# "ON FARM" VALIDATION OF NITROGEN FERTILIZATION RECOMMENDATIONS FOR SUGAR BEETS

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Ontario, Oregon, 1995

## Introduction

Sugar beet nitrogen fertilizer guidelines are based on either fall or spring nitrate-N levels to 3-foot depth in the soil and total plant needs estimated at 8 pounds N per ton of beets. These assumptions provide estimates for N fertilization which have been useful for many years. To make beet production and processing as efficient as possible, it is important to use only the N fertilizer needed to grow the crop. In the cases where soil organic matter mineralization is large compared with residual soil nitrate or fertilization, the current guidelines could over-estimate crop fertilizer needs.

When sugar beets receive N in excess of their needs, total beet yield and leaf growth are high, but both beet sugar content and total sugar yields can be depressed. Extra nitrate and ammonium in the beet pulp reduce sugar factory efficiency.

## Objectives

The objectives of this study were to examine the amount and importance of N mineralized from soil organic matter in commercial sugar beet fields and to make observations of sugar beet plant N uptake in N fertilizer trials conducted by beet fieldmen in commercial fields to improve our understanding of beet responses to N fertilizer.

## Procedures

Sugar beet fieldmen have conducting N fertilizer rate trials in growers fields during the last few years. These trials have the basic structure of large plots with several N rates and one to three replicates. In general the recommended N fertilizer rate is based on the soil nitrate present in the soil profile to a depth of 3 feet in each field and a yield goal for that field. Other large field plots are treated with twice the recommended N rate, half the recommended N rate, and no fertilizer as the check. In a few fields with high residual nitrate, the fieldman and grower opted to leave all plots unfertilized. Twelve growers' fields were studied through harvest in 1994 and an additional eight fields in 1995 between Brogan, Oregon, and Burley, Idaho (Table 1). Several other fields were set up each year, but their experimental value was lost in cultivation or harvesting errors.

The growers take care of all of the cultural practices and the fertilizers are applied in cooperation with fertilizer industry representatives. Sugar beet fieldmen kept track of crop progress and coordinated the harvest, collecting yield and quality data based on the entire field plots. Beets were evaluated for total yield, tare, sucrose content, conductivity, and beet pulp nitrate by the Amalgamated Sugar Co.

Additional work was done by the Malheur Experiment Station. The percent sugar extraction and recoverable sugar were calculated based on empirical formulas. Soil samples were collected in the spring for estimates of N mineralization via three methods: anaerobic incubation, aerobic incubation, and the buried-bag method. Twelve to fourteen representative beets with their leaves and crowns were harvested from each plot just prior to harvest and taken to the Malheur Experiment Station. Leaves and crowns were dried, weighed, ground, and analyzed for total N content. The beets were weighed fresh after the leaves and crown were removed, ground, and a subsample of the beet pulp was weighed wet and oven-dried to determine dry matter content, then analyzed for total N content. Beet N uptake per acre in the leaves, crowns, and beets was calculated based on the clean beet yield of each plot, the beet dry weight to fresh weight ratio, the proportion of dry crown and leaf tissue to dry beet in the tissue samples, and the tissue sample N contents.

Total available soil N supply was calculated based on the sum of spring available nitrate and ammonium, any applied fertilizer N, and N mineralization (estimated by anaerobic incubation or seasonal N balance). Nitrogen use efficiency was calculated for each plot by dividing the total plant N uptake by the total available N supply for each plot and multiplying by 100.

## Results and Discussion

Spring soil nitrate N ranged from 61 to 284 lb N/acre, depending on the field (Table 2). Optimistic yield goals ranging from 25 to 40 tons of beets per acre implied N fertilizer needs of 0 to 216 lb N/acre. The lowest applied N rates were 0 lb N/acre at thirteen of the twenty sites.

The 1994 season was favorable for high yields (Table 3), and all cooperating growers kept weeds and diseases under control. The 1995 season was far less favorable, with lower temperatures and cloud cover during the growing season. Repeated rainfall events in 1995 made efficient N use difficult and reduced residual nitrate and ammonium in the fields at harvest. Repeated hail in the Treasure Valley was damaging at certain locations.

The highest-yielding N fertilizer rates ranged from 0 to 205 lb N/acre depending on the field studied. Sugar beet response to N fertilizer varied substantially. Reasonable yields were obtained in certain fields with low rates of N fertilizer (Tables 2 and 3). Beet pulp nitrate at 0 applied N suggested that there was extra N supplies in five fields without any fertilizer nitrogen (Table 3). Beet petiole nitrate was consistent with high yields at low N fertilizer inputs in these fields (data not shown).

The optimal N rate was determined independently for each field based on the highest yield of recoverable sugar. Beet plants at the optimal-applied N levels contained 126 to 426 lb N/acre at harvest depending on the field (Table 4). Anaerobic incubation estimates of N mineralization ranged from 88 to 251 lb N/acre depending on the field (Table 5). Mineralized N appears to be a large N source averaging 163 lb N/ac over the 20 fields (Table 4). Fields with high spring residual nitrate are not necessarily going to have high rates of N mineralization; fields with low spring residual nitrate are not necessarily going to have to low rates of N mineralization , $r^2$=0.029.

In 1994, the anaerobic incubation estimates of N mineralized ranged in the same order of magnitude as field method of N balance method. The N balance method was based on measuring residual soil nitrate and ammonium at harvest and plant N content at harvest, then subtracting all known available N sources. The N balance was not comparable in 1995, as would be expected after a season with untimely rainfall events.

At the most productive N level tested at each site, sugar beets were able to recover between 40.4 and 88.8 percent of the estimated total N supply (based on the sum of soil nitrate and ammonium to the 3-foot depth, fertilizer N, and N mineralization in Table 4). Efficiencies less than 75 percent appear to be related to very high N supply at 0 N applied, irrigations and rainfall in excess of evapotranspiration, or sugar beet cyst nematode.

Acknowledgments

These trials depended of the work of many growers and fertilizer fieldmen, without which the effort would have been impossible.

Table 1. Characteristics of 20 sugar beet fields used for soil N mineralization studies in 1994 and 1995. Malheur Experiment Station, Oregon State University, Ontario, Oregon.

| Field | Location | Soil texture | pH | Organic matter | Soil depth | Variety | Planting date | Irrigation system | Comments | Previous crop |
|---|---|---|---|---|---|---|---|---|---|---|
| 1994 | | | | % | | | | | | |
| 1 | Burley | sandy loam | 8.4 | 1.25 | > 6' | MH 9455 | April 11 | side roll | cyst nematode | beets |
| 2 | Minidoka | silt loam | 8.0 | 1.5 | 2.5' | PM-9 | March 19 | side roll | rock at 2-3' | wheat |
| 3 | Minidoka | silt loam | 8.0 | 2.35 | 2.5' | WS91 | March 20 | side roll | rock at 2-3' | wheat |
| 4 | Jerome | loam | 7.55 | 1.05 | 2.5' | WS91 | April 25 | side roll | rock at 2-3' | potatoes |
| 5 | Nyssa | silt loam | 7.65 | 1.4 | >6' | PM-9 | last week March | furrow | | onions |
| 6 | Ontario-Vale | fine sandy loam | 7.5 | 1.6 | >6' | PM-9 | March 7 | furrow | | onions |
| 7 | Ontario-Vale | silt loam | 7.75 | 2.2 | >6' | PM-9 | March 12 | furrow | | onions |
| 8 | Ontario-Nyssa | fine sandy loam | 7.4 | 1.75 | >6' | PM-9 | 2nd week March | furrow | | onions |
| 9 | Nyssa | silt loam | 7.9 | 2.1 | >6' | PM-9 | March 26 | furrow | B deficient | potatoes |
| 10 | Vale | silt loam | 7.6 | 2.05 | >6' | PM-9 | March 18 | furrow | | onions |
| 11 | Brogan | silt loam | 7.6 | 1.6 | >6' | RSW-81 | March 14 | furrow | | onions |
| 12 | Ontario | silt loam | 7.6 | 1.5 | >6' | PM-9 | April 5 | furrow | | beans |
| 1995 | | | | | | | | | | |
| 1 | Buhl | silt loam | 8.1 | 1.2 | >6' | PM-9 | May 10 | furrow | | beans |
| 2 | Burley | silt loam | 8.1 | 1.49 | 2.5' | Beta 8422 | April 10 | side roll | | wheat |
| 3 | Rupert | sandy loam | 7.8 | 1.28 | >6' | WS62 | April 20 | furrow | | beans |
| 4 | Minidoka | silt loam | 8.2 | 1.65 | 2.5' | PM-9 | April 4 | side roll | | potatoes |
| 5 | Nyssa | silt loam | 7.6 | 1.45 | >6' | PM-9 | March 30 | furrow | rhizoctonia | onions |
| 6 | Vale | silt loam | 7.8 | 3.29 | >6' | PM-9 | | furrow | | potatoes |
| 7 | Ontario | silt loam | 7.7 | 1.43 | >6' | PM-9 | March 29 | sideroll | | potatoes |
| 8 | Nyssa | silt loam | 7.4 | 1.47 | >6' | PM-9 | March 27 | furrow | rhizoctonia, flooding | beans |

Table 2. Optimistic yield goals, soil nitrate, recommended N fertilizer rates, grower's preferred N fertilizer rates, and best fertilizer N rates for 1994 and 1995. Malheur Experiment Station, Oregon State University, Ontario, Oregon.

| Field | Location | Optimistic yield goal | Soil nitrate 0-3' | Total N needed for optimistic yield goal | Recommended N fertilizer for optimistic yield goal | Growers' preferred N rate | Lowest N rate used in 1994 trial | Highest yielding N rate for 1994 trial |
|---|---|---|---|---|---|---|---|---|
| 1994 | | t/ac | lb N/ac | | | | | |
| 1 | Burley | 28 | 164 | 224 | 60 | 80 | 0 | 40 |
| 2 | Minidoka | 35 | 171 | 280 | 109 | 110 | 0 | 110 |
| 3 | Minidoka | 35 | 85 | 280 | 195 | 205 | 80 | 205 |
| 4 | Jerome | 35 | 155 | 280 | 125 | 50 | 0 | 25 |
| 5 | Nyssa | 40 | 207 | 320 | 113 | - | 0 | 0 |
| 6 | Ontario-Vale | 40 | 284 | 320 | 36 | 75 | 0 | 0 |
| 7 | Ontario-Vale | 40 | 238 | 320 | 82 | 0 | 0 | 0 |
| 8 | Ontario-Nyssa | 40 | 148 | 320 | 172 | - | 60 | 60 |
| 9 | Nyssa | 40 | 165 | 320 | 154 | - | 60* | 80 |
| 10 | Vale | 40 | 356 | 320 | -36 | 150 | 0 | 0 |
| 11 | Brogan | 35 | 165 | 280 | 115 | 100 | 0 | 0 |
| 12 | Ontario | 40 | 104 | 320 | 216 | - | 0 | 0 |
| 1995 | | | | | | | | |
| 1 | Buhl | 25 | 199 | 200 | 1 | 100 | 0 | 0 |
| 2 | Burley | 25 | 61 | 200 | 139 | 160 | 80 | 160 |
| 3 | Rupert | 35 | 95 | 280 | 185 | 120 | 19 | 171 |
| 4 | Minidoka | 25 | 105 | 200 | 95 | 163 | 0 | 85 |
| 5 | Nyssa | 30 | 115 | 240 | 125 | 100 | 35 | 35 |
| 6 | Vale | 40 | 122 | 320 | 198 | 150 | 0 | 150 |
| 7 | Ontario | 34 | 108 | 272 | 164 | 170 | 80 | 80 |
| 8 | Nyssa | 32 | 138 | 256 | 118 | 100 | 0 | 40 |

*Boron deficient part of field.

Table 3. Beet yield and quality at the best N rate for each of 20 growers' fields. Malheur Experiment Station, Oregon State University, Ontario, Oregon, 1994 and 1995.

| Summary of characteristics | | | | | Highest yielding plant performance | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| Field | Location | Optimistic yield goal | Soil nitrate 0-3' | Most productive N rate for 1994 trial | Clean beet yield | Sucrose | Conductivity | Extraction | Recoverable sugar | Pulp nitrate |
| 1994 | | t/ac | lb N/ac | lb N/ac | t/ac | % | | % | lb/ac | ppm |
| 1 | Burley | 28 | 164 | 40 | 24. 0 | 16.9 | 0.73 | 86.4 | 6,998 | 187 |
| 2 | Minidoka | 35 | 171 | 110 | 35.5 | 18.1 | 0.73 | 86.5 | 10,799 | 148 |
| 3 | Minidoka | 35 | 85 | 205 | 39.2 | 17.4 | 0.9 | 84.2 | 11,479 | na |
| 4 | Jerome | 35 | 155 | 25 | 32.7 | 16.8 | 1. 00 | 82.8 | 9,064 | 411 |
| 5 | Nyssa | 40 | 207 | 0 | 31.3 | 15. 0 | 0.84 | 84.7 | 7,950 | 552 |
| 6 | Ontario-Vale | 40 | 284 | 0 | 40.9 | 15.8 | 0.87 | 84.4 | 10,925 | 483 |
| 7 | Ontario-Vale | 40 | 238 | 0 | 34.8 | 13.7 | 1.09 | 81. 0 | 7,708 | 701 |
| 8 | Ontario-Nyssa | 40 | 148 | 60 | 39. 0 | 16.7 | 0.68 | 87.1 | 11,342 | 294 |
| 9 | Nyssa | 40 | 165 | 80 | 33.4 | 16.2 | 0.72 | 86.4 | 9,372 | 283 |
| 10 | Vale | 40 | 356 | 0 | 38.3 | 14.8 | 0.98 | 82.7 | 9,406 | 581 |
| 11 | Brogan | 35 | 165 | 0 | 29.4 | 14.9 | 0.95 | 83.1 | 7,280 | 629 |
| 12 | Ontario | 40 | 104 | 0 | 45.6 | 16.2 | 0.75 | 86.1 | 12,732 | 175 |
| 1995 | | | | | | | | | | |
| 1 | Buhl | 25 | 199 | 0 | 21.3 | 16.9 | 0.60 | 88.1 | 6,352 | 145 |
| 2 | Burley | 25 | 61 | 100 | 22.9 | 19.2 | 0.88 | 84.6 | 7,452 | 178 |
| 3 | Rupert | 35 | 95 | 171 | 31.9 | 16.6 | 0.77 | 85.8 | 9,110 | 313 |
| 4 | Minidoka | 25 | 105 | 85 | 21.4 | 16.6 | 0.62 | 87.8 | 6,787 | 152 |
| 5 | Nyssa | 30 | 115 | 35 | 25.2 | 16.3 | 0.72 | 86.4 | 7,078 | 243 |
| 6 | Vale | 40 | 122 | 150 | 31.4 | 14.9 | 1.06 | 81.6 | 7,630 | 691 |
| 7 | Ontario | 34 | 108 | 80 | 28.0 | 17.6 | 0.64 | 87.7 | 8,649 | 161 |
| 8 | Nyssa | 32 | 138 | 40 | 31.8 | 16.9 | 0.71 | 86.7 | 9,283 | 194 |

Table 4. Comparison of soil nitrogen supply, beet plant nitrogen content, and N use efficiency at harvest for beets grown at the highest-yielding N level in 20 fields. Malheur Experiment Station, Oregon State University, Ontario, Oregon, 1994 and 1995.

| | | Beet plant performance | | N supply | | | | | Plant N content | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Field | Location | Beet yield | Recoverable sugar | Most productive N rate for 1994 trial | Spring soil nitrate-N 0-3' | Spring soil ammonium -N 0-3' | Estimate of N-mineralization (anaerobic) | Total available N supply | Leaves | Crown | Beets | Total | Total plant N content at harvest per ton of beets | N use efficiency[2] |
| 1994 | | t/ac | lb/ac | | lb N/ac | lb N/ac | lb N/ac | | lb N/ac | | | | lb N/ton | % |
| 1 | Burley | 24.0 | 6,998 | 40 | 164 | 23 | 112 | 339 | 70 | 20 | 94 | 184 | 7.65 | 54.2 |
| 2 | Minidoka | 35.5 | 10,799 | 110 | 171 | 17 | 172 | 469 | 63 | 18 | 148 | 229 | 6.65 | 48.9 |
| 3 | Minidoka | 39.2 | 11,479 | 205 | 85 | 14 | 167 | 470 | 98 | 23 | 187 | 308 | 7.82 | 65.4 |
| 4 | Jerome | 32.7 | 9,064 | 25 | 155 | 16 | 135 | 331 | 103 | 15 | 145 | 263 | 8.07 | 79.5 |
| 5 | Nyssa | 31.3 | 7,950 | 0 | 207 | 64 | 88 | 359 | 127 | 18 | 150 | 295 | 9.42 | 82.3 |
| 6 | Ontario-Vale | 40.9 | 10,925 | 0 | 284 | 30 | 149 | 459 | 122 | 19 | 225 | 366 | 8.93 | 79.9 |
| 7 | Ontario-Vale | 34.8 | 7,708 | 0 | 238 | 32 | 251 | 520 | 162 | 17 | 197 | 376 | 10.87 | 72.4 |
| 8 | Ontario-Nyssa | 39.0 | 11,342 | 60 | 148 | 48 | 115 | 371 | 111 | 23 | 180 | 314 | 8.06 | 84.6 |
| 9 | Nyssa | 33.4 | 9,372 | 80 | 165 | 31 | 97 | 373 | 87 | 27 | 129 | 243 | 7.26 | 65.1 |
| 10 | Vale | 38.3 | 9,406 | 0 | 356 | 39 | 236 | 631 | 165 | 35 | 226 | 426 | 11.06 | 67.5 |
| 11 | Brogan | 29.4 | 7,280 | 0 | 165 | 48 | 224[1] | 437[1] | 100 | 37 | 164 | 301 | 10.08 | 68.9[1] |
| 12 | Ontario | 45.6 | 12,732 | 0 | 104 | 49 | 292[1] | 445[1] | 123 | 46 | 226 | 395 | 8.65 | 88.8[1] |
| 1995 | | | | | | | | | | | | | | |
| 1 | Buhl | 21.3 | 6,352 | 0 | 199 | – | 95 | 294 | 88 | 8 | 78 | 174 | 8.20 | 59.2 |
| 2 | Burley | 22.9 | 7,452 | 100 | 61 | 17 | 158 | 336 | 79 | 5 | 65 | 149 | 6.50 | 44.4 |
| 3 | Rupert | 31.9 | 9,110 | 171 | 95 | – | 195 | 461 | 92 | 9 | 116 | 217 | 6.79 | 47.1 |
| 4 | Minidoka | 21.4 | 6,787 | 85 | 105 | – | 130 | 320 | 52 | 6 | 77 | 135 | 5.80 | 42.2 |
| 5 | Nyssa | 25.2 | 7,078 | 35 | 115 | 34 | 121 | 305 | 52 | 4 | 70 | 126 | 5.00 | 41.3 |
| 6 | Vale | 31.4 | 7,630 | 150 | 122 | 27 | 210 | 509 | 130 | 13 | 112 | 255 | 8.10 | 50.1 |
| 7 | Ontario | 28.0 | 8,649 | 80 | 108 | 24 | 189 | 401 | 55 | 9 | 98 | 162 | 5.80 | 40.4 |
| 8 | Nyssa | 31.8 | 9,283 | 40 | 138 | 30 | 136 | 344 | 72 | 8 | 136 | 216 | 6.80 | 62.8 |

[1]N mineralization estimate by season-long N balance.

[2]Total plant N content as a percent of the total available N supply.

Table 5. Estimates of N mineralization made in 20 growers' sugar beet fields by four different methods. Malheur Experiment Station, Oregon State University, Ontario, Oregon, 1994 and 1995.

| | | | | N-mineralization estimate | | | |
|---|---|---|---|---|---|---|---|
| Grower | Location | Soil texture | Organic matter | Anaerobic incubation | Aerobic incubation | Available nitrogen balance | Buried bags |
| 1994 | | | % | lb N/ac | | | |
| 1 | Burley | sandy loam | 1.25 | 112 | 170 | - | - |
| 2 | Minidoka | silt loam | 1.5 | 172 | 155 | - | - |
| 3 | Minidoka | silt loam | 2.35 | 167 | 137 | - | - |
| 4 | Jerome | loam | 1.05 | 135 | 132 | 283 | 110 |
| 5 | Nyssa | silt loam | 1.4 | 88 | 120 | 238 | - |
| 6 | Ontario-Vale | fine sandy loam | 1.6 | 149 | 182 | 238 | - |
| 7 | Ontario-Vale | silt loam | 2.2 | 251 | 298 | 304 | - |
| 8 | Ontario-Nyssa | fine sandy loam | 1.75 | 115 | 134 | 125 | - |
| 9 | Nyssa | silt loam | 2.1 | 97 | 110 | 61 | - |
| 10 | Vale | silt loam | 2.05 | 236 | 291 | 251 | - |
| 11 | Brogan | silt loam | 1.6 | 149 | - | 224 | - |
| 12 | Ontario | silt loam | 1.5 | 159 | 123 | 293 | 255 |
| 1995 | | | | | | | |
| 1 | Buhl | silt loam | 1.2 | 95 | | - | |
| 2 | Burley | silt loam | 1.49 | 158 | | -11 | |
| 3 | Rupert | sandy loam | 1.28 | 195 | | 12 | |
| 4 | Minidoka | silt loam | 1.65 | 130 | | 3 | |
| 5 | Nyssa | silt loam | 1.45 | 121 | | 16 | |
| 6 | Vale | silt loam | 3.29 | 210 | | - | |
| 7 | Ontario | silt loam | 1.43 | 189 | | 48 | |
| 8 | Nyssa | silt loam | 1.47 | 136 | | 38 | |