TILLAGE AND NITROGEN MANAGEMENT FOR IRRIGATED SUGAR BEET PRODUCTION IN EASTERN MONTANA

A. Sutradhar, W. Frank, R. Garza, and C. Chen
Eastern Agricultural Research Center, Montana State University, Sidney, MT
cchen@montana.edu (406)433-2208

ABSTRACT

Sugar beet (*Beta vulgaris* L.) is an important cash crop in the Lower Yellowstone River region. Nitrogen management is very critical while farmers are transitioning sugar beet production from conventional tillage to no-till system. The objectives of this study were to: (i) evaluate the effects of fertilizer-N rate and application timing on sugar beet root yield, sugar content, and quality under conventional and no-till managements, (ii) determine N uptake and N use efficiency (NUE) as influenced by fertilizer-N and tillage management, and (iii) evaluate if foliar application of Mg and Zn improves root yield, sugar content, and sugar quality. A field study was initiated in the fall of 2018 on a clay loam soil at the Eastern Agricultural Research center, near Sidney, Montana in a rotation with spring wheat (*Triticum aestivum* L.). Nitrogen management included fertilizer-N applied in the fall of 2018 and in the spring of 2019 at the rate of 120, 160, and 200 lb N ac^{-1} prior to sugar beet planting. A single rate of Mg and Zn was foliar-sprayed with each tillage and N management to evaluate if these two nutrients improve root yield and sugar content. Soil NO_3-N increased with the increase of fertilizer-N rates in the 12 inch deep profile. Although not statistically significant, there was evidence of NO_3-N loss during winter when fertilizer-N was applied in the fall. Sugar beet root yield was greater under no-till management and was not affected by fertilizer N rates. Higher sugar content and quality was achieved at lower fertilizer-N rates. Foliar application of Mg, when applied with a higher rate of fertilizer-N, increased root yield without affecting sugar content and quality. Plant N uptake and NUE were not affected by tillage managements but N uptake increased with the increase of fertilizer-N rates. Higher NUE was achieved with lower rate of fertilizer-N application. After one year of observation, data indicated that no-till management can be a promising cultural management in the eastern Montana and the western North Dakota area. The study will be continued in the 2020 growing season to support the data we have collected in 2019 to make robust conclusions in decision making.

INTRODUCTION

In modern agriculture, the most important challenge is to maximize the crop production with minimum farm inputs. Sugar beet is an important cash crop for eastern Montana and western North Dakota. In Montana, sugar beet harvested from 42,700 acres with a production value of more than $57.7M in 2017 (NASS, 2019). Sugar beet growers get paid by tonnage and sucrose concentration in the root. Therefore, it is important to increase sugar concentration in addition to root yield.

Nitrogen management is very critical for sustainable sugar beet production. Adequate N is needed for optimum growth and root development. Farmers tend to apply fertilizer-N based on yield goal and greater economic return which often lead to over application of fertilizer-N. Excessive uptake of NO_3-N from soil can stimulate excessive canopy growth but reduce sugar content in the roots (Afshar et al., 2019). Higher rate of N is also associated with higher concentration of ammonium-N including Na and K in the brei, which in turns reduce the overall extractable sugar.

All N sources are very mobile in the soil, and N in excess of crop need may lose to ground and surface water through leaching. The amount of N lost is an increasing concern for the environment and human health. Therefore, it is needed to minimize N loss and improve NUE for a sustainable agricultural production system. The most efficient way to improve nitrogen use efficiency and minimize N leaching is to determine the best N application timing with appropriate rates.

Fall fertilizer-N application can benefit farmers in many ways including extended time of fertilizer application, lower input cost, and better soil conditions for farm equipment operations. Soil temperatures are usually below 50 degrees F in late October and early November. The cool soil temperature in fall helps delay nitrification to applied ammonium-based N fertilizer (Havlin et al., 1999). Under low cool temperature, applied N fertilizer is still in the NH_4^+ form which is not subject to leaching or denitrification. In contrast, Time is usually limited in the spring for field work especially in cooler temperature in the eastern Montana.

Most sugar beet fields in Montana are in conventional tillage management. No-till farming offers a range of benefits including improving soil health, help soil nutrient balance, and suppress weed and disease pressure. With less farm operations and off-farm input net profits can be maximized. Some sugar beet producers in eastern Montana has switched to no-till system, however, facing a number of challenges. One of the challenges is the adoption of efficient N management strategies. Not enough work has been done and there are limited data available on how no-till and N managements interact with each other and affect sugar beet production.

This research is intended to address the challenges in N and tillage managements for sugar beet production and will identify the best management practices to maximize farm profit and promote environmental sustainability. The objectives of this study were to: (i) evaluate the effects of N rate and application timing on sugar beet root yield, sugar content, and sugar quality under conventional and no-till managements, (ii) determine N uptake, and N use efficiency as influenced by N and tillage managements, and (iii) evaluate if foliar application of Mg and Zn improves root yield, sugar content, and sugar quality. The soils in eastern Montana are predominantly high in Mg, however, conditions such as cooler temperature, application of ammonia-based N fertilizers, and higher concentration of competing cations (K^+ and Ca^{+2}) may lead to a response to supplemental Mg application in sugar beet (Hermans et al., 2005).

Table 1. Initial soil test results. Composite soil samples were collected from conventional tillage (CT) and no-till (NT) managements from 12 inch depth in the spring before sugar beet planting.

Tillage	pH	OM	NO_3-N	P-Olsen	K	Ca	Mg	Na	Zn	Fe	Mn	Cu	B	CEC
		%	ppm											meq/100g
CT	8.2	3.7	38	17	431	6050	615	148	0.57	8.1	6.08	1.18	1.8	37.1
NT	8.3	3.3	32	15	351	6209	614	156	0.54	8.5	5.74	1.33	1.8	37.7

MATERIALS AND METHODS

The experiment was performed in 2019 under sprinkler irrigation system near Sidney, MT. The soil at this site is a deep, well drained, nearly level savage clay loam (fine, smectitic, frigid Vertic Argiustolls) containing 210 g kg^{-1} sand, 460 g kg^{-1} silt, and 330 g kg^{-1} clay (Afshar et al., 2019). Initial composite soil samples were collected to determine the soil fertility status and are given in Table 1. The site had 10.4 inch of precipitation from April to August and was irrigated with 9.81 inch of water from planting to harvesting. Mean monthly air temperature ranged from 44 degrees F in April to 67 degrees F in August. Sugar beet trials has been in a rotation with spring wheat.

Table 2: Significance of the main effects of tillage management (Till), N application timing (Time), fertilizer treatments (Tmt) and their interactions of the ANOVA for soil NO_3-N, root yield, sugar content and quality, nutrient uptake, and nitrogen use efficiency in 2019 at the Eastern Agricultural Research Center near Sidney, MT.

Parameter	Till	Time	Tmt	Till×Time	Till×Tmt	Tmt×Time	Till×Time×Tmt
	-- *P* > F --						
Soil NO_3-N†	<0.01	0.22	<0.01	0.19	0.01	0.09	0.32
Stand count	<0.01	0.68	0.32	0.55	<0.01	0.46	0.25
Root yield	<0.01	0.84	0.02	0.09	0.83	0.49	0.93
Sugar content	0.47	0.79	<0.01	0.01	0.80	0.97	0.33
Sugar yield	<0.01	0.85	0.16	0.47	0.83	0.60	0.84
Sodium conc.	0.20	0.68	0.03	0.33	0.33	0.23	0.85
Potassium conc.	0.34	0.15	<0.01	0.22	0.68	0.67	0.94
Amino-N conc.	0.14	0.06	<0.01	0.44	0.36	0.70	0.29
Impurity value	0.49	0.18	<0.01	0.39	0.84	0.48	0.98
Sucrose loss	0.49	0.18	<0.01	0.39	0.84	0.48	0.98
Ext. sugar	<0.01	0.90	0.21	0.53	0.84	0.59	0.84
Ext. sugar yield	<0.01	0.89	0.21	0.53	0.84	0.59	0.84
N uptake	0.38	0.09	<0.01	0.65	0.57	0.64	0.95
Mg uptake	0.14	0.06	<0.01	0.77	0.58	0.74	0.67
Zn uptake	0.56	0.07	0.35	0.92	0.60	0.99	0.69
NUE	0.08	0.08	<0.01	0.14	0.90	0.02	0.70

† Composite soil samples were collected from 12″ depth.

The experiment was set up in a split-split-plot randomized complete block design with four replications. Conventional tillage and no-till managements were the main plots. Sub-plots were two fertilizer-N application timings. Fertilizer-N was applied in October 2018 for fall application and applied in April 2019 for spring application. Sub-sub plots consisted of three N rates (120, 160, and 200 lb N/ac) and foliar application of Mg and Zn. Each plot was 24 ft wide and 30 ft in length with 5 ft alley ways between plots. The row spacing was 24 inch which means each plot had 12 rows of sugar beets. All 12 rows received fertilizer-N treatments. To avoid excessive application of fertilizer-N, the rates of N were adjusted with the residual soil NO_3-N to a depth of 60 cm measured in the fall of the previous year. Fertilizer-P was applied based on the Montana State University recommended guidelines as initial results indicated low P in the soil. Soil test K was within the sufficiency range and therefore, fertilizer-K was not applied. Soil test Mg was considered to be above the sufficiency range for many agronomic crops. Zinc was not deficient but close to the borderline to be considered deficient for other crops. All soil applied fertilizers were broadcast.

Three separate rows were used for single rate of Mg (1.0 lb Mg/ac) and Zn (0.8 lb Zn/ac) application. Chelated EDTA-Mg and EDTA-Zn liquid fertilizers were used as sources of Mg and Zn and were sprayed with a CO_2 backpack sprayer when the plants were at least 8-10 leaf stage.

Glyphosate was applied at the rate of 24 oz/ac three times for weed control including a preplant application. Inspire XT was aerial sprayed at the rate of 8.5 oz/ac in August to control *cercospora* leaf spot disease.

Sugar beet variety Crystal S696 GEM 100 was planted on April 24th with a no-till drill. Measurements were taken throughout the growing season and at the final harvest to determine soil NO_3-N, crop stand, root yield, sugar content and quality, nutrient uptake, and nutrient use efficiency. A composite soil sample of at least three cores were collected from each plot from 12 inch depth to measure available NO_3-N before planting sugar beet. Sub-samples of roots and shoots were dried in the oven, ground, and analyzed for nutrient concentrations. Sugar content and analysis of impurities were conducted using standard laboratory procedures. Nitrogen removed by the roots was used to calculate NUE. Final sugar beet was harvested on September 24th.

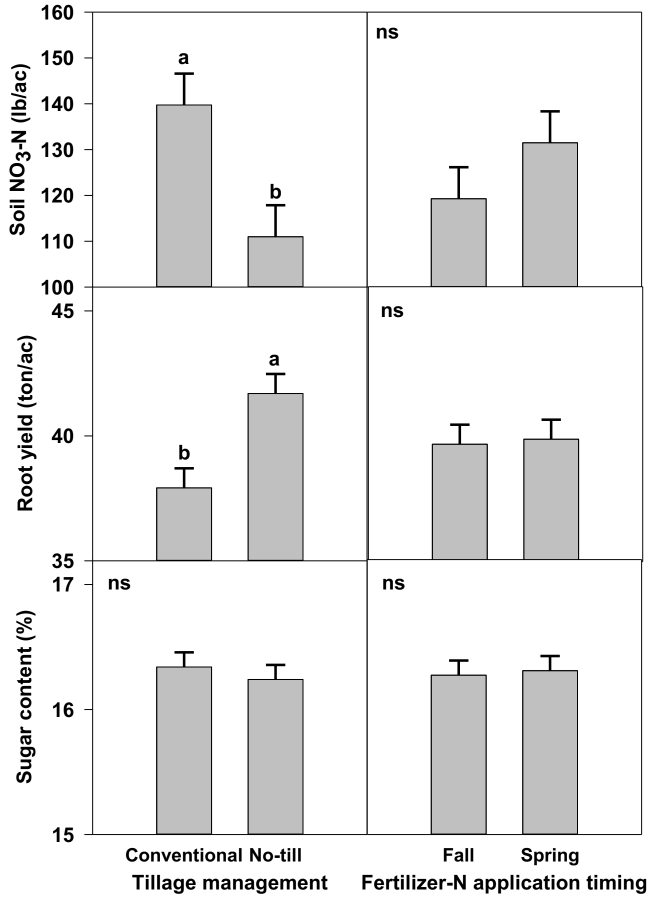

Fig. 1: Soil NO_3-N concentration at 12 inch depth and sugar beet root yield and sugar content as influenced by tillage and fertilizer-N application timing. Error bars are standard errors of the mean. Means with the same letters are not significantly different at $P \leq 0.05$.

All data were analyzed using GLIMMIX procedure of SAS 9.4 software.

RESULTS AND DISCUSSION

A summary of the significance of the main effects of tillage managements, N application timings, fertilizer treatments, and their interactions for the ANOVA for the measured parameters are presented in Table 2.

Soil NO_3-N concentration was affected by both tillage managements and fertilizer-N rates but was not affected by whether N was applied in the fall or in the spring (Fig. 1). Conventional tillage had higher soil NO_3-N on the top 12 inch compared to no-till but in both tillage managements, application of higher rates of fertilizer-N increased soil NO_3-N. The exception was that under conventional tillage management, soil NO_3-N was similar when fertilized with 200 and 160 lb N/ac and greater compared when fertilized with 120 lb N/ac. In contrast, under no-tillage management, soil NO_3-N was greater when fertilized with 200 lb N/ac compared to when fertilized with 160 and 120 lb N/ac. Although not statistically significant, across tillage and fertilizer-N rates, at least 12 lb N/ac was lost when N was applied in the fall compared to N applied in spring.

Both conventional tillage and no-till sites had good sugar beet stand. Compared to no-till, conventional tillage had higher plant density (40888 plants/ac) indicating higher seed germination rate, but the plant density in the no-till (34082 plants/ac) was considered to be normal.

Sugar beet had about 4.0 ton/ac higher root yield under no-till management compared to conventional tillage (Fig. 1). Fertilizer-N application timing and rate had no effect on root yield, however, when Mg was applied with higher rates of N, root yield increased, indicating Mg may have effects on root yield only when N was applied at higher rates (Fig 2a). Magnesium deficiency induced by other cations has been reported in the literature for many crops. This induced Mg deficiency is caused due to reduced Mg uptake by plants in the presence of high rate of K^+, NH_4^+, Ca^{+2}, and Mn^{+2} ions in the soil (Marschner, 2002). Ammonia-based fertilizer urea for N was applied in this study. Fertilizer-N might still be in the NH_4^+ form in the cool spring when sugar beet was planted which is conducive to the weather condition in eastern Montana. There was no evidence of root yield increase by the application of Zn.

Sugar concentration was slightly higher when fertilizer-N was applied in the spring under conventional tillage management (data not shown). Across tillage managements, concentration of sugar decreased with the increase of N rates (Fig. 2b). Application of Mg and Zn did not improve sugar concentration in the root. Because root yield was higher under no-till system and the concentration of sugar did not differ between the two tillage managements, sucrose yield was higher under no-till than conventional tillage management.

Sugar impurities such as concentration of Na, K, and amino-N in the root extract generally increased as nitrogen rate increased. The difference between N application timings on the root amino-N was very close to the significant level (P = 0.06) where concentration of

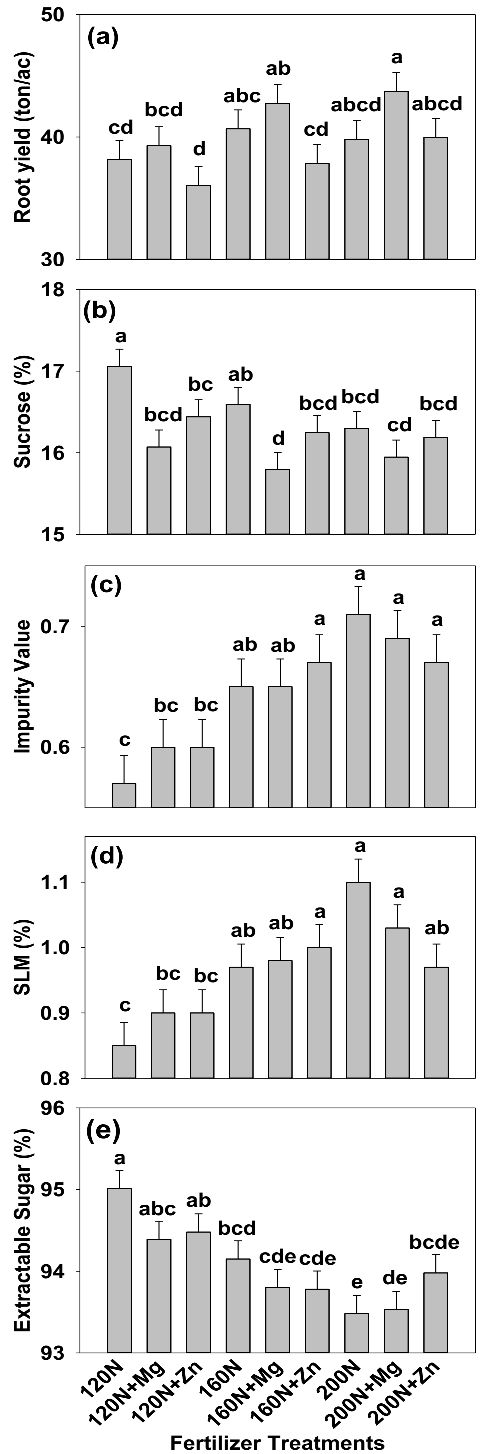

Fig. 2: Sugar beet root yield (a), sugar content (b), impurity value (c), sucrose loss to molasses (d), and percent extractable sugar as influenced by fertilizer application. Error bars are standard errors of the mean. Means with the same letters are not significantly different at $P < 0.05$.

amino-N increased when fertilizer-N was applied in the spring (data not shown). This was because soil NO_3-N was higher when fertilizer-N was applied in the spring. Likewise, impurity value and sucrose loss to molasses (SLM) were also increased with the increase of N rates (Fig. 2c and 2d). These results indicated that higher concentration of soil NO^3-N will likely to reduce sugar extractability. Extractable sugar in the brei was 95.0% with the lowest N rate and decreased to 93.5% when N was applied at the rate of 200 lb N/ac (Fig. 2e). The decrease in percent extractable sugar fertilizer-N rates was too small that fertilizer-N rates did not affect extractable sugar yield (data not shown). Greater extractable sugar yield was obtained under no-till management due to higher root yield compared to conventional tillage management. There was no evidence that sugar impurities was affected by the application of Mg and Zn.

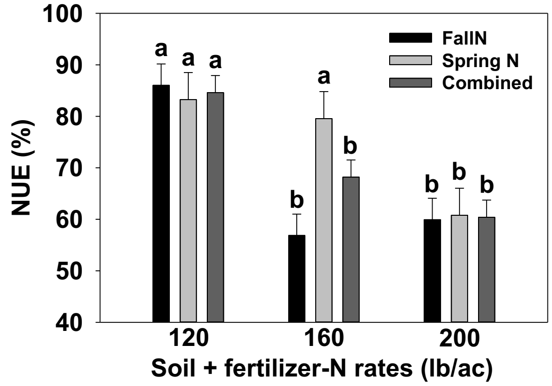

Fig. 3: Nitrogen use efficiency as affected by the interaction of fertilizer-N application timing and rates. Error bars are standard errors of the mean. Means with the same letters are not significantly different at $P \leq 0.05$.

Nitrogen uptake was similar between all N rates but increased with the application of Mg and Zn when N was applied at the rate of 200 lb N/ac. Uptake of Mg increased due to increase in root yield and root and shoot Mg concentration when Mg was applied with high rates of N. Although tissue Zn was increased by the application of foliar Zn, however, uptake of Zn was not affected by any of the main effects and their interactions likely due to increase of tissue Zn concentration was too small to make statistically significant difference.

Nitrogen use efficiency (NUE) was similar under both tillage managements. Greater NUE was obtained with the lowest rate of N (120 lb N/ac) when applied in the fall (Fig. 3). In contrast, when fertilizer-N was applied in the spring, NUE was similar between 120 and 160 lb N/ac which was greater compared to when 200 lb N/ac was applied. This means higher NUE can be achieved with higher rate of fertilizer-N when applied in the spring.

REFERENCES

Afshar, R.K., A. Nilahyane, C. Chen, H. He, W.B. Stevens, and W.M. Iversen. 2019. Impact of conservation tillage and nitrogen on sugarbeet yield and quality.

Havlin, J.L., J.D. Beaton, S.L. Tisdale, and W.L. Nelson. 1999. Soil Fertility and Fertilizers: An Introduction to Nutrient Management. Sixth ed. Prentice Hall, Upper Saddle River, New Jersey.

Hermans, C., Bourgis, F., Faucher, M., Strasser, R. J., Delrot, S. and Verbruggen, N. (2005). Magnesium deficiency in sugar beets alters sugar partitioning and phloem loading in young mature leaves. Planta 220, 541-549.

Marschner, H. 2002. Mineral Nutrition of Higher Plants. Second ed. Academic Press, London.

NASS, 2019. Montana Annual Bulletin, 2019, U.S. Department of Agriculture.