EFFECT OF STRIP TILLAGE, ROW ORIENTATION, AND SEED PRIMING ON SUGARBEET YIELD AND QUALITY

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Introduction/Objectives

2010 was the third and final year of a strip tillage and row orientation study, with some modifications from the first year. This study was initiated in fall 2007 at the Prosper research experiment station to determine if strip tillage and row orientation directly affect soil temperature and moisture at the seeding depth (1.25 inch) in the first four weeks following sugarbeet planting. We also wanted to determine if tillage management and row orientation would affect sugarbeet seedling emergence, final stand, root yield, and sugar content. Other researchers have investigated the effect of tillage and row orientation on soil warming and drainage, but no such studies have been conducted for sugarbeet production in the Red River Valley using the high precision instrumentation (dual probe heat capacity sensors) employed in this study. Reduced tillage systems have seen minimal implementation in the Red River Valley due in large part to 1) the real or perceived idea of cooler soil temperatures in spring and 2) the reality of frequent spring flooding and soils that retain water longer under high residue conditions. Despite real and perceived risks, there are a number of advantages provided by strip tillage including reduced soil erosion, reduced wind-related crop damage, lower fuel costs, potentially reduced fertilizer requirements, potentially improved phosphorus and potassium fertilizer uptake efficiency, improved soil conditions (increased aggregate stability and improved soil structure), reduced soil crusting, conservation credits, and improved water infiltration and drainage over time.

As a modification to the study conducted in 2008, we included a seed priming treatment in 2009 and 2010 to compare primed and non-primed sugarbeet seeds. A number of independent research studies have determined that sugarbeet seed priming effectively accelerates seed germination and emergence and can result in greater harvestable root yield and sucrose content. Effective seed priming is particularly beneficial during cold, wet springs and in reduced tillage systems where cool, wet soil conditions may inhibit rapid and uniform germination of non-primed sugarbeet seed. Although some seed companies have recently converted to selling only primed seed, priming is provided at an added cost and so we are interested in investigating the benefit of seed priming specifically for strip tillage systems in the event that seed priming does not become a standard industry practice.

Dual probes were carefully installed in the tillage treatments in years 2008 and 2010. We planned to replicate the dual probe study in 2009; however, the fall 2008 and spring 2009 conditions were too wet to allow for fall strip tillage or early spring planting.

The objectives of this project were to determine if row orientation (north/south or east/west planted rows) is related to soil warming and moisture content in early season fields under strip tillage and conventional tillage and to determine if observed early season differences affect final yield and quality in sugarbeet production. In 2009 and 2010 we additionally investigated the potential for seed priming to overcome moisture and temperature differences that may make germination conditions less favorable in strip tillage systems.

Materials and Methods

In 2008 and 2009, the experiments were established on a Beardon-Perella silt loam (coarse-silty, frigid Aeric Calciaquoll) at the NDSU research station near Prosper, ND, and the 2010 location was planted on a grower farm near Amenia, ND, on a Glyndon-Tiffany silt loam (coarse-loamy, mixed, frigid Typic Haplaquoll). Soil temperature and moisture sensors were not installed in spring 2009 as planned due to excessively wet soil conditions in both fall 2008 and spring 2009. The study was established in spring 2009 at two locations to collect agronomic data despite a late planting date and poor seedbed preparations, especially for strip tillage treatments. Details of 2008 and 2009 study methods including planting and harvesting dates and cultivars are provided in Overstreet et al. 2008 and 2009 and Gegner et al. 2008.

In the present study, strips were applied in fall 2009 with a single pass into wheat residue chopped to ~7 inches high. Conventional tillage was conducted by chisel plowing plots in fall and cultivating with a harrow in the spring. Soil nitrogen levels were adjusted to 130 lb N/a to a depth of 4 feet with urea. Phosphorus fertilizer was applied as 3 gallons per acre of 10-34-0 starter fertilizer in spring according to recommendations in the Sugarbeet

Production Guide. Potassium fertilizer was not required. Fertilizer was applied in fall 2009 in a band with the strip tiller in the strip tillage treatments and in the conventionally tilled treatments by surface broadcasting and incorporating fertilizer.

Dual-probe heat capacity sensors (DPHCS) were placed 2-inches below the soil surface to measure soil temperature and moisture in the environment of the sugarbeet seed. A total of forty-eight sensors were installed in the field experiment; twelve sensors were placed in each treatment, six in the crop row and six between the rows (inter-row area). Sensors were installed on April 15th, 2010, one week prior to planting and were carefully removed prior to planting on April 23. Sensors were then re-installed for POST planting data collection and removed on June 21, 2010, retaining the soil between the sensor needles to allow determination of volumetric soil moisture content for verification of sensor accuracy. DPHCS data was statistically analyzed using PC SAS 9.1.3 (SAS Institute Inc.); data was partitioned into weekly increments and analyzed using Proc Mixed.

The experimental design was a randomized complete split plot design with 4 replications; the whole plot treatment consisted of two row orientation planting directions (north/south and east/west) and the subplots consisted of two tillage systems (chisel plow and strip-till) and two seed priming levels (with and without seed priming). Individual treatment plots measured 11 feet wide and 30 feet long and contained 6 rows per plot with a spacing of 22-inches between rows. SESVanderHave Roundup Ready variety 36813 seed (primed and non-primed from the same seed lot) was planted with a John Deere MaxEmerge II planter. Sugarbeet was placed 1.25 inches deep, and was planted to stand at a 4.5-inch in-row seed spacing. Roundup herbicide was applied three times; plots were not cultivated and some late hand labor was used as needed for weed control. Two fungicide applications, Eminent and Headline, were applied for Cercospora leaf spot control.

The middle two rows were harvested for root yield determination and sugar quality evaluation on September 22, 2010. Yield determinations were made and quality analysis performed at the American Crystal Sugar Quality Lab, East Grand Forks, MN.

Results and Discussion

Review of previous years' results: 2008: According to anecdotal wisdom, it was expected that soil temperatures in strip tilled fields would be cooler than in conventionally tilled fields, regardless of row orientation. The agronomic data produced from this study in 2008 provided some interesting insights and encouraging results to support future research for sugarbeet production using strip tillage. Even under unfavorable weather conditions in 2008 which produced lower-than-average yields regardless of the tillage system, strip tillage was not statistically disadvantaged in terms of sugarbeet root yield or sugarbeet quality. The best-yielding strip tillage treatment produced essentially the same sugarbeet tonnage as the best-yielding conventional tillage treatment in this study (strip-till with north-south oriented rows = 26.2 ton/a; Chisel Plow with north-south oriented rows = 26.3 ton/a). Between these two best treatments, strip tillage yielded slightly greater net sugar than the chisel plow treatment (14.8% compared to 14.5%). These factors combined to result in recoverable sugar per acre values of 7665 lb/a for conventional tillage and 7767 lb/a for strip tillage.

Soil moisture and temperature data in 2008 revealed that in-row soil temperature was not significantly different between row orientations or tillage systems during the first four weeks of the growing season. In-row volumetric water content differed significantly based on row orientation. North/south oriented treatments held significantly more water the first three weeks after planting than east/west oriented treatments. The increased moisture content in north/south oriented rows could have been due to reduced evaporation from the north/south oriented treatment due to reduced wind movement across rows. Another explanation for the observed reduction in moisture content in east/west oriented rows was the greater in-row soil temperatures in the east-west oriented treatment, which may have resulted in greater water evaporation in the east/west oriented treatments. Significant differences were also observed between in-row volumetric water contents by tillage system. The chisel plowed treatment held significantly more water in-row than the strip-tilled treatments. However, the strip-tilled treatments held more water between-rows.

2009: Agronomic results from the two study locations in 2009 revealed that in an unfavorable growing season with late planting and cool temperatures, primed seed yielded about 0.85 ton per acre greater root yield than unprimed seed. Additionally, there was a visual advantage for primed seed treatments for early season seedling vigor and growth rate. East-west oriented rows yielded significantly greater root tonnage in the chisel plow treatment at Prosper, but not in the strip tillage treatment. This was the only significantly different root yield due to row orientation. Probably due to the poor seedbed conditions resulting from spring strip tillage (as opposed to the recommended practice of fall strip tillage), most strip tillage treatments yielded significantly lower root yields compared to chisel plowed treatments at Amenia; the average difference was 2.75 ton per acre. At Prosper, strip tillage root yield was equal to the chisel plow treatment (34.0 ton/acre) for north-south oriented rows, but was 1-2 ton/acre less than chisel plow in east-west oriented rows. As has been noticed in other tillage studies in other years, there was greater sugar loss to molasses (SLM) in strip tillage treatments compared to chisel plowed treatments at Amenia. This was not observed at Prosper. This has become a recognized trend and could result from several factors: 1) poorer defoliation of beets at harvest in strip tillage treatments, probably resulting from greater variability in beet sizes and smaller beets retaining more beet top than desired; 2) reduced sugarbeet stand in strip tillage resulting in larger than desired beets with lower sugar content and/or higher impurities, and 3) too much fertilizer applied in the strip tillage system; it may be appropriate to reduce the N fertilizer recommendation for strip tillage due to the banded application of fertilizer in this system. The lower number of beets per row at harvest for strip tillage at Amenia suggests that the greater loss to molasses may have resulted from fewer beets that were larger. Recoverable sugar per acre (RSA) was lower for strip tillage than for chisel plowing at Amenia. RSA values were statistically the same for the tillage methods at Prosper.

Results from 2010:

<u>Soil Temperature and Moisture Results:</u>

Prior to planting (Week 0; April 16-22), in-row chisel plow soil temperature was significantly greater in north/south than east/west row orientation; however, the opposite was true for in-row strip-till soil temperature where east/west was significantly greater than north/south row orientation (Table 1). Warmer in-row soil temperatures for east-west oriented rows in strip tillage systems (relative to north-south oriented rows in strip tillage) are generally expected as a result of reduced shading and light interception in east-west orientations. Comparing pre-plant (Week 0) in-row temperatures between tillage systems, chisel plow was warmer than strip tillage when rows were oriented north-south, but there were no soil temperature differences between tillage systems when rows were oriented east-west (Table 1). During the first week after planting (April 24-30), in-row soil temperatures were significantly warmer for chisel plow treatments than for strip-till treatment plots, regardless of row orientation (Table 2). A trend emerges in week 1 that continues through week 4: chisel plow treatments display greater soil temperature and moisture differences among row orientations and row locations than strip tillage treatments, which appear to moderate soil temperature and moisture more effectively. The Red River Valley experienced cooler than average air temperatures as well as over two inches of rainfall during the first two weeks of May (North Dakota Ag Weather Network, 2010). As a result, no significant differences in soil temperature were observed among tillage or row orientation treatments two and three weeks after planting (Tables 3 and 4). Four weeks after planting (May 15-21), east/west-oriented chisel plow treatments (both in-row and between-row) were significantly warmer than all other treatments, (Table 5). North/south orientated chisel plow treatment plots (both in-row and between-row) were slightly cooler than east/west, perhaps due to shading from sugarbeet seedlings, however, all chisel plow treatments were significantly warmer than all strip-till treatments.

Prior to planting, in-row volumetric water content of north/south-oriented strip-till treatments were significantly lower than all other treatments (Table 1). It was observed that there was more rapid snow melt from north-south oriented strip tillage plots than other treatments perhaps due to the strong southerly influence of the sun at this northern latitude in late winter and early spring. Since this study was located on a well-drained sandy loam, the moisture apparently drained below the 2-inch measuring depth. It has been observed that frost layers remain for a longer time lower in the soil profile, below the tillage zone, in strip tillage and similar reduced tillage systems (Deibert, unpublished data) due to insulation from snow and residue layers. It is possible that there was still a frost layer remaining deeper in the soil profile, retaining water at lower depths and keeping soil temperatures from rising as might be expected in a conventionally tilled system. Nearly one inch of rain fell during the first week after planting which caused no significant soil volumetric water content differences between treatments during week 1 (Table 2) (North Dakota Ag Weather Network, 2010). By the second week after planting (May 1-7), soil vol. water content was significantly greatest in north/south-oriented in-row chisel plow treatment plots (Table 3). In week 2 significant differences in vol. moisture content are apparent for north-south vs. east-west row orientations for chisel plow treatments, but not for strip tillage treatments. East/west-oriented chisel plow treatments (both in-row and between-row) were significantly drier than all other treatments (Table 3). The same trend was also seen three and four weeks after planting (May 8-21) (Tables 4 and 5). In general, differences in soil moisture content for strip tillage treatments are more moderate and less variable than for chisel plow, probably reflecting reduced soil moisture evaporation from strip tillage systems.

Agronomic Results:

*Note: two plots (both strip-till) were removed as outliers from the 2010 dataset. One plots was planted late and therefore had lower yield measurements. The other plot yielded greater than other treatments but we aren't sure why.

In general, no simple treatment effect (Tillage, Row Orientation, or Priming) was statistically significant ($P<0.05$), however nearly all yield measurements displayed significant interactions between Tillage and Row Orientation such that greater yield measurements were determined for the east-west orientation in conventionally tilled plots but strip tilled plots yielded greater in north-south oriented rows (Table 6). Conventional tillage with east-west oriented plots (averaged over priming effects) averaged 38.49 ton/a, 15.05% net sugar, and 11,580 lb sugar/a. In contrast, conventionally tilled treatments with north-south oriented plots yielded 36.48 ton/a, 14.57% net sugar, and 10,646 lb sugar/a. Strip tillage with north-south oriented rows averaged 38.41 ton/a, 14.96% net sugar, and 11,499 lb sugar/a. In contrast, strip tillage treatments with east-west oriented rows averaged 37.38 ton/a, 14.10% net sugar, and 10,527 lb sugar/a. Why conventionally tilled treatments yielded greater with east-west oriented rows and strip tillage treatments would perform better with north-south oriented plots in 2010 cannot be fully explained. Most sugarbeet growers in the Red River Valley region orient their crop rows in a north-south direction, citing reduced wind damage from winds that come predominantly from the north-northwest. There were no major wind events at the study location in 2010, so wind protection as a result of row orientation could not be tested. Since soil temperature and moisture was collected for only the first four weeks after planting, it is also not possible to estimate the effect of row orientation on soil temperature and moisture later in the growing season when root growth and sugar accumulation are occurring. Anecdotal evidence and some research studies agree that east-west oriented rows generally result in higher soil temperatures in the top 0-6 inches relative to north-south oriented rows. High soil temperatures later in the growing season are not considered positive for some crops, including corn and root crops, because it encourages higher rates of root respiration which reduces starches and sugars in plant biomass.

When averaged over tillage and row orientation, seed priming treatment did not result in significant harvest differences (Table 6). 2010 was a very favorable growing season with early planting conditions and good heat unit accumulation early in the growing season, so priming effects would not be as evident as in a year with less favorable early season growth conditions. Primed seed resulted in an average root tonnage of 37.39 ton/a compared to 37.93 ton/a for unprimed seed. Sugar loss to molasses was non-significantly lower for primed seed vs. unprimed seed, 1.1651% vs. 1.2053%. Net sugar was likewise non-significantly greater for primed seed, 14.85% compared to 14.53% for non-primed seed. Recoverable sugar per acre was 11,122 lb/a and 11,018 lb/a for primed and non-primed seed, respectively.

When averaged over row orientation and priming effect, strip tillage and conventional tillage yielded very similar root weights, 37.90 and 37.49 ton/acre, respectively. In previous years we have noted a higher sugar loss to molasses (%slm) in strip tillage treatments compared to conventional tillage, but this was not noted in this study (1.1798% vs. 1.1924% for strip till vs. conventional tillage). Similarly, other research studies examining strip tillage and conventional tillage did not reveal the expected greater %slm; a favorable fall season in 2009 allowed very good seedbed preparation and berm building compared to other years, resulting in good seed planting conditions in spring and final stand counts at harvest that were as good as in conventionally tilled treatments. Additionally, we learned that in some cases, we need to take pay attention when defoliating strip tillage plots because the settings for conventional tillage can leave more sugarbeet top remaining on the beets in strip tillage systems, which results in greater %slm. Net sugar was statistically equal for strip tillage and conventional tillage, 14.5309% and 14.8082%. Gross income per acre was also statistically equal between strip tillage and conventional tillage, $1797/a and $1843/a. The difference in gross income between tillage treatments would be minimized by fuel savings resulting from strip tillage relative to conventional tillage.

When averaged over tillage and priming treatments, row orientation alone did not result in any significant differences in yield measurements. Tonnage was 37.38 and 37.97 for north-south and east-west oriented rows, respectively. Although there was 0.05% percent greater sugar loss to molasses determined for north-south vs. east-west oriented rows, this was also not a statistically significant difference and was off-set by the higher gross sugar content of north-south oriented rows relative to east-west oriented rows (15.97% vs. 15.76%). The resulting differences in net sugar were 14.75% for north-south oriented rows and 14.60% for east-west orientations. The difference in recoverable sugar per acre was small between orientations, 11,044 and 11,088 lb sugar/a for north-south vs. east-west orientations.

Tare values may explain high sugar loss to molasses (slm) values since excess foliage (tops) on roots results in greater %slm. High tare values may also be an indication that soils were wetter at harvest time in a particular treatment since tare can represent soil remaining on beet roots when they arrive at the factory and this is most often associated with high soil moisture conditions at harvest. In this study, there were no significant differences in soil tare among main treatments, however, there was again a significant tillage*rotation interaction (p=0.0056) resulting in lower tare values in the conventionally tilled/east-west oriented treatment and the strip-tilled/north-south oriented treatment. Higher tare values were determined for the conventionally tilled/north-south oriented treatment and the strip-tilled/east-west oriented treatment. It's unknown what field conditions or tillage treatment effects may have resulted in greater tare in some treatments than others since harvest conditions were generally good and we did not measure soil moisture through harvest. It is possible that the east-west oriented strip tillage treatment may have been wetter at harvest time than other treatments, but it did not adversely affect sugarbeet harvesting.

Conclusions:

Effect of row orientation on tillage and corresponding sugarbeet root yield and quality measurements was not consistent across years. There is no indication that north-south or east-west row orientations are more effective for sugarbeet production in strip tillage systems. Similarly, there was no evidence that either row orientation was superior in conventionally tilled chisel plow systems. It should be noted that north-south row orientations are favored in the Red River Valley region among sugarbeet growers due to the predominant north-northwesterly winds that can cause crop damage during particularly strong wind events. No such wind events were recorded at the site locations during this study, so they could not be evaluated with this data. The 2008 and 2009 growing seasons were unusually wet years. During a 2-week period without precipitation immediately following planting in 2008, it was demonstrated that there was a clear seedling emergence advantage in strip tilled treatments, even though there was less soil moisture at the seed depth in the strip tilled seedbed. There were reserves of soil moisture in the inter-row area to provide adequate moisture for seed germination and seedling emergence. However, under wet soil conditions, strip tillage does not result in a production advantage. In years like 2009, when strip tillage could not be performed in fall and when spring tillage and planting was delayed by wet conditions, spring strip tillage resulted in a poor seedbed and, consequently, poor stand and sugarbeet yield and sugar measurements. Therefore, spring strip tillage is not recommended in the Red River Valley.

In 2008 and 2009, sugar loss to molasses (%slm) was higher for strip tillage than chisel plow, possibly due to poor seedbed conditions at planting. In 2010, a year that provided very good seedbed conditions at planting, high %slm in strip tillage treatments was not observed. During 2010, a favorable production year, strip tillage and conventional tillage yielded very similar root tonnage and similar (though slightly lower) net sugar. The final difference in gross revenue per acre (GRA) between tillage treatments, averaged over row orientation and priming effect, was $50 per acre greater for conventional tillage. This value does not reflect savings from conservation payments, reduced fuel use, elimination of replanting costs, or other potential savings from strip tillage. Seed priming appears to provide a net advantage in early season emergence and stand establishment and probably provides a yield advantage in a poor growing season, as seen in 2009, but does not appear to provide a net advantage for yield or sugar in a good year when vigorous and appropriate cultivars are selected.

In 2008, row orientation had a significant effect on soil moisture content such that moisture was greater in north-south oriented treatments. Greater moisture content was also observed for north-south oriented rows for chisel plowed plots in 2010, but this was not observed for strip tillage. Greater soil moisture content was measured in the inter-row (between rows) area for the strip tillage treatments in 2008; this inter-row region can act as a moisture reserve for crop plants during dry periods. The higher moisture content in the inter-row region was not consistently observed in the 2010 growing season. In terms of tillage differences for moisture content <u>in the crop row</u>, the results agree in both years despite very different weather patterns: there was greater moisture content in the conventionally tilled (chisel plow) treatments than in the strip tillage treatments. This is contrary to what is generally expected (i.e. greater moisture content in the crop row in strip tillage). It should be remembered, though, that these results are limited to the first four weeks after planting and do not represent a season-long trend. Likewise, these results provide adequate reason to question conventional thought which maintains that strip tillage systems result in greater water content in the crop rows that can potentially harm seedlings.

Soil temperatures did not differ between strip till and conventional tillage during the first four weeks after planting in 2008. In 2010, tillage did not act independently of other treatment effects to significantly influence soil temperature. However, in most cases soils were warmer in chisel plowed treatments.

This study indicates that strip tillage is not an advantage in under very wet growing conditions, especially when a good sugarbeet seed bed cannot be created. However in a good growing season with sufficient moisture and heat accumulation, strip tillage performs competitively with conventional tillage and may result in a net profit when all economic factors are considered. The three years of this study did not provide a means of testing strip tillage in a dry growing season, but it is likely that strip tillage would result in greater sugarbeet yields and sugar content compared to conventional full-width tillage systems under moisture limiting soil conditions.

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Table 1. Week 0 (7 days prior to planting; April 16-22, 2010) average soil temperature and soil volumetric water content near Amenia, ND.

Treatment	Soil temperature	Soil moisture
	-------- °F --------	---- $m^3 m^{-3}$ ----
North/south†		
In-row‡		
Chisel plow§	52.6 ab ¶	0.28 abc¶
Strip-till§	50.6 d	0.24 e
Between-row‡		
Chisel plow	52.9 a	0.28 bc
Strip-till	50.5 d	0.26 d
East/west†		
In-row		
Chisel plow	51.1 cd	0.28 ab
Strip-till	51.9 bc	0.29 a
Between-row		
Chisel plow	52.7 a	0.26 cd
Strip-till	51.0 d	0.28 ab

† Row orientation, north/south vs. east/west.
‡ In-row, within the crop row; between-row, between the crop rows and beneath residue in strip-tillage treatments.
§ Tillage treatments: Chisel plow, conventional tillage vs. strip-tillage.
¶ Within columns, means followed by the same letter are not significantly different according to Fisher's Protected LSD ($P < 0.01$).

Table 2. Week 1 (April 24-30, 2010; POSTplant) average soil temperature and soil volumetric water content near Amenia, ND.

Treatment	Soil temperature	Soil moisture
	-------- °F --------	---- $m^3 m^{-3}$ ----
North/south†		
In-row‡		
Chisel plow§	53.8 a¶	0.37 a¶
Strip-till§	53.1 bc	0.31 a
Between-row‡		
Chisel plow	53.5 ab	0.27 a
Strip-till	53.1 bc	0.30 a
East/west†		
In-row		
Chisel plow	53.6 a	0.22 a
Strip-till	53.1 bc	0.25 a
Between-row		
Chisel plow	53.7 a	0.19 a
Strip-till	52.9 c	0.30 a

† Row orientation, north/south vs. east/west.
‡ In-row, within the crop row; between-row, between the crop rows and beneath residue in strip-tillage treatments.
§ Tillage treatments: Chisel plow, conventional tillage vs. strip-tillage.
¶ Within columns, means followed by the same letter are not significantly different according to Fisher's Protected LSD ($P < 0.01$).

Table 3. Week 2 (May 1-7, 2010; POSTplant) average soil temperature and soil volumetric water content near Amenia, ND.

Treatment	Soil temperature	Soil moisture
	-------- °F --------	---- $m^3 m^{-3}$ ----
North/south[†]		
In-row[‡]		
Chisel plow[§]	46.4 a[¶]	0.40 a[¶]
Strip-till[§]	46.0 a	0.32 b
Between-row[‡]		
Chisel plow	46.0 a	0.30 b
Strip-till	45.8 a	0.31 b
East/west[†]		
In-row		
Chisel plow	46.3 a	0.19 c
Strip-till	46.1 a	0.30 b
Between-row		
Chisel plow	46.2 a	0.18 c
Strip-till	46.0 a	0.30 b

† Row orientation, north/south vs. east/west.

‡ In-row, within the crop row; between-row, between the crop rows and beneath residue in strip-tillage treatments.

§ Tillage treatments: Chisel plow, conventional tillage vs. strip-tillage.

¶ Within columns, means followed by the same letter are not significantly different according to Fisher’s Protected LSD ($P < 0.01$).

Table 4. Week 3 (May 8-14, 2010; POSTplant) average soil temperature and soil volumetric water content near Amenia, ND.

Treatment	Soil temperature	Soil moisture
	-------- °F --------	---- $m^3\ m^{-3}$ ----
North/south†		
In-row‡		
Chisel plow§	47.1 a¶	0.43 a¶
Strip-till§	46.7 a	0.34 b
Between-row‡		
Chisel plow	46.8 a	0.34 bc
Strip-till	46.6 a	0.31 cd
East/west†		
In-row		
Chisel plow	47.1 a	0.21 d
Strip-till	46.8 a	0.34 bc
Between-row		
Chisel plow	47.2 a	0.13 e
Strip-till	46.5 a	0.31 cd

† Row orientation, north/south vs. east/west.

‡ In-row, within the crop row; between-row, between the crop rows and beneath residue in strip-tillage treatments.

§ Tillage treatments: Chisel plow, conventional tillage vs. strip-tillage.

¶ Within columns, means followed by the same letter are not significantly different according to Fisher's Protected LSD ($P < 0.01$).

Table 5. Week 4 (May 15-21, 2010; POSTplant) average soil temperature and soil volumetric water content near Amenia, ND.

Treatment	Soil temperature	Soil moisture
	-------- °F --------	---- $m^3 m^{-3}$ ----
North/south†		
In-row‡		
Chisel plow§	63.4 b¶	0.39 a¶
Strip-till§	61.9 de	0.33 b
Between-row‡		
Chisel plow	63.2 b	0.30 c
Strip-till	62.2 c	0.30 cd
East/west†		
In-row		
Chisel plow	63.9 a	0.23 e
Strip-till	62.2 cd	0.29 d
Between-row		
Chisel plow	64.2 a	0.22 e
Strip-till	61.8 e	0.29 cd

† Row orientation, north/south vs. east/west.
‡ In-row, within the crop row; between-row, between the crop rows and beneath residue in strip-tillage treatments.
§ Tillage treatments: Chisel plow, conventional tillage vs. strip-tillage.
¶ Within columns, means followed by the same letter are not significantly different according to Fisher's Protected LSD ($P < 0.01$).

Table 6. Sugarbeet yields and yield components reflecting Least significant difference (LSD) is determined for alpha=0.95 (P<0.05). 2010 Growing Season.

Tillage Treatment	Row Orientation	Primed/ Unprimed Seed	Tare (%)	Root Yield (Tons/a)	Gross Sugar (%)	%SLM (%)	Net Sugar (%)	RSA* (lb/a)	RST** (lb/ton)	Stand (Beets/100ft)	GROSS-TON	GROSS-ACRE
CONVENTIONAL	NS	UNPRIMED	3.9	37.06	15.7675	1.2628	14.5047	10780	290.09	193	47.60	1759.91
CONVENTIONAL	NS	PRIMED	3.9	35.90	15.915	1.2794	14.6356	10514	292.71	197	48.04	1726.52
CONVENTIONAL	EW	UNPRIMED	3.5	38.50	15.9275	1.1781	14.7494	11349	294.99	190	48.73	1873.78
CONVENTIONAL	EW	PRIMED	3.1	38.49	16.3925	1.0494	15.3431	11811	306.86	209	52.29	2012.46
STRIP TILL	NS	UNPRIMED	3.4	39.75	15.9625	1.1746	14.7879	11726	295.76	198	48.96	1937.15
STRIP TILL	NS	PRIMED	3.3	36.64	16.3033	1.105	15.1984	11196	303.97	217	51.42	1901.65
STRIP TILL	EW	UNPRIMED	3.9	36.41	15.265	1.2058	14.0592	10217	281.18	175	44.59	1617.14
STRIP TILL	EW	PRIMED	4.2	38.68	15.3767	1.2271	14.1496	10941	282.99	198	45.13	1743.92
LSD (P<0.05)			**0.44**	**1.71**	**0.4419**	**0.0618**	**0.4761**	**813**	**9.52**	**14**	**2.86**	**167.08**

* Recoverable Sugar per Acre
** Recoverable Sugar per Ton