EFFECTS OF ROW ORIENTATION AND TILLAGE ON SUGARBEET YIELD AND QUALITY
II. SOIL TEMPERATURE, MOISTURE, AND SEEDLING EMERGENCE

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Introduction

Tillage management decisions have a strong influence on water and temperature relationships in crop fields. Reduced tillage intensity generally increases soil moisture content. Greater moisture content in strip-tillage systems can result from decreased bulk density (greater soil porosity) (Pagliai et al. 2004), reduced moisture loss from evaporation, and increased soil organic matter content which results in larger, more stable soil aggregates which creates a greater proportion of small- and medium-sized soil pores (0.5-50 μm) (Pagliai et al., 1995). Small- and medium-sized pore retain water longer than larger pores, making water available for plant uptake for a longer period of time. Research studies documenting greater water holding capacity as a result of increased soil organic matter content, greater aggregate stability, and/or lower bulk density have usually been conducted in a no-till or reduced tillage regime for at least 8 years (Unger and Fulton, 1990; Anderson et al., 1990; Pagliai et al., 1995). Evaporation is an important source of water loss from agricultural fields that can be reduced by strip-tillage. Residues between strips provide a physical barrier to diffusion of water vapor from the surface soil, which serves to conserve water in the seedbed (Sadler and Turner, 1994). In a study conducted in northwest Montana by Aase and Tanaka in 1987, it was determined that tillage intensity, surface residue quantity, and position of the residue (laid down vs. standing) influenced evaporation from the 0-4 inch soil depth. Wind movement across plots with a mixture of standing and flat residues measured at a height of 8 inches above the soil surface was found to be about 50% of that over bare ground. The authors determined that residue-covered soils (as in reduced tillage systems) reduced the rate of water evaporation early in the growing season compared with bare soil when measured at the 0-4 inch soil depth.

Previous research conducted in 2007 examining effect of strip-tillage on soil temperature and moisture suggested that row-orientation of strips (north/south vs. east/west) could influence soil temperature near the seeding depth prior to planting. Results from this study indicated that the temperature of the soil in the strips that were oriented north/south were 5-8 degrees F warmer than strips oriented east/west. Because the 2007 study was not designed specifically to examine the effect of row orientation, further research was needed to make conclusions about the effect of row orientation on early season soil temperatures in strip and conventionally tilled plots. **The objectives of the 2008 study were: 1) determine if row orientation and seed bed preparation (conventional vs strip tillage) is related to soil warming and soil water content in the early growing season and 2) if differences in soil temperature and moisture has a consequent effect on seedling emergence.**

Materials and Methods

A field experiment was conducted on a Beardon Perella silt loam at a research station near Prosper, ND. The experiment was designed as a randomized complete block with a split plot arrangement; the whole plot consisted of two row orientation planting directions (north/south and east/west) and the subplot consisted of three tillage machines (chisel plow, strip-tiller 1, and strip-tiller 2). Modifications of each strip-till machine are detailed in Overstreet et al., 2008. Individual treatment plots measured 11 feet wide and 30 feet long. Non-Roundup Ready Beta 1305R sugarbeet seed was planted on May 6, 2008. Sugarbeet seeds were placed 1.25 inches deep and were planted to stand in 22-inch row spacing. Agronomic aspects of this experiment are detailed in Overstreet et al., 2008.

Dual-probe heat capacity sensors (DPHCS) were constructed and calibrated according to Ham and Benson (2004) and Heitman et al. (2003). Each sensor consists of two 1.27-mm-outside diameter needles separated by a distance of 6 mm (Heitman et al., 2003). A temperature sensor (thermistor) is placed inside one needle and a heating element (Nichrome 80 alloy) is placed inside the other needle. A data logger was used to control a timed (8 sec) voltage to the heating element. The heat energy moved from the heater across the 6-mm distance through the soil and was measured by the thermistor. The magnitude of temperature rise and the time for maximum temperature rise to occur is a function of volumetric soil moisture. Soil moisture was monitored only during the first 20 minutes of every hour and thereafter the thermistors monitored soil temperature. The 6-mm spacing of the parallel needles allows for precise measurements of temperature and volumetric water content of the soil near the soil surface.

The 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. Eight sensors were placed in each treatment; four in the crop row and four between the rows (inter-row area). Temperature and volumetric water content measurements were measured hourly. Data was stored on a data logger in the field. Approximately every two days the data was downloaded from the data logger and transferred to a computer for analysis. Sensors were carefully removed on September 19, 2008, retaining the soil between the sensor needles to allow determination of volumetric soil moisture content for verification of sensor accuracy.

Stand counts were taken every two days (or as soon as possible after heavy rains) beginning May 19 (14 days after planting) until June 24. The middle two thirty-foot rows were counted for seedling emergence and reported in plants/100feet of row. Final stand counts are reported in Overstreet et al., 2008.

Data was statistically analyzed using JMP IN (5.1.2, SAS Institute Inc). Data was partitioned into weekly increments and analyzed using One Way Analysis of Variance. Each individual sensor was calibrated to the lab-determined volumetric water content. Soil volumetric water content readings from the data logger were transformed using a correction factor determined from Heitman et al. (2003). The simplified equation from Heitman et al. (2003) is

$$\theta = 1/C_w\,[(q/e\pi r^2 T_m) - (P_b C_s)]$$

where θ ($m^3\ m^{-3}$) is the volumetric water content of the soil, C_w ($Jm^{-3}{}^\circ C^{-1}$) is the volumetric heat capacity of water, q ($J\ m^{-1}$) is the given heat input, the maximum temperature rise T_m (°C) measured at a distance r (m) from the line source, P_b ($kg\ m^{-3}$) is the soil bulk density, and C_s ($J\ kg^{-1}\ {}^\circ C^{-1}$) is the specific heat of the soil mineral and organic (solid) constituents

Results and Discussion

Agronomic

The 2008 field season was dry immediately after planting and did not experience a significant rain event until 3 weeks after planting. Throughout the growing season (June 1st through September 30th) the research site experienced 19.5 inches of precipitation, almost double the normal rainfall average (North Dakota Agricultural Weather Network). Early season sugar beet emergence was significantly greater in the strip-tilled plots than in the conventionally tilled plots (Figure 1). However, once the rain began, the conventional tillage treatment caught up and soon exceeded sugar beet emergence in the strip-tillage treatments (Figure 1).

Stand count data do not positively correlate with the in-row volumetric moisture contents—the chisel plowed treatment held significantly more water yet exhibited significantly reduced stand counts. We believe this is due to the strip-tilled plots utilizing moisture from the inter-row area from the previous winter, which was held by the remaining wheat residue (data not shown).

Moisture

When pooled, north-south oriented treatments had significantly more in-row water content than east-west oriented treatments (Figure 2). This may have resulted in the significantly greater emergence recorded during the first three weeks after planting in the north-south oriented plots (Fig. 1).

During week one (May 7-13), chisel plowed treatments had significantly greater volumetric moisture content in-row than either strip-tilled treatment (Table 1, Fig. 3). The mean volumetric moisture contents throughout the first four weeks are illustrated in Figure 3. During week two (May 14-20), Strip-Tiller 1 (ST1) gained in-row moisture and was statistically equal to the chisel plowed treatment. However, the chisel plowed treatment was still significantly greater than Strip-Tiller 2 (ST2) (Table 1). During week three (May 21-27), treatment ST1 lost moisture in-row and was equal to treatment ST2; whereas, the chisel plowed treatment still had significantly more water in-row than both strip-tilled treatments (Table 1) due to low evaporation rates resulting from cooler than average air temperatures. The rain began on May 28 (beginning of week 4) and all treatments became saturated or near-saturated at the end of week 4 and into week 5 (June 2 through 7). During week 4, treatment ST2 maintained significantly lower volumetric water content in-row than the chisel plowed treatment (Table 1).

Based on theories of water movement and field observations, we propose that strip-tilled treatments store more water deeper in the soil profile (> 12 inches) than the chisel plowed treatment. Soil moisture content below the depth of tillage would be expected to be relatively higher in strip-tilled systems as a result of higher soil moisture content in the undisturbed inter-row region at all depths, which serves as a reservoir for water in the strip-tillage system and reduces the area of surface soil subject to evaporation. Since soil dries rapidly to the depth of soil tillage, a greater volume of water evaporates from the soil surface more rapidly in a chisel plowed field where more of the surface is tilled relative to a reduced tillage system (Aase and Tanaka, 1987). In conventionally tilled fields, water is then wicked from below the tillage zone by capillary action and create a gradient of moisture loss throughout the soil profile in a conventionally tilled field to a depth of one or more feet below the soil surface.

Temperature

In-row soil temperatures were not significantly different between tillage equipment or between row orientations. All treatment temperature averages were within 1 degree Fahrenheit of one another for weeks 1 through 4. Given other environmental variables, it is unlikely that such minor differences in temperature could affect seedling germination or emergence rate. When pooled, east-west oriented treatments in-row soil temperatures were numerically higher than north-south oriented treatments throughout the first 4 weeks (data not shown).

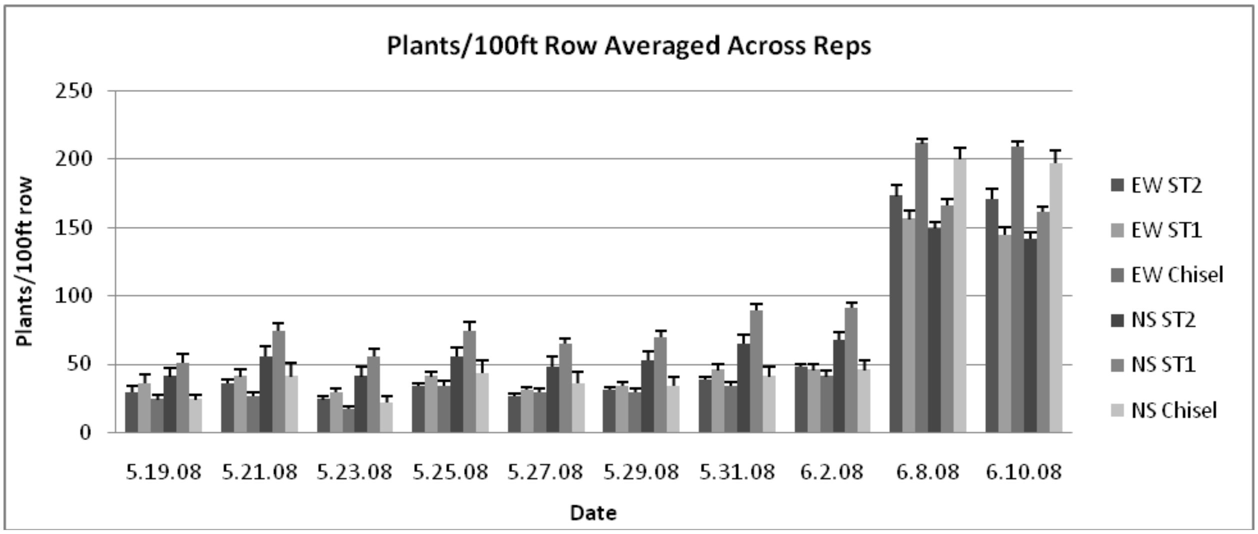

Figure 1. Sugar beet early season stand counts for north-south (NS) and east-west (EW) oriented plots for all tillage treatments (strip-tiller 1, ST1; strip-tiller 2, ST2; and chisel plow) at Prosper Research site. Error bars represent standard error of the data set. Sugarbeet planting occurred on May 6th, 2008.

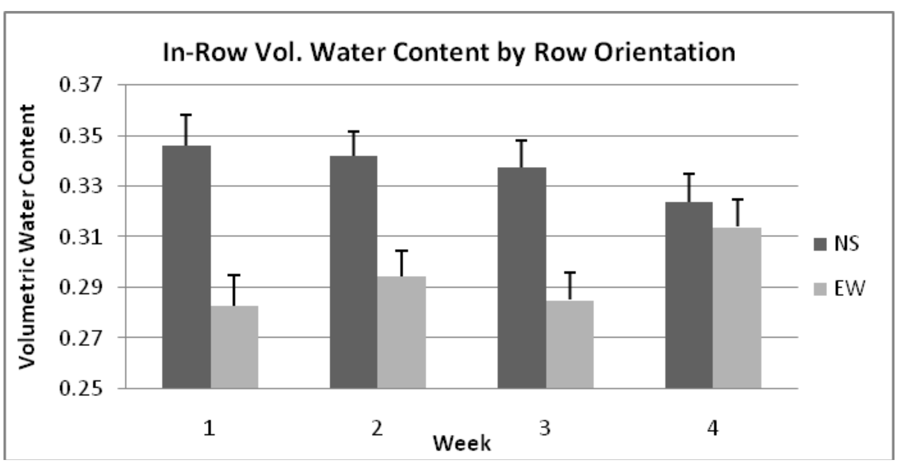

Figure 2. In-row volumetric water content per week in North-South (NS) and East-West (EW) orientated plots. Weeks correspond to 7 day periods starting May 7th. Error bars represent standard error of the data set.

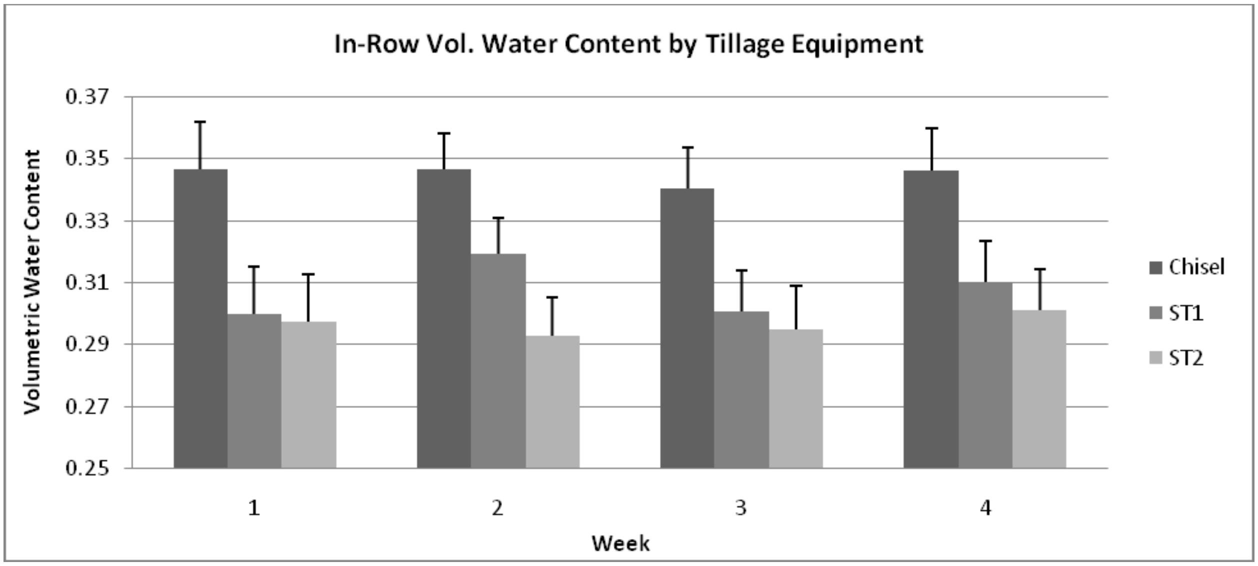

Figure 3. In-row volumetric water content by week for each tillage treatment: chisel plow, Strip-tiller 1 (ST1), and Strip-tiller 2 (ST2). Weeks represent 7 day periods beginning May 7th. Error bars represent standard error of the data set.

Table 1. Week 1-4 (May 7th through June 3rd) in-row mean volumetric water content and mean soil temperatures of all three tillage treatments: chisel plow, Strip-tiller 1 (ST1), and Strip-tiller 2 (ST2). Statistical differences are determined on a per week basis at $P<0.05$. Statistically different treatment effects are those which do not share the same letters.

Tillage	Week	Mean Vol. Water Content			Mean Soil Temp.	
Chisel	1	0.3465	A		50.05	A
ST1	1	0.3000		B	49.88	A
ST2	1	0.2974		B	49.47	A
Chisel	2	0.3465	A		53.80	A
ST1	2	0.3193	A	B	54.27	A
ST2	2	0.2927		B	54.45	A
Chisel	3	0.3404	A		58.50	A
ST1	3	0.3009		B	58.79	A
ST2	3	0.2950		B	59.01	A
Chisel	4	0.3462	A		60.75	A
ST1	4	0.3104	A	B	60.69	A
ST2	4	0.3011		B	60.97	A

Conclusions

In-row soil temperature was not significantly different between row orientation or tillage equipment. 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 the east-west oriented treatments. We believe increased moisture content in north-south oriented rows could be 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 is 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 equipment. The chisel plowed treatment held significantly more water in-row than both of the strip-tilled treatments. However, the strip-tilled treatments held more water between-rows, which may have accounted for the greater emergence during the first three weeks.

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