EFFECTS OF ALTERNATIVE MIDSEASON SIDE DRESS NITROGEN APPLICATION METHODS ON SUGAR BEETS

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ABSTRACT

Split applications are an effective way to increase N use efficiency in sugar beet production. Research has shown that the efficiency of a midseason N application is greater when N is placed near the plant row than when broadcast. Comparisons of banded and broadcast midseason applications sometimes result in stark visual differences in response. More information is needed regarding the dynamics of this response and its influence on harvested yield. A study was conducted in Powell, WY under a furrow irrigation system to compare four different methods of applying midseason N. Knife injection, point injection, and coulter injection was used to apply liquid urea-ammonium nitrate (UAN) and a broadcast spreader was used to apply prilled ammonium nitrate (AN) to field length strips. Petiole nitrate concentrations 21 days after N application (DAA) showed that fertilizer N was absorbed more rapidly with the injected UAN than with the broadcast AN. By 55 DAA, petiole nitrate concentrations among methods were similar, with the broadcast treatments having slightly higher levels injection treatments. This indicates a more even and gradual response to broadcast N and this was confirmed by root dry matter accumulation data. Harvested yield was also greatest with the injected UAN, but the benefit was not as great as was observed 38 DAA and the expected pattern was only observed in 2004. Petiole nitrate concentration and N uptake data suggest that N was more limiting at the time of N application in 2004 than in 2005. It was concluded that under conditions of low N availability, placement of N fertilizer near the row is more effective than broadcast applications; however, the resulting yield advantage is not as great as might be expected based on visual response following application. When soil N was abundant at the time of N application, the difference among methods was not as clear.

INTRODUCTION

The sugar beet production is important agricultural industry in Wyoming. Approximately 55,000 acres of sugar beet are planted each year in the state, but industry instability and rising input costs are further increasing the economic pressures felt by growers. The recent rise in energy costs has resulted in a dramatic increase in the price of N fertilizer. The combination of increased transportation and production costs has led to an increased N costs more than 30% since 2000. This makes it even more important to maximize the effectiveness of N inputs. Nitrogen fertilizer management is challenging for sugar beet producers due to the relationship between price, sugar content and root yield (Van Tassell et al., 1996). A profitable sugar beet yield requires a high rate of N, but when N is in excess, the sugar content in the root will decrease (Carter and Traveller, 1981). Given the rising cost of N fertilizer and the importance of careful N management it is important to know how one might most efficiently apply N fertilizer.

Ammonium nitrate has been a popular N source for sugar beet producers in northwest Wyoming for many years, but this product is now commercially unavailable, forcing farmers to use a different N fertilizer. The use of liquid urea-ammonium nitrate (UAN) is becoming more popular due to its handling advantages. Blaylock and Krall (1995) found that point and knife injection of UAN allowed the use of lower application rates than did broadcast applications of ammonium nitrate. It has been visually observed that the growth response to injected UAN is sometimes substantially more rapid than the response to broadcast applications of ammonium nitrate. There is uncertainty regarding whether this early visual response leads to a significant yield advantage at the end of the growing season. Our objectives were to determine (i) the effects of alternative midseason N application methods on yield and quality and (ii) the effect on top and root growth dynamics from N application through harvest.

MATERIALS AND METHODS

A experiment was conducted in 2004 and 2005 at the Powell Research and Extension Center to compare different midseason nitrogen (N) fertilizer application methods. Four different application methods were evaluated for their effectiveness as a means to efficiently add supplemental N to an established sugar beet crop. Dry ammonium nitrate (AN) was broadcast and liquid urea-ammonium nitrate (UAN; 32% N) was injected into the soil using three different methods (knife, point, and coulter injection). UAN was applied according to UW recommendations and AN was applied both at the recommended rate and at a rate 20% higher than the recommendation. The five treatments were replicated three times in strips 11 ft wide by 660 ft long. Petiole nitrate concentration, biomass yield, and total plant N content were determined at different times during the growing season and yield was determined in the fall.

Prilled ammonium nitrated was applied preplant at a rate of 100 pounds N per acre and N treatments were applied when beets were at about the 10 to 12 leaf stage. The total amount of N applied was 220 lb/acre in both years, except for the broadcast+20 treatment where the midseason application rate was increased by 20% for a total of 244 lb N/acre. Irrigation water was applied using a continuous-flow furrow irrigation system. In 2004 germination was initiated by irrigating immediately after planting. This was not necessary in 2005 because precipitation was sufficient to germinate the crop and sustain it until after midseason N was applied. Midseason N was applied on June 18 in 2004 and on June 17 in 2005.

Petioles were collected two different times approximately one month apart. The first were collected 21 days after N application (DAA) and the second 55 DAA. Approximately 30 petioles of recently expanded leaves were taken from the center rows of each six-row plot. Whole plant samples were collected twice during the summer to determine nitrogen uptake and dry matter accumulation. During the first collection of these samples (38 DAA) 15 beets were be collected. Due to the large size of the beets in late August, only eight beets were harvested from each plot for the second harvest (68 DAA). Sugar beets were harvested for final yield determination in early October (117 DAA). The center four rows of each plot were harvested using a production-scale four-row beet harvester and loaded into a truck which was weighed after each plot had been harvested. Two subsamples of ten beets each were collected from each plot for sugar content, tare (adhering soil), and impurities.

RESULTS AND DISCUSSION

Petiole Nitrate Content

The level of nitrate in petioles is an indicator of the N status of the sugar beet plant. Petiole nitrate levels 21 days after N application (DAA) were generally higher for methods that placed the N close to the plant roots than for the granular broadcast methods (Table 1). At 55 DAA this pattern shifted to favor the broadcast treatments indicating that much of the injected N was absorbed shortly after application while the broadcast N was absorbed more evenly between application and harvest. None of the petiole nitrate levels show severely deficient (1000 ppm) N status, but the level observed at 21 DAA in 2004 with the broadcast method (1600 ppm) came close. These low concentrations were not observed in 2005. These data suggest that in 2005 there was more pre-plant N remaining in the soil at the time of midseason N application than in 2004. This conclusion is plausible considering that above normal precipitation in April, May and June 2005 (Table 2) caused the sugar beet seed to germinate without irrigation. This pre-germination irrigation typically requires two to four times the amount of water a post-emergence irrigation does because water must wet the soil surface up to the seed row. As a result, there is likely a substantial amount of N leached from the profile with this initial irrigation. Because this early irrigation was not applied in 2005, there was abundant N available when the midseason N was applied. In 2004, plants were likely at or near N deficiency status when the post-emergence application was made as evidenced by the low petiole nitrate level in the broadcast treatment.

Table 1. Effect of N application method on sugar beet petiole nitrate-N content (ppm) at 21 and 55 days following midseason N fertilization.

		2004		2005	
Method	N Source	21 DAA	55 DAA	21 DAA	55 DAA
		ppm NO_3-N			
Knife inject	UAN	13500 a	3033 b	15932 a	5335 a
Point inject	UAN	13733 a	2567 b	13326 b	5357 a
Coulter inject	UAN	5867 b	2633 b	14154 b	3775 a
Broadcast+20	AN	3700 c	4533 a	10628 d	6192 a
Broadcast	AN	1600 d	2200 a	12203 c	4564 a

Table 2. Monthly precipitation during the 2004 and 2005 growing seasons at Powell, WY.

	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Total
	inches								
2004	0.02	0.24	0.56	0.47	1.07	0.7	0.71	1.05	4.85
2005	0.16	1.92	2.63	1.64	0.15	0.96	0.87	0.78	9.11
21-yr average	0.30	0.58	1.33	1.35	1.01	0.48	0.62	0.55	6.22

Whole Plant Samples

There were visual differences in top growth among the treatments in 2004 and this effect was confirmed by dry matter data showing greater accumulation in tops treated with knife or point injection than in tops where AN was broadcast (Table 3). Coulter injection resulted in an intermediate level of top dry matter production. Root dry matter accumulation showed the same trend as did top dry matter production, but differences were not significant. There was a 74% increase in root dry matter from 38 DAA to 68 DAA, but top dry matter did not increase during the same time suggesting that carbohydrate partitioning favored root production. Injection of liquid UAN close to the plant resulted in significantly more N uptake than broadcast AN, even when the AN application rate was increased by 20%. These data also provide strong evidence that N uptake was slowing by 68 DAA. Specifically, total N uptake did not differ from 38 DAA to 68 DAA and it appears that N was being translocated from tops to roots.

In 2005 the results were quite different than in 2004 (Table 3). We hypothesize that this is due to greater amounts of available N present in 2005 than in 2004 because an early irrigation wan not necessary in the second year. Spring moisture is usually insufficient to cause complete and uniform germination in this region (Table 2). This initial irrigation typically is the largest (i.e. most water applied) of any during the growing season resulting in a high probability that substantial amounts of preplant fertilizer and residual soil N are leached from the root zone during this event. In 2005 there is no indication that growth of the sugar beet plant was being limited at any point by N availability. Dry matter accumulation and N uptake were not affected by N application method. Further, total N uptake was 48% greater in 2005 than in 2004. Moreover, top dry matter (68%) and top N uptake (49%) both increased substantially between 38 DAA and 68 DAA indicating that N availability in the soil was still high and promoting top growth at a time when photosynthate should have been directed toward root development.

Table 3. Dry matter production and N uptake for sugar beets fertilized using five different midseason N application methods. Plants were harvest 38 and 68 days after N application (DAA). Data are averaged over two years, 2004 and 2005.

		Tops		Roots		Total	
	N Source	Dry wt (lb/ac)	N uptake (lb N/ac)	Dry wt (lb/ac)	N uptake (lb N/ac)	Dry wt (lb/ac)	N uptake (lb N/ac)
				2004			
Application Method							
Knife inject	UAN	5085 ab	155 a	7560 a	53 a	12645 a	209 a
Point inject	UAN	5154 a	165 a	7642 a	51 a	12796 a	216 a
Coulter inject	UAN	4192 bc	114 b	7764 a	51 a	11956 ab	165 b
Broadcast+20	AN	3889 cd	114 b	6342 a	40 b	10230 bc	154 b
Broadcast	AN	3119 d	97 b	6026 a	38 b	9145 c	135 b
Harvest Date							
38 DAA		4048 a	138 a	5154 b	38 b	9202 b	177 a
68 DAA		4527 a	120 a	8980 a	55 a	13507 a	175 a
				2005			
Application Method							
Knife inject	UAN	6758 a	226 a	8140 a	59 a	14898 a	285 a
Point inject	UAN	6104 a	198 a	8293 a	54 a	14397 a	252 a
Coulter inject	UAN	7115 a	233 a	8473 a	53 a	15588 a	285 a
Broadcast+20	AN	5952 a	189 a	8287 a	47 a	13449 a	236 a
Broadcast	AN	6104 a	192 a	7497 a	51 a	14477 a	242 a
Harvest Date							
38 DAA		4793 b	167 b	4593 b	18 b	9386 b	185 b
68 DAA		8056 a	249 a	11683 a	87 a	19739 a	336 a

Figure 1 shows the pattern of root growth in 2004 and 2005 with each N application method. Results from 2004 show that the coulter injection method had a higher yield 38 DAA, but this advantage did not last through final harvest, when the knife and point injection methods produced slightly higher yields. The broadcast AN treatments yielded significantly less than the liquid treatments throughout the growing season, but regained nearly all the deficit by the final harvest. In 2005 there were no differences in root yield at 38 and 68 DAA (Table 3) and differences in final yield were not consistent with results in 2004 (Table 4). The 2005 final yield results are not easily explained, but the lack of treatment effect at 38 and 68 DAA data suggest that factors other than N availability were responsible for the differences observed. The petiole nitrate (Table 1) and N uptake (Table 2) suggest that more N was absorbed by the plants more quickly with the injection application methods than with the broadcast methods. Despite this seemingly more efficient uptake, yield was not affected because N availability was apparently never a limiting factor. It appears that in both years there is a slight decrease in root yield from 68 to 117 DAA, but this is likely a result of how roots were harvested on those two dates. Roots were harvested by hand for the two midseason dates (38 and 68 DAA), but were harvested using production scale harvest equipment for the final harvest. Root yield is typically higher with hand-harvest methods than with mechanical methods because the former is nearly 100% efficiency while the latter is not.

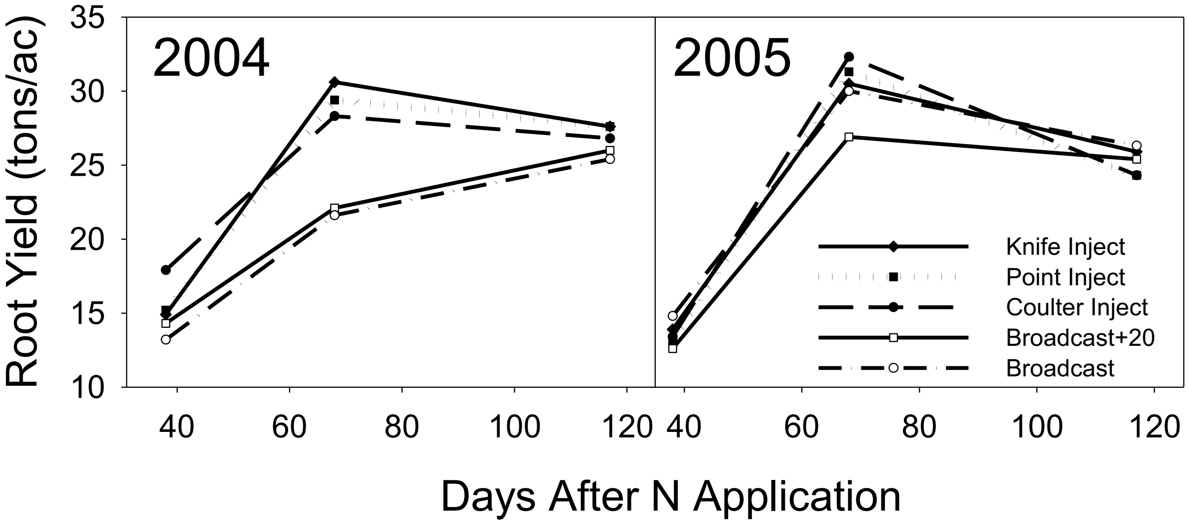

Figure 1. Root yield at one month intervals during the latter half of the growing season. Powell, WY. Measurements were taken 38, 68 and 117 days after midseason N application.

Table 4. Sugar beet final yield as affected by different fertilizer N application methods.

Method	N Source	Final Yield 2004	Final Yield 2005	Sucrose 2004	Sucrose 2005	Sugar Yield 2004	Sugar Yield 2005
		---- tons/ac ----		------- % -------		----- lbs/ac -----	
Knife Inject	UAN	27.6 a	25.9 a	18.3 a	18.4 a	10,119 ab	9509 ab
Point Inject	UAN	27.6 a	24.3 b	19.2 a	18.5 a	10,570 a	8972 c
Coulter Inject	UAN	26.8 ab	24.3 b	18.6 a	18.7 a	9,982 ab	9070 bc
Broadcast+20	AN	26.0 ab	25.4 ab	18.7 a	18.5 a	9,701 ab	9374 abc
Broadcast	AN	25.4 b	26.3 a	18.3 a	18.3 a	9,298 b	9641 a
Average		**26.7**	**25.2**	**18.6**	**18.5**	**9,934**	**9,313**

Final Yield

Final root and sugar yield data for each of the different fertilizer application methods are shown in Table 4. In 2004, results were as expected based on the visual differences in growth observed during the season. The injection applications resulted in the highest root and sugar yield while the broadcast method produced yields that were approximately 10% lower. When the broadcast N application rate was increased by 20%, yield did not differ significantly from the injection methods, despite the fact that root yield with both broadcast methods was significantly lower than with the injection methods at 68 DAA (Figure 1). These results suggest that broadcast application with ammonium nitrate can be as effective as injection of UAN, but that the application rate should be increased by about 20%. Yield results from 2005 are less clear than for 2004. Visual observation and midseason petiole nitrate and whole plant dry matter and N data show no differences among the application methods, yet final root and sugar yield were significantly lower with the point and coulter injection methods than with knife injection and broadcast methods (Table 4).

SUMMARY AND CONCLUSIONS

Climatic conditions were different in the two years of this study. The first year was drier than normal requiring that sugar beets be irrigated to initiate germination. It is likely that some of the preplant N was leached from the profile as a result. Greater than normal precipitation throughout the spring of the second year was sufficient to germinate seeds and support early season growth, eliminating the need for the conventional practice of irrigating to initiate germination, thus preserving much of the preplant N. These circumstances led to conditions of higher soil N availability when the midseason N fertilizer was applied in 2005, while N reserves were beginning to be depleted at the same time in 2004. Consequently, under the 2004 conditions, applying N using the knife, point and coulter injection methods led to a rapid growth response while the response to the broadcast of dry ammonium nitrate was more modest and gradual. Increasing the N application rate by 20% produced the same yield with the broadcast method as was obtained with injection of liquid UAN. In 2005, midseason dry matter data indicated that all application methods performed equally well; however, final yield data showed that the point and coulter injection produced from 1.6 to 2.0 tons/acre lower root yield and about 500 to 650 lb/acre less sucrose than the knife injection and broadcast methods. These results were unexpected and are not easily explained. It seems clear, though, that when soil N reserves are low at the time of midseason N application, the injection methods (knife, point, and coulter) are preferable to broadcast methods because they allow for more rapid N uptake. If the midseason N is applied before soil N is depleted, any of the methods should perform equally well. Results show a disadvantage to the point and coulter injection methods under these circumstances, but the reason for this is not apparent and requires further investigation.

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