Fall and Spring Tillage Effects on Sugarbeet Production

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ABSTRACT

The ability to vary primary tillage timing between fall and spring for sugarbeet production could benefit producers by providing flexibility for when field work occurs and may allow earlier planting in the spring. This study was conducted to evaluate the effects of strip (ST) and conventional (CT) tillage conducted in the spring and fall under various N supply levels on sugarbeet production in the northwest U.S. Experimental treatments included tillage time (fall and spring), tillage system (moldboard plow [MP], chisel plow [CP] and strip tillage [ST]), and N supply (5 levels including a control). The study was conducted in Kimberly, ID in 2008 and 2009 on a Portneuf silt loam. Within each year and tillage type, estimated recoverable sucrose (ERS) and root yields were not different between fall and spring tillage timings. These data suggest that sugarbeet growers in the northwest U.S. have flexibility in timing their tillage practices across various tillage systems.

Additional key words: strip tillage, strip till, moldboard plow, chisel plow, nitrogen

Abbreviations: ST = strip tillage, CT = conventional tillage, CP = chisel plow, MP = moldboard plow, ERS = estimated recoverable sucrose, UAN = urea ammonium nitrate

Sugarbeet (*Beta vulgaris* L.) production in the northwest U.S. growing area uses an array of conventional tillage (CT) practices such as moldboard plow, chisel plow, disc, roller harrow, and bedding, often in combination. Strip tillage (ST) in sugarbeet production has become more popular in the area in recent years. In the northwest U.S. it is common for producers to make up to five tillage passes over a field in preparation for planting a sugarbeet crop using CT practices (Evans et al., 2010), whereas with ST, one pass is typical. Potential fuel and time savings with ST compared to CT are attractive to the sugarbeet industry but there are concerns that soil temperature maybe cooler without tillage in the early spring when sugarbeet is planted. With the availability of genetically modified Genuity® RoundUp Ready® (Monsanto Company, St. Louis, MO) sugarbeet seed in 2008, the use of ST became even more attractive as weed control became economically feasible in a reduced tillage system. Reliable post-emergence weed control also reduces the need for spring tillage to incorporate herbicides before planting.

Current ST equipment designs typically incorporate a series of coulters and shanks to create a residue-free zone where the crop can be planted with fertilizers placed below the seed (Overstreet, 2009). The tilled area is approximately 15 to 20 cm wide with the remaining area of the field left undisturbed with residue from the previous crop remaining on the soil surface (Overstreet, 2009).

Often in strip tillage, the surface residue is swept to the side and not incorporated into the soil. With CT practices, the residue is incorporated to varying degrees. The differences in residue incorporation between tillage practices and over time could influence N mineralization dynamics in soils. Regarding the time of tillage, there has been very little research that compared the differences in sugarbeet production factors between fall and spring tillage in the Pacific Northwest. There has been not research comparing strip tillage in the fall and spring on sugarbeet production. Smith et al. (2002) evaluated sugarbeet production under CT in the fall and spring, finding no differences in emergence rates and sucrose yields between the two tillage times. Research has been conducted comparing fall and spring tillage timing for other crops. Hargrove et al. (1982) showed no difference in wheat-soybean double crop yields between a fall and spring CT system (moldboard plow and disk) in the U.S. southeast. Vyn and Raimbault (1993) found that corn yields did not differ when CT (moldboard plow system) was conducted in the fall or spring in Canada. Asae and Pikul (1995) reported no differences in soil nitrate-N (NO3-N) concentrations between a fall and spring CT system (sweep tillage) in a wheat-fallow system in the Northern Great Plains area of the U.S. Strip tillage has been compared to conventional tillage in several studies (Tarkalson et al., 2102; Franzen et al., 2005; Hartman, 1984).

The objectives of this study were to compare selected production factors from sugarbeet grown after fall and spring tillage (CT and

ST) receiving varying N supplies in the northwest U.S. sugarbeet growing area.

MATERIALS AND METHODS

This study contains an unpublished subset of data from a research study conducted by Tarkalson et al. (2012). The research reported in Tarkalson et al. (2012) was conducted on over a three-year period (2008 to 2010) at the USDA-ARS Northwest Irrigation & Soils Research Lab in Kimberly, ID on a Portneuf silt loam (coarse-silty mixed superactive, mesic Durixerollic Xeric Haplocalcids). The treatments evaluated by Tarkalson et al. (2012) were tillage system (strip till [ST], moldboard plow [MP], and chisel plow [CP]), and N fertilizer application rate. The reported tillage system treatments took place in the spring. During the first two years of the study, a fall tillage (Fall 2007 and Fall 2008) was also included as an additional treatment. Due to research constraints, fall tillage was not included during the 2010 growing season, thus only data from the spring tillage were included in Tarkalson et al. (2012). The objectives evaluated by Tarkalson et al. (2012) were to compare ST to conventional tillage (CT) systems, and evaluate the N response of sugarbeet grown under ST in the Pacific Northwest relative to CT systems. The objective of this study was to evaluate the effect of tillage time (fall and spring) and tillage time/N supply interactions within each tillage system on selected sugarbeet production factors. Refer to Tarkalson (2012) for detailed research practices. A summary of the research methods are given here.

A Strip Cat tillage implement was used for ST (Twin Diamond Industries, LLC, Minden, NE). Barley was grown the year previous to the study at each site. Tillage passes for the MP and CP are detailed in Tarkalson et al. (2012) and included one main tillage pass (MP or CP) and multiple other tillage passes (disk, roller harrow, bedding) to prepare the seed bed. The number of tillage passes within each tillage method treatment was based on farmer knowledge and judgment to obtain suitable seedbed conditions.

Prior to N fertilizer application in spring, three soil cores (4.4 cm diameter) in 0.3 m increments to a depth of 0.6 m were taken in 2008, and to a depth of 0.9 m in 2009 in each tillage system main plot of each replication. Soil samples were analyzed for nitrate-N (NO_3-N) and ammonium-N (NH_4-N) after extraction in 2M KCl (Mulvaney, 1996) using a flow injection analyzer (Lachat Instruments, Loveland, CO). These data were used to determine spring soil residual N (NO_3-N and NH_4-N).

In the spring of 2008 (April 25) and 2009 (May 13), N fertilizer (urea ammonium nitrate [UAN, 32-0-0]) was broadcast applied to the soil surface in a single application prior to planting. Fertilizer N rates for both years were 0, 56, 112, 168, and 224 kg N ha^{-1}. A nitrification inhibitor (Agrotain®, Saint Louis, MO) was applied at a rate of 3.5 L Mg^{-1} of UAN prior to application to prevent significant NH_3 losses from the UAN as a result of microbial urease activity on the soil surface. The UAN was irrigated into the soil with 15 mm of irrigation water within three days after application using a solid set irrigation system.

The study was planted to sugarbeet on April 25, 2008 and May 5, 2009 at rate of 128,000 plant ha^{-1}. In 2009, beets were re-planted on June 18 at the same seeding rate as the first planting due to poor emergence across the entire study area after the May 5 planting. Seed varieties planted in 2008 and 2009 were BTS 25RR05 and BTS 27RR10, respectively. Good weed control was obtained during both years by applying glyphosate according labeled instructions.

The study area was irrigated uniformly to meet estimated crop evapotranspiration (ET_c) rates. The ET_c rates were estimated using the Kimberly-Penman ET model (Wright, 1982) using data from an Agrimet weather station (U.S. Bureau of Reclamation, Boise, ID) located on the research farm.

Roots were harvested on October 23 and 24, 2008 and October 22 and 23, 2009. Total root yield was determined from each plot using a load cell-scale on the plot harvester and percent tare data from the tare lab. From each plot, two random 8-root samples were collected and sent to the Amalgamated Sugar Company tare lab in Paul, ID for analysis of percent sugar and quality analysis (nitrate and conductivity). Root yields were combined with the tare lab analysis to determine estimated recoverable sucrose yield (Tarkalson et al., 2012).

Within each year and tillage system, tillage time and nitrogen supply were analyzed using Statistix (Analytical Software - Tallahassee, FL) as a split-plot design. Tillage time (fall/spring) was the main plot and N fertilizer application rate was the subplot. Treatments were replicated three times in 2008 and four times in 2009.

RESULTS AND DISCUSSION

For a detailed results and discussion on the effects of the tillage systems and N rate on sugarbeet production and quality factors, residual soil inorganic N, soil water, N use efficiencies, and N economics refer to Tarkalson et al. (2012). The main conclusions from Tarkalson et al. (2012) were: 1. There were no differences in N response across tillage systems; 2. Strip tillage could be used and decrease tillage costs; and 3. Nitrogen requirements for all tillage practices could be reduced on heavier textured soils compared to past recommendations in the Pacific Northwest of 4 kg N supply Mg^{-1} root yield.

In 2008, there were no differences in soil inorganic N (NO_3-N + NH_4-N) between tillage type and time treatments (Table 1). The average spring residual soil N in the 0-30.5 and 0-60 cm depth (a root restrictive layer was present at 60 cm) was 48 and 97 kg N ha^{-1}. In

Table 1. Probability values (P>F) from analysis of variance for spring soil inorganic N in the soil surface and rooting zone.

Year	Source	df†	Spring Soil NO_3-N + NH_4-N	
			0-30.5 cm	*0-60 cm*
2008	Tillage Type (Type)	2	0.358	0.275
	Tillage Time (Time)	1	0.612	0.087
	Type × Time	2	0.442	0.226
			0-30.5 cm	*0-91.4 cm*
2009	Tillage Time (T)	2	0.239	0.737
	N Supply (NS)	1	0.565	0.926
	T × NS	2	**0.006**	0.960

† Degrees of Freedom

Table 2. Probability values (P>F) from analysis of variance for measured yield related factors.

Tillage	Year	Source	df†	ERS‡	Root Yield	Root Sucrose	Brei Nitrate
ST	2008	Tillage Time (T)	1	0.3177	0.6513	0.5833	0.2825
		N Supply (NS)	4	**0.0001**	**0.0005**	**0.0412**	**0.0135**
		T × NS	4	**0.0078**	0.1260	0.3641	0.2251
	2009	Tillage Time (T)	1	0.4879	0.4334	0.9484	0.6440
		N Supply (NS)	4	0.5366	0.9067	**0.0260**	**0.0012**
		T × NS	4	0.8933	0.8139	0.9717	0.1907
MP	2008	Tillage Time (T)	1	0.2096	0.1396	0.4482	0.7128
		N Supply (NS)	4	0.6312	0.2495	**0.0064**	**0.0277**
		T × NS	4	0.6752	0.6145	**0.0255**	0.7047
	2009	Tillage Time (T)	1	0.2224	0.3143	0.6787	0.0679
		N Supply (NS)	4	0.6355	0.7898	0.3906	**0.0154**
		T × NS	4	0.1550	0.3259	0.7842	0.1285
CP	2008	Tillage Time (T)	1	0.4987	0.3077	0.9896	1.0000
		N Supply (NS)	4	**0.0037**	**0.0204**	0.3761	**0.0000**
		T × NS	4	**0.0467**	0.3847	0.2388	0.0683
	2009	Tillage Time (T)	1	0.3445	0.2188	0.5880	0.4692
		N Supply (NS)	4	0.9079	0.4996	0.2310	**0.0003**

† Degrees of Freedom ‡ Estimated Recoverable Sucrose

Table 3. Estimated recoverable sucrose (ERS) yield, root yield, root sucrose concentration and brei nitrate concentration at for tillage time and tillage type treatments in 2008, 2009, and 2010. Data are averaged over N supply.

Year	Tillage Time	Tillage Type	ERS	Root Yield	Sucrose	Brei Nitrate
			kg ha⁻¹	*Mg ha⁻¹*	*%*	*mg kg⁻¹*
2008	Fall	ST	11,345	74.9	17.7	62.3
	Spring	ST	11,680	76.6	17.9	96.7
	Fall	MP	10,741	70.0	17.9	68.4
	Spring	MP	11,247	73.7	17.7	75.9
	Fall	CP	10,474	69.5	17.6	86.4
	Spring	CP	9,879	65.3	17.6	78.2
2009	Fall	ST	4,164	36.8	14.4	1,184.8
	Spring	ST	4,429	38.6	14.5	1,141.0
	Fall	MP	4,820	41.1	14.9	1,195.0
	Spring	MP	5,004	42.3	14.9	1,083.7
	Fall	CP	4,501	39.0	14.6	1,166.5
	Spring	CP	4,818	41.3	14.7	1,134.8

2009, the tillage time by tillage type interaction was significant at the 0-30.5 cm depth. The significant interaction was due to greater soil inorganic N for ST in the fall (80.7 kg N ha^{-1}) compared to ST in the spring (59.6 kg N ha^{-1}) (Table 1). However, in 2009, there was no difference in soil inorganic N (NO_3-N + NH_4-N) between tillage type and time treatments at the 0-91.4 cm (Table 1). The average spring residual soil N in the 0-30.5 and 0-91.4 cm depth was 71 and 240 kg N ha^{-1}.

Within each year and tillage type, tillage time had no effect on reported production and quality factors (Table 2 and 3). There were four cases of significant tillage time by N rate interactions. In 2008, tillage by N rate interaction for ERS was significant for both CP and ST. These significant interactions were due to differences in how the factors for each tillage time responded to N supply, although at each N supply there were no differences between the fall and spring tillage (Table 2, Figures 1 and 2). Fall and spring tillage resulted in similar sugarbeet yields. The similarity in yields between tillage times was also observed by Smith et al. (2002) for CT. Timing of residue incorporation for the treatments did not result in differences in production factors under the N supply levels in this study. During wet springs,

Figure 1. Interaction between ERS Yield and N supply (Table 1) between the fall and spring strip and chisel plow tillage treatments in 2008. Significant interaction was a result in different relationships between yield and N supply within each tillage time. For each tillage type, differences between tillage times at each N supply were not significant (NS).

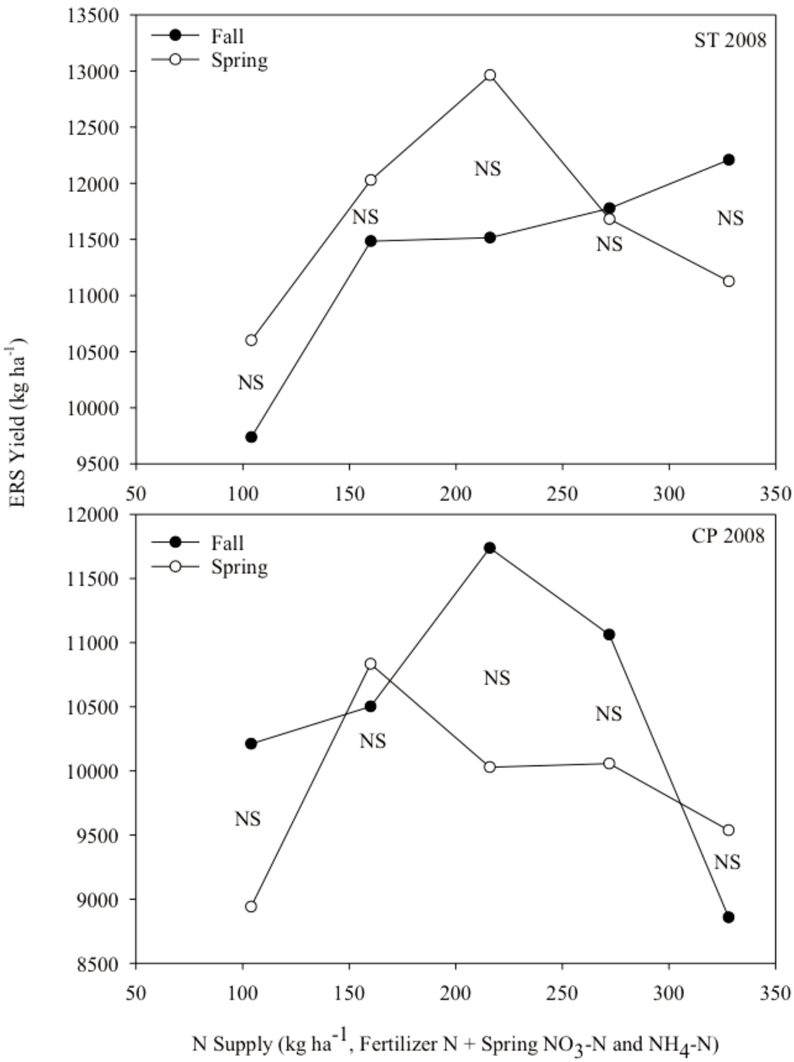
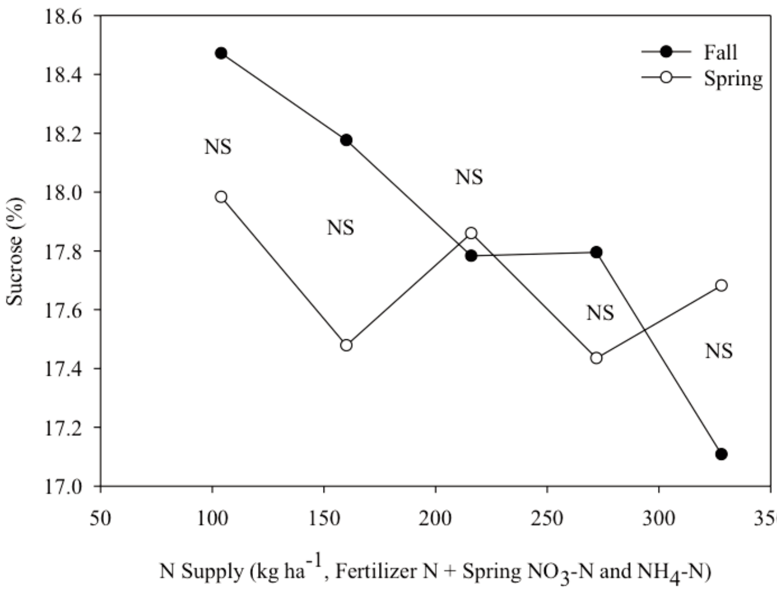


Figure 2. Interaction between Percent Sucrose and N supply (Table 1) for the fall and spring moldboard plow tillage treatment in 2008. Significant interaction resulted in different relationships between percent sucrose and N supply within each tillage time. For each tillage type, differences between tillage times at each N supply were not significant (NS).



fall tillage could result in the ability to plant sugarbeets at an earlier date potentially increasing the chances for higher yield and quality. Late winter and spring weather is highly variable in the northwest U.S. For example, in south central Idaho the percent of annual precipitation between the months of January and April ranges between 30 and 52% (10-year average, Agrimet weather data, usbr.gov/pn/agrimet).

ERS and Brei nitrate was greatly affected by the late replanting date in 2009. ERS in 2009 was less than half of the ERS in 2008. Brei nitrate was more than 10 times greater in 2009. While replanting in June is not typical, it does happen. These results emphasize the effect that late planting has on sucrose yields.

These data suggest that sugarbeet growers in the northwest U.S. Northwest have flexibility in timing their tillage practices across various tillage systems.

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