Appendix 7

Greenhouse Gas Mitigation Program for Canadian Agriculture
Soil Conservation Council of Canada
Demonstration and Awareness Activities

Final Report - April 2006

to

Ontario Greenhouse Gas Mitigation Committee

by

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Highlighting Nitrogen Use Efficiency in Horticultural Operations

Highlighting Nitrogen Use Efficiency in Horticultural Operations

Projects:

1. Nitrogen Rate Trials
2. Fertigation and In Season Nitrogen Monitoring
3. Evaluation of Irrigation Efficiencies
4. Evaluation of Cover Crops for Biomass Production and Nitrogen Cycling

Project Summary

Most greenhouse gas projects focus on reducing GHG emissions in field crop, pasture and livestock based production systems. In Ontario there is significant acreage in high value horticultural crops. Many of these crops are intensively cropped with the use of nitrogen fertilizers, irrigation and numerous tractor passes over the field between tillage and pest control. Often horticultural crops are grown on light sandy soils with low organic carbon.

The “Highlighting Nitrogen Use Efficiency in Horticultural Operations” project features four main project areas. Within those areas there are more than 10 projects and 62 project sites over the time period 2003 to 2006.

Nitrogen Rate Trials: The advent of the Nutrient Management Act, higher nitrogen prices and some of the on farm projects under this program have helped to increase grower awareness and interest in the need for nitrogen rate trials. The larger acreage crops like potatoes and tomatoes have had some small plot research trials in the past. The high soil variability found in many vegetable crop areas and the variety specific response of some vegetables means that on farm strip trials are necessary for many of the horticultural crops grown in Ontario. (28 sites)

Fertigation and In Season Nitrogen Monitoring: Applying fertilizer through drip irrigation systems promises the opportunity to apply nitrogen “just in time”, in response to plant needs and weather conditions. This offers a tremendous opportunity to enhance nitrogen use efficiency and increase yields. In season monitoring with quick test techniques is needed to ensure that nitrogen applications are accurately applied and adequate for plant needs. (10 sites)

Evaluation of Irrigation Efficiencies: Drier mid summer weather in recent years and the need for consistent, predictable, high yields has lead to the rapid expansion of irrigation in vegetable growing areas. Drip irrigation promises high water use efficiency with small amounts of water applied at any time. Low pressure boom irrigation also has higher water use efficiency that the high pressure traveling guns and a degree of flexibility of use that drip does not have. (5 sites)

Evaluation of Cover Crops for Biomass Production and Nitrogen Cycling: Cover crops are commonly used for erosion control on many vegetable farms. There is increased interest in the nitrogen cycling value of cover crops to subsequent crops. There are a number of crops like peas, snap beans and cucumbers that are harvested in early to mid summer, allowing a large window for cover crops to be established and put on significant growth. This project looked at the potential for nitrogen scavenging, biomass production and nitrogen release. (19 sites)

Project details and results were communicated through a variety of media. Numerous written reports, newletter and newspaper articles, posters and radio reports were prepared. Presentations were given at small grower meetings, agribusiness locations and at the larger commodity events like the Processing Vegetable Conference and the Ontario Fruit and

Vegetable Convention. Reports on the horticultural GHG Mitigation projects were a prominent part of the GHG Roadshow program “Advances in Soil and Nitrogen Management”. Information, plot locations and project equipment was displayed through a variety of tour dates over the three years.

This project report attempts to give an overview of the project activities over the past three years.

1.Nitrogen Rate Trials

Introduction

A series of on-farm reduced rate strip trials were established to demonstrate the potential of reduced rate nitrogen fertilizer programs for a variety of horticultural crops. In the past much of the nitrogen fertility work has focused on horticultural crops like tomatoes and potatoes. There are a number of other crop types within the horticultural sector that are known to be high users of nitrogen such as peppers, ginseng, sweet corn and cole crops like cauliflower, broccoli and cabbage. In addition the harvested portion of some of these crops is quite small, leaving large amounts of high nitrogen residues behind. There are opportunities with these crops to fine tune nitrogen rates (and save on fertilizer expenses) and through that reduce the potential for losses of nitrogen into the environment either through leaching or through losses as nitrous oxide. With horticultural crops there is a concern about maintaining crop quality while fine tuning nitrogen rates. Consumers have high visual expectations from many of these crops.

The goals of the various projects within this heading vary slightly in detail but the over-riding goal was to demonstrate that nitrogen rates could be fine tuned, in some cases reduced from current recommendations with little impact on yield or quality.

Methodology

The details vary slightly with the projects ranging from small plot, replicated designs with the pepper, work that Dr. L.van Eerd was conducting both on site at Ridgetown and on farm fields to field scale replicated strips in the sweet corn projects. The cole crop comparisons were based on single treatments and in some cases depending upon the cooperator, just a “zero N” window was used for comparison against the grower’s nitrogen rates.

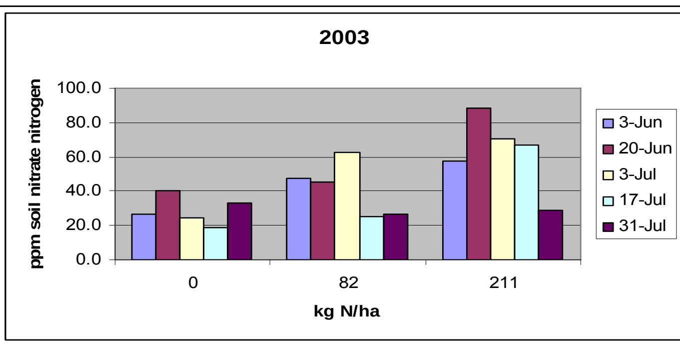
Results and Discussion

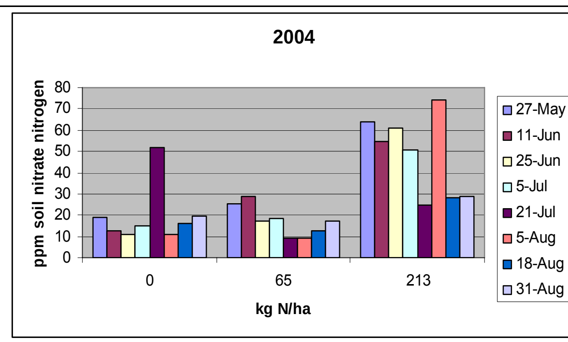
Cole Crop

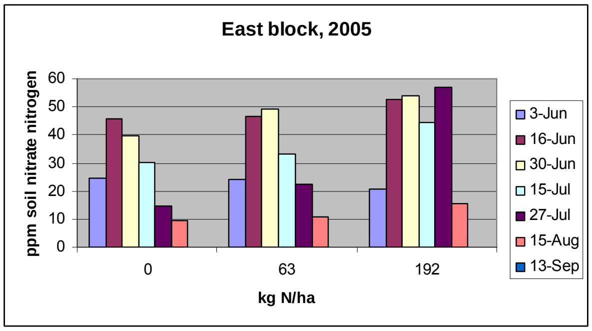
Soil nitrate nitrogen

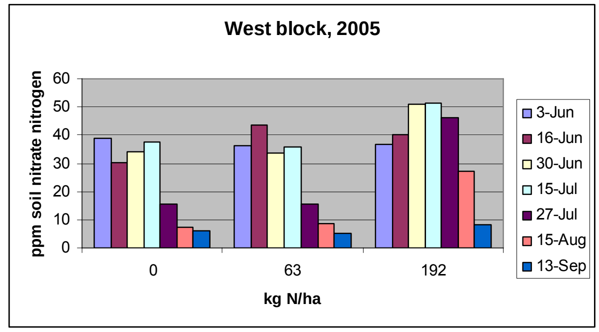
In 2004 the 0 nitrogen rate plot was located on the same 0 nitrogen plot in 2003. The general trend in all sampling years was for increased soil nitrate nitrogen with increasing applied fertilizer rates. The 0 and 63 kg N/ha rate had similar soil nitrate nitrogen levels. With increasing nitrogen rates, there was increasing soil nitrate nitrogen levels.

Figure 1. Soil nitrate-nitrogen sampled during cauliflower production 2003-2005





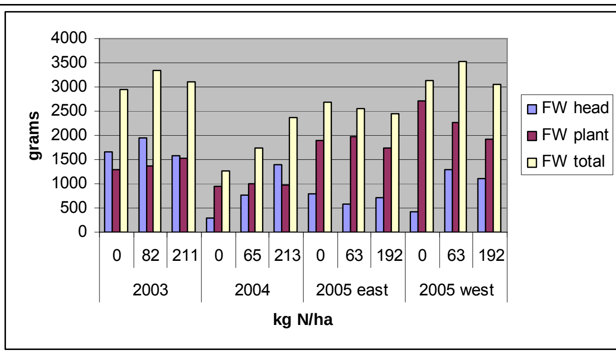




Fresh and dry weight of the crop & crop residue

In fresh weight (FW) of the harvested portions varied from 1.5-1.9 kg. The 100% N rate had the lowest FW, 1.5 kg (table 1). This could reflect field variability, as plots were not replicated through the field. However dry weight (DW) for harvested portion was highest in the 100% plot. According the plants sampled from each plot, increasing the nitrogen rated did not increase the fresh weight significantly when compared to the 0 or 30% plot. Growers estimated yield from the field was 12 ton/ac. Yield per treatment was calculated using the fresh weights determined from each treatment. Estimated yield (tons/ac) per treatment, Table 1, was 13 (0 rate), 15.5 (30% rate) and 12.6 (100% rate) .

Figure 2. Average fresh (FW) and dry (DW) weight of harvested portions, remaining plant and total plant 2003-2005



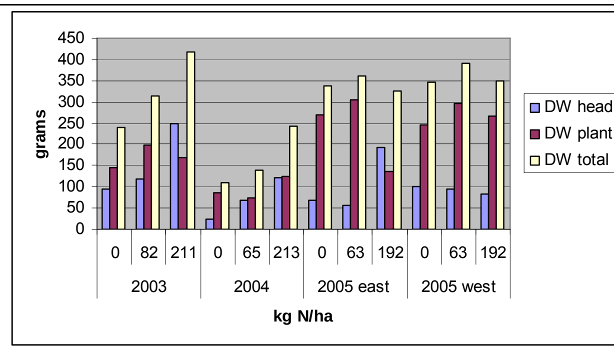


Table 1. Average percent nitrogen (N) in dry weight 2003 and 2005.

		Average % N	
% fertilizer rate	**kg N/ha**	**Harvested head**	**Remaining plant portion**
2003			
0	0	4.3	3.2
30	82	4.4	2.6
100	211	4.7	3.2
2005 east block			
0	0	4.1	3.6
30	63	4.4	3.1
100	192	4.2	3.7
2005 west block			
0	0	3.2	2.6
30	63	3.6	2.6
100	192	4.2	3.2

2004 % N not determined

Apparent nitrogen use efficiency

Nitrogen use efficiency (NUE) is the per cent of nitrogen taken up by the plant from applied nitrogen sources. In some cases it is calculated by including all possible nitrogen inputs. In this case it was calculated as apparent nitrogen use efficiency. It was calculated using the following equation: (Apparent N recovery – Apparent N recovery 0 plot)/total fertilizer applied * 100. It is important to keep in mind that these calculations are based on the 5 samples harvested for each treatment. The estimated yield per treatment was used to calculate the apparent NUE.

Table 2. Apparent Nitrogen Use Efficiency (NUE), per cent 2003 and 2005

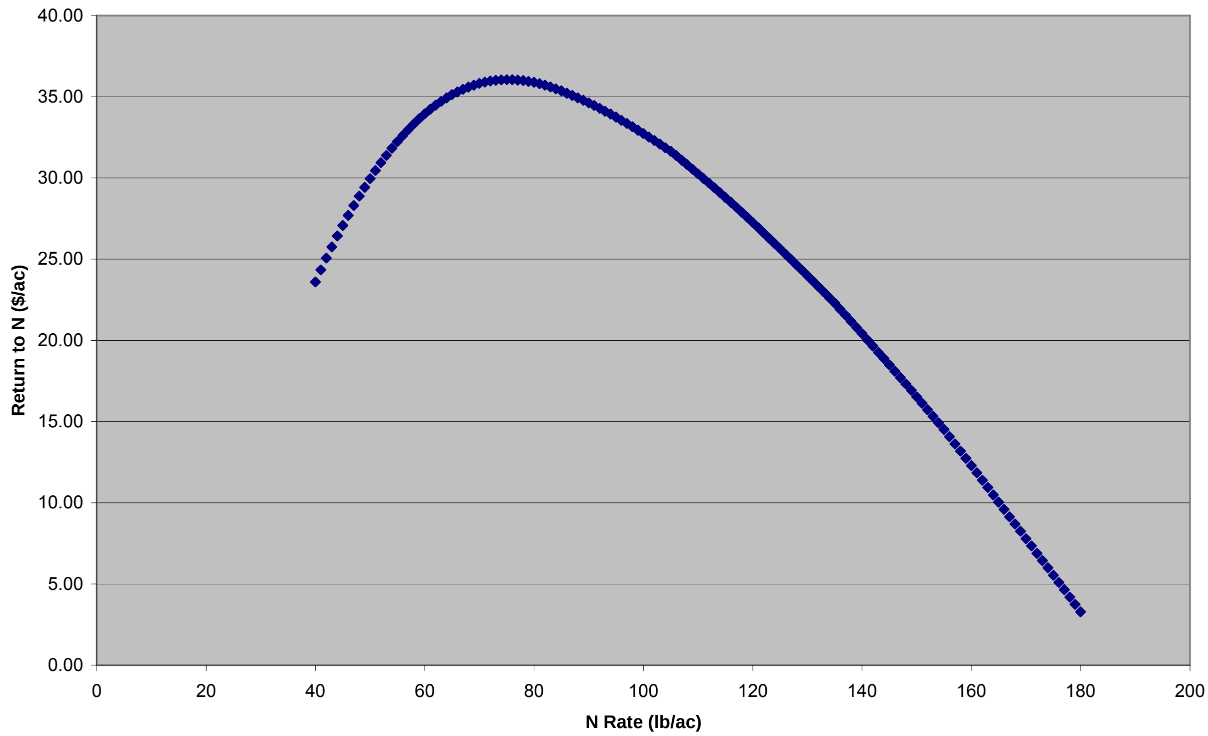
	%					
	2003		**2005 east**		**2005 west**	
Kg N/ha	**82**	**211**	**63**	**192**	**63**	**192**
Harvested plant	2	6	-7	46	6	1
Residue remaining	6	6	-10	-54	48	10
Total plant	29	12	-16	-9	54	11

Because of the low and negative NUE, it is likely that these sites may be inherently unresponsive to nitrogen.

Sweet Corn

Depending on the location, the economic return to N was maximized between 70-100 lbs actual fertilizer N per acre. Only 3/15 locations showed response to fertilizer nitrogen above 100 lbs/ac. This indicates that current average application rates of 100-120 lbs/ac are higher than the actual crop requirements for late season processing sweet corn. As a result, there is no strong support to revise the current OMAFRA nitrogen rate (80 lbs/ac) for late-season processing sweet corn fields.

Return to N vs. N Rate (all Sweet Corn data)



OMAFRA's N-MAN nitrogen credits developed for use in field corn may not accurately reflect nitrogen availability for a sweet corn crop. An economic analysis was done comparing the OMAFRA recommendations (with and without N-MAN credits) to the MERN rate. Where the N-MAN credits were utilized, there was a trend towards under application of nitrogen (as compared to MERN.) Where the base rate of 80 lbs/ac was used, the risk of over application equaled the risk of under application (Table 1).

Table 1: Risk of Over/Under Fertilization based on the Use of Manure Credits.

	Average Cost of Over Application	Average Cost of Under Application
OMAFRA Rec (80 lbs/ac) minus N-Man Credits	$19.65	$35.94
OMAFRA Rec (80 lbs/ac)	$15.20	$15.78

Pre-Side Dress Nitrogen Test

PSNT samples (30" soil nitrate taken at the 5-6 leaf stage) were taken at all plots and locations. There are currently no PSNT thresholds established for use in sweet corn in Ontario. However, a preliminary analysis was used based on the following assumptions.

PSNT (ppm N03)	**Potential Recommendations[1]**
0-10	1.5 x OMAFRA Recommendation
10-20	OMAFRA Recommendation
20-30	0.5 x OMAFRA Recommendation
>30	No additional N required.

[1] These potential recommendations were arbitrarily developed based on experience in field corn in Ontario and on sweet corn research from other jurisdictions.

PSNT predictions within all 15 sweet corn sites were remarkably accurate. Based on our economic analysis, this method was by far the most accurate at predicting MERN. While the PSNT results were encouraging at all locations, perhaps its use on sites receiving manure was perhaps the most promising, as the current OMAFRA nitrogen credits often resulted in an over-estimation of the available N derived from manure.

The economic returns to nitrogen based on the PSNT recommendations were on average within $5.00 per acre of the MERN yield.

Peppers

Nitrogen use efficiency experiments were conducted on green bell peppers. In 2005, there were no statistical differences in pepper yields with ammonium nitrate preplant broadcast application of N from 0 to 220 kg N/ha. Likewise, there was no difference between nitrogen treatments in first-pick yields. There were no yield differences when the same quantity of N was applied in a split application (i.e. ½ applied preplant and ½ before fruit set). Similarly, the preplant broadcast application UMAXX®, which is an urea-based fertilizer impregnated with urease and nitrification inhibitors, did not improve pepper yield. The overall lack of yield response to nitrogen was likely due to the relatively dry growing season, where moisture, not N, was a limiting factor on pepper yields. Moreover, there was adequate plant available soil nitrogen (≥20 ppm) throughout the season and moisture stress. Pepper plant tissue analysis indicated an adequate to high plant nitrogen status, which supports the lack of yield differences between different nitrogen treatments. Total plant N uptake (i.e. N content in fruit and shoots) at harvest was not significantly higher for the split N application compared to preplant application when a similar quantity of N was applied. This indicates that in-season N applications, as well as UMAXX® did not improve nitrogen use efficiency in peppers. A preliminary presidedress soil N test (PSNT) value of >24 ppm indicated no yield benefit with additional nitrogen fertilizer applied at the time of split nitrogen application.

Conclusions

Cole Crops

The cole crop trials demonstrated that further fine tuning of cole crop nitrogen rates can be done. Depending upon crop rotation and field history, some fields may not be highly responsive to applied nitrogen fertilizers, meaning that fertilization can be reduced. The large amounts of post harvest nitrogen available in the soil prompted further work on these sites in the form of cover crop plantings overlaid on the nitrogen trial (see the cover crop portion of this report for more details)

Sweet Corn

During the 2003-2005 demonstration trials it became apparent that while N is not usually a limiting factor for late-season sweet corn production, certain sites do exist where the N requirements are in-excess of the current recommendations. Further investigation into planting date, soil texture and organic matter levels may help to identify these highly responsive sites in the future, giving growers more confidence in the existing OMAFRA recommendations.

Replicated (small plot) trials investigating manure availability to a sweet corn crop are needed to accurately characterize the fertilizer value of organic nitrogen sources such as red clover and manure.

Next steps: The interest in nitrogen trials has increased in the last 3 years. Pepper nitrogen trials will continue for one more year at Ridgetown. Similar “zero window” plots on cole crops and a few other crops are planned for 2006 based on a Nutrient Management funded project. The sweet corn nitrogen plots will continue in a limited but similar format in 2006 based upon grower funding.

GHG Mitigation Significance:
Many horticultural crops are heavy users of nitrogen, but for some types i.e. cole crops like cauliflower, broccoli, very little of the plant actually leaves the field, leaving large amounts of nitrogen for succeeding crops or cover crops. Through fine tuning of fertilizer rate, losses of nitrogen to denitrification (loss as nitrous oxide) and leaching will be minimized.

Key Extension Messages:

- Nitrogen use can be refine in most vegetable crops

- On farm strip trials will build confidence in reducing nitrogen use. “Zero N” window treatments are a viable alternative.

2. Fertigation and In Season Nitrogen Monitoring

Fertigation

Introduction

Fertigation is a common horticultural production technique in many parts of the world, particularly in dry land culture like Israel and California. It does not have an extensive history in Ontario but is gaining in acceptance. Fertigation has the potential to be a “prescription” approach to nitrogen application by adding nitrogen as the crop needs it thereby reducing the potential for excess nitrogen to be present in the soil and available for leaching or denitrification. However most fertigation “recipes” come from areas with a much drier climate. Ontario growers are not willing to chance their crop by applying nitrogen only through fertigation – under wet weather conditions they would be forced to apply water in order to apply their fertility. Fertigation has also been found to increase overall yields on many sites, thereby increasing the crop residues returned to the soil.

Methodology

From 2003 to 2005 there were a number of sites and crops with demonstration fertigation trials monitored under this program, including strawberries, melons, peppers, ginseng and tomatoes. For the strawberry and melon sites, these trials built on demonstrations that have been initiated 2002. In 2003 and 2004 there was some evaluation of the consistency and calibration of fertigation systems in regards to the delivery efficiency of water and fertilizer. Individual projects varied in their details, most sites compared a fertigated program to different fertigation program.

In Season Monitoring

Introduction

Similar to the nitrogen rate trials, the goal of these trials was the refinement and reduction of nitrogen use. The key difference was to target the potential to use a tool like quick tests for soil and plant nitrate levels to make it possible to do in crop adjustments of nitrogen. In a number of cases the monitoring was overlaid on nitrogen rate trials and sampled in conjunction with soil nitrate samples.

Methodology

The details vary slightly with the project that the in season sampling was laid over. From 2003 and 2004, samples for analysis were gathered from the fertigated melons, strawberries and tomatoes. Through 2004 and 2005 this was expanded to include tobacco and peppers.

Results and Discussion

Strawberries

Soil and petiole sap nitrate-nitrogen There was a general trend for petiole sap nitrate-nitrogen to increase over the season. A similar increase appears to occur in the soil nitrate nitrogen. The greatest increase in petiole sap nitrate-nitrogen occurred from mid-Aug through September. For the early season sampling dates, petiole sap nitrate-nitrogen did not appear to change in response to fertigation applications. However, in the samplings during August and later fertigated petiole sap nitrate-nitrogen seems to be higher.

Soil nitrate-nitrogen and percent leaf nitrogen Soil nitrate-nitrogen increases slowly over the season. But the percent leaf nitrogen decreases from early in the season (May-June) to harvest. During harvest it is relatively unchanged (June-July). After renovation in late July there was a large increase in percent leaf nitrogen followed by a slow decline to through August and October. The increase in soil nitrate-nitrogen after September 15 is not reflected in the percent leaf nitrogen. Percent leaf nitrogen does not appear to change in response to fertigation applications.

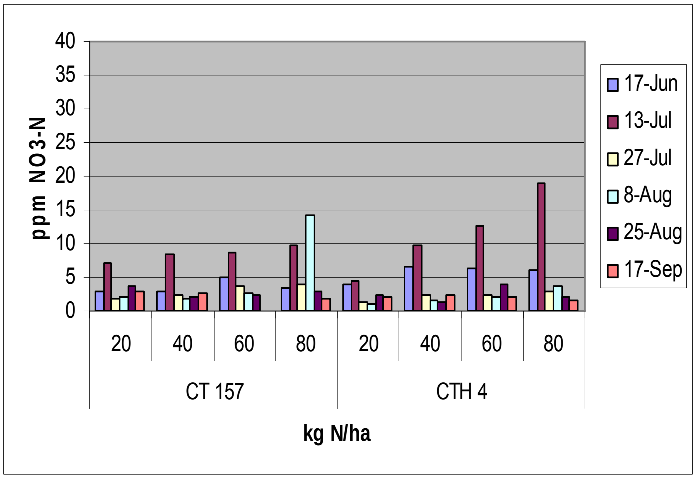
Petiole sap NO3-N & % leaf N The seasonal percent leaf nitrogen decreases from May until July and increases again after renovation, declining into October. These changes are not reflected in the petiole sap nitrate-nitrogen concentrations. Petiole sap nitrate-nitrogen increases in August to last sampling date, while percent leaf nitrogen decreases.

Peppers

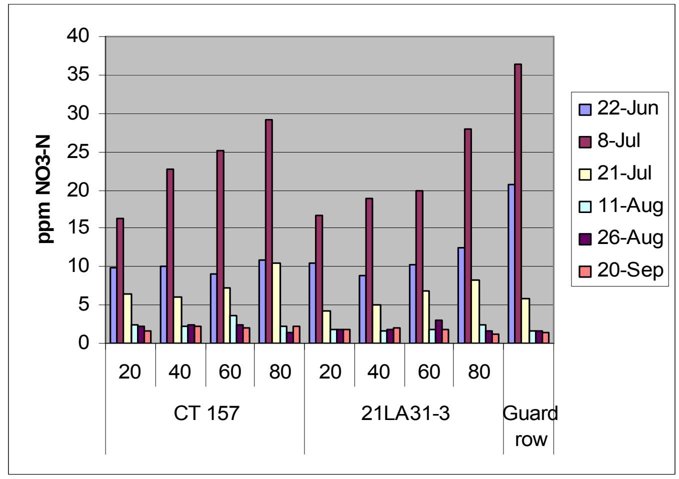
As part of the Ridgetown College hub site, soil samples were collected and analysed with a number of quick test methods under controlled laboratory conditions. The improvements in accuracy may be due to the speed of analysis after soil and tissue harvesting that was lacking in previous attempts by OMAFRA staff. Soil on-farm quick tests accurately determined soil nitrate-N when compared to certified laboratory analysis. The CARDY® meter and/or the Reflectoquant® are on-farm quick test tools recommended to growers who want to quantify soil nitrate.

Tobacco

Soil and tissue samples were collected and analyzed using and laboratory method and a quick test method (Cardy Meter). The objective is to determine the potential of a quick test method for in-season nitrogen (N.) monitoring to assist growers in determining the crop's N. requirements throughout the season. Because of the difficulty in using the Cardy meter to determine soil nitrate nitrogen, it was not used in 2005.

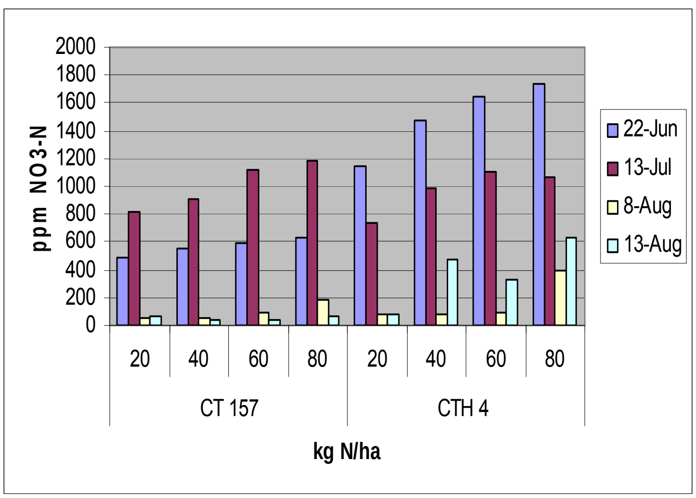


2004

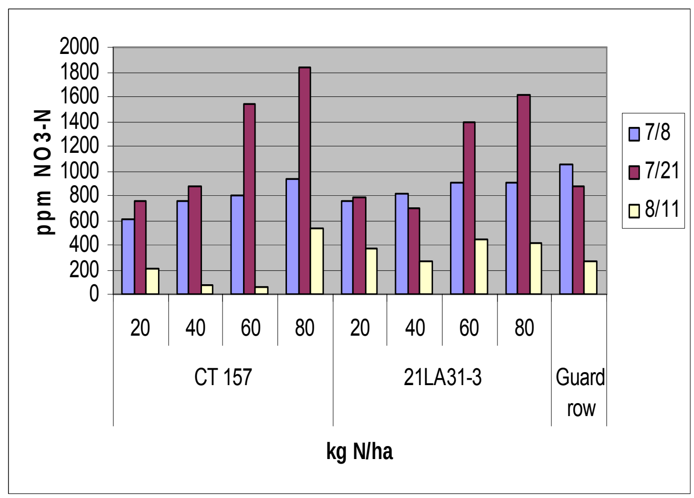


2005

Soil nitrate nitrogen (figure1): The overall trends are similar between years and cultivars. 2005 seemed to have higher soil nitrate nitrogen levels than 2004. This may have been a factor of rainfall and other weather conditions. The increased level at the second sampling date is a result of the side dress application,

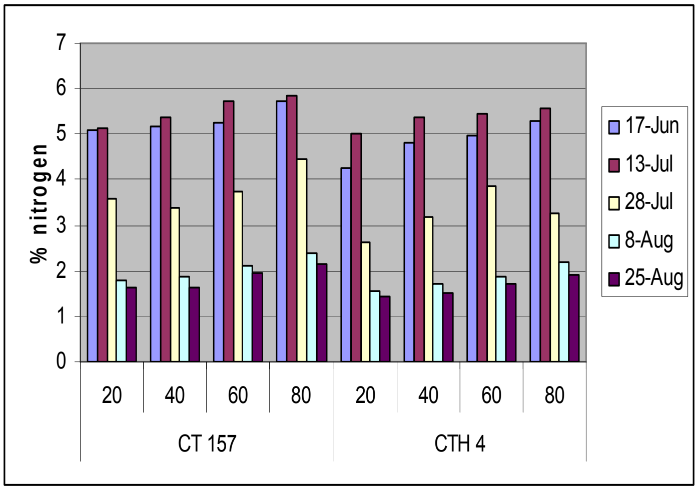


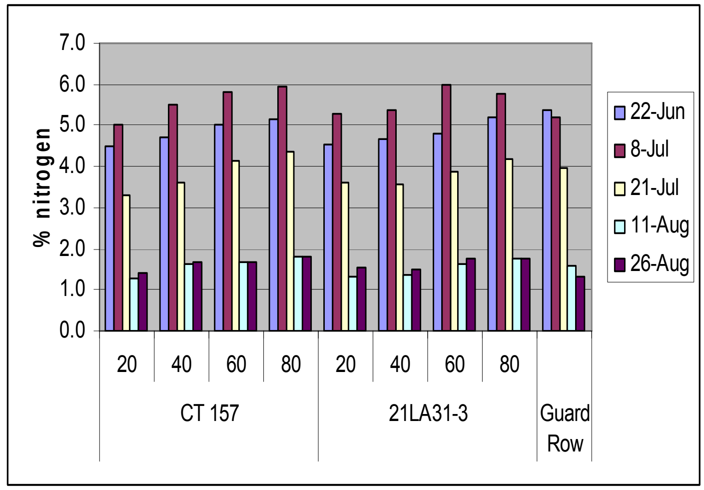
2004



2005

Petiole sap nitrate-nitrogen (figure 2): There was high variability of petiole nitrate (NO_3^-) sap concentration between cultivars in both years. In 2004 and 2005 the petiole sap concentrations in CT157 spiked at the second sampling and then decreased throughout the rest of the growing season. The variety 21LA31-3 followed the same pattern. CTH4 exhibited a consistent decline in petiole sap nitrate concentrations throughout the whole season. Published nitrate ranges for tobacco are 5000 ppm (final cultivation), 3000 ppm (flowering) and less than 2500 ppm (start of harvest).





2004 **2005**

Percent leaf nitrogen (figure 3): Levels increase to the second sampling and then decline. This trend seems to reflect that of the soil and the petioles.

Conclusions

Strawberries

No clear relationship between soil and petiole nitrate-nitrogen; petiole nitrate-nitrogen and the percent leaf nitrogen, and soil nitrate-nitrogen and percent leaf nitrogen could be determined. So the usefulness in using petiole nitrate-nitrogen or percent leaf nitrogen as an indicator of the soil nitrate-nitrogen status is questionable. This is probably because the strawberry is a perennial woody plant. The nitrogen that is measured using petiole sap or tissue analysis is derived from internally stored, soil organic and inorganic, and finally fertilizer nitrogen. However, these tools may be used to determine the adequate status of nitrogen in the strawberry plant at certain phonological stages of crop development.

Ginseng

In this ginseng garden, there has been no improvement of root weight because of nitrogen source or rate. In fact in the seedling year, the check plot, which received no additional nitrogen except for pre-plant treatments, yielded roots comparable to treated beds. However, ginseng is usually harvested after its third or fourth growing season. It will be interesting to observe the impact on next season.

Water management is crucial to nitrogen management in fertigated crops. The lower soil solution nitrate nitrogen concentration in 2005 at the 90 cm depth seems to indicate that fewer nitrates were leached through the soil profile. This may reflect the reduced irrigation cycle. This trend however is not strongly reflected in the soil nitrate nitrogen levels.

Tobacco

In both years statistical correlations seem to indicate some potential for the Cardy quick test nitrogen method to be effective for in-season nitrogen monitoring. These correlations are strongest up till the third sampling. However, statistically significant relationships between the quick test nitrogen values (petiole sap), soil nitrate levels, leaf tissue %N and treatments are not present at every sampling date. Research trials with burley tobacco have noted the effectiveness of plant nitrate tests early in the season, 3-5 weeks after transplanting, Correlations between soil nitrate nitrogen sampled one week with the percent leaf nitrogen sampled two weeks later are considered strong. Similar strong correlation exist between percent leaf nitrogen and petiole sap nitrate nitrogen sampled two weeks later.

There does seem to be some potential of the Cardy quick test method for in-season N. monitoring to determine the crop's nitrogen requirement. The Cardy methodology for soil nitrate measurement should be investigated as well. There appears to some validity and reliability concerns with soil nitrate measurement. Combining data over the years, with a larger sample size can be used to determine either benchmark numbers and/or the relationships that exist for that specific crop.

Next steps: The ginseng project is a cooperative effort that is slated to continue to harvest in 2006.

GHG Mitigation Significance:

Refining nitrogen use through fertigation offers the opportunity to growers to better target nitrogen applications and timing – reducing the potential for nitrogen loss to denitrification and leaching. The potential for higher yields through fertigation increases the amount of crop residues returned to the field and the potential carbon sequestration.

Typically ginseng growers use considerable amounts of nitrogen fertilizers and manure in establishing ginseng gardens. GHG mitigation is furthered by the ginseng portion of the project through the refinement of nitrogen needs – thereby reducing the potential for loss of nitrogen through denitrification.

Quick N test methods offer the promise of in season adjustments of nitrogen in response to weather conditions. This would be valuable for refining nitrogen use in many horticultural crops – thereby reducing potential nitrogen losses.

Key Extension Messages:

- Fertigation can increase nitrogen use efficiency while reducing nitrogen use impacts on the environment.

- Quick tests may have a role for some growers as a way to check nitrogen applications and need on high value crops.

• *3.* Evaluation of Irrigation Efficiencies

Introduction

Irrigation is a common and growing practice among horticultural producers, especially on the lighter soil types. It helps to ensure high quality produce and competitive yields. In recent years there has been a significant trend to drip irrigation and low pressure boom irrigation systems. Lower energy requirements and better water efficiency help to reduce GHG emissions. Higher yields from well managed irrigation systems will result in more crop residues being returned to the field.

Methodology

The emphasis in this project has been on in field evaluation and demonstration of soil moisture monitoring equipment as part of an irrigation scheduling strategy. To this end the equipment has been installed in strip trials and featured at field days and extension meetings.

In each year monitoring sites were established in grower fields, the results from the various scheduling devices compared and the growers provided with weekly updates to assist them with their irrigation scheduling.

2003 - Two sites were established in processing tomatoes. The Wallaceburg site compared no irrigation to both drip irrigation and a travelling boom system treatments. The other site (Tilbury) looked at no irrigation versus a travelling boom system. In both sites the lack of irrigation became obvious over the growing season even though the weather was not particularly dry and the sites were on well managed soils.

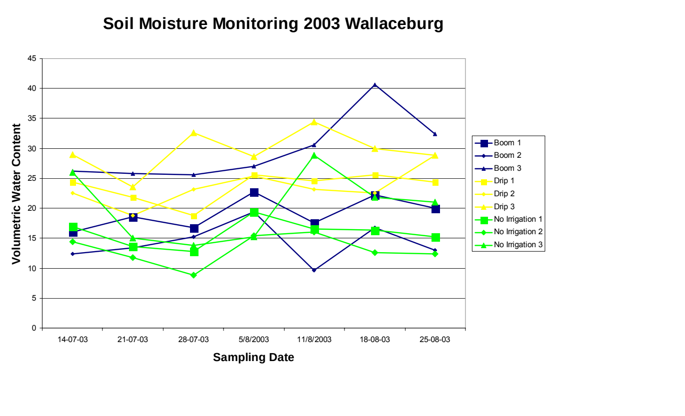
In 2004 two sites were established in processing tomatoes. Similar to 2003, the Wallaceburg site compared drip irrigation and travelling boom system treatments. The other site (Tilbury) again looked at no irrigation versus a travelling boom system. However 2004 was a very different year with more rainfall than 2003. The Tilbury site did not require irrigation until late in the season – too close to harvest to be effective.

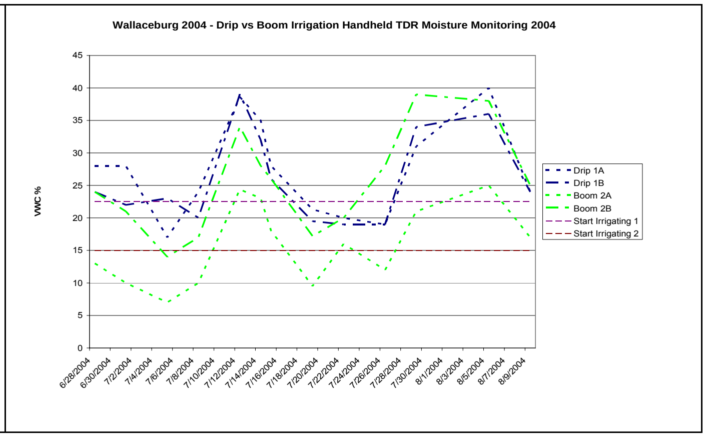
For 2005 only one paired site was established and monitored, near Wallaceburg. More focus was put on selecting the most representative monitoring site – to that end 6 individual locations within each field where monitored throughout the summer.

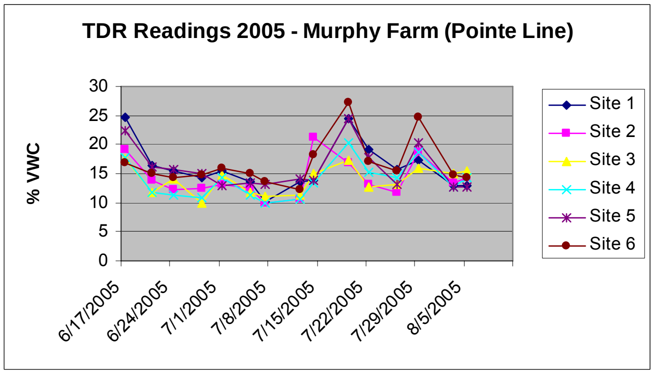
Results and Discussion

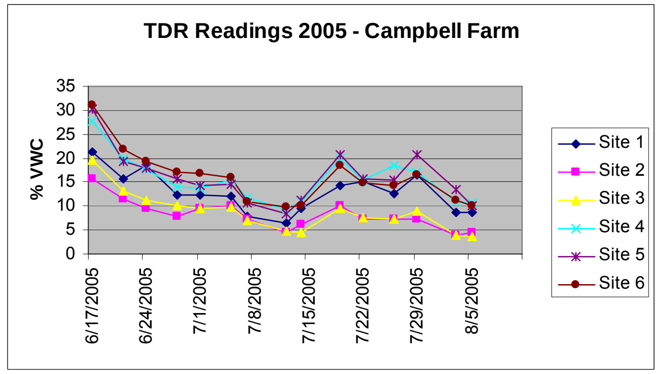
Season by season weather plays a large part in an assessment of irrigation efficiency and economic advantages.

Drip irrigation is more water efficient and easier to use once installed. Boom irrigation requires more labour especially if they are shared among several fields. Often hitting the irrigation timing suggested by the soil moisture monitoring equipment is difficult.









2005 Drip Irrigated field vs Boom Irrigated Field

Conclusions

Watermarks appear to be long lived and rugged. They do not interfere with field operations but are not highly responsive i.e. quickly. Tensiometers require maintenance through the season but are easily read. TDR units whether buried or portable are read quickly and are highly flexible for use. Automation of data collection is important to improve more use of these techniques.

Placement of the soil moisture monitoring equipment is crucial. Site selection is important for easy access and to ensure that the soil is representative of the majority of the field.

Next steps: There is ongoing interest with some growers in making use of soil moisture monitoring equipment. As drip becomes more common, growers have more interest in the wetting patterns from drip tape on their specific soil types. Further work in the area with the TDR units and a dye test are planned.

GHG Mitigation Significance

There are a number of potential greenhouse gas mitigation benefits with good irrigation choices. Drip irrigation and even the low pressure booms require much smaller pumps for moving water, thereby reducing the fuel usage. Drip and boom irrigation also usually means less overland water flow as compared to the high pressure guns. Irrigation scheduling, whether based upon a computer schedule or actual physical soil moisture measurements can help to improve water use efficiency.

Key Extension Messages:

- Drip irrigation has higher water use efficiency than low pressure boom application.
- Soil moisture monitoring tools like TDR are useful to monitor soil moisture levels and variability across the field.

4. Evaluation of Cover Crops for Biomass and Nitrogen Cycling

Introduction

Cover crops are used in many horticultural production areas. Typically the main use is as a ground cover for over the late fall and winter to prevent blowing soil. Cover crops have the potential to mitigate greenhouse gases in two distinct ways; sequestering carbon and reducing nitrogen losses. Cover crops offer the chance to return more green material to the soil in production systems that typically use intensive tillage and return little residue to the soil.

Many horticultural crops are harvested “green” or before physiological maturity. There can be a significant amount of nitrogen remaining in both the soil and the crop residues returned to the field. There are a number of horticultural crops like peas, cucumbers, snap beans and sweet corn that can be harvested early in the season allowing a sizeable growing window for cover crops to produce biomass. The short growing season for some vegetable crops also poses some challenges in establishing cover crops in the form of herbicide residues, soil moisture levels for establishment in mid to late summer and work load or time.

Methodology

Cover crop establishment after machine harvested processing cucumbers was targeted for most of the project but other early harvest horticultural crops like snap beans and early cauliflower were also used. This timing allows for the greatest length of cover crop growth usually found in horticultural crop production systems.

Generally the plots were large field scale strips, replicated several times across the field. However there were some cover crop plots established after small plot harvest of nitrogen rate trials in cucumbers. Soil nitrate samples were taken shortly after planting, followed by plant tissue (biomass) and soil nitrate samples approximately 1 and 2 months after planting. Soil nitrate samples were taken when possible at two depths 0-30 cm and 30-6- cm. Biomass samples were taken only from above ground plant materials.

Some efforts were made to follow nitrogen release from cover crops to subsequent crops with limited success due to plot size and mechanical harvesting issues
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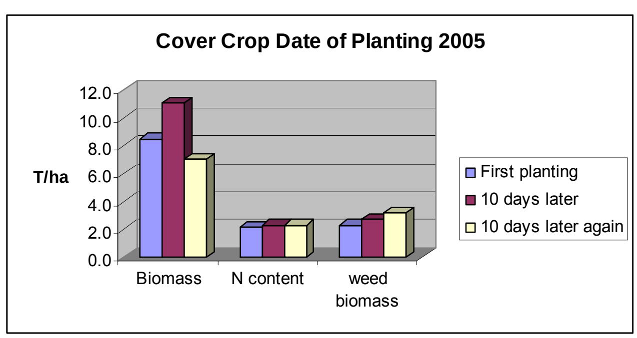
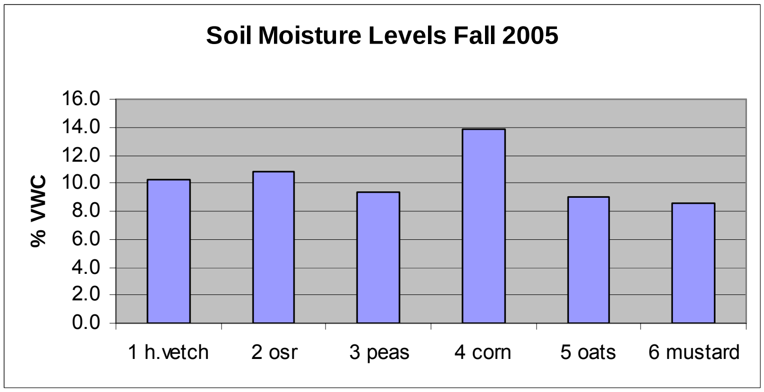
Results and Discussion

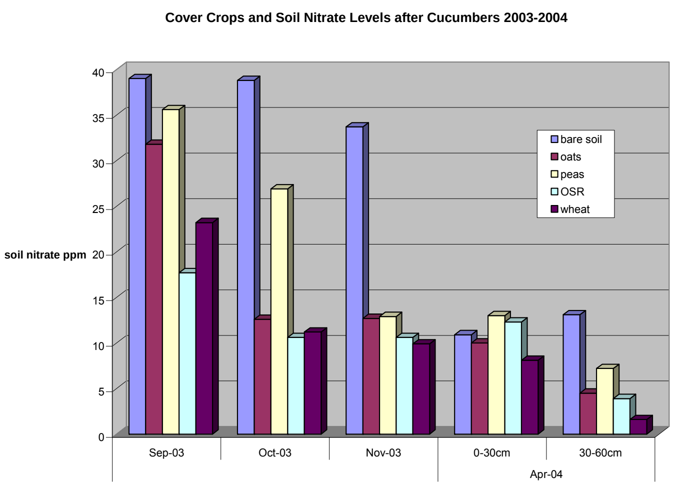
Each summer and fall establishment conditions were slightly different. High heat and low soil moisture often makes the mid summer plantings slow to start. The cover crop demonstration plots allowed for evaluation of cover crops for suitability based on growth habit and biomass production. Not surprisingly the tried and true cover crop species are best suited for use in vegetable crop rotations. Oats and brassicas like oilseed radish and mustard grow rapidly, take up significant amounts of nitrogen, retard weed growth and die out over winter. Winter hardy cover crops like winter wheat and cereal rye work well as over wintering cover crops. However they often do not have a lot of top growth in the fall and consequently may not pick up as much nitrogen from the soil.

Rapid establishment of cover crops after harvest is crucial to achieving the greatest amount of biomass production, weed control potential and the potential uptake of soil nitrate into cover crop plant tissues.



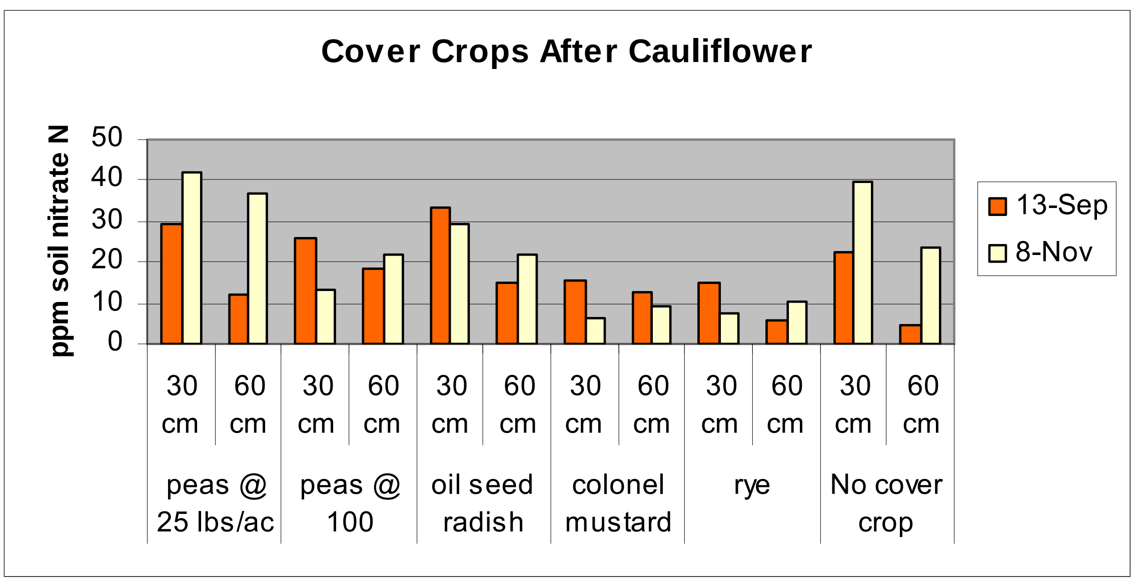


Cover crop researchers suggest that cover crops may reduce the potential for denitrification in the fall by reducing the soil moisture levels in the cover crop root zone. Measurements were taken with a TDR in the fall 2005 to confirm this. Further measurements in the spring did not suggest that cover crops kept the soil wetter.
The corn treatment has a higher volumetric water content as it had froze and was dead.



Cover crops can take up significant amounts of soil nitrate after the harvest of horticultural crops.

In 2004 and 2005 cover crops were established after early harvested cauliflower in the nitrogen trial area. The cover crops were able to reduce the soil nitrate nitrogen levels in both years. In 2004 the cover crop was in place for almost 12 weeks. In 2005 the cover crop in the east block was in place for 8 weeks, while the west block was only 6 weeks. This accounts for the cover crops' effectiveness in reducing residual soil nitrogen.



In both years, all cover crops were able to reduce residual nitrate nitrogen from seeding to the final sampling in November at the 30 and 60 cm depths. In 2004 and 2005 the oats, colonel mustard and rye were most effective at reducing nitrate nitrogen levels at 60 cm. Establishing cover crops as soon as possible following a cauliflower harvest is an opportunity to manage residual nitrogen.

Early harvest crops like machine harvested cucumbers offer large windows of cover crop opportunity. Many of the demonstrations were established after cucumber harvest.

Ridgetown plot – October sampling 2004
The oats, rye and oilseed radish were affected by herbicide residues at establishment but with time and rainfall overcame that.

Cover Crop Survey:

The Cover Crop Survey was started both years in early November and snowfall and increasing soil moisture forced the finish of the survey by early December. The survey is meant as a snapshot of cover crop growth after establishment but before freeze up. A biomass sample was collected from each survey field and an associated soil nitrate sample. The biomass was only collected from above ground growth. In the second year the protocol was refined and three biomass samples were collected from each site. The soil samples were standard 30 cm soil nitrate samples and were analyzed at Agri-Food Labs in Guelph. Sampling costs were partially supported through Nutrient Management.

Survey Results:

Almost 60 cover crop fields were sampled under the two years of the survey representing a variety of commercial vegetable operations in Southwestern Ontario. Previous crops included peas, snap beans, tomatoes, cucumbers, sweet corn, potatoes, onions, cole crops and celery. The cover crop species sampled included rye, oats, barley and oilseed radish.

Cover crop growth

Cover crop growth within the survey fields ranged from mere centimeters to over a meter in height. The plant density was also quite variable depending upon the field. The biomass or dry matter produced by cover crops surveyed ranged from less than 70 kg/ha to over 7000 kg/ha. Generally biomass production was greater the longer the growth period after crop harvest as long as cover crops were established promptly. Also biomass production does appear to be greater where there were greater amounts of nitrogen left after crop harvest or where nitrogen fixing crops were harvested.

Nitrogen uptake by the cover crop

Nitrogen uptake by the cover crop or the amount of nitrogen held within cover crop tissues at sampling was also variable. It ranged from as little as 4kg/ha (a very light, late planted cover crop) to 135 kg/ha. The amount of nitrogen held in the cover crop tissues is directly related to the amount of biomass produced and the growth stage of the cover crop. Generally the oats had the lowest % nitrogen in tissues but some of the greatest biomass production. In contrast barley had higher % nitrogen but very little biomass in the samples taken.

Soil nitrate levels

Given that the fields sampled ranged widely in texture, soil organic matter levels and previous crop, it is not surprising that the soil nitrate levels measured in the top 30cm (12 inches) varied greatly, from 0.5ppm (2kg/ha) to 75 ppm (300kg/ha).

Next steps: There continues to be growing interest in cover crops as nitrogen cycling and also as potential energy sources. The cover crop sites initiated in the fall of 2005 will be followed through to harvest in 2006. In particular the hub cover crop site will be at least partially incorporated into a larger cover crop research trial looking at nitrogen cycling and weed relations in cover crops through Ridgetown College.

GHG Mitigation Significance

Cover crops do appear to have some ability to reduce nitrogen levels in soil after the harvest of early season horticultural crops, as long as the nitrogen use in crop is reasonable. Observation suggests that cover crops do "dry down" the soil in fall making denitrification less likely. Some cover crops do return significant amounts of biomass which will help to maintain soil carbon levels.

Key Extension Messages:

- Cover crops can reduce soil nitrate levels after vegetable crop harvest.
- Cover crop species that overwinter are the most effective in reducing soil nitrate levels in the spring.
- "Plant early, plant often" is the key strategy in cover crop establishment to ensure the greatest biomass production.
- Cover crops planted after early harvested vegetable crops can provide significant amounts of feed for pastured animals.