Sugarbeet Response to Nitrogen under Sprinkler and Furrow Irrigation

J. L.A. Eckhoff and C.R. Flynn

Montana State University, Eastern Agricultural Research Center, 1501 N. Central Ave., Sidney, MT 59270

ABSTRACT

Nitrogen (N) management is of utmost importance in production of a high-yielding, high-quality sugarbeet (*Beta vulgaris*) crop. While not enough N can limit yield, too much N can reduce quality, cause surface and ground water contamination and increase input costs. In a previous study, sugarbeet under sprinkler irrigation was shown to have higher impurities and lower extraction than furrow irrigated sugarbeet. The objective of the current study was to evaluate sugarbeet response to varying rates of nitrogen under sprinkler and furrow irrigation. Plots with varying rates of nitrogen were set up under a linear overhead sprinkler irrigation system and under furrow irrigation. Each year, the two irrigation sites were located in the same field and were separated by 15 sugarbeet rows (9 m). Sugarbeet grown under furrow irrigation achieved greatest sucrose yield with available N amounts ranging from 141-197 kg/ha. Under furrow irrigation, sodium and amino-N continued to increase as applied N was increased. This resulted in sucrose loss to molasses continuing to increase with increased applied N, while percent extraction continued to decrease. Sugarbeet grown under sprinkler irrigation achieved greatest sucrose yield when available N ranged from 112-169 kg/ha. Impurities and sucrose loss to molasses were significantly increased in sprinkler irrigated sugarbeet when N at any rate was applied when compared to sugarbeet with no applied N.

Additional key words: *Beta vulgaris,* sugarbeet, sprinkler irrigation, flood irrigation, nitrogen management

Furrow irrigation is currently the predominant irrigation system for sugarbeet in the lower Yellowstone River Valley. The amount of irrigated land in this area is expanding, with overhead sprinkler irrigation being installed because of its greater application and labor efficiency. Land now under furrow irrigation is also being converted to sprinkler irrigation systems.

Good nitrogen (N) management is critical for production of a high-yielding, high-quality sugarbeet crop. Not enough N can limit yield, while too much N can reduce quality (Halvorson, et al., 1978; Adams, et al., 1983). Excess N can also cause surface and ground water contamination (U.S. Department of Agriculture, 1991) and increases input costs.

Carter, et al. (1975) compared sugarbeet production under sprinkler and furrow irrigation with two rates of N and two irrigation treatments. The study was conducted on silt-loam soil in Idaho. Greatest root and sucrose yields were achieved with lower rates of N under sprinkler irrigation, while greatest root and sucrose yields were achieved with higher rates of N under furrow irrigation. Winter (1988, 1990) compared sugarbeet response to various N rates under three irrigation levels on clay loam soil and reported that sucrose loss to molasses (SLM) increased with reduced irrigation because of increased amino-N and possible increased K in the root.

Geleta, et al. (1994) compared furrow, surge, sprinkler and low energy precision application (LEPA) irrigation systems. The furrow and surge irrigation systems both resulted in greater nitrate-N losses to leaching and run-off than the sprinkler or LEPA systems. These results were reported for both fine-textured and coarse-textured soils. Sharmasarkar et al. (2001) compared drip and furrow irrigation on sugarbeet. They reported that sugarbeet yield and sucrose content were greater under drip irrigation than under furrow irrigation. Soil was sandy loam.

An irrigation management study conducted at Sidney, MT, from 1997-2002 compared sugarbeet grown under furrow irrigation and sprinkler irrigation (Eckhoff et al. 2005). Less water was applied under sprinkler irrigation than under furrow irrigation. Sprinkler irrigated sugarbeet consistently had lower sucrose content and greater SLM. Ground water under furrow irrigation had greater nitrate concentration than ground water under sprinkler irrigation. Runoff water from furrow irrigation had greater nitrate concentration than the irrigation water applied to the field. There was no runoff under sprinkler irrigation. The authors concluded that N was lost to leaching and runoff under furrow irrigation while N was not lost under sprinkler irrigation, resulting in more available N at the end of the growing season under sprinkler irrigation.

A sugarbeet crop under sprinkler irrigation on clay soil appears to need less nitrogen because less N is lost to leaching and runoff. The objective of this study was to evaluate sugarbeet response to varying rates of nitrogen under sprinkler and furrow irrigation.

MATERIALS AND METHODS

The study was conducted from 2003-2006 at the Montana State University Eastern Agricultural Research Center in Sidney, MT. Soil is a fine smectitic frigid Vertic Argiustolls (Savage silty clay). Average growing season (April-August) precipitation is 27.3 cm. In the fall prior to each spring planting season, the site was irrigated, plowed, mulched twice and leveled. Residual soil N was measured to a depth of 120 cm in 30-cm increments, so that applied N rates could be determined. Soil NO_3-N levels prior to N application for each year are shown in Table 1, along with previous crops, N application dates, planting dates, harvest dates, irrigation dates, and growing season precipitation for each year. In two years of the study, N was applied in the fall and immediately incorporated, while in the other two years, N was applied in the spring just prior to planting, and immediately incorporated. In all years, N was applied in the form of liquid N, 28-0-0.

Nitrogen rates were randomized with 6 replications under each irrigation system. Nitrogen was applied at rates so that available N, including residual soil N, to 120 cm was 112, 141, 169, 197, and 225 kg N/ha. A check treatment with no applied N was included.

Irrigation systems were next to each other in the field, but separated by 15 rows of sugarbeet, to avoid influence of one irrigation system on the other. Rows were 60 cm wide. Each irrigation treatment was 72 rows wide, with six replications of each N treatment. Furrow irrigation was administered using gated pipe, and sprinkler irrigation was an overhead, low-pressure system. Furrow irrigation delivered 7.6 cm of water with each application, and sprinkler irrigation delivered 2.5 – 3.0 cm with each application. The two irrigation systems were previously compared and shown to result in different quality of sugarbeet when the same N rate was used (Eckhoff et al. 2005). In the current study, irrigation systems were not compared, but N rates within each irrigation system were compared.

Sugarbeet was planted to stand at a rate of one seed every 10 cm (Eckhoff et al, 1991) using a commercial six-row planter with 60 cm between rows. The variety was American Crystal Hybrid 927. When seedlings were in the two- to four-leaf growth stage, plots were trimmed so that plots were 11 m long and six rows wide. Plots were not thinned.

Insecticides, herbicides and fungicides were applied as needed. Plots were also hand-weeded. Plots were irrigated when necessary, as determined by monitoring soil water. Soil water was monitored in 2003 and 2006 using a Paul Brown probe, and in 2004 and 2005 using ECH_2O soil probes that were placed under both irrigation regimes. The ECH_2O probes measured soil water at 30 and 60 cm. The years 2004 and 2005 were dry early in the season and sprinkler irrigated fields were irrigated soon after planting while furrow irrigated fields were not (Table 1). Furrow irrigated sugarbeet were not irrigated immediately after planting because application of furrow flood irrigation water before plant establishment can wash out beds, seed, and seedlings.

One center row of each plot (11 m) was harvested for yield and quality determinations. Plot weight was determined 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 Sidney Sugars factory located in Sidney. Brei samples were analyzed for sodium (Na), potassium (K), and amino-N by AgTerra Technologies, Inc., in Sheridan, WY. Brei samples were frozen until analyses were performed. Percent extraction was calculated using a modified Carruthers formula (Carruthers et al., 1962). Data were analyzed across years for each irrigation system using ANOVA in the MSUSTAT program (Lund, 1991).

RESULTS

Harvest stands under furrow irrigation were not affected by available N (Table 2). Differences in root yield, sucrose, or impurities were not caused by differences in stand under furrow irrigation.

The percent sucrose of furrow irrigated sugarbeet decreased as available N increased (Table 2). Sugarbeet with the greatest available N had significantly lower sucrose content than sugarbeet with 141 kg/ha or less available N.

When analyzed across four years, sugarbeet under furrow irrigation had greatest root yield when available N was in the range of 169-197 kg/ha. Greatest gross sucrose yield and extractable sucrose yield were achieved within the range of 141-197 kg/ha available N (Table 2).

The impurities Na and amino-N increased gradually as more N was applied under furrow irrigation, while K was not affected by N rate (Table 2). This resulted in a gradual increase of SLM and a gradual decrease in percent extraction as available N increased (Table 2).

Stands under sprinkler irrigation decreased significantly as N rate increased (Table 3). This was particularly pronounced when N was

Table 1. Residual soil N and applied soil N on sugarbeet grown under sprinkler and furrow irrigation, Sidney, Montana, 2003-2006.

	2003	2004	2005	2006
previous crop, 1 year prior	malt barley	durum	malt barley	malt barley
previous crop, 2 years prior	potatoes	potatoes	sugarbeets	sugarbeets
residual soil N to 120 cm, kg/ha	51	32	82	52
N application date	Oct 4, 2002	Sep 17, 2003	Apr 26, 2005	May 11, 2006
planting date	Apr 28	Apr 22	Apr 26	May 11
harvest date	Sep 18	Oct 1	Sep 27	Sep 26
growing season precip, cm	22.40	19.35	25.81	30.00
Irrigation dates - flood	Jun 30, Jul 16, Jul 24, Aug 5, Aug 19	Jun 22, Jul 7, Aug 4, Aug 17, Aug 30	Jun 9, Jul 21, Aug 2, Aug 24, Sep 8	Jun 30, Jul 24, Jul 31, Aug 14, Aug 29
Irrigation dates - sprinkler	Jul 1, Jul 12, Jul 17, Jul 24, Jul 31, Aug 12, Aug 26	Apr 29, May 4, May 22, Jun 29, Jul 15, Jul 21, Jul 28, Aug 5, Aug 12, Aug 23, Sep 7	May 5, Jun 20, Jul 8, Jul 14, Jul 20, Aug 1, Aug 15, Aug 23, Sep 6	Jun 30, Jul 5, Jul 13, Aug 3, Aug 15, Aug 30

Table 2. Root yield, sucrose yield, extractable sucrose yield, impurities, SLM, and percent extraction of furrow irrigated sugarbeet with 6 N-rates, Sidney, Montana, 2003-2006.

Available N	Harvest stand	Sucrose	Root yield	Gross sucrose yield	Extractable sucrose yield	Na	K	Amino-N	SLM	Extraction
kg/ha	plants/ha	percent	Mg/ha	kg/ha	kg/ha	ug/g	ug/g	ug/g	percent	percent
†	78300	18.93d	68.3a	12859a	12218ab	242a	1647	142a	0.95a	95.0c
112	79040	18.79bcd	70.6ab	13151ab	12465ab	253ab	1608	165ab	0.97a	94.8c
141	80225	18.84cd	72.4b	13489bc	12758bc	269abc	1625	176b	1.00ab	94.6bc
169	78750	18.63abc	72.8bc	13410abc	12634abc	293bc	1631	201c	1.05bc	94.3ab
197	77930	18.50ab	75.5c	13770c	12938c	288bc	1643	215c	1.07c	94.1a
225	76025	18.39a	70.8ab	12926a	12172a	306c	1632	210c	1.07c	94.1a

† 52 kg/ha in 2006, 82 kg/ha in 2005, 32 kg/ha in 2004, 51 kg/ha in 2003different letters behind numbers in the same column indicate significant difference at probability ≤ 0.05.

Table 3. Root yield, sucrose yield, extractable sucrose yield, impurities, SLM, and percent extraction of sprinkler irrigated sugarbeet with 6 N-rates, Sidney, Montana, 2003-2006.

Available N	Harvest stand	Sucrose	Root yield	Gross sucrose yield	Extractable sucrose yield	Na	K	Amino-N	SLM	Extraction
kg/ha	plants/ha	percent	Mg/ha	kg/ha	kg/ha	ug/g	ug/g	ug/g	percent	percent
†	89590b	19.13c	67.9a	12915a	12240abc	266a	1617a	169a	0.99a	94.8b
112	87315b	18.59b	71.5bc	13208ab	12398bc	321ab	1754b	211b	1.13b	93.8a
141	87810b	18.60b	73.7c	13624b	12791c	314ab	1729b	219b	1.13b	93.9a
169	86230ab	18.47ab	71.5bc	13151ab	12330abc	330b	1711b	226b	1.14b	93.8a
197	81265a	18.34ab	70.3abc	12780a	11981ab	345b	1682ab	221b	1.13b	93.8a
225	80990a	18.20a	69.4ab	12566a	11768a	356b	1699b	231b	1.15b	93.6a

† 52 kg/ha in 2006, 82 kg/ha in 2005, 32 kg/ha in 2004, 51 kg/ha in 2003 different letters behind numbers in the same column indicate significant difference at probability ≤ 0.05.

applied just prior planting (data not shown).

When analyzed across four years, sugarbeets under sprinkler irrigation had greatest root yield when available N was in the range of 112-197 kg/ha. Gross sucrose yield and extractable sucrose yield were greatest with a range of 112-169 kg/ha available N (Table 3). Reductions in stand with the higher rates of N may have caused reductions in root and sucrose yield.

Applied N under sprinkler irrigation resulted in increased Na, K and amino-N concentrations (Table 3). The concentration of Na increased rapidly as available N increased, while K and amino-N concentrations were significantly greater when any N fertilizer was applied than when no N was applied. Under sprinkler irrigation, K and amino-N concentrations increased significantly with the lowest rate of applied N. This resulted in significantly greater SLM and significantly lower percent extraction with any rate of applied N when compared to the untreated check under sprinkler irrigation (Table 3).

DISCUSSION

Higher rates of N significantly reduced harvest stand under sprinkler irrigation but not furrow irrigation. Eckhoff et al. (2005) reported no difference in harvest stand between sugarbeet grown under sprinkler and furrow irrigation. In that study, applied N rates were the same between the two irrigation systems, and over the years, ranged from 150-180 kg/ha of available N. In the current study under sprinkler irrigation, the 2 highest rates of N, 197 and 225 kg/ha of available N, reduced harvest stands to populations significantly lower than those with 141 kg/ha or less available N. There appears to be an interaction between sprinkler irrigation and high N rates. Less water is applied at each irrigation with sprinkler irrigation, so high rates of N may have damaged young sugarbeet plants because it was not leached out of the root zone. Sprinkler irrigation wets foliage and causes conditions conducive to disease infection. Perhaps very high N rates weaken the plants enough to make them more susceptible to disease infection.

The impurities Na and amino-N increased gradually as more N was applied under furrow irrigation, while K was not affected by N rate (Table 2). This resulted in a gradual increase of SLM and decrease in percent extraction as available N increased (Table 2). Any rate of applied N under sprinkler irrigation resulted in increased K, and amino-N concentrations, (Table 3). The concentration of Na increased rapidly as available N increased, while K and amino-N concentrations were significantly greater when any N was applied N than when no N was applied. This resulted in significantly greater SLM and significantly lower percent extraction with any rate of applied N when compared to the untreated check under sprinkler irrigation (Table 3). Halvorson, et al. (1978) reported that excess available N late in the growing season resulted in increased crown tissue, which contained much greater concentrations of sodium (Na) and amino-N than 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. The gradual increase of SLM and decrease of percent extraction under furrow irrigation (Table 2) indicate that as applied N is increased, available N later in the season may increase slightly. The rapid increase of SLM and decrease of percent extraction under sprinkler irrigation (Table 3) indicate that N is available late in the season with any amount of applied N.

Sugarbeet grown under furrow irrigation achieved greatest root and sucrose yield with rates of available N ranging from 169-197 kg/ha. Under furrow irrigation, Na and amino-N continued to increase as applied N was increased. This resulted in SLM continuing to increase with increased applied N, while percent extraction continued to decrease.

Sugarbeet grown under sprinkler irrigation achieved greatest root and sucrose yield with rates of available N ranging from 112-197 kg/ha. Impurities and SLM were significantly increased when any rate of N was applied N compared with no applied N. Sugarbeet under sprinkler irrigation would not respond in this way under circumstances in which the sprinkler is turned on and allowed to run constantly, as is necessary with sandy soil. In that case, leaching and runoff would probably result in loss of available N.

ACKNOWLEDGEMENT

This research was funded in part by Sidney Sugars, Inc, the Montana/Dakota Beet Growers Association, and the Montana Fertilizer Advisory Committee.

LITERATURE CITED

Adams, R.M., P.J. Farris, and A.D. Halvorson. 1983. Sugar beet N fertilization and economic optima: recoverable sucrose vs. root yield. Agron. J. 75:173-176.

Carruthers, A., J.F.T. Oldfield, and H.J. Teague. 1962. Assessment of beet quality. Fifteenth Annual Technical Conf. of the British Sugar Corp. LTD. Nottingham, England.

Carter, J.N., C.H. Pair, and D.T. Westerrmann. 1975. Effect of irrigation method and late season nitrate-nitrogen concentration on sucrose production by sugarbeets. J. Amer. Soc. Sugar Beet Technol. 18:332-342.

Carter, J.N. 1986. Potassium and sodium uptake by sugarbeets as affected by nitrogen fertilization rate, location, and year. J. Amer. Soc. Sugar Beet Technol. 23:121-141.

Eckhoff, J.L.A., A.D. Halvorson, M.J. Weiss, and J.W. Bergman. 1991. Planting populations for nonthinned sugarbeets. Agron. J. 83:929-932.

Eckhoff, J. L.A., J.W. Bergman, and C.R. Flynn. 2005. Sugarbeet (Beta vulgaris L.) production under sprinkler and flood irrigation. J. Sugar Beet Res. 42:19-30.

Geleta, S., G.J. Sabbagh, J.F. Stone, R.L. Elliott, H.P. Mapp, D.J. Bernardo, and K.B. Watkins. 1994. Importance of soil and cropping systems in the development of regional water quality policies. J. Environ. Qual. 23:36-42.

Halvorson, A.D., G.P. Hartman, D.F. Cole, V.A. Haby, and D.E. Baldridge. 1978. Effect of N fertilization on sugarbeet crown tissue production and processing quality. Agon. J. 70:876-880.

Lund, R.E., 1991. MSUSTAT Statistical Analysis Package, Ver. 5.0, Montana Ag. Exp. Sta., Montana State University, Bozeman.

Sharmasarkar, F.C., S. Sharmasarkar, S.D. Miller, G.F. Vamce, and R. Zhang. 2001. Assessment of drip and flood irrigation on water and fertilizer use efficiencies for sugarbeets. Agric. Water Man. 46:241-251.

U.S. Department of Agriculture. 1991. Nitrate occurrence in U.S. waters (and related questions). A reference summary of published sources from an agricultural perspective, Washington, D.C.

U.S. Environmental Protection Agency. 1973. Water Quality Criteria. U.S. Govt. Printing Office, Washington, D.C.

Winter, S. 1988. Influence of seasonal irrigation amount on sugarbeet yield and quality. J. Sugar Beet Res. 25:1-10.

Winter, S. 1990. Sugarbeet response to nitrogen as affected by seasonal irrigation. Agron. J. 82:984-988.