STRIP TILLAGE AND HIGH-EFFICIENCY SPRAY IRRIGATION METHOD IN A SUGARBEET-MALTING BARLEY CROPPING SYSTEM

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Introduction:

Uncertainty in fuel and labor markets along with growing demands on limited irrigation water resources has increased interest in strip tillage and high-efficiency spray irrigation methods for sugarbeet (*Beta vulgaris* L.)-malting barley (*Hordeum vulgar*e L.) cropping systems. Strip tillage (ST), which is also referred to as zone tillage, involves tillage of only the seed row while leaving stubble between rows undisturbed, offering a compromise between conventional tillage (CT) and no-till systems. Early research results with ST in sugarbeet were favorable (Halvorson and Hartman, 1984; Sojka et al., 1980), but equipment limitations and concerns about weed control prevented widespread adoption. Advances in equipment design and the development of glyphosate-resistant varieties has led to renewed interest in ST, which besides reducing input costs, also protects seedlings from wind-blown soil. Maintaining crop production through more efficient use of rain and irrigation is also a key to helping sugarbeet growers overcome problems resulting from increased competition for water from municipalities, industries, recreation, and environmental uses. Innovative irrigation techniques and management systems will be necessary to increase the cost-effectiveness of crop production, reduce soil erosion, and reduce energy requirements while sustaining or even enhancing crop production, the environment and water use efficiency. A five-year field study was conducted to compare (1) conventional and strip tillage practices (2) mid-elevation spray application (MESA) and low-energy precision application (LEPA) irrigation methods for their effects on yield and quality of sugarbeet and malting barley.

Materials and Methods:

The field study was conducted on a 7-acre site near 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-yr rotation of malting barley and sugarbeet was implemented so that both conventional till (CT) and strip till (ST) sugarbeet were planted following barley. Management of barley was the same regardless of whether CT or ST was used for the subsequent sugarbeet crop. All barley 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. The two cropping system treatments (i.e, CT sugarbeet/ CT barley and ST sugarbeet/CT barley) were randomly assigned to 14 field-length (420 ft) strips each 50-ft wide so that a given strip could be planted uniformly to one crop using one tillage system, but containing four 48 × 80-foot plots. Blocks divided each strip into two halves with each half containing two plots each randomly assigned one of the two irrigation treatments. Each treatment combination was replicated either six (2005, 2007) or eight (2004, 2006, 2008) times according to the unbalanced design.

Strip tillage was accomplished using a custom-built, six-row strip tiller (Schlagel Mfg., Torrington, WY[1]) that leaves alternating 12-inch strips of tilled and undisturbed soil. Each row included a straight coulter in front of a semi-parabolic shank, which was followed by two fluted coulters and a pair of packer wheels. All tillage and fertilizer application was done in the fall, except for a light tillage operation in the spring on CT plots just prior to planting. Urea [$CO(NH_2)_2$] and monoammonium phosphate ($NH_4H_2PO_4$) were applied based on soil test results with typical application rates of about 50 lb P_2O_5 per acre and 110 lb N per acre for both tillage treatments. Fertilizer with CT was broadcast and incorporated into the top 3 inches of soil while with ST, fertilizer was banded during the tillage operation approximately 3 inches directly under the seed row, except in 2004 when the fertilizer band was placed 9 inches below the seed.

Irrigation water was applied using a custom overhead linear sprinkler irrigation system interfaced with a programmable logic controller (PLC) and GPS receiver to allow water application method to be changed from one plot to another as the self-propelled machine traveled across the field (Evans and Iversen, 2005). Each 48-ft wide plot was irrigated with either MESA heads about 3 ft from the canopy and 15 ft apart, or LEPA heads spaced every 4 ft that apply water (bubbler) about 6 inches above the soil surface between every other crop row (24-inch row widths) with minimal wetting of the canopy. Equivalent depths of water were applied with both irrigation methods.

Root samples were collected in late September or early October by hand-digging 5 ft of row from four different rows in the center of each plot for a total of 20 ft per plot. Samples were weighed and analyzed for sucrose content and Brei impurities by the Sidney Sugars tare laboratory (Sidney, MT). Sucrose yield was calculated by multiplying the fresh-weight root yield by the fresh-weight root sucrose concentration adjusted for sugar loss to molasses (SLM), which was calculated using an empirical formula based on Brei Na^+ and K^+ concentrations.

Barley yield was determined by hand-harvesting two 5.4-ft^2 areas randomly selected from the middle portion of each plot. Barley collected was threshed using a stationary thresher (Wintersteiger USA, Inc.; Salt Lake City, UT) and weighed to determine yield. Quality parameters including protein, moisture and plumpness were determined by the Busch Ag grain quality lab (Sidney, MT).

Data analysis was performed using the MIXED procedure of SAS (SAS Institute, 2002). Tillage and irrigation method were considered fixed effects, while year, block, block interactions and strip (main tillage plot) were considered random effects. Cropping system was considered a main plot and irrigation treatment a subplot and appropriate error terms were included in the RANDOM statement. Differences were considered significant if P was ≤ 0.1.

Results:

Weather conditions in three of five years were generally favorable and tillage system did not affect yield in these individual years. A spring windstorm in 2005 caused blowing soil to severely damage sugarbeet seedlings (cotyledon stage to 2 leaf stage) in CT plots while seedlings in the ST plots were relatively unaffected. This resulted in a small, but nonsignificant advantage in plant population for ST relative to CT and a significant yield advantage. In 2006 spring weather conditions were wetter than normal and unincorporated crop residues apparently caused

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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.

ST plots to have higher soil moisture at planting than CT plots, resulting in poorer emergence with ST due to smearing of the seed furrow walls. Surprisingly, ST produced more sucrose than CT in 2006 despite the lower plant population. In two of five years, ST resulted in root sucrose content that was about 0.5 percentage points higher than with CT (data not shown). When averaged over all years, root yield, root sucrose concentration and extractable sucrose yield were not different for the two tillage systems. Irrigation method did not affect sugarbeet yield (Table 1). Irrigation method had little effect on sugarbeet yield, but a significant T × I interaction suggests that MESA was more effective in combination with ST while LEPA was more effective with CT (Table 1).

Table 1. Effect of tillage system and irrigation method on sugarbeet yield parameters. Sidney, MT 2004 – 2008.

Tillage†	Irrigation‡	Sucrose Content	Root Size	Root Yield	Extractable Sucrose¶
		%	lb/root	tons/ac	lb/ac
CT	MESA	19.15	1.49	24.9	9137
	LEPA	19.12	1.59	26.3	9604
ST	MESA	19.27	1.71	27.3	10030
	LEPA	19.08	1.72	26.6	9643
Source		*P > F*			
Tillage (T)		*0.2205*	*0.0255*	*0.5677*	*0.8219*
Irrigation (I)		*0.8888*	*0.2200*	*0.5333*	*0.5942*
T × I		*0.4054*	*0.3546*	*0.0333*	*0.0184*

† CT, conventional tillage; ST, strip tillage

‡ MESA, mid-elevation spray application; LEPA, low energy precision application

¶ Extractable Sucrose = root yield, lbs × (sucrose content – SLM)/100.

Brei impurities and SLM were higher with LEPA than with MESA (Table 2). The difference between irrigation system seemed to be more pronounced under ST than under CT as indicated by the significant T × I interaction for sodium. Possible explanations included effects of tillage and irrigation method on nitrogen use efficiency, release of nutrients (N, K, and Na) from minerals and organic matter, and water availability.

Table 2. Effect of tillage system and irrigation method on sugarbeet Brei impurities and sugar loss to molasses (SLM). Sidney, MT 2004 – 2008.

Tillage†	Irrigation‡	Sodium	Potassium	Amino-N	SLM
		ppm			%
CT	MESA	394.1	1040	121.8	0.777
	LEPA	395.0	1117	125.1	0.812
ST	MESA	386.3	1017	123.4	0.772
	LEPA	436.5	1102	132.2	0.843
Source		*P > F*			
Tillage (T)		*0.5560*	*0.8003*	*0.8055*	*0.6697*
Irrigation (I)		*0.0271*	*<.0001*	*0.0737*	*0.0001*
T × I		*0.0335*	*0.8308*	*0.4136*	*0.1747*

† CT, conventional tillage; ST, strip tillage

‡ MESA, mid-elevation spray application; LEPA, low energy precision application

Barley yield and quality were not affected by irrigation method but yield was 8% lower and protein was 2.7% lower following ST sugarbeet than when following CT sugarbeet (Table 3); however, evidence suggests that this effect may be due to soil variability within the plot area rather than being a true tillage effect. There was no visual indication that residual banded fertilizer from the ST sugarbeet crop had any effect on the uniformity or productivity of the succeeding barley crop.

Table 3. Effect of tillage system and irrigation method on malt barley yield and quality parameters. Sidney, MT 2004 – 2008.

Tillage†	Irrigation‡	Protein	Plumpness	Yield
		%		bu/ac
CT	MESA	12.01	89.65	110
	LEPA	11.92	89.43	114
ST	MESA	11.79	88.70	102
	LEPA	11.51	90.16	104
Source		*P > F*		
Tillage (T)		*0.0188*	*0.8870*	*0.0777*
Irrigation (I)		*0.3535*	*0.6408*	*0.6820*
T × I		*0.4993*	*0.2697*	*0.9064*

† CT, conventional tillage; ST, strip tillage

‡ MESA, mid-elevation spray application; LEPA, low energy precision application

Conclusions:

Results of this study show that fall strip tillage is an effective alternative to conventional practices for sugarbeet producers. Sugarbeet yield with strip tillage equaled that with conventional tillage under typical growing conditions. In severe spring winds, strip tillage effectively protected sugarbeet seedlings from wind-blown soil. Observations from the five year study suggest that spring soil moisture is greater with strip tillage than with conventional practices when offseason precipitation occurs. When weather conditions at planting and during stand establishment are dry, the higher soil moisture in the strip tillage system will likely lead to improved emergence compared to conventional tillage. When weather conditions leading up to planting are wet and cool, planting into strip tillage fields may have to be delayed somewhat to prevent seed furrow wall smearing by planter opener disks. With strip tillage, extractable sucrose was higher with MESA than with LEPA; with conventional tillage, extractable sucrose was higher with LEPA than with MESA. This interaction is not well understood, but may be a result of different irrigation application efficiencies combined with differences in evaporation of soil moisture as influenced by differing levels of crop residues under the two tillage systems. Barley yield and quality were largely unaffected by irrigation method or sugarbeet tillage system.

References:

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