Use of Whole Field Research to Change Farm Management Practices

D. W. Franzen,* J. F. Giles, L. J. Reitmeier, A. J. Hapka, N. R. Cattanach, and A. C. Cattanach

ABSTRACT

On-farm demonstration trials have been used for many years to introduce new techniques and management practices to farmers. With new precision agriculture technology, it is now possible to work more effectively using whole fields instead of small test plots. Sugarbeet (*Beta vulgaris* L.) growers in the Drayton, ND, and St. Thomas, ND, sugarbeet cooperative districts have delivered sugarbeet historically lower in recoverable sugar and higher in impurities than the Red River Valley average. Resulting payments to these growers on a per-hectare basis also have been lower. Growers did not know why their sugarbeet harvest was lower in quality. It generally was believed by the growers that high available soil N was not a reason for the low quality sugarbeet because unusually high soil N levels generally were not seen following potato (*Solanum tuberosum* L.) through their normal soil sampling practices. A whole-field study was undertaken using precision farming techniques with the following objectives: (i) to determine the reason for the low quality sugarbeet, (ii) to test methods to improve the quality of sugarbeet, and (iii) to introduce those methods to growers to improve sugarbeet quality. Results of the study were shared annually with growers in a local town setting. Feedback from farmers was used to construct on-going demonstrations and studies. The studies reinforced ideas reported in previous research, but which had not yet been widely adopted by growers. The whole field studies resulted in an improvement in overall sugarbeet quality in the districts through increased adoption of better management techniques.

LOCAL grower meetings and on-farm demonstrations have long been a standard method of introducing farmers to new technologies and management techniques. In a Nebraska survey (Rzewnicki, 1991), although about 75% of the respondents indicated that experiment station small plot research resulted in helpful information, more than 90% indicated that on-farm trials provided useful information. In the same survey delivered to a special interest group that had a history of on-farm strip-trials, only 59% indicated that small plot research was useful. A survey of extension specialists and agents in South Carolina indicated a tendency for producers to be reluctant to attend production meetings outside of county lines. These surveys suggest that larger trials conducted close to the problem area, combined with locally held meetings, would tend to have more impact than small plot research and meetings held a significant distance away from the local area.

People adopt new technologies because the new techniques are perceived as bringing higher profits or are more convenient than the methods they are currently utilizing (Faber and Snyder, 1990). In a survey of irrigation scheduling users in California (Faber and Snyder, 1990), promotion of new techniques by local research and extension workers, a progressive grower population, and support of local government and the press helped some counties to have higher adoption rates than others. This study stressed that multiple methods of delivering information by multiple, cooperating groups is essential in achieving higher adoption rates of new technologies.

Sugarbeet growers in the Drayton and St. Thomas districts have had historically lower recoverable sugar and higher impurities than the Red River Valley of Minnesota and North Dakota average. Resulting payments to these growers on a per-hectare basis also have been lower. The rotation that dominated in the lower payment hectares included potato. Growers did not know why their sugarbeet plants were lower in quality. Soil testing at recommended sampling depths before sugarbeet planting usually was used as a basis for N fertilization by growers. Growers speculated that possible sources of the problem were a water table high in excess N, a nutrient imbalance other than N, or some unexplained soil N variability that might be found using grid soil sampling.

Successful sugarbeet production is the result of high sugarbeet yield, high beet sugar content, and low levels of impurities. Mathematical formulas incorporating all of these factors are used to calculate grower sugarbeet delivery payments from the processing plants. Undesirable impurities consist of high K, Na, and amino-N concentration in the extracted juice and result in a high loss of sugar to molasses.

Sugarbeet production and refining is managed as a grower cooperative in this region. The cooperative has an in-house agricultural consulting staff consisting of a supervisor and a number of field consultants that work with growers daily on production issues, including on-farm in-season visits. A meeting was scheduled in 1997 between certain sugar cooperative agricultural staff, producers, and certain interested extension and research personnel. A review of the quality problem and possible reasons for the situation were discussed. It was generally believed by the growers that soil N was not a reason for the low quality sugarbeet, since unusually high soil N levels were generally not seen following potato. Some guesses as to the source of the problem included a water table high in excess N, a nutrient imbalance other than N, or some unexplained soil N variability that might be found with grid sampling.

Nitrogen management is key to higher beet yields, higher recoverable sugar, and lower levels of impurities (Draycott, 1972; Hobbis, 1973). High soil N results in higher sugarbeet yield, but also results in lower sucrose concentration and higher levels of unrecoverable sugar and amino-N concentration, which increases processing costs. It is, therefore, very important that enough N is available for high yields, but that N levels are low enough by late season to encourage sugar storage and not continued foliar growth, which results in lower sucrose content in the roots.

To limit the amount of available N to the sugarbeet crop, but still supply enough N to provide for yield demands, soil sampling and NO_3–N analysis of the samples is recommended

Walster Hall, Room 229, North Dakota State Univ., P.O. Box 5758, Fargo, ND 58105-5758. Received 10 Oct. 2002. *Corresponding author (david.franzen@ndsu.nodak.edu).

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Table 1. Crop rotation of the fields during the 4 years of research.

Field	Area, ha	Years			
		1997	1998	1999	2000
29 E	12.5	potato	sugarbeet	spring wheat	potato
29 W	20.2	sugarbeet	spring wheat	potato	sugarbeet
34 N	12.5	potato	sugarbeet	spring wheat	potato
34 S	15.4	sugarbeet	spring wheat	potato	sugarbeet

before applying supplemental N to sugarbeet. In North Dakota and northwest Minnesota, sampling for available nitrate is effective in the fall because the long winters, with deeply frozen soils, limit N movement and N transformations. Nitrogen sampling typically is conducted at the 0- to 120-cm depth (Franzen and Cihacek, 1998); however, significant N also can be extracted from deeper depths by sugarbeet (Rudolph, 1980; Moraghan, 1985).

Draycott (1972) pointed out the value of sugarbeet tops as a green manure due to their high N content. Crohain and Rixhon (1967) showed that crops subsequent to sugarbeet may benefit from N released from sugarbeet top residue. Abshahi et al. (1984) traced the application of ^{15}N-isotope labeled fertilizer N through a sugarbeet crop and into the following wheat (*Triticum aestivum* L.) crop. Moraghan and Smith (1996) applied sugarbeet tops as one would apply a manure application. A high rate of sugarbeet top residues contributed N similar to the yield response of 135 to 202 kg ha^{-1} N as urea, illustrating that sugarbeet tops should be considered a potential N source to subsequent crops. Previous work had warned area growers of the possibility that high-N sugarbeet tops could be a problem (Moraghan and Anath, 1985; Moraghan, 1984). However, many growers had ignored or forgotten the warnings. As a result of the initial meeting with producers, a study was planned with the following objectives: (i) to determine the reason for the low quality sugarbeet, (ii) to study methods to improve the quality of sugarbeet, and (iii) to introduce those methods to growers so that sugarbeet quality could improve.

METHODS

The study was conducted on four fields consisting mostly of Glyndon silt loams (coarse-loamy, frigid Aeric Calciaquolls) located southwest of St. Thomas, ND. The fields were in a sugarbeet–spring wheat–potato rotation, in that order. The fields were either in sugarbeet or potato (Table 1) the first year of the project. Fertilization of the sugarbeet and the spring wheat during the study was controlled and applied by the cooperator, who used a variable-rate anhydrous ammonia applicator. Fertilization of the potato was left to the renters, who were independent of the cooperator in our study.

There was some discussion at the initial grower meeting that perhaps the problem could be solved through grid sampling and variable rate application using normal sampling practices. The fields going into sugarbeet were sampled in the fall of 1996 using a 120-m grid, which was a sampling density common in the Red River Valley at that time. Nitrogen recommendations of each grid varied from 0 to 119 kg ha^{-1} N in Field 34 S, and from 11 to 128 kg ha^{-1} N in Field 29 W. Grid areas were randomly assigned N fertilization rates based on either the grid sample residual nitrate-N value or a composite soil test value. Variable-rate N was applied as anhydrous ammonia by the cooperator in the spring of 1997 before seeding. Multiple yield and quality samples were taken from each grid at harvest.

From 1997 through 2000, the potato and sugarbeet fields were divided into 0.2-ha grids for subsequent plant and soil sampling. Aerial color photographs were taken of the crop during August to compare with harvest top N content of sugarbeet and potato. Previous work had shown the value of using imagery to divide sugarbeet fields into zones through which N credits could be imposed (Moraghan et al., 1997; Moraghan, 1998, 1999). Sugarbeet and potato top total N levels at harvest were obtained from each 0.2-ha grid. Soil cores to 180 cm were taken at harvest in the same grid from both the sugarbeet and potato fields and separated into 0- to 60-cm, 60-to120-cm, and 120- to 180-cm samples. Potato culls were also collected from a 9-m^2 area and analyzed for total N content. Wheat yields in 1998–2000 were obtained using a combine yield monitor.

In 1998, the fields in sugarbeet in 1997 were seeded to spring wheat. Following wheat emergence, an area about 2.4 m long by 2.4 m wide at the center of the 0.2-ha grids was killed by an application of glyphosate when the wheat was at the three-leaf stage. Five soil cores were obtained from each grid. In 1998, cores were taken at a soil depth of 0 to15 and 15 to 30 cm for the growing season sampling, followed by a post-harvest sampling at soils depths of 0 to15, 15 to 60, 60 to120, and 120 to180 cm. In 1999, cores were taken from the 0- to15-, 15- to 30-, and 30- to 60-cm depth, followed by a similar post-harvest sampling as in 1998. These soil samples were analyzed for nitrate N.

A buried residue bag study was conducted in 2000 at both Fargo and St. Thomas to illustrate the speed of residue decompostion. Samples of residue from canola (*Brassica napus* L.), spring wheat, corn (*Zea mays* L.), potato, sugarbeet, and sunflower *(Helianthus annuus* L.) of varying N contents were collected, dried, weighed, and placed in 0.3-m^3 (1-foot^2) fiberglass mesh bags. More complete methods are described in Hapka et al. (2001). The bags were buried in early November 1999 at about a 5-cm depth in randomized split blocks at each location. Bags were disinterred on 15 May, 29 May, 19 June, and 3 July 2000. Soil was washed off the residue bags. A screening of residue during washing revealed wash losses of less than 0.1 g of residue per sample.

RESULTS AND DISCUSSION

In 1998, there was no difference in yield and quality between the variably applied grids and the composite fertilized grids. Since variable-rate N application did not improve beet quality, this meant that N sources from some unknown source were probably so high that varying N rates in a particular grid had no effect. At the conclusion of Year 1, the possibility that high N availability was the cause of the quality problem was reinforced by the low sugar (163–167 g kg^{-1}) and high impurities (nitrate grade 31.8–36.7 g kg^{-1} and sugar loss to molasses 14.8–15.3 g kg^{-1}) found in the harvest sample.

Soil samples following sugarbeet showed low levels of soil N to 180 cm (6 feet) in depth in all areas except where sugarbeet growth was low due to excess water that season (Fig. 1). However, sugarbeet top analysis showed very high levels of N. Some tops were as high as 448 kg ha^{-1}, which would be

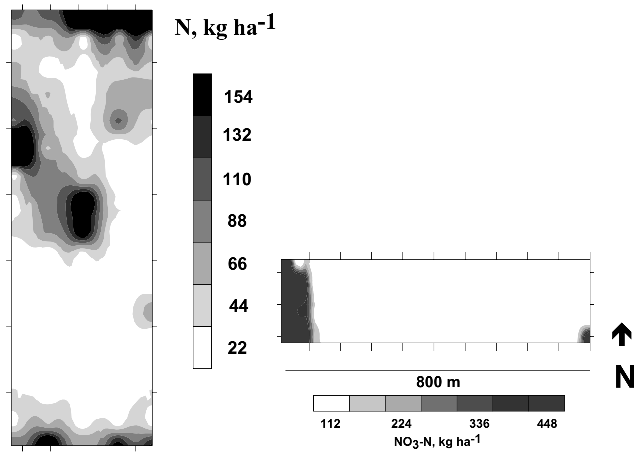

Fig. 1. Field 29W (left) and 34 S nitrate-N levels to 180 cm (6 feet) following 1997 sugarbeet.

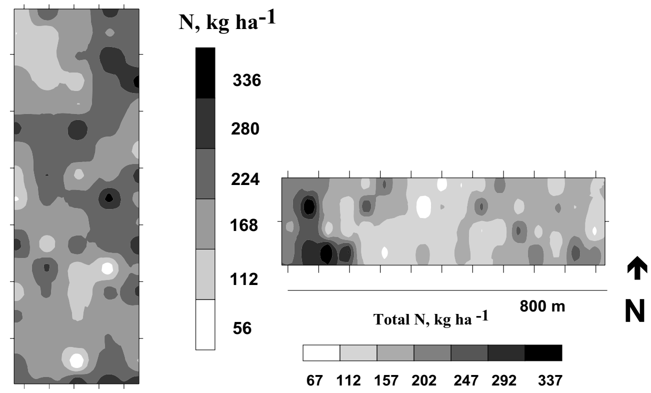

Fig. 2. Fields 29 W and 34 S, sugarbeet top total N, 1997.

the equivalent of tilling under a 9 t ha^{-1} alfalfa crop (Fig. 2). It was estimated that about one-half of the top total N would be available to the subsequent wheat crop.

At the conclusion of Year 1, a meeting was held in the local town and growers were invited to attend and provide feedback. Although it was clear to the researchers that high N in the sugarbeet tops and high levels of N following potato at the 120- to 180-cm depth was probably the cause of the quality problem, growers remained unconvinced and were afraid that the implementation of N credits to wheat following sugarbeet would result in lower yield. Even if they had credited some N from sugarbeet tops, the amount of N in this area was higher than credits proposed through previous studies.

Therefore, in subsequent years, satellite and/or aerial photographs were used to identify more and less vigorous areas, which would identify differences in top N levels but would not quantify the amount of N. Aerial photos of the 1997 fields showed areas of higher vigor and/or greenness in areas with higher N content (Fig. 3).

Potato precedes sugarbeet in this rotation, so it was also important to evaluate the residual N following potato, which might lead to high N levels in the sugarbeet leaves. Levels of N in the 0- to 120-cm depth following potato were moderate. However, high levels of N were found from the 120- to 180-cm depth. In addition, the high N content of the potato tops also prompted an N adjustment as a previous crop credit (Fig. 4).

Due to soil test N to 120 cm from 67 to 135 kg ha^{-1}, an added 33 to 56 kg ha^{-1} N from potato tops, and generally high N levels from 120 to180 cm in depth, it was decided not to apply any additional N as fertilizer for the subsequent 1998 sugarbeet crop. In addition, substantial N credits were given for sugarbeet tops to the subsequent spring wheat crop (Fig. 5). In one zone, 0 kg ha^{-1} N credits were given and fertilized at the 168 kg ha^{-1} rate. In the other two zones, 56 and 78 kg ha^{-1} N credits were given, respectively. The cooperator bravely consented to use our recommendations, which was critical to the outcome of our demonstrations.

Following sugarbeet harvest in 1997, mean NO_3–N levels at the 0- to 30-cm depth were 21 kg ha^{-1}, compared with a mean of 146.6 kg ha^{-1} for the 15 May 1998 sampling (Table 2). Subsequent sampling showed a consistently high level of available NO_3–N throughout the season. These data suggest that N was being released from the previous year's sugarbeet tops at the same time that the wheat crop was taking up substantial amounts of N. There were no significant differences

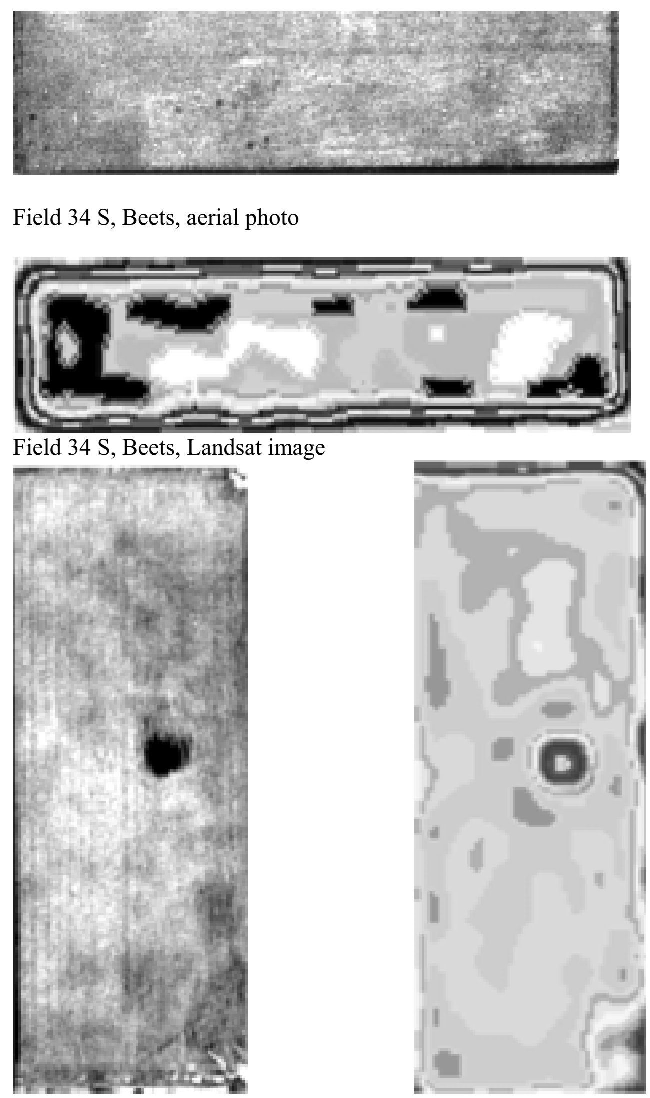

Fig. 3. Fields 29 W and 34 S, sugarbeet, 1997, aerial and satellite images.

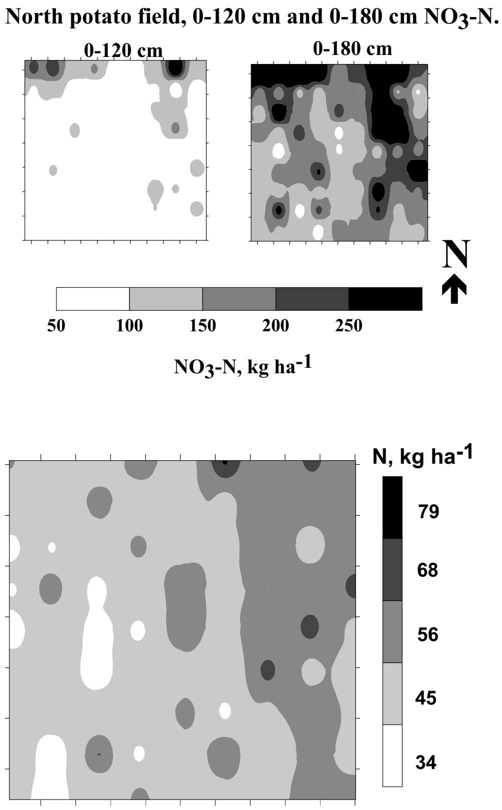

Fig. 4. Field 29 E, potato, 1997, soil test N to 180 cm (6 feet) and potato top N levels.

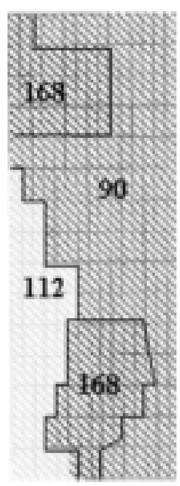

Fig. 5. Field 29 W fertilizer application map for spring wheat, 1998, kg ha^{-1}.

in the 1 June 1998 sampling date NO_3–N or yield between zones (Table 3). Similar results were observed in 1999 with two fields of wheat following sugarbeet (data not shown).

The two sugarbeet fields, 34 N and 29 E, received no N fertilizer for the 1998 crop. Field 29 E was destroyed by hail close to harvest, so no yield or quality measurements were made. However, the crop yield in Field 34 N was 49.3 Mg ha^{-1}, with more than 170 g kg^{-1} sugar. Based on a comparison by sugar cooperative agriculturalists on neighboring fields in the township, this was comparable to tonnage with about 10 g kg^{-1} greater sugar than other conventionally fertilized fields.

Table 2. Field 29W, 1998 NO_3–N levels in a wheat field following sugarbeet through the growing season.

Sampling date	Mean NO_3–N levels				
	0–15 cm	15–30 cm	0–30 cm	30–60 cm	60–120 cm
	kg ha^{-1}				
Oct. 1997	14.7	6.7	21.4	13.3	18.6
15 May 1998	125.8	20.8	146.6		
1 June 1998	105.7	73.1	178.9		
15 June 1998	64.1	35.1	99.0		
1 July 1998	76.7	77.2	153.9		
Harvest 17 Aug. 1998	69.2	44.0	113.3	23.9	24.0

Table 3. Nitrate–N levels by zone, 1 June sampling date and spring wheat yields by N fertilization zones following sugarbeet. Field 29W, 1998.

Zone rate of N	NO_3–N	Yield
	kg ha^{-1}	
168	149	3790
112	129	3823
90	127	3695
Significance	NS	NS

At the conclusion of 1999, another grower meeting was organized in the local town and was attended by many of the same growers who had followed the project from its beginning, as well as others who had heard about the work. After sharing the information regarding the previous 3 years of work, we expected enthusiastic response from the growers. However, there was still reluctance to adopt the N credit idea because there was a fear that being so far north in the state decomposition of leaves might not release N soon enough to be of value to the next crop. It was therefore determined to do a residue decomposition study beginning that fall.

Rainfall in 2000 at the Fargo buried residue study was higher than at the St. Thomas site (data not shown). The higher rainfall at Fargo is reflected in the increased degradation and rate of degradation of residue at this site compared with St. Thomas. A range between 500 and 850 g kg^{-1} of the residue had decomposed by the 15 May sampling date at both sites (Fig. 6 and 7). Decomposition was faster at Fargo than at St. Thomas, but even in a marginal drought situation at St. Thomas, significant decomposition and probable release of N from some of the residues had taken place. Sugarbeet, potato, and sunflower decomposition was most rapid, which was expected, since the C/N ratio of these residues was less than for corn, canola, and wheat. Wheat decomposition was slowest, followed by canola and corn, then sunflower, potato, and sugarbeet.

Although the residue bag study could not quantify the available plant N from N disappearance, the study illustrated that potato and sugarbeet top decomposition was very rapid, which served to answer concerns against the use of potato and sugarbeet residues as a previous crop N credit.

Within 2 years of the onset of the project, quality improvement began to be seen in the two districts (Fig. 8). The differences in sugar content between the Red River Valley average and the two districts decreased, and the Drayton district usually exceeded the average quality components. By 2003, about 75% of growers in the St. Thomas district were using satellite imagery to direct previous crop credits from sugarbeet to the next crop, and many growers were giving N cred-

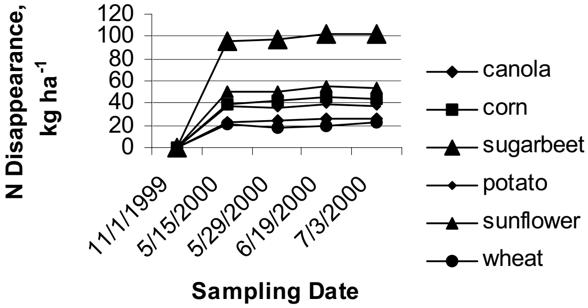

Fig. 6. Nitrogen disappearance from residue, Fargo, ND.

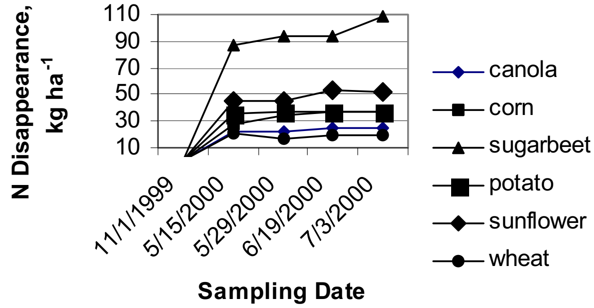

Fig. 7. Nitrogen disappearance from residue, St. Thomas, ND.

its from potato when going to sugarbeet (Tom Hermann, American Crystal Agriculturalist, personal communication, 2004).

SUMMARY AND CONCLUSIONS

Changing grower management habits is never easy. The history of farming is one of conservative change. However, generally sugarbeet growers tend to be more innovative and willing to change management than the general farm population if the research is solid. Most of the conclusions reached in this study could have been adopted and adapted from previous work showing these concepts in North Dakota, Minnesota, and elsewhere. However, sometimes there needs to be larger and more local demonstrations than small plot studies, which establish the principles.

One factor that seemed to help sway growers in this project was the whole field nature of the study. Precision techniques, especially being able to obtain yield monitor data and apply variable-rate N, were especially useful. Sugarbeet top research had certainly been thoroughly investigated before and during this study, but its use through a rotation on a whole field basis in this study was probably a factor in management changes in the area.

The following were steps leading to management change:

1. A local cooperator was found who was agreeable to any recommendations we gave.
2. Measurements and treatments were made in a site-specific manner.
3. Growers presented feedback regarding their skepticism of previous work.
4. Solutions to solve the problem were advanced through changes in experimental design.
5. Growers began to adopt the recommended practices.
6. Sugar content and impurity levels in the sugarbeet improved.

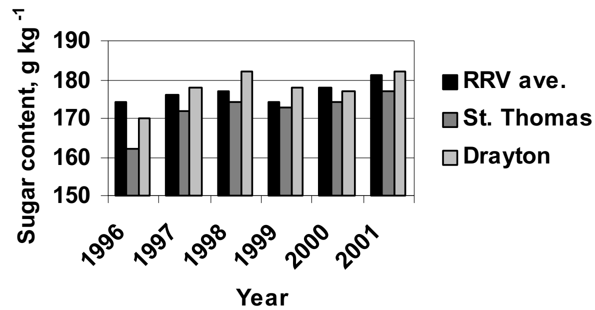

Fig. 8. Sugar content from 1996 through 2000 for the Drayton, ND, and St. Thomas, ND, districts compared with the Red River Valley average.

REFERENCES

Abshahi, A., F.J. Hills, and F.E. Broadbent. 1984. Nitrogen utilization from residual sugarbeet fertilizer and soil incorporated sugarbeet tops. Agron. J. 76:954–958.

Crohain, A., and L. Rixhon. 1967. Practical fertiliser value of sugar-beet leaves and crowns. (In French.) Bull. Rech Agron. Gembloux. 2:397–428.

Draycott, A.P.1972. Sugar-beet nutrition. Applied Science Publ., Ltd., London.

Faber, B.A., and R.L. Snyder. 1990. Extension activities needed to expand use of evapotranspiration data for irrigation. J. Agron. Educ. 19:8–13.

Franzen, D.W., and L.J. Cihacek. 1998. Soil sampling as a basis for fertilizer application. NDSU Extension Circ. SF-990. North Dakota State Univ., Fargo, ND.

Hapka, A.J., D.W. Franzen, J.F. Giles, and N.R. Cattanach. 2001. Timing and release of nitrogen from residues. p. 114–121. *In* 2000 Sugarbeet Research and Extension Reports. Sugarbeet Research and Education Board of Minnesota and North Dakota, Fargo, ND.

Hobbis, J.K. 1973. What do the nitrate N and conductance reading from the tare laboratory sugar samples mean? *In* 1973 Sugarbeet Research and Extension Reports. North Dakota State Univ., Fargo, ND, and Univ. of Minnesota, St. Paul, MN.

Moraghan, J.T. 1984. Soil fertility research. p. 93–106. *In* 1983 Sugarbeet Research and Extension Reports. Sugarbeet Research and Education Board of Minnesota and North Dakota, Fargo, ND.

Moraghan, J.T. 1985. Nitrogen studies with sugarbeets. p. 86–95. *In* 1984 Sugarbeet Research and Extension Reports. Sugarbeet Research and Education Board of Minnesota and North Dakota, Fargo, ND.

Moraghan, J.T. 1998. Sugarbeet canopy type and accumulation of plant nitrogen as delineated by aerial photography and global positioning systems. Commun. Soil Sci. Plant Anal. 29:2953–2959.

Moraghan, J.T. 1999. A successful application of a new precision farming technique by a sugarbeet grower. p. 113–117. *In* 1998 Sugarbeet Research and Extension Reports. Sugarbeet Research and Education Board of Minnesota and North Dakota, Fargo, ND.

Moraghan, J.T., and S. Anath. 1985. Return of sugarbeet tops and the accumulation of certain chemical constituents in soil. J. Am. Soc. Sugar Beet Technol. 23:72–79.

Moraghan, J.T., K. Horsager, L. Smith, A. Sims, and J. Holland. 1997. Canopy reflectance and GPS technology in relation to sugar production. p. 121–133. *In* 1996 Sugarbeet Research and Extension Reports. Sugarbeet Research and Education Board of Minnesota and North Dakota, Fargo, ND.

Moraghan, J.T., and L.J. Smith. 1996. Nitrogen in sugarbeet tops and the growth of a subsequent wheat crop. Agron. J. 88:521–526.

Rzewnicki, P. 1991. Farmers' perceptions of experiment station research, demonstrations, and on-farm research in agronomy. J. Agron. Educ. 20:31–36.

Rudolph, G., R. Dahl, and J. Coffman. 1980. Soil sampling and the effect of nitrogen on quality sugarbeets. p. 134–137. *In* 1979 Sugarbeet Research and Extension Reports. Sugarbeet Research and Education Board of Minnesota and North Dakota, Fargo, ND.