"ON FARM" IMPLEMENTATION OF LOWER NITROGEN FERTILIZER INPUTS THROUGH NITROGEN ACCOUNTING AND VALIDATION OF ORGANIC MATTER MINERALIZATION

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Introduction

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.

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 lb N/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 overestimate 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.

Methods

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 some of the fields with high residual nitrate, the fieldman and grower opted to leave all plots unfertilized. Ten fields were studied between Parma, Idaho, and Vale, Oregon, in 1996. 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 took care of all of the cultural practices, and the fertilizers were applied in cooperation with fertilizer industry representatives. Sugar beet fieldmen kept track of crop progress and coordinated the harvest, collecting data on yield and quality 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 before harvest then 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, 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 ratio of beet dry weight to fresh weight, 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. Nitrogen mineralization was also estimated by aerobic incubation and buried bag methods.

Results and Discussion

Spring soil nitrate N ranged from 61 to 399 lb N/acre, depending on the field (Table 2). Optimistic yield goals ranging from 25 to 40 ton/acre of beets implied N fertilizer needs of 0 to 216 lb N/acre. The lowest applied N rates were 0 lb N/acre at twenty two of the thirty 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 during 1995 in the Treasure Valley was damaging at certain locations. The 1996 season was more favorable.

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 routinely obtained near Vale, Ontario, and Nyssa with low rates of N fertilizer (Tables 2 and 3). Clear increases in beet yield and sugar production occurred on shallow soils with irrigation apparently in excess of evapotranspiration. Beet pulp nitrate at 0 applied N suggested that there was excessive N supplies in many fields, even without any fertilizer nitrogen (Table 3). Beet petiole nitrate levels were 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 439 lb N/acre at harvest depending on the field (Table 4). Anaerobic incubation estimates of N mineralization ranged from 88 to 285 lb N/acre, depending on the field (Table 5). Mineralized N appears to be a large N source averaging 163 lb N/acre 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, based on 1994 and 1995 data.

In 1994, the anaerobic incubation estimates of mineralized N ranged in the same order of magnitude as field method using N balance. 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. In 1996, fields with suspected heavy irrigation showed low available N balances. The buried bag method of N mineralization was laborious and provided numbers similar and less than the anaerobic method. The aerobic method of soil incubation provided estimates of N mineralization in the same range as the anaerobic method, but the numerical values were more erratic.

At the most productive N level tested at each site, sugar beets were able to recover between 35.4 and 90.4 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). The one efficiency of 125.7 percent occurred in a field irrigated with considerable nitrate in the irrigation water. 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.

Conclusions

1. The mineralization of organic matter provided on average 163 lb N/acre per year, but the fertilizer guides assume that only 30 to 50 lb N/acre will be mineralized.

2. Nitrogen fertilizer guides overestimated crop fertilizer needs. Nitrogen fertilization was of marginal benefit for sugar beets when nitrogen mineralization is high on deep soils without excessive irrigation. In these studies, N fertilization was often counter productive.

3. The anaerobic incubation method of estimating N mineralization was useful.

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Table 1. Characteristics of 20 sugar beet fields used for soil N mineralization studies in 1994, 1995 and 1996, Malheur Experiment Station, Oregon State University, Ontario, Oregon.

Field	Location	Soil texture	Soil pH	Soil organic matter	Soil depth	Variety	Planting date	Irrigation system	Comments	Previous crop
1994				%	feet					
1	Burley	sandy loam	8.4	1.25	> 6	MH 9455	April 11	side roll	cyst nematode	beets
2	Minidoka	silt loam	8	1.5	2.5	PM-9	March 19	side roll	rock at 2-3	wheat
3	Minidoka	silt loam	8	2.35	2.5	WS 91	March 20	side roll	rock at 2-3	wheat
4	Jerome	loam	7.55	1.05	2.5	WS 91	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	WS 62	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
1996										
1	Ontario	silt loam	8.5	1.5	>6'			furrow		
2	Nyssa	silt loam	7.8	1.7	>6'			furrow		
3	Parma	silt loam	8.0	2.2	>6'	PM-9	April 11	solid		radish
4	Nyssa	silt loam	7.7	1.4	>6'			furrow		
5	Vale	silt loam	8.0	1.4	>6'	WS 91	April 8	furrow		onions
6	Vale	silt loam	8.0	1.4	>6'	WS 91	April 8	furrow		onions
7	Vale	silt loam	8.0	1.3	>6'	WS 91	April 8	furrow		onions
8	Ontario	silt loam	7.8	1.2	>6'	WS 62	March 19	furrow		onions
9	Ontario	silt loam	7.8	1.5	>6'	WS 62	March 25	furrow		onions
10	Ontario	silt loam	7.8	1.5	>6'	WS 91	March 26	furrow		onions

Table 2. Optimistic yield goals, soil nitrate, recommended N fertilizer rates, grower's preferred N fertilizer rates, and best fertilizer N rates for 1994, 1995 and 1996, Malheur Experiment Station, Oregon State University, Ontario, Oregon.

Field	Location	Optimistic yield goal	Soil nitrate 0-3 ft	Total N needed for optimistic yield goal	Recommended N fertilizer for optimistic yield goal	Growers' preferred N rate	Lowest N rate used in trial	Highest yielding N rate for the trial
1994		ton/acre	------------	------------	lb N/acre	------------	------------	------------
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	NA[1]	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	NA	60	60
9	Nyssa	40	165	320	154	NA	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	NA	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
1996								
1	Ontario	40	190	320	130	80	0	40
2	Nyssa	40	188	320	132	125	0	30
3	Parma	40	289	320	31	200	200	NA
4	Nyssa	40	164	320	156	75	0	0
5	Vale	40	399	320	0	100	0	0
6	Vale	40	399	320	0	100	0	0
7	Vale	40	357	320	0	100	0	0
8	Ontario	40	254	320	56	100	0	0
9	Ontario	40	261	320	59	100	0	0
10	Ontario	40	261	320	59	100	0	0

*Boron deficient part of field.
[1]NA: data not available.

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, 1995 and 1996.

		Summary of characteristics			Highest yielding plant performance					
Field	Location	Optimistic yield goal	Soil nitrate 0-3'	Most productive N rate for trial	Clean beet yield	Sucrose	Conductivity	Extraction	Recoverable sugar	Pulp nitrate
1994		ton/acre	lb N/acre	lb N/acre	ton/acre	%		%	lb/acre	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	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
1996										
1	Ontario	40	190	40	43.5	14.5	1.09	86	10,876	739
2	Nyssa	40	188	30	36.9	16.6	0.74	86.3	10,572	303
3	Parma	40	289	200	34.1	15.1		86	8,856	
4	Nyssa	40	164	0	33.5	15.4	1.02	84	8,667	599
5	Vale	40	399	0	31.0	16.2	1.00	86	8,638	546
6	Vale	40	399	0	31.0	16.1	1.00	86	8,585	546
7	Vale	40	357	0	33.5	15.8	1.02	86	9,104	481
8	Ontario	40	254	0	32.3	15.9	0.73	86	8,833	343
9	Ontario	40	261	0	33.1	15.6	1.03	86	8,881	596
10	Ontario	40	261	0	29.8	15.5	0.99	86	7,945	576

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, 1995 and 1996.

		Best 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 ft	Spring soil ammonium -N 0-3 ft	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[1]
1994		ton/acre					lb N/acre						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	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[2]	437[2]	100	37	164	301	10.08	68.9[2]
12	Ontario	45.6	12,732	0	104	49	292[2]	445[2]	123	46	226	395	8.65	88.8[2]
1995														
1	Buhl	21.3	6,352	0	199	NA[3]	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	NA	195	461	92	9	116	217	6.79	47.1
4	Minidoka	21.4	6,787	85	105	NA	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
1996														
1	Ontario	41.8	10,568	40	190	14	141	346	129	53	265	439	10.40	125.7
2	Nyssa	36.9	10,572	30	188	27	130	375	80	33	193	306	8.30	81.4
3	Parma	34.1	8,856	200	289	11	172	672	109	47	185	341	10.10	50.9
4	Nyssa	33.5	8,667	0	164	42	125	331	84	50	170	304	9.10	91.7
5	Vale	31.0	8,638	0	399	46	285	730	80	43	135	258	8.30	35.4
6	Vale	31.0	8,585	0	399	46	253	698	91	31	170	294	9.50	42.1
7	Vale	33.5	9,104	0	357	42	177	576	54	31	138	223	6.70	38.7
8	Ontario	32.3	8,833	0	254	36	111	401	84	100	179	363	11.20	90.4
9	Ontario	33.1	8,881	0	261	43	144	448	120	40	201	361	10.90	80.7
10	Ontario	29.8	7,945	0	261	43	93	397	92	52	192	336	11.30	84.9

[1]Total plant N content as a percent of the total available N supply.
[2]N mineralization estimate by season-long N balance.
[3]NA: data not available.

Table 5. Estimates of N mineralization made in 30 growers' sugar beet fields by two different methods, Malheur Experiment Station, Oregon State University, Ontario, Oregon, 1994, 1995, and 1996.

				N-mineralization estimate	
Grower	Location	Soil texture	Organic matter	Anaerobic incubation	Available nitrogen balance
1994			%	-- lb N/acre --	
1	Burley	sandy loam	1.25	112	NA
2	Minidoka	silt loam	1.5	172	NA
3	Minidoka	silt loam	2.35	167	NA
4	Jerome	loam	1.05	135	283
5	Nyssa	silt loam	1.4	88	238
6	Ontario-Vale	fine sandy loam	1.6	149	238
7	Ontario-Vale	silt loam	2.2	251	304
8	Ontario-Nyssa	fine sandy loam	1.75	115	125
9	Nyssa	silt loam	2.1	97	61
10	Vale	silt loam	2.05	236	251
11	Brogan	silt loam	1.6	149	224
12	Ontario	silt loam	1.5	159	293
1995					
1	Buhl	silt loam	1.2	95	NA
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	NA
7	Ontario	silt loam	1.43	189	48
8	Nyssa	silt loam	1.47	136	38
1996					
1	Ontario	silt loam	1.5	141	339
2	Nyssa	silt loam	1.7	130	166
3	Parma	silt loam	2.2	172	-28
4	Nyssa	silt loam	1.4	125	-43
5	Vale	silt loam	1.4	285	-13
6	Vale	silt loam	1.4	253	23
7	Vale	silt loam	1.3	177	31
8	Ontario	silt loam	1.2	111	197
9	Ontario	silt loam	1.5	144	219
10	Ontario	silt loam	1.5	93	196