MANAGING CHAFF TRAILS AND NITROGEN FERTILIZER APPLICATIONS IN STRIP-TILL SUGAR BEET PRODUCTION

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ABSTRACT

Idaho sugar beet growers are interested in applying strip-till technologies to their fields, but are concerned about inconsistencies in growth related to small grain chaff trails left behind the combine. There is also interest in how residue cover and the strip-till system affect plant nitrogen (N) use from broadcasted N fertilizer and banded N fertilizer. The objective of this three-year study was to determine how small grain residue level, nitrogen application method, and nitrogen fertilizer rate affect beet yield, beet quality, plant available soil N, N uptake, soil temperature, and soil moisture.

INTRODUCTION

The introduction of strip-tillage to sugar beet production in Southern Idaho has brought challenges as well as opportunities to local sugar beet growers. One challenge is dealing with the chaff (residue) rows left behind by combines. These rows create uneven distribution of residue throughout the field, which can be a challenge for crop production with strip-tillage. Specifically, growers are concerned that the areas will little residue will be droughty and will be more susceptible to weed growth, while areas with heavy residue coverage may have more fertilizer and herbicide binding in the residue and more soil-borne disease pressure under cooler, moister, and higher carbon soil environment.

Another major hurdle in strip-tillage systems is nitrogen application. Because broadcasted fertilizers can no longer be incorporated into the soil, growers have to either broadcast nitrogen fertilizers and rely on irrigation to move the fertilizer into the soil, or the nitrogen fertilizer can be shanked (knifed, banded) in simultaneously during spring strip-tillage. Surface-applying nitrogen fertilizers increase the potential for volatilization losses (conversion of fertilizer ammonium to ammonia gas) and binding with surface residues. Shanking is effective for avoiding these issues, but may be costly for the grower to outfit tillage equipment for fertilizer applications. Using recommended rates of fertilizer may also be problematic for shanking, as the concentrated band of nitrogen fertilizer can potentially burn roots.

The objective of this study is to determine how small grain residue level, nitrogen application method, and nitrogen fertilizer rate affect beet yield, beet quality, plant available soil N, N uptake, soil temperature, and soil moisture.

METHODS

This study was conducted at the UI Kimberly Research and Extension Center over a 3 year period from 2009 to 2011. The experimental design was a 3 by 3 by 2 factorial randomized complete block design (4 replicates), with 3 residue levels, 3 N application rates, and 2 N application methods. Residue levels were established during the previous fall for each year of the study by bailing off small grain residue (wheat, barley, or oat, respectively), weighing residue bails to target levels, and hand spreading the residue over plots. Nitrogen application rates were established at 4 and 6 lbs N/beet ton, using 32 ton/acre as the realistic yield goal. This method caused yearly fluctuations in N fertilizer rates, depending on the soil test N values. A control treatment was also included, where no N source was applied. The two nitrogen application methods were broadcast and shank. For the broadcast treatment, dry urea fertilizer was applied to plots using hand-crank fertilizer spreaders several days after planting, and then irrigated within 2 to 4 days to prevent volatilization losses. For the shank treatment, liquid urea ammonium nitrate was shanked into the soil to a depth of approximately 6 – 8 inches along with a strip-till implement on the same day as planting, using a CapStan fertilizer application system. A StripCat strip till implement was used in 2009; an Orthman Strip Till implement was used in 2010 and 2011. Operation dates, temperature, and precipitation accumulations are listed in table 1.

Table 1. Air temperature (April 20th – October 20th), precipitation, and operation timing summaries for each year of the three-year study.

Year	Strip-till and N shank date	Planting Date	Broadcast N date	Min temp (F)	Max temp (F)	Average temp (F)	Precipitation (inches)	Harvest Date
2009	4/23	4/27	5/4	25	97	61	5.3	10/8
2010	4/20	4/20 & 5/14*	4/26	23	99	60	3.6	10/13
2011	5/22	5/22	5/25	26	96	61	4.1	10/24

*Plants were replanted on 5/14/2010 as a result of a late spring freeze.

Stand counts were conducted every year shortly after germination. Sugar beet production parameters evaluated at harvest included fresh beet yield, average beet weight, sugar content, Brei nitrate concentration (measurement of nitrate impurities that impedes sugar extraction), and estimated recoverable sugar yield (ERS). Composite soil samples were collected within one week after harvest to a 1-foot depth to evaluate the quantity of excess N not utilized by plants. Soil samples were analyzed for nitrate content via KCl extraction and FIA spectrometry. Plant N uptake was evaluated in years 2010 and 2011. Eight tops per plot were harvested in non-yield rows within one week of beet harvest, and beet pulp was collected from 8-10 beets submitted to Amagalmated TARE labs for quality parameters described above. Tops and pulp were measured for total N content via combustion. Soil temperature was measured at 3 and 6 inch depths every 6 hours from May to October using Hobo soil temperature meters for low, moderate, and high residue levels on low N shank treatments (3 replicates per residue level). Soil moisture tension was measured during the same period on the same plots that were use for soil temperature collection at a depth of 12 inches using Hansen meters. This data is not shown in this publication, but will be included in future reporting of this study.

Factorial effects (year, residue level, N rate, and N application method) were determined with the PROC GLM procedure using SAS 9.0 statistical software. Treatment differences were evaluated using Duncan's multiple comparison analysis.

RESULTS AND DISCUSSION

Data collected in 2010 is not shown due to issues related to replanting after a late spring freeze and uneven distribution of residue on plots caused by clogged residue managers. For years 2009 and 2011, results listed in tables were averaged over other effects when there was no statistically significant interaction (at the alpha = 0.05 level) between the factor(s) shown and the other factors (year, N application method, N fertilizer rate, and/or residue level) for the specified parameter.

Nitrogen application method

There was no significant application method X year interaction for sugar content, beet weight, Brei nitrate levels, or soil nitrate, therefore the data was averaged over these variables (table 2). We found that differences in N application method had no significant effect on these four parameters. The lack of application method effect on sugar content, beet weight, and Brei nitrate levels suggests that germinated beets grow similarly, regardless of application method. While differences varied between the two years, we found significantly lower beet stand for broadcast than for shank treatment in both years of the study, and significantly lower beet yield for broadcast than for shank in 2009 (tables 3 and 4). It is possible that the concentrated fertilizer in broadcasted urea granules may be causing seedling burn, which would lower stand counts. In the case of 2009, where the N rates were higher (71 and 142 lb N/acre), it appears that the stand was reduced severely enough to lower yield.

Table 2. Effect of N fertilizer application on specified strip-tilled sugar beet production parameters, averaged over year, N rate, and residue level. Sugar beets were grown in Kimberly, Idaho.

N Application Method	Sugar (%)	Beet Wt. (lb/beet)	Beet Brei Nitrate (ppm)	Soil Nitrate (lb N/acre)
Broadcast	17.0	9.7	88	2.2
Shank	16.9	10.1	84	2.8
p value	0.250	0.486	0.648	0.083

Table 3. Effect of N fertilizer application on specified strip-tilled sugar beet production parameters, averaged over N rate and residue level. Sugar beets were grown in Kimberly, Idaho.

Year	N Application Method	Yield (beet ton/acre)	ERS (lb sugar/acre)	Plant N uptake (lb N/acre)	Stand (# beets/100 ft.)
2009	Broadcast	25.6b	6941a	NA	See
	Shank	30.0a	8154b	NA	Table 4
	p value	*0.0024*	*0.0014*	NA	
2011	Broadcast	29.4	9695	203	216a
	Shank	29.4	9611	231	238b
	p value	*0.961*	*0.813*	*0.151*	*0.025*

Table 4. Effect of N fertilizer application on specified strip-tilled sugar beet production parameters in 2009, averaged over residue level. Sugar beets were grown in Kimberly, Idaho.

N Application Method	N rate (lb N/acre)	Soil + fertilizer N (lb N/acre)	Stand (# beets/100 ft.)
Broadcast	71	140	117a
	142	210	81b
p value			*0.0032*
Shank	71	140	156
	142	210	148
p value			*0.338*

Nitrogen fertilizer rate

Increasing N fertilizer rate had similar effect in both years on sugar content, beet weight, stand, and soil nitrate levels (table 5). Beet weight increased significantly by 23% from 0 to 4 lb N/acre rate, with no significant increase from 4 to 6 lb N/acre. However, beet stand did decrease significantly from 4 to 6 lb N/acre by 9 %, possibly again due to seedling burn and root stunting issues described above. These findings suggest that increasing N rates above 71 lb N/acre at our site may not be effective for increasing strip-till sugar beet yields, due to stand losses that appear at N rates of 124 lb N/acre and above. This is supported by 2011 N rate results, where increasing N rate from 4 to 6 lb N/acre had no significant effect on beet yield (table 6).

Table 5. Effect of N fertilizer rate on strip-tilled sugar beet production parameters, averaged across application method, year, and residue level. Sugar beets were grown in Kimberly, Idaho.

N rate (lb N/acre)	Soil + fertilizer N (lb N/acre)	Sugar (%)	Beet Wt. (lb/beet)	Stand (# beets/100 ft.)	Soil Nitrate (lb N/acre)
0	69 - 82	17.17	7.9a	187a	1.9a
47-71	129-140	16.91	9.7b	184a	2.1ab
124-142	206-210	16.87	10.1b	168b	2.8b
p value		*0.098*	*0.0043*	*0.026*	*0.063*

Table 6. Effect of N fertilizer rate on strip-tilled sugar beet production parameters in 2011, averaged across application method and residue level. Sugar beets were grown in Kimberly, Idaho.

N rate (lb N/acre)	Soil + fertilizer N (lb N/acre)	Yield (beet ton/acre)	ERS (lb sugar/acre)	Beet Brei Nitrate (ppm)	Plant N uptake (lb N/acre)
0	82	24.4a	8025a	50	195
47	129	28.2b	9263b	64	207
124	206	30.6b	10,043b	63	227
p value		*0.0005*	*0.0002*	*0.427*	*0.306*

Residue level

Due to unexpected differences in residue level ranges applied in 2009 (1.2 – 5.3 ton/acre) compared to 2011 (6.9 - 14.8 ton/acre), comparisons of residue levels was separated by year. In 2009, there was a significant N rate X N application method X residue level interaction for the yield, sugar content, ERS, beet weight, soil nitrate, and Brei nitrate response variables, therefore we analyzed each of these parameters individually (table 7). On control plots not receiving N fertilizer applications, there was no significant residue level effect on yield, sugar content, ERS, or Brei Nitrates. This finding suggests that, in the absence of N fertilizer, increasing residue levels from 1.2 to 5.3 ton/acre did not have any impact of sugar yields. However, the addition of N fertilizer did cause significantly affect yield, ERS, and Brei nitrates, depending both on residue level and N application method. For 71 lb N/acre shank treatment, beet yields significantly increased with increasing residue level from 1.2 to 5.3 ton/acre. However, beet yield decreased significantly with increasing residue level for the 142 lb N/acre shank treatment. One explanation may be that the 71 lb N/acre rate supported optimal beet growth, and that the beets were able to grow better increasing residues, which provided a buffer against excessively high temperatures during the summer months. Because the 142 lb N/acre was likely too high and caused stunted growth, these "weaker" beets were possibly unable to thrive under the cool and wet conditions that are also associated with higher residue coverage.

Table 7. Effect of N rate, N application method, and small grain residue level on strip-tilled sugar beet production parameters in 2009. Sugar beets were grown in Kimberly, Idaho.

N rate (lb N/acre)	Soil + fertilizer N (lb N/acre)	N App. Method	Residue (ton/acre)	Yield (beet ton/acre)	Sugar (%)	ERS (lb sugar/acre)	Beet Wt. (lb/beet)	Soil Nitrate (lb N/acre)	Beet Brei Nitrate (ppm)
0	69	None	1.2	26.0bcde	15.7ab	7139bcde	7.2bc	2.1c	59b
			2.7	27.2bcde	15.7ab	7896bcd	7.0bc	4.3bc	44b
			5.3	24.2bcde	16.2a	6710bcde	6.1bc	3.1bc	66b
71	140	Broadcast	1.2	28.1bcde	15.2b	7445bcde	8.2abc	2.1c	91ab
			2.7	28.8bcd	15.4ab	7795bcde	8.5abc	4.7bc	119ab
			5.3	19.4e	15.9ab	5440e	5.2c	3.7bc	73b
		Shank	1.2	30.0bc	15.8ab	8402abc	8.4abc	2.7bc	66b
			2.7	29.4bcd	15.7ab	8263abc	9.0abc	3.1bc	69b
			5.3	38.7a	15.2b	10354a	10.8ab	4.1bc	97ab
142	210	Broadcast	1.2	26.0bcde	15.6ab	7128bcde	8.3abc	4.3bc	117ab
			2.7	28.2bcde	15.6ab	7805bcde	8.6abc	3.4bc	78ab
			5.3	22.2cde	14.9b	6035cde	8.1abc	2.4c	168a
		Shank	1.2	32.4ab	15.3ab	8754ab	12.5a	6.1ab	123ab
			2.7	28.3bcde	15.0b	7462bcde	7.5bc	8.3a	178a
			5.3	20.9de	15.5ab	5689de	5.6c	2.8bc	125ab
p value				*0.003*	*0.145*	*0.002*	*0.138*	*0.010*	*0.031*

For the 2009 broadcast treatment, increasing residue levels from 1.2 to 5.3 ton/acre significantly lowered yields for the 71 lb N/acre rate but not for the 142 lb N/acre rate. It is likely that with more N fertilizer, there was less potential for N to be immobilized by the carbon-rich residues, therefore the residue effect was not as critical for the 142 lb N/acre rate as it was for the 71 lb N/acre rate.

There was no significant interaction between residue, N rate, or N application method for parameters measured in the 2011 portion of this study. The lack of an interaction was possibly due to decreased N fertilizer rates (47 and 124 lb N/acre in comparison to 71 and 142 lb N/acre), which would have reduced the potential for seedling burn and root stunting. Beet yield and beet weight were significantly reduced from 30.3 to 27.1 ton/acre and 11.9 to 10.1 lb/beet, respectively, with increasing residue cover from 6.9 to 14.8 ton/acre (table 8). It is possible that the increased soil moisture detected in the 14.8 ton/acre residue plots may have caused greater nitrate leaching, poor root development, and/or decreased aeration, which would have reduce beet weight (soil moisture data not shown).

Table 8. Effect of small grain residue level on strip-tilled sugar beet production parameters, averaged across N rates and N fertilizer application method. Sugar beets were grown in Kimberly, Idaho.

Year	Residue (ton/acre)	Yield (beet ton/acre)	Sugar (%)	ERS (lb sugar/acre)	Beet Brei Nitrate (ppm)	Plant N uptake (lb N/acre)	Soil Nitrate (lb N/acre)	Beet Wt. (lb/beet)	Stand (# beets/100 ft.)
2009	1.2	See Table 7	See Table 7	See Table 7	See Table 7	NA	See Table 7	See Table 7	130ab
	2.7					NA			138a
	5.3					NA			119b
	p value								*0.030*
2011	6.9	30.3 a	18.3	9912a	66	197	0.9	11.9 a	236
	10.8	27.8 ab	18.4	9162ab	58	224	0.8	10.4 b	221
	14.8	27.1 b	18.4	8908b	57	217	1.1	10.1 b	227
	p value	*0.035*	*0.539*	*0.035*	*0.610*	*0.460*	*0.816*	*0.004*	*0.393*

CONCLUSION

In conclusion, it appears the residue cover, N application method, and N application rate can impact sugar beet production. Residue cover lowered yields and beet weight at high residue rates (greater than 6.9 ton/acre) and when there appeared to be both in cases of too much and too little N fertilizer. Broadcast applications of N significantly reduced stand in both years of the study, and decreased beet yield in one year of the study, suggesting that shanking in N may be helpful to prevent stand and even yield losses. Growers should also be cautious of shanking or broadcasting N at high rates (140 lb N/acre or greater) on areas with residue cover of 5 ton/acre or greater, as we saw dramatic yield losses in these scenarios.