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Task. 2. Soil and Plant Test Calibration to Improve Nutrient Management

Introduction

Soil and plant tissue tests can provide valuable information to aid in dairy nutrient management planning. The tests are used to indicate if nutrient deficiencies are likely and additional fertilization would be beneficial, or if nutrient levels are likely to be sufficient or excessive.

In this task we evaluated soil and plant nitrogen (N) testing, with two main objectives: 1) to determine if the tests could predict potential the need or lack of need for additional N for silage corn planted at sites with a history of manure applications, and 2) to give dairy farmers a first hand experience with the tests as reflected in the yields of their crops. Nitrogen was the focus of this task, because it is required in large amounts by corn and is also the nutrient most likely to leach into ground water if it is present in excess amounts. We compared our results with similar studies done in the Northwest by Marx (1995) and Zebarth et al. (1999).

Methods

Tests included pre-plant soil nitrate, pre-sidedress soil nitrate (PSNT), post-harvest soil nitrate (report-card test), leaf tissue chlorophyll, and post-harvest stalk nitrate. This report will focus on PSNT and post-harvest soil nitrate tests, because they are the most reliable and widely used tests.

On farm trials were established in 1995 and 1996 in field plots planted to silage corn on dairy farms on the Sumas-Abbotsford aquifer. The experiment included 13 trials in 1995 and 14 trials in 1996. Each trial was laid out in farm fields and each consisted of two treatments. One treatment received 135 kg/ha N fertilizer as ammonium nitrate during the mid season, while the other treatment received no supplemental N. The treatments were replicated 4 times in each trial, in a randomized complete block design. Plots were 6.1 m long and 4 to 6 rows wide. With the exception of sidedress fertilizer, all field work was done by the cooperating farmers as part of their normal practices (including variety selection, field preparation, planting, starter fertilizer, irrigation, and weed management). A number of the trials received manure before planting, or as irrigation from the lagoon during the growing season.

Soil samples for PSNT were collected when the corn was at the 3 to 6 leaf stage, immediately before applying the side-dress N. Samples were collected from the 0 to 30 cm depth using a cylindrical hand probe 2 cm in diameter. Six to nine subsamples were collected from each replicate plot and combined for analysis. After harvest, sampling was done in a similar fashion, except that samples were collected from the 0 to 30 and 30 to 60 cm depths. Soil samples were air dried, and nitrate was extracted using 2 M KCl (Gavlak et al., 1994). Nitrate N was determined in the extracts by an automated cadmium reduction method (APHA, 1992). A nitrate quick test was also done on the PSNT soil samples using a portable ion meter designed for field use.

We harvested 3.1 m sections from the center two rows of each plot. We cut plants 5 cm above ground surface and determined dry matter yield on the harvested portion of each plot. The trial plots were harvested before the farmers began field harvesting. As a result the corn was not as mature as what is normally harvested. Planting, sampling and harvest dates, soil type, starter fertilizer N, and manure use for each trial is summarized in Table 1.

Table 1. Dates, fertilizer and manure use, soil series, and corn variety for PSNT trials.

	Dates			Starter	Manure			Corn
Trial	Planting	PSNT	Harvest	N	Pre-plant	Irrigation	Soil	Variety
				lb/ac				
9501-1	31-May	14-Jun	6-Sep	38	Y	manure	Briscot	
9501-2	31-May	14-Jun	6-Sep	38	Y	manure	Mt Vernon	
9502-1	12-May	14-Jun	5-Sep	27	Y	manure	Hale	
9502-2	12-May	14-Jun	5-Sep	27	Y	manure	Hale	
9504-1	18-May	14-Jun	7-Sep	57	Y	?	Hale	
9505-1	19-May	14-Jun	11-Sep	36	Y	clean	Hale	
9505-2	9-May	14-Jun	7-Sep	21	Y	manure	E-W	
9505-3	18-May	14-Jun	11-Sep	67	N	clean	E-W	
9505-4	18-May	14-Jun	11-Sep	67	N	clean	Tromp	
9507-1	5-May	14-Jun	6-Sep	20	Y	clean	Lynden	
9507-2	5-May	14-Jun	7-Sep	20	Y	clean	Laxton	
9508-1	4-May	14-Jun	7-Sep	56	Y	manure	Mt Vernon	
9509-1	4-May	14-Jun	6-Sep	42	N	?	Kickerville	
9602-3	4-Jun	2-Jul	18-Sep	0	N	manure	Hale	Quanta
9602-4	4-Jun	2-Jul	18-Sep	0	N	manure	Hale	Quanta
9604-2	7-Jun	2-Jul	18-Sep	0	Y	clean	Hale	NK Mix
9605-1	4-Jun	2-Jul	17-Sep	?	Y	clean	Hale	Quanta
9605-2	4-Jun	2-Jul	17-Sep	?	N	manure	E-W	SB Northrup
9605-5	4-Jun	2-Jul	17-Sep	?	Y	clean	Hale	Quanta
9608-2	30-May	2-Jul	16-Sep	48	Y	clean	Mt Vernon	NK 9055
9609-1	10-May	2-Jul	17-Sep	40	Y	manure	Kickerville	Pion. 3845
9611-1	6-Jun	2-Jul	16-Sep	48	Y	clean	Briscot	CIBA 4066
9611-2	6-Jun	2-Jul	16-Sep	57	Y	clean	Briscot	NK 2001
9612-1	30-May	2-Jul	16-Sep	60	Y	clean	Mt Vernon	CIBA 4066
9613-1	27-May	2-Jul	17-Sep	45	Y	none	Tromp	Quanta
9613-2	11-May	2-Jul	17-Sep	45	N	none	E-W	Quanta
9614-1	30-May	2-Jul	18-Sep	57	Y	clean	Lynden	Pion. 3839

Per cent relative yield was determined based on dry matter yield for the fertilized and unfertilized treatments for each trial:

Relative yield = (Dry matter yield of unfertilized treatment / Dry matter yield of fertilized treatment) x 100

Table 2 summarizes weather during the growing seasons in 1995 and 1996. Weather was more favorable for corn production in 1995, with a drier spring that allowed earlier planting, and above normal rainfall during the summer. In 1996, spring was wet and cool, delaying planting on most farms. Corn was less mature at harvest in 1996, which accounts in part for lower yields that year.

Table 2. Growing season weather, Clearbrook, WA. 1995-1996.

Month	Precipitation (mm)			Mean Temperature (°C)		
	1995	1996	Normal	1995	1996	Normal
April	89	170	89	9.8	10.7	9.3
May	19	113	77	14.3	11.5	12.4
June	47	25	61	16.4	15.0	15.2
July	68	36	45	18.4	18.1	17.2
August	58	25	47	16.4	18.0	17.2
September	53	131	75	16.6	13.9	14.4

Results and Discussion

Relative yield is a way to differentiate among treatments that were responsive to sidedress N and those that were not. Marx (1995) used a relative yield of 94% for the unfertilized treatment as an indication responsiveness, while Zebarth et al. (1999) used a relative yield of 90%. Of the 27 trials in this experiment, only 5 had relative yields of 94% or less, and only one of those was statistically significant (t-test, P<.05) (Table 3). Six trials had unfertilized yields > 106% of the fertilized yield, but none were statistically significant. The one statistically responsive site (9505-2) had a low PSNT value (Table 3). But, a trial done in the same field in 1996 (trial 9605-2) did not respond to N fertilizer, even though the PSNT was still low. If we use a critical relative yield of 90% instead of 94%, only one site was responsive, and it was not statistically significant because of high variability among the replicates.

These results suggest that under conditions typical of manured corn fields on the Sumas-Abbotsford aquifer, there is little or no yield response to fertilizer N applied at side-dress time. The additional fertilizer N (135 kg/ha) increased post-harvest soil nitrate by an average of 130 kg/ha in 1995 and 100 kg/ha in 1996. This suggests that the crop used little of the sidedress N, and most of it remained in the soil as nitrate, where it would be vulnerable to leaching during the winter (Table 4).

Table 3. PSNT and corn dry matter yield, Sumas-Abbotsford project, 1995-96.

Site No.	PSNT	Dry Matter Yield (Mg ha^{-1})		C.V.	Rel. Yld.	T-test
	(mg NO_3-N kg^{-1})	0 kg N ha^{-1}	168 kg N ha^{-1}	(%)	(%)	P-value
		1995				
9505-2	15	13.4	14.8	4	90.8	0.03
9505-3	15	17.5	16.4	6	106.7	0.22
9505-4	18	11.4	12.2	4	93.7	0.44
9505-1	33	13.6	14.1	4	96.7	0.53
9509-1	38	14.7	16.1	11	91.1	0.17
9502-2	50	13.5	13.8	13	97.7	0.78
9504-1	51	15.0	12.6	18	118.6	0.09
9501-1	59	13.5	14.0	14	96.7	0.78
9507-1	59	14.5	15.2	12	95.3	0.67
9508-1	68	17.8	18.8	6	94.8	0.22
9502-1	70	14.3	14.9	11	95.9	0.53
9507-2	76	15.7	15.3	3	102.5	0.57
9501-2	102	16.6	14.5	24	114.5	0.35
mean	50.3	14.7	14.8			
		1996				
9605-2	13	4.7	4.3	27	108.9	0.59
9614-1	17	10.0	10.2	3	97.5	0.58
9613-2	21	7.3	4.9	37	148.3	0.17
9609-1	23	8.2	8.8	14	92.5	0.44
9604-2	24	6.7	6.7	8	99.3	0.93
9605-5	26	7.4	7.9	16	94.5	0.59
9605-1	28	7.7	7.8	12	97.9	0.82
9613-1	32	6.7	6.4	17	104.9	0.70
9611-1	37	10.8	10.1	10	106.7	0.29
9608-2	37	11.2	13.2	19	85.1	0.23
9612-1	42	10.9	11.4	15	95.7	0.69
9602-4	45	8.9	8.9	9	99.8	0.98
9602-3	47	10.7	10.2	5	104.9	0.23
9611-2	49	10.3	9.9	5	104.4	0.20
mean	32.8	9.0	9.0			

Table 4. Effect of mid-season N fertilizer on post-harvest soil nitrate-N.

	1995 Soil profile nitrate (0-60 cm) kg/ha			1996 Soil profile nitrate (0-60 cm) kg/ha	
	Fertilizer rate			Fertilizer rate	
Site	0 kg N/ha	134 kg N/ha	Site	0 kg N/ha	134 kg N/ha
9501-1	167	337	9602-3	188	265
9501-2	244	272	9602-4	245	583
9502-1	306	353	9604-2	110	268
9502-2	322	390	9605-1	49	141
9504-1	183	485	9605-2	57	143
9505-1	122	249	9605-5	58	164
9505-2	157	326	9608-2	217	291
9505-3	16	97	9609-1	274	313
9505-4	15	83	9611-1	210	177
9507-1	170	400	9611-2	141	351
9507-2	232	350	9612-1	149	212
9508-1	83	116	9613-1	138	254
9509-1	89	351	9613-2	64	81
			9614-1	48	92
Mean	162	293		139	238

Some of the sites were irrigated during the summer with liquid manure from lagoons, which would be extra N that would not be accounted for by the PSNT. But, even sites with no manure added during the spring or summer were not responsive to the N fertilizer. This suggests that there is enough mineralization of soil N occurring to provide sufficient N for corn silage on many sites, even without manure application or sidedress fertilizer application during the current year.

Similar tests of the PSNT on corn grown on manured land were done by Marx (1995) and Zebarth et al. (1999). Marx (1995) established 29 trials in the Willamette Valley of Oregon, using a similar design to this experiment. Some sites received manure during the year of application. He found that only 7 of the 29 trials showed a response to fertilizer N, based on a relative yield < 94%. Of the 7 sites only 4 had statistically significant (P <.05) responses. He included 3 sites that did not have a history of manure application, and 2 of those were among the statistically significant responses.

Although most of his sites were not responsive, Marx had enough responsive sites to determine a critical soil PSNT level using a Cate-Nelson statistical analysis. The Cate-Nelson analysis divides the data into two populations using an iterative process. The first iteration places the two lowest X-values (in this case PSNT soil test values) in one population, and all other values in the second population. The second iteration adds the next lowest value to the first population, and so on. The critical value for each iteration is the point midway between the highest value of the first population and the lowest value of the second population. The critical value of the iteration that has the best least-squares fit to the means of the Y values in each population (relative yield) is the critical PSNT.

Marx calculated a PSNT value of 21 mg NO_3^- N/ kg soil for his data set. We did not use a Cate-Nelson analysis for our data because we had so few responsive sites and a limited range of relative yield values.

Marx (1995) noted that his best-fit Cate-Nelson analysis had 3 sites where no fertilizer response was predicted, but a response occurred in the field. This is a Type II error. It is a conservative error in terms of protecting water quality, but could result in some economic loss to the farmer. He concluded the cost of applying fertilizer was probably greater than economic loss averaged over several years, and did not recommend raising the PSNT to a higher value. Based on this PSNT research, the following guidelines were developed (Table 5).

Table 5. Presidedress soil nitrate test recommendations for silage corn for the Pacific Northwest (Marx et al., 1997).

PSNT mg nitrate N/kg soil	Fertilizer N Recommendation lb/acre
0-10	100-175
10-20	50-100
20-25	0-50
>25	0

Zebarth et al. (1999) did a larger study in southwestern British Columbia that included some sites on the Canadian portion of the Sumas-Abbotsford aquifer. They had more trials (70 in 3 years), and included more fertilizer rates on some of their trials. All of their sites had a history of manure application. At many sites they conducted two trials; one with normal spring application of manure and one with no manure application in the spring. Their results were similar to the Oregon study and our study in that most of the trials were not responsive to fertilizer. Using a relative yield of 90% to differentiate responsive from non-responsive sites, they identified 24 responsive sites. Zebarth et al. (1999) also measured post-harvest soil nitrate, and found that levels increased on sites receiving fertilizer. The average amount of the increase was not as great as we observed, probably in part because they had more responsive sites.

A Cate-Nelson analysis of their data predicted a critical PSNT of 19 mg NO_3^- N/ kg soil. When only the sites receiving spring manure applications were considered, the critical PSNT was 14 mg NO_3^- N / kg soil. Using a PSNT of 19 mg NO_3^- N / kg soil produced a Type II error rate of 10%. As noted above, Type II errors may result in economic loss to the farmer. By using a critical PSNT of 30 mg NO_3^- N / kg soil, the Type II error rate was reduced to 4%. The Type I error rate (sites predicted to need fertilizer that showed no response) would increase to about 30%. Zebarth et al. (1999) developed the following guidelines for supplemental fertilizer applications based on PSNT results (Table 6). They noted that using these guidelines would result in a substantial decline in supplemental N fertilizer use in silage corn in southwestern BC.

Table 7. Presidedress soil nitrate test fertilizer recommendations for silage corn in south coastal British Columbia.

PSNT mg nitrate-N/kg soil	Fertilizer N Recommendation Kg/ha
<14	125
14-18	100
18-21	75
21-26	50
26-30	25
>30	0

The three Northwest studies (this study, Willamette Valley (Marx, 1995), and southwestern BC (Zebarth et al., 1999)) all showed that most of the trials had sufficient N available that silage corn did not respond to mid-season application of fertilizer N. Mid-season fertilizer N did increase post-harvest soil nitrate-N, and thus increased the pool of potentially leachable N.

The reason for the lack of response to fertilizer N is likely that soils have a large pool of mineralizable organic N, which becomes available during the growing season. In many cases enough N becomes available from these soils to meet the needs of a corn silage crop. At least part of this pool is the result of past manure applications, which have increased the amount of organic N in the soil. This hypothesis is supported by our results from Task 3, which show increased mineralization of N in soils with a history of manure application.

Summary and Recommendations

Although our study had too few responsive sites and too narrow a range of relative yields to determine a PSNT critical level, the results of our study were similar to the results of Marx (1995) and Zebarth et al. (1999), and we can use either set of recommendations as a basis for interpreting PSNT tests.

Reducing N fertilizer use on soils that have sufficient N for corn will save farmers time and money, and will result in less nitrate-N remaining in the soil profile at the end of the growing season. Farmers may see the PSNT test as extra work and time, however, and may not be inclined to do it. Quick testing for nitrate can save the considerable time, because the results do not have to be returned from a laboratory.

To determine if quick testing was reliable, we compared soil NO_3^- N quick tests using a portable ion meter with results from the standard laboratory procedure. In 1995 quick test results were very similar to laboratory results, but in 1996 quick test levels were inconsistent and tended to be lower (data not shown). It is not clear if this was a problem with standardization of the instrument or with the reagents. Zebarth et al. (1999) found a good relationship (r^2=.86) between laboratory values and a similar quick test, and concluded that it could be used with reasonable confidence. These results suggest that quick testing can be a time saving alternative with a small sacrifice in accuracy, provided the user calibrates the meter and does regular checks with lab results.

Some farmers may want to forego PSNT testing and mid-season fertilizer application in soils with a history of manure application. This would save sampling time and reduce fertilizer use, but farmers would have less confidence that their corn crop was receiving adequate N.

In conclusion:

- Most sites studied were not responsive to mid-season fertilizer N applications to silage corn.
- This is likely the result of a history of manure applications increasing the amount of mineralizable N.
- PSNT tests can increase farmers' confidence about whether they need supplemental mid-season fertilizer N or manure on soils with a history of manure applications.
- Following PSNT recommendations can reduce fertilizer N use and reduce the amount of potentially leachable N in soils planted to silage corn
- PSNT recommendations from Oregon or British Columbia appear to be adequate for use in the Sumas-Abbotsford aquifer area.

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