Split Application of Nitrogen on Irrigated Sugarbeet

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ABSTRACT

Fertilizer nitrogen (N) on sugarbeet (*Beta vulgaris* L.) must be managed carefully to optimize sucrose yield. Excess N reduces sucrose content and increases impurities, while N deficiency reduces root yield and consequently, sucrose yield. The objective of this study was to compare response of sugarbeet produced using the recommended rate of N with sugarbeet produced using a reduced rate of N with three application schedules. The study was conducted for three years under furrow flood irrigation at Sidney, Montana. Soil was tested to 120 cm to determine residual soil N, and applied N rates were calculated. The recommended rate of N or 80% of the recommended rate was applied under three strategies: 1) a single preplant application, 2) a single postemergence application, and 3) a split application with a small portion applied preplant and the remainder applied post emergence. Petiole nitrate contents were measured several times during the season in two of the three years. Root yield, sucrose content and yield, and root impurities were measured. June petiole nitrate contents were greatest when all N was applied preplant and continued to be greatest in July. By August, no difference in petiole nitrate was detected among treatments, indicating rapid uptake of available N early in the season. Root yield was not affected by N rate or time of application. Sucrose content was reduced when N was applied in a single postemergence application at both N rates. Reduced N resulted in significantly lower amino-N content, but timing of N application had no effect on impurities. Harvest date in all years was relatively early. Greater differences in response to N rate may have been seen at a later harvest date.

Additional key words: nitrogen management, *Beta vulgaris,* root yield, sucrose

Optimizing sugarbeet root yield is a major priority, but optimizing quality has become more crucial to producers and processors in recent years. Increased nitrogen (N) use by producers in the mid twentieth century resulted in greater root yields, but resulted in lower sucrose contents (Haddock, J.L., et al., 1959). Excess N adversely affects crop quality by reducing sucrose content (Carter and Traveller, 1981; Lauer, 1994), increasing impurities (Carter, 1986; Bravo et al., 1989; Lauer, 1994) and increasing crown tissue (Halvorson, et al., 1978). Recoverable sucrose yields are maximized at N rates less than those required for maximum root yields (Adams et al, 1983; Anderson and Peterson, 1988).

Nitrates in the soil are mobile and can leach below the root zone early in the season under irrigation, depriving early season beets of adequate N and N accumulated below early season rooting depths can become available late in the season when high amounts of N can be detrimental to sugarbeet quality. Applying N in increments instead of in a single application is one method that may reduce leaching. Carter and Traveller (1981) applied three rates of N to irrigated sugarbeet in Idaho at four stages during the growing season and concluded that N fertilizer should be applied before planting or during early growth stages so that uptake and plant growth can occur as early as possible. Application of excess N or application late in the season increased top growth at the expense of root growth and sucrose accumulation. Anderson and Peterson (1988) applied increments of N to sugarbeet to supply only enough N for immediate plant needs under sprinkler irrigation in Nebraska and concluded that incremental application increased root development and thus sucrose production. Lamb (1989) split the N application on rainfed sugarbeet in Minnesota with a preplant application and three postemergence applications. He reported no significant differences in root yield or recoverable sucrose, but that root and sucrose yields tended to be greater with preplant and early growth stage applications than yields when N was applied at later growth stages. Eckhoff (1991) split the N application on irrigated sugarbeet in Montana, using the same rate for all treatments, but applying different proportions preplant and the rest at the four- to six-leaf stage. Sucrose content at both early and late harvest dates decreased and impurities increased as the proportion of N applied after emergence increased. Foliar application of postemergence liquid N as 10-34-0 and 28-0-0 did not improve sugarbeet yield or quality in the Red River Valley (Cattanach and Luecke, 1994).

Reduction of N rate would be valuable for reducing fertilizer costs and for reducing the potential for leaching of nitrates into ground water. The objective of this study was to determine if the recommended rate of N for optimum sucrose production in the lower Yellowstone River Valley could be reduced when the N was applied in increments.

MATERIALS AND METHODS

The study was conducted for three years (1991 through 1993) under furrow flood irrigation at the Montana State University Eastern Agricultural Research Center (EARC) at Sidney, Montana. Soil was fine montmorillonitic Typic Argiboroll (Savage silty clay).

The recommended rate of N for sugarbeet in the lower Yellowstone Valley is 5 kg per Mg of expected yield, and calculation for applied N includes N expected to be released from organic matter (33.75 kg/ha for each 1% OM), residual soil N, and N expected to be taken up by residue from the previous crop (Hartman and Halvorson, 1973). Organic matter content of the soil at EARC is 2.5%, so 84 kg/ha was expected to be made available to the crop. Ten kg N/ha are taken up by each metric ton of small grain residue.

Soil was tested for residual soil N to a depth of 120 cm in the fall prior to planting (Table 1). Applied N rates were calculated (Table 1) and three application schedules were tested, with each schedule including both N rates. The schedules were 1) a single preplant application, 2) a single postemergence application at the four- to six-leaf stage, and 3) 11 kg N/ha applied preplant with the remaining N applied at the four- to six-leaf stage.

Table 1. Residual soil N and applied N for sugarbeet grown under two N rates and three application schedules. Total N requirement was calculated for a yield goal of 56 Mg/ha in 1991 and 1992, and for a yield goal of 54 Mg/ha in 1993.

Year	Percent of recommended rate	Total N requirement kg/ha	Residual N 0-60 cm kg/ha	Residual N 60-120 cm kg/ha	N released by OM kg/ha[1]	N uptake by residue kg/ha[2]	Applied N kg/ha
1991	100%	280	- 55	- 56	- 84	+ 54	= 139
	80%	224	- 55	- 56	- 84	+ 54	= 83
1992	100%	280	- 74	- 35	- 84	+ 45	= 132
	80%	224	- 74	- 35	- 84	+ 45	= 76
1993	100%	270	- 23	- 66	- 84	+ 90	= 187
	80%	216	- 23	- 66	- 84	+ 90	= 133

[1] Available N expected from organic matter is 33.75 kg/ha for each percent OM, with 2.5% OM on this farm.
[2] N expected to be taken up by residue of previous crop is 10 kg/ha for each ton of residue.

Experimental design was a randomized complete block with six replicates. Plots were 30.5 m long and 3.7 m wide. The experimental sites were ridged in the fall in 0.6 m rows and liquid N (28-0-0) was injected between the ridges of those plots with N applied preplant (Table 2). The experimental site was deridged in the spring prior to planting. 'Monohikari' sugarbeet was planted to stand at a rate of one live seed per 14.2 cm of row (Eckhoff et al., 1991). Liquid N (28-0-0) was injected between rows of the plots with N applied after emergence, when the sugarbeet plants were in the four- to six-leaf stage. Sugarbeet petioles were collected from each plot in June, July, and August in 1991, and in June and July in 1992. Petiole nitrate contents were determined using a nitrate electrode at the Holly Sugar Company lab in Sidney, MT.

Sugarbeet from nine m of row was harvested from each plot for root yield, tare, sucrose, and impurity evaluations. Yield, tare, and sucrose content were measured by the Holly Sugar Company tare lab in Sidney, MT. Sodium (Na), potassium (K), and amino-N concentrations were determined by Inter Mountain Labs in Sheridan, WY.

Data were analyzed with ANOVA using MSUSTAT (Lund, 1991). Differences among treatments were analyzed using student Newman-Keuls range.

Table 2. Nitrogen application dates, planting dates, and harvest dates of sugarbeet grown under two N rates and three application schedules.

Year	Pre-plant application	Planting date	Post emergence application	Harvest date
1991	18 Oct 90	9 May 91	21 Jun 91	7 Oct 91
1992	21 Nov 91	1 May 92	10 Jun 92	21 Sep 92
1993	9 Apr 93	22 Apr 93	28 Jun 93	27 Sep 93

RESULTS AND DISCUSSION

Petiole nitrate contents were determined in 1991 and 1992 (Table 3). Late June petiole nitrates were greatest in the single preplant N application treatments in both years. The higher petiole nitrate for the preplant N applications persisted into July in 1991 but not in 1992. No differences were seen among treatments in petiole nitrate content by August in either year. These data suggest that applying all N preplant allows for abundant uptake early in the season when rapid top growth is important. This supports Armstrong, et al. (1986), who reported that sugarbeet takes up large amounts of N early in the season and stores it as leaf protein. This protein is remobilized to sustain growth later in the season if uptake from the soil is not adequate. All postemergence applications had been completed by the time the June petiole sampling occurred (one week in 1991, two weeks in 1992). Rainfall in the interval between the time of postemergence N application and the June petiole sampling date was 4.37 cm in 1991 and 3.28 cm in 1992, but sugarbeet in this treatment had not yet taken up as much N as those with 100% N applied preplant. Placement of the N closer to the row may have increased uptake early in the season by sugarbeet under all application schedules.

Table 3. Sugarbeet petiole nitrate contents in ppm under two fertilizer N rates and three application schedules in 1991 and 1992. Petiole samples were not collected in August in 1992. Different letters behind numbers in the same column indicate significant difference at probability <0.05. No N X timing or treatment X year interactions were significant.

Year	Treatment	Petiole nitrate content, Jun	Petiole nitrate content, Jul	Petiole nitrate content, Aug
	100% N rate	23140	9601a	1370
1991	80% N rate	22610	8047 b	1103
	100% N rate	18020	8613	
1992	80% N rate	18230	8287	
	preplant N	24670 b	10760 b	1206
1991	postemergence N	21280a	7166a	989
	split N	22680a	8584a	1516
	preplant N	19500 b	7963	
1992	postemergence N	17900a	10040	
	split N	17100a	7350	

Reducing the fertilizer N rate did not reduce root or sucrose yield (Table 4). The timing of N application did not affect root or sucrose yield, and N rate X timing interactions were not significant. Harvest date was relatively early in all years when compared to date of the main harvest campaign (Table 2). Differences in response to N rate may have been more evident if sugarbeet had been harvested later in the season (Held, et al., 1994). These data indicate that the recommended N rate may be excessive, at least for early harvested sugarbeet. The N recommendation rates, especially for early harvested sugarbeet, should be evaluated further.

Sucrose content of sugarbeet which had all N applied after emergence was significantly lower than that of sugarbeet which had all N applied preplant (Table 4). Splitting the N application resulted in sucrose content intermediate of the sucrose contents of the two other treatments. A trend in which the lower rate of N resulted in greater sucrose content was seen in all years, but was not significant in any year. Sucrose content was reduced when all N was applied postemergence under both N rates (Table 5). Sugarbeet with abundant N had a greater rate of increase in leaf area than sugarbeet with inadequate N (Carter and Traveller, 1981; Milford, et al., 1985). Early leaf canopy production increases the chance for higher sucrose production, because sucrose accumulation begins very early in seedling development and occurs concurrently with root growth

Table 4. Sugarbeet yield and quality across three years under two fertilizer N rates and three N application schedules. Different letters after numbers in the same column indicate significant difference at probability <0.05. No N X timing or treatment X year interactions were significant.

Treatment	Root yield Mg/ha	Sucrose content percent	Sucrose yield kg/ha	Na, ppm	K, ppm	Amino-N, ppm
100% N rate	57.8	17.96	10440	436	1662	165
80% N rate	57.7	18.08	10465	428	1659	152
preplant N	57.7	18.11 b	10506	430	1635	158
postemergence N	57.7	17.92a	10380	434	1676	162
split N	57.9	18.02ab	10472	431	1671	157

(Theurer, 1979). The data in this study support these ideas because sugarbeet that took up the N most rapidly, as evidenced by the petiole nitrate contents, resulted in greater sucrose content (Table 4).

The reduced rate of N resulted in significantly lower amino-N content in the sugarbeet brei (Table 4). This concentration was greatest when the high rate of N was applied in a single application, either preplant or postemergence (Table 5). Other impurities were not affected by either N rate or timing of N application.

Reducing the N rate to 80% of the recommended rate did not reduce sugarbeet root yield or sucrose yield in this study. Yield may have been reduced at a later harvest date, although Lauer (1994) reported that management adjustments for early vs. late harvested sugarbeet were not necessary. Splitting the N application did not improve sugarbeet yield under the conditions of this study. Placement of the N, particularly in the post-emergence applications, may have increased availability earlier in the season. Nitrogen placement and rate should be evaluated further.

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Table 5. Treatment combination means of sugarbeet yield and quality across three years under two fertilizer N rates and three N application schedules. Different letters after numbers in the same column indicate significant difference at probability < 0.05. No treatment X year interactions were significant.

Percent of recommended N rate	Application schedule	Root yield, Mg/ha	Sucrose content, percent	Sucrose yield, kg/ha	Na, ppm	K, ppm	Amino -N, ppm
100%	preplant	58.0	18.02ab	10498	441	1656	168 b
	postemergence	56.8	17.84a	10177	437	1687	168 b
	split N	58.8	18.04ab	10646	429	1643	160ab
80%	preplant	57.4	18.21 b	10515	418	1613	147a
	postemergence	58.6	17.99a	10583	432	1665	156ab
	split N	57.0	18.01ab	10297	433	1699	154ab

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