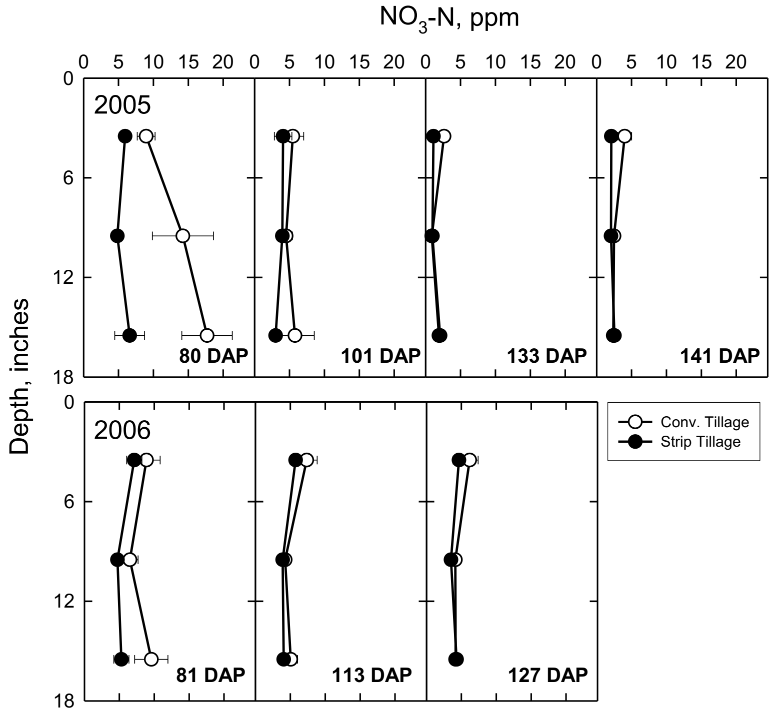

Figure 2. Soil NO_3-N concentration in an 18-inch soil profile as affected by placement/tillage system at Sidney, MT. Four sampling times are represented in terms of the number of days after planting (DAP). Error bars show 2SE of the mean.

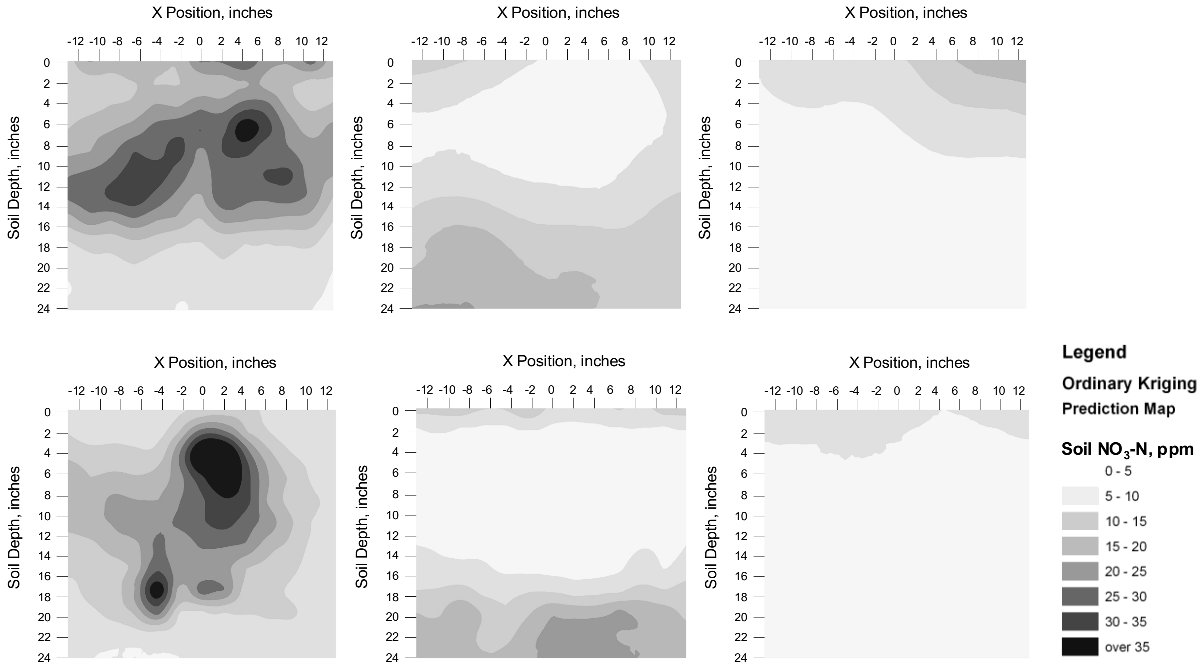

Figure 3. Spatial distribution of NO_3-N in a 24 × 24-inch vertical cross-section bisected by the crop row (x position = 0). The effects of tillage (CT = top row; ST = bottom row) and date (-7 DAP = left column; 76 DAP = middle column; 132 DAP = right column) are illustrated. Each figure represents the kriged mean values from two replicate plots. DAP = days after planting. with ST. However, this effect would be expected to be short-lived due to the high concentration of N between 2 and 10 cm in ST plots.

By 76 DAP, soil NO_3-N concentrations between 2 to 16 inches had been depleted to about 3 ppm (Fig. 3). One month prior to harvest (132 DAP) most of the sampling zone was depleted of NO_3-N regardless of tillage system (Fig. 3), with many mean concentrations less than 4 ppm (data not shown). Concentrations were slightly higher in the top 2 inches, due presumably to mineralization of organic N.

Glenn and Dotzenko (1978) reported that NO_3-N movement was greater with minimum tillage sugarbeet production than with CT production, but while our results show small differences between CT and ST, it does not appear that NO_3-N movement differs enough to cause substantial differences in crop uptake and response.

SUMMARY AND CONCLUSIONS

Petiole NO_3-N concentration was lower for ST than CT in 2005 while there was no difference in the 2006. Despite the lower N status in 2005, sucrose yield with ST was either equal to or greater than with CT in all three years. Available N (NO_3-N) in the top 18 inches of soil was greater with CT than with ST for the 80 DAP, but was similar at sampling dates thereafter. Considerable downward movement of fertilizer N occurred with both tillage systems, but the movement was greater with ST. Spatial distribution of available N (NO_3-N + NH_4-N) in the top 24 inches of soil suggested that seedlings may temporarily be N deficient with ST because of a N-depleted zone between the seed and fertilizer band. Starter fertilizer may be beneficial with ST to compensate for low NO_3-N concentrations in the top 2 inches of soil.

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