Sugarbeet Response To Nitrogen At Four Harvest Dates

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ABSTRACT

Early sugarbeet (*Beta vulgaris* L.) harvest in the Northern Great Plains extends the processing period by a month or more. Early harvest starts before optimum sugarbeet yield and quality are achieved, so practices which increase yield or quality of early harvested sugarbeet are valuable. Nitrogen (N) management is an important component of sugarbeet production that may be a way to improve yield and quality of both early and late harvested sugarbeet. Yield and quality of sugarbeet to three rates of fertilizer N were evaluated when harvested at different dates. The study was conducted under furrow flood irrigation from 1992 to 1995 at the Eastern Agricultural Research Center in Sidney, Montana. Applied N was based on a budget that considered residual soil N to 120 cm, N expected to be mineralized from organic matter, and expected yield. Three rates of N, 75%, 100%, and 125% of the recommended N rate (5 kg for each Mg of expected root yield) were applied in random strips through the field prior to planting by knifing liquid N (28-0-0) between rows. Four harvest dates were the beginning of early harvest, the beginning of main harvest, a date midway between the first and third dates, and a date near the end of the main harvest campaign. The lowest N rate usually resulted in greater sucrose content, and greater extraction than the recommended and increased N rates. Economic returns for sugarbeet fertilized with each N rate varied from year to year, but on average, the recommended N rate resulted in greatest income per acre at the earliest harvest date and the latest harvest date, the lowest N rate resulted in greatest income at the later date of the early harvest period, and increased N rate resulted in the

greatest income at the earlier date of the main harvest campaign.

Additional Key Words: *Beta vulgaris* L., harvest date, early harvest, nitrogen.

Sugarbeet in the Northern Great Plains is planted in April or May and harvested in September and October. Early harvest of sugarbeet in September extends the factory campaign, expanding the processing period a month or more. This increases output of the factory and expands acreage needed to meet the added demand. Sugarbeet yield and quality continue to increase until a hard freeze kills the sugarbeet tops. Early harvest usually starts before this occurs. Identification of practices to increase yield and quality of early harvested sugarbeet is important.

Varieties that are more adapted to early harvest may exist, but they have not been identified. Oldemeyer et al. (1977) tested many experimental and commercial hybrids and concluded that harvest date had greater effect than variety on yield, sucrose content, and juice purity. Theurer (1979) reported that sugarbeet lines with greatest sucrose content at the beginning of the growing season also had greatest sucrose content at the end of the harvest season, while those low in sucrose remained low throughout the entire growing period. Different environmental conditions at different growth stages influenced variation in yield and sucrose content among years. An eight-year study in Montana showed that varieties with the greatest economic return early in the season generally had the greatest economic return later in the season, although varieties with greatest economic return in one year were not necessarily the varieties with the greatest economic return in another year (Eckhoff and Bergman, 1997). Lauer (1997) reported that sugarbeet genotypic ranking of recoverable sucrose at early harvest was similar to the genotypic ranking at late harvest.

Because varieties more adapted to early harvest have not been identified, higher yield and quality of early harvested sugarbeet will probably be achieved through better management of population, fertilization, and irrigation rather than varietal choice. Nitrogen (N) management is one of the most important components of sugarbeet production. Optimum N for maximum root yield has been shown to be greater than optimum N for sucrose yield in Montana (Halvorson and Hartman,1975; Adams, et al., 1983), and Wyoming (Blaylock, 1995). Van Tassel et al. (1996) reported that maximizing root yield required the most N, but returned the least income. Too much N also results in low sucrose content and high concentrations of impurities, particularly sodium and amino-N (Halvorson , et al 1979; Carter, 1986). Nitrogen management may be one way to improve sucrose yield and economic return of early harvested sugarbeet. Reduced

N may improve quality of the early harvested sugarbeet, and increased N may improve root and sucrose yield of sugarbeet harvested late in the season.

Lauer (1994) evaluated several cultivars with several N rates and several harvest dates and reported little interaction among cultivar, N rate, and harvest date. He observed tendencies that suggested reduced N might increase quality of early harvested sugarbeet, but concluded that adjustment in management for early harvested sugarbeet was not necessary. In a later study, Lauer (1995) reported no interaction between harvest date and plant density, but reported interactions between harvest date and N rate for recoverable sucrose and suggested that N rates could be decreased for earlier harvest dates.

Held, et al. (1994) determined optimum N rates for Wyoming growers for every harvest date from 10 September to 24 October. Optimum N rate increased 1.125-2.25 kg/ha for each day that harvest was delayed. To make management easier, the authors grouped the harvest dates into one-week intervals, and predicted an optimum N rate for each harvest period. These recommendations did not take length of growing season or climatic conditions into account.

Reports on nitrogen management of sugarbeet harvested at several dates are conflicting and sometimes confusing. The objective of this study was to evaluate the effect of nitrogen rate on yield, quality, and economic return of irrigated sugarbeet when harvested at several harvest dates.

MATERIALS AND METHODS

The study was conducted from 1992 through 1995 at the Eastern Agricultural Research Center in Sidney, Montana, under furrow flood irrigation. Soil on the Eastern Agricultural Research Center is fine montmorillonitic Typic Argiboroll (Savage silty clay) with 8.5 pH and 2.5% organic matter. Previous crop was spring barley in 1993 and 1994, and spring wheat in 1992 and 1995. Following harvest of small grain in the fall prior to planting sugarbeet, residual soil N was measured to a depth of 120 cm in 30-cm increments. Residual soil NO_3-N levels for each year are shown in Table 1. Residual soil NO_3-N levels from 0 to 120 cm in the experimental plots ranged from 94 to 121 kg/ha in 1992, from 58 to 99 in 1993, from 88 to 134 in 1994, and from 101 to 133 in 1995.

The experimental site was fall disked, irrigated, plowed, mulched twice, leveled, and ridged. Applied N rates used in this study were 75%, 100%, and 125% of the rate recommended to irrigated sugarbeet growers in Montana (Christensen, et al, 1976; Lichthardt and Jacobsen, 1992). Recommended N rate in the Lower Yellowstone River Valley is 5 kg for

Table 1. Residual soil N, recommended rate of applied N, planting and harvest dates of sugarbeet. Three rates of N were used, 75%, 100%, and 125% of the recommended rate. First harvest date was at the beginning of the early harvest period, second harvest date was during the last week of the early harvest period, third harvest date was during the first week of the main harvest, and fourth harvest date was near the end of the main harvest.

Year	1992	1993	1994	1995
Planted	May 1	Apr 23	May 5	May 2
1st harvest	Sept 3	Sept 22	Sept 12	Sept 15
2nd harvest	Sept 17	Sept 29	Sept 23	Sept 25
3rd harvest	Oct 1	Oct 6	Oct 4	Oct 9
4th harvest	Oct 13	Oct 13	Oct 20	Oct 17
Residual soil NO_3-N, kg/ha				
0-30 cm	48	36	56	53
30-60 cm	33	21	31	27
60-120 cm	28	32	39	42
0-120 cm	109	89	126	122
Applied N, kg/ha				
75%	9	29	0	0
100%	76	96	59	63
125%	143	163	126	130

each Mg of expected root yield, and is based on a budget that considers residual soil NO_3-N to 120 cm and N expected to be mineralized from organic matter. Yield goal in this study was 53.8 Mg/ha. Nitrogen rates were calculated by subtracting residual soil NO_3-N to 120 cm and N expected to be mineralized from organic matter (33.75 kg N/ha for each 1% of O.M, for a total of 84 kg/ha in this study) from the total N recommendation. Applied N rates for each year are shown in Table 1.

Experimental design was a randomized complete block, with N rates as the treatments. Harvest dates were not randomized because harvest dates were not compared, only response to N rates within harvest dates

were compared. The N rates were applied prior to planting, by knifing liquid N (28-0-0) between ridges. Each N treatment was replicated six times for each harvest date. The site was deridged and the cultivar 'Monohikari' was planted to stand at a rate of one seed every 14.2 cm (Eckhoff, et al, 1991). Plots were 11 m long, and were six rows wide with 60 cm between rows.

The first and third harvest dates were dictated by the harvest campaigns of the factory. Because growers harvest dates are also dictated by the harvest campaigns of the factory, grower dates were used for this study. The first harvest date was during the first week of the early harvest period, the third harvest date was during the first week of the main harvest campaign, the second date was about half the time between the first and third harvest dates, and the last harvest date was near the end of the main campaign (Table 1). Cool, wet weather delayed the start of early harvest in 1993.

One center row of each plot (11 m) was harvested for yield and quality determinations. Sugarbeet roots were weighed in the field, and 12 to 15 roots were collected from each plot for quality determinations. The quality samples were processed for tare and sucrose content in the tare laboratory at the Holly Sugar factory located in Sidney. Brei samples were analyzed for sodium (Na), potassium (K), and amino-N by Inter Mountain Labs in Sheridan, WY. Percent extraction was calculated using a modified Carruthers formula (Carruthers et al., 1962). Data were analyzed using MSUSTAT (Lund, 1991).

RESULTS

Yield and Quality

Sucrose content at all N rates increased with later harvest dates in all years (Table 2). Significant interactions between N rate and year were seen for all but the first harvest date. The recommended rate of N resulted in significantly greater sucrose content than the increased rate of N at the first harvest date in 1992, the third harvest date in 1994, and the last harvest date in 1995. The reduced rate of N resulted in a significantly greater sucrose content than the increased rate of N at the second harvest date in 1993 and 1995, at the third harvest date in 1994, and the fourth harvest date in 1994 and 1995. Nitrogen application rate had little effect on sucrose contents at the first harvest date. The highest N rate resulted in the lowest sucrose content in every case in which significant differences were detected. Sucrose yield can be reduced if too much N is available late in the growing season, because sucrose content is lowered even if root yield is increased (Carter and Traveller, 1981; Eckhoff, 1995).

Table 2. Root sucrose content of sugarbeet as a percent (%) at three N rates and four harvest dates from 1992-1995.

Year	Available N as % of RR[1]	Harvest Date 1	Harvest Date 2	Harvest Date 3	Harvest Date 4
1992	75	16.7	18.6	19.7	20.2
	100	16.8	18.5	19.7	20.6
	125	16.5	18.4	19.9	20.4
$LSD_{0.05}$		0.2	NS	NS	NS
1993	75	16.4	18.3	19.2	19.5
	100	16.3	18.2	19.2	19.4
	125	16.3	18.0	19.3	19.3
$LSD_{0.05}$		NS	0.2	NS	NS
1994	75	16. 9	18.0	18.9	19.3
	100	17.0	17.7	18.7	19.1
	125	16.9	17.8	18.4	18.7
$LSD_{0.05}$		NS	NS	0.3	0.4
1995	75	16.4	17.6	17.6	18.2
	100	16.2	17.3	17.5	18.2
	125	16.2	17.0	17.2	17.7
$LSD_{0.05}$		NS	0.3	NS	0.3
ANOVA, N X Y		NS	0.01	0.01	0.0004

[1] Percent of recommended rate - includes applied N, residual soil N, and N expected to be mineralized from organic matter.

Interactions between N rate and year for root yield were significant only at the first harvest date (Table 3). Sugarbeet with the lowest N rate resulted in significantly lower root yield than sugarbeet with the recommended rate of N and sugarbeet with the increased rate of N at the last harvest date in 1993, and at all harvest dates in 1994. Sugarbeet root yields with the recommended and the highest rate of N continued to increase until

Table 3. Root yield of sugarbeet in Mg/ha at three N rates and four harvest dates from 1992-1995.

Year	Available N as % of RR[1]	Harvest Date 1	Harvest Date 2	Harvest Date 3	Harvest Date 4
1992	75	58.9	66.3	71.2	70.1
	100	60.7	65.2	69.2	70.1
	125	60.9	65.0	70.3	71.7
$LSD_{0.05}$		NS	NS	NS	NS
1993	75	49.7	54.2	55.1	52.9
	100	49.5	55.3	55.6	58.2
	125	52.0	55.1	56.4	56.9
$LSD_{0.05}$		NS	NS	NS	3.4
1994	75	51.5	60.7	62.7	76.2
	100	56.9	67.6	69.4	82.2
	125	54.4	66.1	68.5	80.9
$LSD_{0.05}$		2.5	3.4	2.7	2.0
1995	75	58.7	58.9	64.1	61.6
	100	58.0	55.8	66.5	64.1
	125	60.5	59.8	62.1	63.6
$LSD_{0.05}$		NS	NS	4.7	NS
ANOVA, N X Y		0.012	NS	NS	NS

[1] Percent of recommended rate - includes applied N, residual soil N, and N expected to be mineralized from organic matter.

final harvest date in all years except 1995. Root yield of sugarbeet with the reduced N rate increased until the third harvest date, but continued to increase at the fourth harvest date only in 1994. This suggests that the low N rate is generally not sufficient for sugarbeets harvested during the main harvest campaign.

The lowest N rate resulted in significantly lower root yields at all harvest dates in 1994. Growing conditions were excellent in 1994. Aver-

age root yield in this study in 1994 was 79.7 Mg/ha, as compared to average root yields in 1992 (70.6Mg/ha), 1993 (50.0 Mg/ha), and 1995 (63.1 Mg/ha). The lowest N rate apparently was not sufficient to supply the N needs of the crop under such ideal conditions, even when sugarbeet was harvested at the earliest harvest date.

Halvorson, et al. (1978) reported that excess available N late in the growing season resulted in increased crown tissue, which contains much greater concentrations of sodium (Na) and amino-N than does root tissue. Carter (1986) reported that both Na and potassium (K) uptake were associated with N uptake, with major concentrations of these impurities located in the sugarbeet tops and crowns. Percent extraction is determined from impurity concentrations (Carruthers et al., 1962), with higher impurities, particularly Na and amino-N, resulting in lower extraction. The reduced N rate resulted in sugarbeet with significantly greater extraction than sugarbeet produced with the increased rate of N at both harvest dates during the main campaign in 1993, at the last harvest date in 1994, and at all harvest dates in 1995 (Table 4). The recommended rate of N resulted in sugarbeet with significantly greater extraction than the increased rate of N only in the last harvest dates of 1993 and 1995. Percent extraction dropped to the lowest values seen in this study as the harvest season progressed in 1995. Brei sodium (Na) and amino-N concentrations were very low at the first two harvest dates for all N rates in 1995, rose slightly at the third harvest date, then rose sharply at the fourth harvest date (data not shown). Brei Na concentration was 3 to 4 times greater at the fourth harvest date than the third harvest date. Increased Na and amino-N concentrations may have been caused by disease. *Cercospora* leaf spot was virtually not seen in years prior to 1995, but was enough of a problem in the lower Yellowstone River Valley in 1995 for neighboring growers to treat with fungicide. This study was not sprayed. Smith and Cattanach (1982) reported that all varieties tested had improved quality when an effective fungicide program for *Cercospora* infection was used. Significant N rate X year interactions were detected for all harvest dates except the second.

Economic Return

A relative income as $/ha was calculated, comparing returns from reduced and increased N rates to returns from the recommended N rate (Table 5). It included the early harvest premiums and the cost of applied nitrogen, but no fixed costs. Early harvest premiums were calculated from the standard contract used by the local factory and the local growers. It was based on the amount of time between the beginning of the early harvest period and the beginning of the main harvest campaign, and decreased as harvest date within the early harvest period approached the opening of

Table 4. Percent sucrose extraction of sugarbeet at three N rates and four harvest dates from 1992-1995.

Year	Available N as % of RR[1]	Harvest Date 1	Harvest Date 2	Harvest Date 3	Harvest Date 4
1992	75	92.9	95.4	95.5	95.5
	100	92.8	95.0	95.6	95.8
	125	93.9	95.0	95.4	95.0
$LSD_{0.05}$		NS	NS	NS	NS
1993	75	95.1	95.2	96.1	96.0
	100	93.8	95.3	95.6	96.1
	125	93.5	95.5	95.4	95.7
$LSD_{0.05}$		NS	NS	0.4	0.2
1994	75	95.3	95.8	96.4	96.1
	100	96.1	95.3	96.0	95.7
	125	95.0	95.3	96.0	95.6
$LSD_{0.05}$		NS	NS	NS	0.3
1995	75	97.4	97.2	96.3	91.4
	100	96.8	96.6	94.9	91.6
	125	95.8	96.3	94.2	90.0
$LSD_{0.05}$		1.0	0.6	1.0	0.7
ANOVA, N X Y		0.0002	NS	0.04	0.001

[1] Percent of recommended rate - includes applied N, residual soil N, and N expected to be mineralized from organic matter.

the main campaign. Payments at all harvest dates were also based on sucrose content. Relative values were compared to income from the recommended rate of N.

Reduced N resulted in lower returns than the recommended rate of N at the last harvest date in all years, and at the third harvest date in two of the four years. The reduced N rate resulted in greater returns than the

Table 5. Comparative economic return in $/ha of sugarbeet at three N rates and four harvest dates from 1992-1995, based on sugar price of $0.484/kg. Returns of reduced and increased N rates are compared to return of the recommended rate of N. Value includes early harvest premium and cost of nitrogen of $0.23 per unit.

Year	Available N as % of RR[1]	Harvest Date 1	Harvest Date 2	Harvest Date 3	Harvest Date 4
1992	75	-86.48	108.89	132.84	-72.05
	100	0.00	0.00	0.00	0.00
	125	-81.23	-63.81	80.66	7.90
1993	75	60.38	0.22	10.80	-228.87
	100	0.00	0.00	0.00	0.00
	125	69.01	-83.10	43.19	-122.20
1994	75	-243.42	-219.85	-245.42	-211.85
	100	0.00	0.00	0.00	0.00
	125	-171.63	-82.25	-150.07	-161.33
1995	75	99.17	229.08	-58.47	-87.42
	100	0.00	0.00	0.00	0.00
	125	75.07	80.66	137.53	-167.55

[1] Percent of recommended rate - includes applied N, residual soil N, and N expected to be mineralized from organic matter.

recommended N rate at each of the two early harvest dates in two of the four years. The reduced rate of N produced greater economic returns than the recommended rate half of the time during the early harvest.

The increased rate of N improved economic return at the beginning of the main campaign in all years except 1994, but had poor economic return by the last harvest date, having a similar, or much lower, return than the recommended rate. By the time of the last harvest date, sugarbeet with the highest rate of N often had significantly lower sucrose content than sugarbeet with the other N rates, while root yields were not greater. This, along with increased N costs, resulted in the lower economic return.

DISCUSSION

Growing season conditions vary greatly from year to year, making precise predictions about sugarbeet nitrogen needs difficult. Sucrose contents of the earliest harvested sugarbeet in this study were lowest in 1993 and 1995, even though the earliest harvest date in those years were the latest in this study. Conditions at harvest can also vary greatly, and exact early harvest dates are often not known until a few days or weeks before harvest begins. Thus, recommended rates of applied N must necessarily be general in the lower Yellowstone River Valley, as opposed to recommended rates in other areas (Held, et al., 1995).

Sucrose yield and sugarbeet quality can be reduced if N is available too late in the growing season (Halvorson, et al., 1978; Carter and Traveller, 1981; Carter, 1986; Eckhoff, 1995). A grower may use a reduced N rate for early harvested sugarbeet and not lose yield in some years, but N can be depleted prematurely under excellent growing conditions, as happened in 1994, resulting in reduced root and sucrose yield even at the earliest harvest date. A rate of N above the recommended rate did not increase sucrose yield or gross income of sugarbeet harvested late in the harvest campaign, and usually resulted in lower extraction, particularly at the end of the harvest period. The nitrogen rate currently recommended for sugarbeet in the lower Yellowstone River Valley is sufficient for sugarbeet harvested late in the season, and is usually not detrimental to sugarbeet harvested during the early harvest period.

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