Water and Nutrient Use Efficiency in Ontario Agriculture

Water Adaptation Management and Quality Initiative

PROJECTS OF 2014

Growing Forward 2
A federal-provincial-territorial initiative

Water Adaptation Management and Quality Initiative

Farm & Food Care

Ontario

Canada

Foreword

Like many environmental challenges facing farmers today, there is no "one-size-fits-all" solution to improving on-farm water management or nutrient use practices. Every farm and associated watershed is unique. A variety of water demand, water supply and nutrient management solutions are needed to deal with increasing complexities of water efficiency challenges and minimizing off-farm impacts of nutrient use in a changing climate.

Given the potential for many environmental benefits from investments in water efficiency and nutrient use research, the Water Resource Adaptation and Management Initiative (WRAMI) project was launched in 2013 with funding from Agriculture and Agri-Food Canada (AAFC) and the Ontario Ministry of Agriculture, Food and Rural Affairs (OMAFRA). This program was expanded in 2014 with the Water Adaptation Quality and Management Initiative (WAMQI), funded under Growing Forward II.

The key objectives of both WRAMI and WAMQI were to:

- Help Ontario farmers adopt water conservation and efficiency practices to address issues of managing water supply;
- Help Ontario farmers prepare for extreme or damaging weather events and adapt to the impacts of climate change through the development of resilient farm practices;
- Help Ontario farmers better manage nutrients and minimize off-site impacts of nutrients on surface and ground water quality.

These objectives were achieved by funding applied research projects with a focus on water efficiency, nutrient use and the hosting of demonstration projects using innovative technologies or management practices.

Project coordinators had the opportunity to meet each project team and benefited from their enthusiasm for issues relating to water management, water supply, crop quality, agricultural nutrient use and the challenges of dealing with waste water. We appreciated the education growers gave us about the complexity of issues in agricultural water and nutrient use in Ontario and the opportunity to help build a cooperative community with government, academia and commodity research teams.

Both OMAFRA and AAFC are appreciative to Farm & Food Care Ontario for its efforts to make the WRAMI and WAMQI projects successful. The projects have advanced the farming community's knowledge of sustainable agricultural water use practices and nutrient use projects. They have also helped us better understand our nutrient use practices and explore opportunities to reduce fertilizer use and better re-capture and recycle nutrients which could minimize potential impacts on Great Lakes waters. Farm & Food Care is proud to have been part of these two important water efficiency and awareness projects.

Bruce Kelly
Farm & Food Care
Environmental Program Manager

Deborah Brooker
Senior Program Analyst, Environmental Management Branch
Ontario Ministry of Agriculture, Food and Rural Affairs

The content featured in this report includes brief summaries of each of the projects. For full reports and results, including photos and videos, visit the Environment button at www.farmfoodcare.org.

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#1 Dairy Water Use Efficiency (WUE) demonstration

Introduction:

Between April and December 2014, the project team developed five short videos and one whiteboard video for use by the Ontario dairy sector about water use efficiency in dairy operations. These videos are available on-line and also on a touch screen computer for use at dairy industry meetings around the province, at conferences, field days, and more.

The single most widely held opinion about water use efficiencies that was repeated by the farmers surveyed is "Why would farmers do anything? Water is free and plentiful."

The second problem is that farmers think of innovation as being something that will cost them money. They don't necessarily consider them as something that might save them money while at the same time improving the environmental footprint of the industry.

Third, farmers do not know how much water they use nor have much understanding of how small changes on farm can have a massive impact on a bigger industry-wide scale.

Finally, it's a topic that has been discussed many times with farmers with little obvious progress being made. In preliminary interviews with farmers, not one could identify a peer who they knew or had even heard of that did make or is making changes to their system to save water and yet we know that many are and are benefitting financially and environmentally.

Many farmers are implementing systems that use water efficiently in ways that are cost effective, efficient and easy to use. If we could capture these ideas in the context in which they're being applied, others can learn from them.

Methods:

This project produced five short videos and one explanatory 'whiteboard' video that explains why water use efficiency is important. The six videos have been uploaded onto an 'all-in-one' touch screen computer. The idea is that the computer is taken from meeting to meeting and set up on a table somewhere close to discussion locations where producers can touch the screen and play the videos. Those watching the video will get a clear idea of how the systems work, what the systems cost, and the benefits of each system. It is proposed that the video be broken into "chapters" so that viewers can select the system that most closely meets their own system at home.

Results & Conclusions:

The five short videos provide examples of some of these innovative ideas and demonstrate water management can deliver system efficiencies and financial benefits.

There is a water management video for each of the following milking systems:

- Tie Stall
- Rotary
- Parallel (two videos) and
- Robot

The innovations featured cover a wide range of ideas. The common element is the relative simplicity of each and the fact that each has a cost benefit. The videos were on limited display at the 2015 Dairy Farmers of Ontario (DFO) annual meeting (860 people present) and are now in the hands of DFO which have taken charge of the technology and will show it to its members at regional meetings.

The videos are also available through links on the LRIC website, the Farm & Food Care website and the ACER consulting website.

> *"Initial feedback from DFO is very positive especially about the messaging contained in the whiteboard video."*
>
> ***- Tim Nelson, LRIC***

Links to the videos:

Rotary operation - https://www.youtube.com/watch?v=nmus8CD0fQE

Robotic milking parlour - https://www.youtube.com/watch?v=MEWBey7td24

Parallel barn - https://www.youtube.com/watch?v=njmkhBM1_n8

Parallel barn - https://www.youtube.com/watch?v=ZOUiYkH7oyE

Tie-stall operation - http://youtu.be/PaccZYIgyU4

Contact:

Tim Nelson, CEO
Livestock Research Innovation Corporation
519.821.2960
tnelson@livestockresearch.ca

#2 Improvement of irrigation efficiency in orchards and vineyards in Ontario

Introduction:

Rebecca Shortt, OMAFRA, Kathryn Carter, OMAFRA and Bill Schenck, GGO are working to improve how grapes and tender fruit are irrigated.

Insufficient moisture is a major risk for tree fruit and grape growers. Access to water during important physiological stages of tree and fruit growth is required for optimal performance of fruit crops. Shortage of moisture during critical periods of crop growth and fruit development affects both yields and sizing of produce which then affects the volume of production and average price of fruit. With erratic weather patterns increasing, availability of water is becoming more critical for growing quality fruit. Many growers that currently irrigate do so based on personal observations made on-site. Increasing demands mean that farmers are not always available to assess the need for irrigation. Having access to this information remotely would improve their production efficiency. Access to timely rainfall information, evapotranspiration (ET) and soil moisture measurements assist growers in improving their irrigation efficiency in orchards.

The objectives of this project were to:

- Conduct demonstration trials to show the benefits of using soil moisture probes in timing irrigation with respect to irrigation efficiency (improved timing and amount of water applied). These trials will also provide further data to validate that growers are not over-irrigating crops.
- Comparison of different models (ET and soil moisture using the BC irrigation model) in timing irrigation applications in orchards.
- Assist AAFC researchers in obtaining undisturbed soil core samples to develop water retention curves to determine the soil's water holding capacity for different production systems.
- Provide growers with the data they need to make information-based decisions about the timing and need for irrigation.
- Provide information to growers about the economics of irrigation including operating costs for different systems.

Methods:

In addition to the laboratory work, the project sites had additional monitoring of soil moisture, water table, metered irrigation flow and Evapotranspiration. This additional information was helpful in understanding the soil-water dynamics. For example, the confirmation of high water tables at some of the sites explained why soil moisture in the rooting zone remained so constant despite periods with no or limited rainfall. All sites used Decagon EC5 probes. Following the field season, all probes were tested in sand in a laboratory setting and all probes produced very similar readings and tracked together with increasing/decreasing soil moisture.

AAFC collaborated on this project to identify the site-specific field capacity and permanent wilting point which allows for a more accurate determination of the irrigation trigger point. Currently the field capacity is determined from chart values based on assumed soil texture in conjunction with the observed soil moisture data.

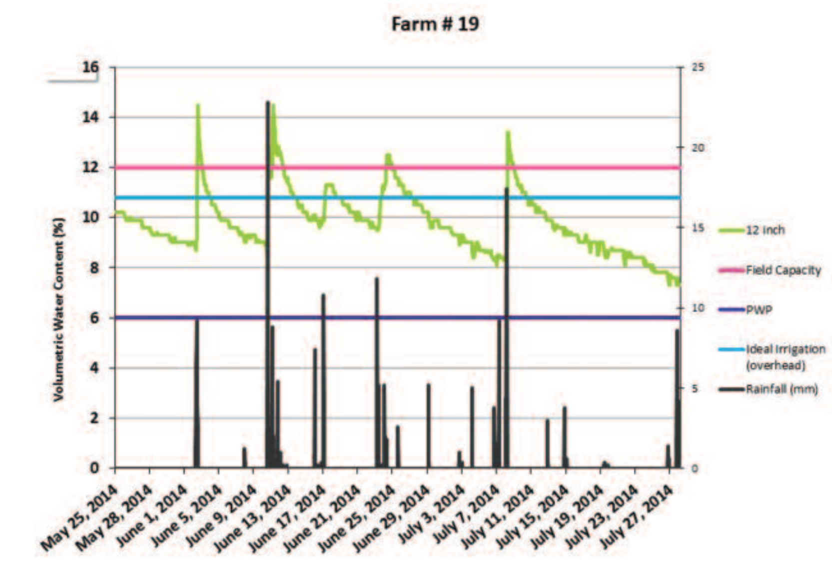
The project subcontracted John Anderson Consulting to establish an outline of capital and operating costs for drip irrigation and overhead irrigation. Grape Growers of Ontario took the outline to a focus group of growers to refine the operating costs and produced an example of each irrigation type in an excel format document so that growers can adjust their specific costs suited to their unique situation. This product is available for grape growers to use as the basis for investment decision making.

Results & Conclusions:

In 2014 soil moisture data from 12 of the demonstration sites was automated to fruit/apple/grape Tracker.com - the online record keeping, tracking and orchard management system that allows growers to record and create reports for food safety and traceability, pest management, crop protection, and more. Real time soil moisture data (updated hourly) was made available to registered growers. This data improves growers' ability to make informed decisions about when and how much to irrigate.

The Tracker.com modules were developed to provide some interpretation of the raw data. Four prepared graphs automatically display the 12" soil moisture probe readings along with the irrigation trigger level, permanent wilting point and field capacity, and the daily rainfall and irrigation amounts. Each time a grower accesses the page, the graphs are updated and display the previous week, previous two weeks, month and previous two months. The grower enters the field capacity and the module calculates an estimated Irrigation trigger level and permanent wilting point.

Overall, the projects help Ontario farmers adopt water conservation and efficiency practices. Improved practices lead to better water supply management and help growers better prepare for, and better manage, extended dry periods.



This graph displays how rainfall and irrigation events affect soil moisture which in turn affects yield and quality of grapes and tender fruit.

Next steps include:

- Refining operation of Tracker.com during the 2015 growing season.
- Improving performance of Lincoln Telemetry for the 2015 growing season.
- Increasing the confidence in the establishment of the field capacity point, permanent wilting point and subsequent irrigation trigger point (through ongoing AAFC research).
- Promoting soil moisture monitoring through Tracker.com.
- Seek funding to increase number of weather monitoring stations which can provide daily ET data in real-time to growers (application of 2014 irrigation scheduling workshop training).

"Overall, the projects help Ontario farmers adopt water conservation and efficiency practices. Improved practices lead to better water supply management and help growers better prepare for, and better manage, extended dry periods."

- Larissa Osborne

Contact:

Larissa Osborne, Marketing and Production Analyst
Ontario Tender Fruit Producers' Marketing Board
905.688.0990
larissa@ontariotenderfruit.ca
www.ontariotenderfruit.ca

#3 Improving uniformity of overhead irrigation systems to reduce water use and maximize the retention of nutrients in container grown nursery crops

Introduction:

Jeanine West of Phytoserv works with researchers to determine how to irrigate nursery crops so more water gets to each plant and is not wasted.

Efficient use of irrigation water in horticultural production systems is a high priority for research in Ontario horticultural crops. The nursery sector is looking for ways to reduce total water applied while improving irrigation application uniformity. Overhead sprinkler systems are the most common form of irrigation for container nursery crops (#1-5 pot size) because overhead systems are relatively inexpensive to install, require minimal maintenance and can be used to cool the plants. However, in outdoor applications, overhead sprinklers often produce patterns of uneven water application that lead to inconsistent water and nutrient uptake, negatively affecting the quality and consistency of product. This research evaluated nozzle types, operating pressure and irrigation layouts (central bed design vs. peripheral design) in outdoor container growing systems in order to improve irrigation delivery uniformity across the zones and reduce the total water applied.

The purpose of this study was to assess sprinkler pattern layout (traditional central bed design vs. new peripheral design) and pressure to increase uniformity and decrease the application period length. The expected result would be a reduction in total water applied and reduced incidence of nutrient losses through leaching.

The specific objectives of this study were to maximize:

- Efficient water use to minimize the operation's demand on the water resource;
- Distribution uniformity across the nozzle application area;
- The retention of nutrients in the container to improve nutrient use efficiency, production uniformity and reduce impacts of runoff water quality.

Methods:

Most traditional overhead irrigation layouts are of a central bed design, consisting of 100-300 foot long beds that are 18 feet wide with 14-foot driveways on either side. Usually, the irrigation sprinkler risers have 360o pattern heads placed 30 feet apart along the centre of the bed. Sprinkler heads on the ends are often replaced with 180o heads. There are no sprinklers on the other two sides of the block (known as "peripheral design"). This sprinkler layout results in dry zones at the corners and edges of the beds due to the radial sprinkler pattern and factors like wind. Some plants are receiving irrigation from only one sprinkler, while others are receiving irrigation from two sprinklers. Containers on the windward side of the bed (usually southwest) receive even less water when winds are greater than 2.2m/s.

Catch can tests were used to calculate the Distribution Uniformity (DU). Both the Lowest Quarter DU (DUlq) and Christiansen's Uniformity Coefficient (CUC) were calculated, as well as determining the Nomograph ranking. Pots were laid out in a five-foot grid pattern, radiating out from a central sprinkler head. At least 20 pots were used for each test, with the volumes listed in increasing order before removing the lowest 25 percent volumes (following the protocol of Dudek and Fernandez (Michigan State). All catch cans were leveled to account for bedside slope.

Leachate fractions were tested by setting one empty pot beside a test plant. Both pots contained a plastic liner to capture both irrigation volume and leachate volume, respectively. The test plant was placed on a block inside the capture pot, to ensure that any leachate from the irrigation event would not be re-absorbed into the plant.

Flow was determined by measuring the amount of time (in seconds) to capture 4L of water coming from each sprinkler head with a tube. The capturing pail was marked at the 4L level, and holes were drilled at the height to increase the visibility of these measurements during the trial.

Pressure was determined with a pitot tube fitted with either a 0-100psi or 0-60psi oil-filled pressure gauge (depending on operating pressure)

Results & Conclusions:

In 2013, OMAFRA and AAFC researchers were able to demonstrate the distribution uniformity of overhead impact sprinklers in the field to be about 40-50%. Industry standards cite 60% as the lowest acceptable threshold for distribution uniformity, with 75% the upper limit of efficiency for this form of irrigation equipment. Catch can tests were used as a tool to determine distribution uniformity at the two sites studied in this project. The results of the catch can tests show a range of 35.5-74.7% uniformity (DUlq) depending on the layout, sprinklers/nozzles, and length of test. Christensen's Uniformity Coefficient (CUC) was calculated to be the same as the lowest quarter Distribution Uniformity (DUlq). The Nomograph Ranking was a third way to categorize the uniformities from the catch can tests, and the results generally matched the DUlq results.

The best DUlq was observed at Site B with the peripheral design and triangle riser pattern on August 14th (74.7%), but repeats of this study on November 3rd resulted in DUlq only slightly above (66.4%) the average for all test layouts (59.1%), due to high winds. The worst performance (55.2% DUlq) was observed at Site A from the peripheral design and opposite riser pattern with Nelson sprinklers fitted with black plates at the 30 foot spacing, but the single line Rainbird sprinklers did not perform significantly better (55.8%). In fact, the Nelson sprinklers fitted with the green plates had the next best performance compared to the Site B layout with DUlq averaging 60.9%.

Leaching Fraction percentages at Site A ranged from 18-554%, far greater than typical leaching fractions of 5-30% expected. Leaching Fraction percentages at Site B ranged from 0-48% with an average of 5%. A Leaching Fraction of <10% is considered to be quite low. Site B conducted very conservative irrigations (2 x 17 minutes) based on ET models and the pulsing of the irrigation events resulted in much more efficient wetting of the root zone. Because of the irrigation BMPs in place at this nursery, a very low leaching fraction was achieved.

"The project's success is due to the support of the Grower's Group of Landscape Ontario and the farmer co-operators across Ontario that participated in this study."
- Dr. Jeanine West, Phytoserv

Contact:

Jeanine West, Owner
Phytoserv
705.796.8812
jwest@phytoserv.com

#4 Outdoor container nursery production water use efficiency and best practices benchmarking study

Introduction:

Water quality characterization data collected through the 2013 WRAMI study of this project suggested that container nursery wastewater discharges are extremely low risk and meet the preliminary greenhouse storm water guidelines proposed by the Ontario Ministry of Environment & Climate Change (MOECC). By repeating the study in 2014, source, on-farm drain, and outlet samples were collected throughout the season at most of the same sites, and at three new sites where samples were always accessible. Source, on-farm drain, and pond/outlet (i.e. discharge from property) water was analyzed for mean nutrient levels compared between nurseries with similar production systems (irrigated by overhead sprinkler systems), and against the storm water Guidelines.

In 2014, water samples of source, on-farm drain and pond/outlet were collected at 11 sites across Ssouthern Ontario over the growing season. Nutrient analysis revealed that in most cases, the discharge water met the storm water guidelines proposed by MOECC for the greenhouse sector. Again, 2014's above average precipitation levels and frequency of rain events resulted in high levels of surface water. Nursery collection ponds were full for much of the season, and a dilution effect may account for the generally low nutrient levels, also observed in 2013. Heavy metals such as cadmium and cobalt were detected in outlet samples in 2013, and again in 2014. Note, however, that while source and outlet samples contained these metals, the on-farm drain samples did not, indicating that the contamination was not a contribution of the nursery operations.

A second year of sampling and characterization of pre and post-production water quality (assisted by the farmers and OMAFRA) was implemented to acquire a more complete data set, including all on-farm drain samples, heavy metal analysis, and continued meteorological data collection.

"Ontario Nursery operations are excellent water recyclers, capturing their irrigation water and returning it to ponds for re-use."
- Dr. Jeanine West, Phytoserv

Methods:

The research trial consisted of a water sampling program, characterizing water supply (source) and comparing it to runoff (on-farm drain water) from the growing areas and the discharges from the farm (outlet). Container nursery sites were chosen that had similar production systems and crops (established deciduous flowering shrubs irrigated by overhead sprinkler systems).

Eleven sites were chosen for the sampling component of the study based on crop production, access and availability of the source, on-farm drain and outlet samples, geographic location and farmer cooperation. In some cases, the source water was also the output water, meaning the sample results were used for both source and outlet data. Records of weather, presence or absence of flow (for on-farm drain and outlet samples) were maintained for each visit. Bi-weekly sampling of 1) source, 2) on-farm drain/bed runoff and 3) outlet water (where possible, i.e. when drain/outlet was running) took place for 11 nurseries from April through October (the entire irrigation/growing season). Samples were analyzed for nutrients, pH and EC (soluble salts), as well as other elements of potential concern to the environment. Temperature (Environment Canada data) and precipitation (as measured by rain gauges at each site) were also recorded.

The water samples included:

- Source water 3 types – groundwater, recycling ponds, off-site surface water (e.g. creek)
- On-farm drain samples – runoff, either collected in a swale or through a catch basin system
- Outlet samples –an irrigation/recycling pond that overflows to environment

The data from each of the 11 nursery sites was averaged on each sample date for each parameter within a sample category (source, on-farm drain or outlet) and the standard deviation was calculated to illustrate the range of variability in the data.

Results & Conclusions:

Sampling was initiated in mid-April, just as farmers were beginning to set up their irrigation systems for the season.

The provincial water quality objectives for surface water are very difficult to meet, even for storm water discharges. In response to this challenge, MOECC developed objectives for greenhouse storm water discharges (referred to as 'MOE targets') that are considered achievable, yet sufficiently conservative to indicate when there are undesirable or unsuitable levels of nutrients in outputs. Farmers that demonstrate storm water pond discharges within the ranges may be able to choose an alternative regulatory tool that is less costly than a formal Environmental Compliance Agreement (ECA). Since most container nurseries have recycling ponds that contain both production water (leachate, filter backwash, etc.) and storm water, these recycling ponds may overflow to the environment during spring thaw and heavy rain events. Under current MOECC regulations these discharges would require an ECA. The data collected through the 2014 season demonstrate clearly that container nursery outputs (from recycling ponds) meet or fall below the thresholds for the MOE greenhouse storm water objectives in nearly every case, as was seen in 2013.

This project contributes relevant data to the development of a water management strategy for the nursery sub-sector. The horticulture sector has engaged OMAFRA and MOECC in the development of comprehensive and sustainable alternative regulations to deal with all waters used and produced in agricultural operations, particularly where there is low-moderate nutrient content in the wastewater or a mixing of storm water and recycled production water. This second year of data confirms the low-risk nature of container nursery wastewater, and will serve to enhance regulatory discussions and the development of legislation suitable for this sector. Nursery growers are encouraged to monitor their source, on-farm drain water and recycling pond water quality.

Ontario nursery operations have good water recycling practices, capturing irrigation water and returning it to ponds for re-use. Water quality is of primary importance, as certain elements and unbalances can impact overall plant yield and quality. Further, nurseries attempt to capture and hold as much water as possible without overflows, since these holding ponds are generally their primary water supply (over 80% of all nurseries rely on ponds).

Rebecca Shortt, OMAFRA Water Engineer, determines the evapotranspiration at an outdoor nursery operation to know its effect on plant water availability.

Contact:

Jeanine West, Water Specialist
Flowers Canada (Ontario) Inc.
519.836.5495
jeanine@fco.ca
http://www.flowerscanadagrowers.com/

#5 Subsurface drip irrigation to enhance water-use efficiency and reduce impact of applied nutrients on water quality in corn production in southern Ontario / aeration of field vegetables

Introduction:

Peter White of the Simcoe research station kneels next to a pressure sensor of the subsurface drip irrigation system being used to irrigate corn.

Subsurface drip irrigation (SDI) is a new technology for Ontario where water is applied below the soil surface by micro-irrigation emitters. It is a low-pressure, high-efficiency system using buried polyethylene drip lines (10-14" depth) to meet crop water needs. SDI has many advantages over traditional overhead irrigation systems. SDI can improve irrigation performance, water use efficiency and reduce environmental impact. SDI helps growers to better manage and conserve water, deal with low water/drought situations, and the growing impact of climate change. In addition, crop yield and quality is improved and vulnerability in corn production is reduced. The performance of subsurface drip irrigation systems can be enhanced by supplying air directly to the root zone of the crop plants to overcome temporary lack of oxygen. An air injection system that can increase root zone aeration can add value to grower's investments in SDI. Corn yields at Judge Farms were 253 bushels per acre. This is well above the average corn yield for this area. The ten-year average corn yield in the Sand Plains Region of Ontario is 146 bushels per acre.

Water supplies are decreasing due to extended drought periods, a decline in groundwater levels and diversion of water from irrigation to environmental and municipal uses. Crop water stress can have a significant impact on growth, development and yield. Water shortages are likely to increase over time due to a combination of demographic and environmental factors. This presents challenges for water-use efficiency and water quality. Compounding the challenge of water allocation amongst a growing population is climate change. This could result in increased frequency and duration of drought conditions as demand for water steadily increases. Recent technological developments in irrigation can increase crop yields and quality, reduce water, fertilizer and energy use. Interest in SDI is growing, especially because of extreme drought in 2012. If patterns from previous droughts are repeated, this has the potential to seriously damage an already impacted agricultural crop production system. Research is needed to better evaluate the economic and technical feasibility of using SDI under local conditions and provide scientifically-based practical information to users on Best Management Practices for SDI.

Methods:

Corn was planted in a 2.5 acre site (replicated plots) at the University of Guelph Simcoe Research Station. Drip lines were placed at 44 or 60 inches apart and 14 inches deep. A non-irrigated check plot was included. Corn and soybeans were planted at La Salette, ON (Judge Farms) on a 75 acre site (six different irrigation zones) on a coarse textured sandy loam soil. Drip lines were placed 44 inches apart and 14 inches deep. Flow meters were installed in both the SDI and the control plots to measure the volumes of water applied. Dielectric sensors were installed in the SDI plots to monitor soil moisture. Subsurface drip irrigation was used to keep the available soil moisture at 75-80 percent of field capacity. Scientific irrigation scheduling (i.e. the use of climate and crop evapotranspiration data and soil moisture sensors) was used to accurately determine when and how much water to apply. This was achieved by using both evapotranspiration and moisture sensor data. Evapotranspiration values are determined by averaging two different ET models (Priestly-Taylor and Penman-Monteith). The evapotranspiration is then multiplied by the appropriate crop coefficient for the growth stage of the crop to give the daily crop requirement.

Moisture sensors were used to monitor soil moisture levels at specific locations above, in, and below the corn root zone. Real-time soil moisture monitoring was accomplished by connecting the dielectric sensors to a wireless cellular data logger used for irrigation scheduling. Scheduling was based on soil moisture thresholds according to dielectric measurements. Monitoring continued throughout the growing season. Natural rainfall and irrigations events were monitored in real time. A deep sensor was used to monitor and confirm when a leaching event had occurred. All plots received liquid in-furrow pop-up (3.3 kg/ha N) plus pre-plant N (44 kg/ha N). P and K were added based on a soil test with 2.4% S. Some plots received a side dress of 140 L/ha liquid 28% at the 2-4 leaf stage (50 kg/ha N) plus a side dress of 187 L/ha liquid 28% later (67 kg/ha N). Fertigated plots received weekly additions of N, starting at V6 for seven weeks with 47 L/ha/wk (Total 117 kg/ha N) or 70 L/ha/wk (Total 175 kg/ha N), applied through the irrigation to compare the benefits of fertigation with early-season broadcast and conventional side dress application of nutrients. Plant tissue-N testing was used in-season and "end-of-season cornstalk N tests" were used to evaluate N management during the growing season. Data on cob size, kernel size, kernel weight, kernels per cob and grain yield were collected. Crops were harvested at physiological maturity and yield and quality parameters recorded.

The subsurface irrigation system consists of intricate pumps, emitters and filters designed to apply water at the root zone when the plant needs it.

Results & Conclusions:

Rainfall during the growing season in 2014 was well above normal with 6.3 inches of rainfall in July. Normal rainfall for July is 3.8 inches. For this reason there was no response to irrigation in 2014. The highest corn yield obtained was 198 bushels per acre. Corn yields at Judge Farms were 253 bushels per acre. This is well above the average corn yield for this area. The ten-year average corn yield in the Sand Plains Region of Ontario is 146 bushels per acre. Soybean yield was 70 bushels per acre. Due to higher than average rainfall in July, there was also no response to added nitrogen. Likewise, there was no yield response to added irrigation or aeration to the drip irrigation lines for tomato, pepper, sweet corn or cucumber.

> *"Below-average rainfall in July can have a serious negative impact on corn yields in the Sand Plains Region of Ontario."*
> ***- Peter White, University of Guelph Simcoe Research Station***

Contact:

Peter White, Technician
University of Guelph Simcoe Research Station
519.426.7127
phwhite@uoguelph.ca
http://www.uoguelph.ca/plant/stations/simcoe

#6 Use of ground covers and irrigation to manage soil moisture in Ontario apple orchards, specifically targeting Bitter pit in Honeycrisp apples

Introduction:

John Zandstra of the University of Guelph's Ridgetown campus stands next to Honeycrisp apple trees, where he hopes research will prevent the trees from the Bitter pit disease.

It is estimated that only 20 percent of Ontario apple orchards are irrigated, including new high density plantings. With an increasingly warmer climate, supplemental irrigation will be more necessary. While installing and operating an irrigation system is expensive, some growers also indicate they simply do not have a source of water available and need other techniques to maintain soil moisture.

Bitter pit is a disorder of apple fruit associated with a lack of calcium that can cause significant losses in susceptible varieties. It may be apparent at harvest, but also can develop in stored fruit and result in extensive losses. Bitter pit characterized by a breakdown of cells under the skin of the fruit, resulting in dark, depressed spotting. It is more common under certain conditions, including large fruit from trees with light crops, excessive nitrogen and potassium and fluctuating soil moisture. Since calcium is involved in plant cell wall development, when in short supply, cell wall integrity is lost, resulting in bitter pit symptoms.

In summary, the project objectives are:

1. Evaluate ground cover as a cost effective alternative to irrigation as a method to improve productivity in Ontario apple orchards;
2. Document the effectiveness of ground covers and/or timely, scheduled irrigation applications in helping manage bitter pit in Honeycrisp apples.

Methods:

Honeycrisp is a relatively new, high value apple cultivar being planted throughout Ontario. It has demonstrated good consumer acceptance and generated significant returns for apple growers. The 2012 Annual Report of the Ontario Apple Growers indicated that in 2011, growers received over 2.7 times the price for Honeycrisp apples compared to the average of all apple varieties. This variety generates 11 percent of the farm gate revenue in the apple sector and accounts for over six percent of the acreage planted to apples.

However, Honeycrisp is quite susceptible to the physiological disorder bitter pit, with growers reporting up to 40 percent grade-out in some seasons (at harvest and/or after taken out of storage). The use of ground covers on non-irrigated Honeycrisp plantings could prove to be another technique to maintain more consistent soil moisture and reduce bitter pit pressure.

Research trials were set up at the University of Guelph's Cedar Springs Research Station on a Honeycrisp/M26 orchard that was established in 2007. This site contains a Fox Gravelly Loam soil (47.8% sand, 38.1% silt, 14.1% clay), which has a high gravel content and requires constant irrigation to maintain adequate soil moisture. This orchard has had challenges with bitter pit in the past.

Treatments were established as a randomized complete block split-plot design, with irrigation as the main plots, and ground cover as sub-plots. Wood chips were used as a ground cover and were compared to bare soil. Individual treatments were replicated four times within the trial. Data was collected on total crop, harvested crop, mean fruit weight, and percentage of fruit with bitter pit at harvest. Fruit samples were stored in a simple cold storage and are continuing to be monitored for bitter pit incidence.

Time Domain Reflectometry soil moisture sensors were installed in each treatment of the first three replicates, and measurements are taken twice weekly; when soil moisture levels fell below 75% of field capacity in any treatment, irrigation was applied.

Table 1. Fruit yields, size, and bitterpit incidence across irrigation treatments

Treatment	Yield kg / tree	Fruit/ tree	Fruit Weight (g)	Bitter Pit # of lesions/fruit	Bitter Pit % of fruit with lesions
No Irrigation	21.4	68	331	12.8	7.5
Irrigation	23.0	73	323	8.9	6.9
P-value	0.6528	0.6213	0.6458	0.1556	0.4422

Table 2. Fruit yield, size and bitterpit incidence across ground cover treatments.

Treatment	Yield kg / tree	Fruit/ tree	Fruit Weight (g)	Bitter Pit # lesions/fruit	Bitter Pit % of fruit with lesions
Bare Ground	24.9	81	321	12.5	7.4
Wood Chips	19.6	61	333	9.3	7.1
P-value	0.1347	0.0566	0.4824	0.2371	0.6679

Results & Conclusions:

Rainfall during the summer of 2014 was more consistent and uniform than many previous years, but soil moisture fell below 75 percent field capacity on several occasions and irrigation events were triggered. Fruit load from tree to tree in the orchard was unusually variable, possibly due to the hard winter of 2013/14.

Since no interactions (irrigation/ground cover) were found, main effects of the trial will be considered. Statistical differences were not noted among any of the variables evaluated, but the number of bitter pit lesions per fruit, and the percent of fruit with bitter pit lesions tended to be lower in treatments with irrigation as well as treatments with ground cover.

"With our increasingly warmer climate, supplemental irrigation of apples will be more necessary."
- John Zandstra, University of Guelph Ridgetown Campus

Contact:

John Zandstra, Professor, Fruit and Vegetable Cropping Systems
University of Guelph, Ridgetown Campus
519.674.1500
jzandstr@uoguelph.ca

#7 Use of ground covers and remote soil moisture monitoring equipment to maximize water use efficiency in peach orchards

Introduction:

John Zandstra of the University of Guelph's Ridgetown campus stands next to peach trees being studied to determine if soil moisture covers can improve moisture retention.

Presently in Ontario there are in excess of 7,419 acres of tender fruit orchards, with peaches making up the majority at 4,469 (OMAFRA, 2013). Many of these acres are not irrigated, but with the changing climate, warmer temperatures and prolonged dry conditions, we anticipate that irrigation may be required more often in this sector. The installation of irrigation systems in new and existing orchards adds to a grower's cost of production. Recent work out of the University of Guelph's Cedar Springs Research Station has suggested that soil amendments applied as ground covers in a peach orchard can go a long way in alleviating soil moisture deficits.

Objectives to evaluate the nutritional status of the tree and soil in response to the various mulch treatments were also included.

The treatment list for the proposed project included:

1. Non irrigated bare soil
2. Irrigated bare soil
3. Non irrigated mushroom compost
4. Irrigated mushroom compost
5. Non irrigated wood chips
6. Irrigated wood chips.

Methods:

The site contains a Fox Gravelly Loam soil (47.8 % sand, 38.1 % silt, 14.1 % clay), which has a high gravel content and requires constant irrigation to maintain adequate soil moisture. Cumulative yields over a three year period (2008 – 2010 inclusive) were increased by 71 percent and 44 percent in plots where spent mushroom compost was applied as a ground cover, when compared to non-irrigated and irrigated bare soil plots respectively. Wood chips were not as effective, but yields were increased by 36 percent and 15 percent when compared to non- irrigated and irrigated bare soil respectively (Table 1).

The trial investigated the use of irrigation with and without mulch cover (wood chips or mushroom compost); due to the wet season irrigation was never necessary based on soil moisture data, so mulch treatments across irrigation method (irrigated vs. non irrigated) were combined. Mulch treatment had an effect on the proportion of large and medium sized fruit. The tonnage of large fruit was doubled when spent mushroom compost was applied, but medium size fruit was reduced with the same treatment.

Soil core samples were taken at the beginning of August and divided into 0-15, 15 – 30, and 30 – 60 cm depths. Leaf tissue samples were also taken at that time according to OMAFRA recommendations and analyzed for total N, P, K, Ca, Mg, Zn, Cu, Fe, B.

> *"In Ontario there are in excess of 7,419 acres of tender fruit orchards, with peaches making up the majority at 4,469 acres."*
> ***– John Zandstra, University of Guelph Ridgetown Campus***

Results & Conclusions:

Due to the cold winter of 2013/14, there was no fruit on the peach trees in 2014. The season was also relatively moist, and irrigation was not triggered. Soil and tissue samples were collected, and lab results will soon be available.

Contact:

John Zandstra, Professor, Fruit and Vegetable Cropping Systems
University of Guelph, Ridgetown Campus
519.674.1500
jzandstr@uoguelph.ca

#8

Advanced oxidation processes for the treatment of organics in recirculated greenhouse nutrient feed water

Introduction:

A significant facet of sustainability in the hydroponic greenhouse industry is tied to recycling of the nutrient feed water. This water is presented continuously to the roots in a nutrient-rich formulation and is displaced from the root matrix material in a depleted form.

To be recycled, this feedwater (about 25% of the original volume supplied) must be made back up in beneficial nutrients, but it must not be allowed to accumulate chemical species which adversely affect plant growth. Such species could be inorganic ions, such as sodium, chloride and sulfate which accumulate to become 'limiters', or certain organic compounds which either have been applied to promote crop health or secreted by the roots as plant growth modulators (the classical example is the auxin, indole acetic acid; others are organic acids and carbohydrates). Several phenolic acids, such as vanillic acid (VA), caffeic acid (CA) and ferulic acid (FA) have been identified from the nutrient water in hydroponic culture of tomato by GC/MS [1, 2]. On the other hand, fungicides, such as Previcur N (propamocarb hydrochloride), are commonly used in greenhouse pepper, tomato and cucumber culture in order to control pythium root diseases. It is toxic to fish, aquatic invertebrates, and marine/estuarine organisms if runoff from greenhouses gets to the lakes. To extend water recirculation in the greenhouse industry, it is important to know the fate of those compounds in the recirculated greenhouse water; thereby, the efficiency of both water and nutrient use can be increased.

"One of the major factors affecting AOPs' performance is the percentage of hydroxyl radicals scavenged by the background water matrix. The presence of carbonate and bicarbonate in greenhouse water could significantly reduce the mineralization of organics."
- Keith Taylor, University of Windsor

Objectives:

The objectives for this study were to:

1. Design and build a pilot-scale unit based on the parameters of Gryphon's UV-O3 treatment unit;
2. Examine the formation of hydroxyl radicals under various AOPs (UV/H_2O_2, O3/UV, O3/ UV/H_2O_2, O3/H_2O_2) using the pilot unit;
3. Determine the hydroxyl radicals' scavenging effect in greenhouse water;
4. Investigate the effect of various AOPs on the removal of total organic compounds in greenhouse water;
5. Determine the concentrations of plant growth modulators and residual fungicides in greenhouse water;
6. Investigate the effect of various AOPs on the removal of plant growth modulators and fungicides in greenhouse water.

Methods:

A combined UV-O3 disinfection treatment unit was recently developed by Gryphon Automation (Leamington, ON) and it has been widely applied in local greenhouses. The design uses UV treatment as the primary disinfection, and ozone treatment as the polishing step with an extended contact time. Besides disinfection, the dissolved oxygen concentration was increased in the nutrient water due to the injection of ozone, which is beneficial to plant growth. The current treatment is not capable of destroying small organic compounds such as plant growth modulators with any appreciable efficiency, but with minor reconfiguration, it can be converted to various advanced oxidation processes (AOPs), which are much more aggressive, having been shown in hundreds of studies to effectively decompose organic molecules, eventually to CO2 (dubbed 'mineralization') if the treatment is prolonged sufficiently. The AOP generates hydroxyl radicals in situ, which are highly reactive with an oxidation potential of 2.8 V. If ozone can be injected into water prior to the UV treatment, dissolved ozone absorbs UV radiation and produces H2O2 as an intermediate, which consecutively reacts with UV to form hydroxyl radicals.

The two-step reaction is shown below:

$$O3 + H2O + hv\ (\lambda=254\ nm) \rightarrow H2O2 + O2 \quad (1)$$

$$H2O2 + hv \rightarrow 2\ HO\cdot \quad (2)$$

Also, hydrogen peroxide is a common source of hydroxyl radical in AOPs. By the addition of H2O2, the treatment can be converted to UV/H2O2, O3/H2O2 or O3/ UV/H2O2. The reaction of O3/H2O2 is shown below:

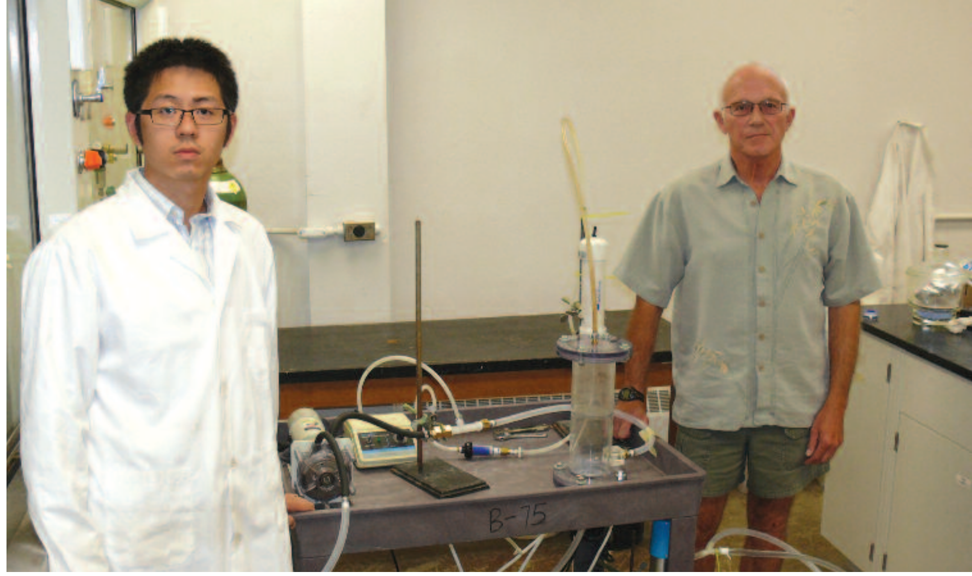
$$2\ O3 + H2O2 \rightarrow 2\ HO\cdot + 3\ O2 \quad (3)$$

A pilot-scale unit was built based on Gryphon's UV-O3 treatment unit to test the proposed AOPs, see Figures 1 and 2. The flow rate was 3 L/min, at which the applied UV dosage was 230 mJ/cm2 at 95% UVT (254 nm), which is commonly used in greenhouses for water disinfection. For treatments containing ozone, pure oxygen was the feed gas to the ozone generator at 3 psi, and air flow rate was controlled at 1 L/min. Fine air bubbles were created when water passed through a venturi injector, which significantly enhanced the mass transfer efficiency of ozone dissolving into water. Excess air and undissolved ozone were separated from the water stream to minimize the interference with UV irradiation. Ozone concentrations in feed and vent lines were measured by the ozone analyzer; dissolved ozone concentration in water was measured by a colorimetric method using indigo trisulfonate reagent [3]. The procedure was developed based on the Standard Methods: 4500-Ozone B: indigo colorimetric method [4]. Hydrogen peroxide was added to the feed tank at 2 mM (68 mg/L) if used.

Source waters were collected by Gryphon from two local greenhouse farms (Leamington, ON), which grow peppers and cucumbers, between July and December 2014. UV absorbance at 254 nm, total organic carbon (TOC) and pH were measured after collection; see Table 1. Samples were stored at room temperature.

Results & Conclusions:

Based on the understanding of greenhouse water gained in this study, it is believed that an integrated ozone and UV process would be ideal for greenhouse industry. Although, with limited time and resources, only a preliminary level of work has been completed, solid results suggest, first, that pre-ozonation dramatically improves UVT in greenhouse water, therefore, it would reduce the size of the required UV system, hence lowering capital and maintenance costs. Secondly, ozone as a strong oxidant can easily react with many organic and inorganic compounds, such as metals, alkenes, alkynes and phenolic acids. The half-lives of the selected model compounds were around three minutes when ozone was used. Third, it is already known that the dissolved oxygen concentration is increased in the nutrient water due to the injection of ozone, which helps with the plant growth. Fourthly, the residual ozone reacts with UV irradiation to form hydroxyl radicals to further react with the remaining organic compounds. Also, it avoids the exposure of workers from the toxic gas. Future work should first determine the relationship between ozone dose and increase of UVT of greenhouse water. By conducting a disinfection test, various combinations of ozone dose and UV dose can be determined. Furthermore, the capital and operating costs can be determined for the selected combinations, to establish a baseline for future work. The second stage would be to quantify the effect of the O_3/UV process on the removal of organic carbon in general and specifically on more plant growth modulators and crop improvement products than the five model compounds studied here. The effect of the O3/UV process would be increased with more ozone provided, however, the balance between cost and efficiency needs to be determined.



Student Wei Feng and University of Windsor Professor Keith Taylor are tackling issues of nutrients in greenhouse water.

Contact:

Keith Taylor, Professor of Chemistry and Biochemistry
University of Windsor
519.253.3000
taylor@uwindsor.ca

#9 Assessment and management of horticultural storm water discharges

Introduction:

Jeanine West of Flowers Canada with Wayne Brown of OMAFRA and Ann Huber of the Soil Resource Group.

Discharges (overflows) from storm water collection ponds to the environment require approval from the Ministry of Environment & Climate Change (MOECC) in Ontario, and nearly every pond overflows at some time during the year in response to storm events and/or spring runoff. Horticulture ponds are typically used for irrigation purposes may have a mix of source waters and have varying volumes of water depending on the time of year and production cycle. The management of these ponds can be an important tool in reducing negative environmental impacts. If the ponds collect nutrients or agricultural process water, then storm events create the risk of this nutrient-enriched water overflowing and discharging to surface water, directly or indirectly. Further, storm water itself may contain significant contaminants, including sediments (influencing total phosphorus levels) if the storm water being captured is runoff from surrounding agricultural lands, or salts from road runoff. The challenges for farmers are:

a) Understanding the contaminant profile of the water flowing out of the pond over the course of a storm event, and

b) Building capacity for their ponds to properly handle these flows, particularly as climate change scientists predict increased storm severity and changing weather patterns.

Objectives

- Collection of field data regarding volume, flow, and water depth (using staff gauges) of ponds over storm events of varying intensities and duration;
- Collection of automated/progressive samples to determine composition of storm water overflows throughout the storm event (from point of overflow to cessation of overflow);
- Evaluation of testing for electrical conductivity (EC) and pH as comparative measures of water quality, relative to full characterization of the water performed at selected intervals;
- Comparison of calculated nutrient loads (if measurable) based on grab samples versus automated sampling systems versus EC/pH continuous monitoring;
- Application of these findings to develop tools to aid producers in collection and reporting of results to MOECC.

Methods:

Records were kept of all the sites examined and information was tabulated, such as pond size, greenhouse roof area, lining material, and typical occurrences of overflows. Three greenhouse/outdoor production operations with process water from irrigation entering their ponds were selected, considering access to inlet and outlet pipes, variety of inputs, availability of flow meters and general pond construction (e.g. clay lined). For each of the selected sites, detailed site evaluation and characterization was performed, including a description of the storm water collection area and area characteristics, pond construction and sizing, potential water sources, location of inlet and outlet pipes, presence of aerators, etc.

Over the course of the study, pond levels were measured a) through a staff gauge inserted into the near-shore area, and b) with HOBO water level loggers (0-4m range).

During regular visits pond level and recent rainfall amounts were recorded on a site-specific checklist. Following the initiation of a storm event, daily visits of the site took place, until overflows ceased.

Both manual and automated progressive collections of overflow samples were conducted in this study. Grab sampling was performed daily during storm events with a Nasco swing-sampler. Autosamplers were used to collect samples over the course of each storm. Hach-Sigma SD900 24-bottle composite sampler or ISCO 3700 24-bottle autosamplers fitted with 1000mL polyethylene bottles were set up at each site from May-June and again from September-October or November. The programs were set up to provide one sample of approximately 900 mL every two hours; two samples were combined so that there was sufficient volume for sample analysis (e.g. bottle one and two, three and four).

First flush sampling was achieved with Nalgene Storwater (ping-pong) samplers. The samplers were mounted on posts in the water, with the top of the bottle set at the level where the pond would just start to overflow. As the pond water level rose to reach the lip of the bottle, the 'first' flush of water would enter the bottle through an opening in the lid. As the bottle filled up, the ping-pong would float, eventually closing off the opening in the lid so that the sample bottle would not continue to fill if the level of the pond continued to rise.

Meteorological data (temperature, precipitation) were collected throughout the test periods. Precipitation was tracked at each site during the test periods with a 16,000 event HOBO pendent event logger with a tipping bucket rain gauge. In addition, a rain gauge was positioned adjacent to the tipping buckets for a second measure of rainfall.

This in-water monitoring station measures factors such as total oxygen and turbidity.

Results & Conclusions:

Farmers need best management practices (BMPs) and management tools to meet MOECC regulations for storm water discharges. Currently, these tools are lacking, yet thousands of farmers in Ontario are encouraged (or mandated) to construct retention ponds to manage storm water. Many, particularly in horticulture, use the collected storm water for irrigation purposes.

During severe storms, however, runoff and agricultural process water (including that from subsurface drainage pipes) may contaminate retention/collection ponds and overflows. If a farmer is able to capture the 'most contaminated' portion of storm events (including any residual recirculation water), and discharge the excess storm water that poses the least environmental risk, then these severe storms (1 in 10 or 1 in 25 year storm events) can be managed to have the least detrimental impact on infrastructure and surrounding surface water.

This study is the first step in securing low-cost practical tools and BMPs that are applicable to not only greenhouse farmers, but to any farmer that collects process water, including: vegetable wash water and processing sites, irrigation recycling ponds, winery process water collection ponds, outdoor greenhouse/nursery production ponds, water collection ponds created during sweet corn cooling, etc.

"This study is the first step in securing low-cost practical tools and BMPs that are applicable to not only greenhouse farmers, but also to any farmer that collects process water, including: vegetable wash water and processing sites, irrigation recycling ponds, winery process water collection ponds, outdoor greenhouse/nursery production ponds."

- Dr. Jeanine West, Flowers Canada

Contact:

Jeanine West, Water Specialist
Flowers Canada (Ontario) Inc.
519.836.5495
jeanine@fco.ca
http://www.flowerscanadagrowers.com/

#10 Evaluation of denitrification bioreactors and constructed wetlands under Ontario conditions

This vertical wetland successfully removes pathogens from greenhouse effluent.

Introduction:

This constructed wetland removes 99.9 percent of E. coli.

Water as a resource is decreasing in availability and increasing in cost. Low cost risk reduction technologies that facilitate its reuse and/or protect surface and ground water resources are needed. Denitrification bioreactors and constructed wetlands are generally installed to remove undesirable levels of nutrients/chemicals from agricultural wastewaters, but previous studies have indicated that they may be useful for removing microbial contaminants as well.

In the 2013 WRAMI project of the same title, an evaluation of the capability of established bioreactors and wetlands to remove microbial contaminants from agricultural wastewaters and runoff was carried out in order to characterize design parameters for the dual roles of removing both chemical and microbial contaminants.

The monitoring program was continued in 2014, with the following objectives:

- Obtain a second year of data for two denitrification bioreactors treating agricultural field runoff to assess the impacts of annual weather and flow variations;
- Assess the impact of significantly increased flow rates in a bioreactor treating greenhouse water;
- Assess the impact of changes made in the chemical and microbial characteristics of input water to a denitrification bioreactor;
- Assess the performance of a newly constructed wetland system designed to treat and recirculate greenhouse water, with critical performance requirements in the cold months.

Methods:

Water sampling programs were established (approximately bi-weekly). Samples were taken from the inlet and outlet of each system; where multiple sampling locations were possible at a single treatment system, intermediate stages were sampled as well. Sites with precipitation-driven flows were sampled opportunistically to catch flows or other significant events (e.g. manure application effects).

Samples were immediately analyzed for indicators of either enteric or plant pathogens, as required. E.coli and total Coliforms were enumerated using either the 3M Petrifilm method or mFC plate count agar for high and low levels of organisms, respectively. Yeast and Mold counts (3M Petrifilm™ method) were used as a surrogate for plant pathogens for routine analysis. Samples were periodically sent to the University of Guelph Laboratory Services Division for DNA multiscan for the detection of specific fungal plant pathogens. Samples were also submitted for analysis of a standard suite of nutrients (greenhouse solution: pH, total salts, NO3-N, NH4-N, TP, K, Ca, Mg, bicarbonate, chloride, sulphate, Na, Zn, Mg, Cu, Zn, Fe, B, Mo, and Si), on an approximately monthly basis.

The design parameters such as flow rates and flow consistency, nominal residence time and variation, dimensions, and media were measured. Temperatures and flow rates were also measured, and local mean air temperatures at nearby weather stations recorded in determining the significance of temperature to treatment performance.

Results & Conclusions:

Five treatment systems were monitored: one recirculating 3-cell vertical flow constructed wetland with pea gravel media and four denitrification woodchip biofilters, each with a different configuration.

The wetland was highly effective at removing microbial contaminants and phosphorus, but not nitrate-N. Since the treated water is reused for irrigation in the greenhouse, retention of nutrients is a desirable outcome. This is a new system, and should be monitored periodically to assess its long-term capacities.

The 13-year-old lateral flow bioreactor treating field tile runoff is still very effective at removing nitrate-N, but performance was strongly correlated with measured temperatures but not flow rates. Demonstration of consistent removal of *E.coli* was difficult because of very low input populations and likely contamination of the site from wild life. The nine-year in-stream bioreactor was effective at removing significant nitrate and *E.coli*. In this case correlations with measured temperature and flow rates were not significant, though trends were noted.

One of the woodchip denitrification bioreactors is still highly effective at removing nitrate and microbial contaminants from greenhouse leachate water. An increase in flows to the system through the 2014 addition of another process water stream for treatment did not reduce its performance. Phosphorus removal also remains significant, although a slight decrease in performance was noted in the 2014 monitoring.

"The information derived from this project is central to the next development stage: designing and evaluating flexible water treatment systems that meet growers' specific water management needs."
- Ann Huber, Soil Resource Group

Contact:

Ann Huber, Environmental, Microbiologist
Soil Resource Group
519.341.2176
ahuber@srgresearch.ca

#11 Evaluation of land application of greenhouse wastewater in field vegetable production

Introduction:

Within the Essex County watershed there are identified areas of concern with respect to nutrient loading to Lake Erie. The greenhouse sector is working to decrease the offsite nutrient solution release through recycling of waters used in the production system. However, over time, limiters such as chlorides and sulphates increase in the solution causing restricted plant growth, and the nutrient solution must be discharged and stored. Effective and environmentally sustainable land application protocols for using greenhouse waste water (GHWW) on field crops currently do not exist. In order to fit into Nutrient Management application protocols, field crop response and the fate of nutrients and other elements need to be documented.

This trial will provide data on the fate of nutrients and elements of concern when using greenhouse waste water as a nutrient source for field crop production. The objective is to generate data to allow greenhouse waste water to fit into Nutrient Management application protocols.

"This trial will provide data on the fate of nutrients and elements of concern when using greenhouse waste water as a nutrient source for field crop production."
- John Zandstra, University of Guelph Ridgetown Campus

Methods:

Trials using GHWW to fertigate bell peppers were completed on a Fox Gravelly Loam in 2013 at the Cedar Spring Research Station. In this trial, no elements or heavy metals were consistently elevated in plant tissue, fruit or soil when using greenhouse waste water, when compared to standard practices. As well, plant development, fruit yield and fruit quality was similar when greenhouse wastewater was compared to standard fertility practices. This trial was repeated in 2014 but was also expanded to include another soil type (Brookston Clay Loam) on the Ridgetown Campus Research Farm. Treatments included:

(1) Pre-plant soil applied fertilizer (19-19-19), 60 lbs N/acre, P and K as per soil test (OMAFRA recommendation);

(2) Fertigation of 3.5 lbs N/acre per week using a soluble 20-20-20 commercial fertilizer, (P and K as per soil test); assuming a 17 week production season this will provide 60 lbs N/acre;

(3) Greenhouse wastewater at a rate to provide 3.5 lbs N/acre.

Trickle irrigation was be installed shortly after establishment. Prior to planting, a composite soil sample from each replicate was taken at the following depths: 0-15, 15-30 and 30-60 cm. Insects and diseases were managed according to industry standards. After planting and fertilizer applications were completed, 2-30 cm and 2-60 cm lysimeters will be installed in each treatment in two replicates. Prior to GHWW application and once it is received, a sample will collected for analysis.

At pepper growth stage "early fruit set", recently matured leaves (with petiole) were collected from each treatment within each replicate, with a minimum of 100 g fresh weight per sample. Fruit was weighed and graded at each harvest. Data was collected on marketable yield (over 2.5" (6.35 cm) in diameter and free from defects), fruit quality (fruit length, wall thickness) and fruit per plant. Fruit tissue samples were collected at the third harvest. Whole plant analysis was completed by collecting whole plant samples (top growth only) from five plants per treatment per replicate. At the final harvest, from each treatment in each replicate a composite soil sample will be collected at the following depths: 0-15, 15-30 and 30-60 cm.

Nutrient-rich treated greenhouse effluent could be an effective source of fertilizer for field peppers.

Results & Conclusions:

Fruit yields, weights and fruit numbers per plant were similar across all fertilizer treatments. The only difference noted was longer fruit from plots with preplant applied fertilizer; fruit weights and wall thicknesses were similar.

Contact:

John Zandstra, Professor, Fruit and Vegetable Cropping Systems
University of Guelph, Ridgetown Campus
519.674.1500
jzandstr@uoguelph.ca

#12 Process water recycle and reuse circuit for the Ontario greenhouse sector using ENPAR's ESD Capacitive Deionization technology

Introduction:

ENPAR Technologies, Inc., with funding from Farm & Food Care through the Water Adaptation Management and Quality Initiative (WAMQI), undertook a demonstration pilot study using its Electrostatic Deionization (ESD) Capacitive Deionization Technology. The study was performed at a partner greenhouse in Leamington, Ontario.

The purpose of the project was to optimize the operation of the ESD system to achieve ≥ 85% water recovery. A potential solution for enhanced water recovery within a greenhouse operation while achieving reduction in limiters, defined as dissolved ions including Sodium, Chloride and Sulphate. These ions are either part of the initial makeup of the fertilizer and not absorbed by the plants or are excreted by the plants. The enhanced performance of the ESD will significantly reduce costs associated with waste water management and disposal.

"Based on the pilot plant operation and testing completed by ENPAR the capacitive deionization system will typically operate between 83 – 85% water recovery. Up to 88% water recovery can be achieved through a series of procedural optimizations of the ESD unit."

- John Motto, Enpar

This demonstration project builds upon the results achieved in the previous study and was conducted in two stages. Stage one, spanning the first two months of the project, was designed to demonstrate that physical and operational changes enabled the ESD to achieve a target ≥ 85% water recovery while maintaining the reduction in limiters as outlined in the previous study. Stage two, covering the final month of the project, involved a series of procedural optimizations in an attempt to further enhance water recovery.

The pilot scale capacitive deionization treatment system was installed by ENPAR and began operating on August 14, 2014 for continuous treatment during the plant growing season, concluding on November 07, 2014. The following provides a summary of the greenhouse operations, pilot system description, experimental program, test results and system operating details.

Methods:

ENPAR's ESD system is based on the principles of Capacitive Deionization. The Capacitive Deionization (CDI) is a low-pressure on-membrane process that removes dissolved ions from a water stream in the presence of an electrical field. In general, intake water from the greenhouse is pumped through cells that contain the charged electrodes. The electrodes attract and retain ions on the electrode surfaces. As the ions build up on the surface of the electrodes, the cells lose efficiency so that treated water produced at the start of the cycle has lowest conductivity, and conductivity gradually increases until a pre-set maximum is reached. The treated water exits the system as a high volume with low total dissolved solids (TDS) content.

The electrodes have a finite capacity for holding ions. When the maximum conductivity setting is reached, the system switches to regeneration. To regenerate the electrodes, the applied potential is reversed and the ions are then repelled back into the gap between the electrodes. A small volume of rinse water then carries the ions from the cells producing a rinse stream that has much smaller volume with higher TDS concentration. Since the CDI process does not require high-pressure pumps, the energy consumption is expected to be low and is related mainly to the DC power request on cells.

ENPAR's technology addresses issues related to greenhouse water recirculation.

The sampling program began August 18, 2014 continuing during the growing season with samples collected on a semi-regular basis with the last sample collected on November 7, 2014. A total of four water samples were collected on four dates including from the greenhouse intake feed; the treated stream; the waste stream.

Samples were shipped to ALS Laboratory, Waterloo, Ontario. Samples were collected and preserved as per ALS lab requirements and were placed on ice or refrigerated (4°C) immediately following sample collection.

Samples were analyzed for major ions. Level of pH and EC were analysed by ENPAR staff on site while collecting samples and verified in the ENPAR analytical laboratory.

Results & Conclusions:

The ESD System has been shown as a viable option for recycle and reuse of greenhouse leach water. Based on the results of the study, the following conclusions can be made:

- During stage 1 testing, water recovery of 83 – 85% was achieved. During stage 2, with optimization of the system, up to 88% water recovery was achievable.
- The treated water stream maintain a desirable level of nutrients of about 384 - 470 mg/L of TDS (777 – 902 uS/cm).
- The volume of Waste Water is less than 15% of total treated water and can be as low as 12%.
- The TDS level in the concentrate stream was in the range 8490 – 9277 mg/L (8.49 – 9.28 mS/cm).
- DC energy consumption for the ESD unit is calculated at 2.5 kWh/m^3 of recycled water

Based on the pilot plant operation and testing completed by ENPAR the capacitive deionization system will typically operate between 83 – 85% water recovery. Up to 88% water recovery can be achieved through a series of procedural optimizations of the ESD unit.

This means that for every m^3 of water treated, between 0.83 and 0.88 m^3 of clean water is produced and between 0.12 and 0.17 m^3 of concentrate requiring disposal is produced.

The optimum ion removal rate was demonstrated to be 75%. A higher removal rate is not recommended since it will affect the water recovery and greenhouse expenses on replenishing the chemicals in the plant feed water.

Contact:

John Motto, Chief Chemist
Enpar Technologies, Inc.
519.836.6155
jmotto@enpar-tech.com
www.enpar-tech.com

#13 A modelling-based protocol for minimizing non-growing season nutrient losses from fall liquid manure applications through the use of controlled tile drainage.

Introduction:

The movement of nutrients (N and P species) to surface water following liquid swine manure (LSM) application poses a serious risk to water quality within agricultural areas, as well as to major water bodies whose tributaries source water from agricultural regions, such as the Great Lakes. While growing season nutrient losses can have serious ecological impacts, the majority of actual nutrient mass is transmitted during the fall through spring non-growing season, and a significant percentage of mass moves in response to individual hydrologic events such as winter and spring melts. As a result, it is important to understand how nutrients (and water) move during these major hydrologic events in order to design and optimize strategies to mitigate annual nutrient losses from agricultural lands.

Typically, field experiments are conducted in order to assess the efficiency of water and nutrient management practices for mitigating the environmental impacts of agriculture. However, field experiments are generally: expensive to conduct, site specific, and highly dependent on soil and climate conditions during the course of the study. Furthermore, there have already been an extensive number of field experiments conducted in Ontario from which to base localized agricultural management decisions. The challenge is to now extend the results of the localized field research across a larger land base.

"The results from this work have demonstrated that advanced numerical simulation technology can be used very effectively to help evaluate agricultural water and nutrient management practicesthe ESD unit."

- Steven Frey, Aquanty Inc.

Methods:

The three sites selected for this modeling focused study were Winchester (North Gower clay loam), Sebringville (Huron silt loam), and Delhi (Fox sand). The sites were selected based on the availability of background information and on their history as manure application research sites. The objective of using the three different soil types was to assess the influence of soil structure and composition on liquid swine manure movement to tile drains.

The Winchester site in eastern Ontario Canada has flat lying field plots consisting of poorly drained North Gower clay loam with macropore features (root and worm burrows) extending to 2 m depth and a compacted plow pan layer existing at 20 cm depth. Plastic tile drains with 0.1 m diameter, spaced 15 m apart, and at a depth of approximately 0.8 m were installed at the site in the 1980s and in-line tile drain discharge control structures were installed in mid-September 2010. During the course of the 2010 field experiments there were six tile drains that were monitored, with three of the drains being left in free flowing condition and the other three drains being controlled by the stop logs inside the control structures, which were maintained at a depth of approximately 0.30 m below the surface. This stop log depth was set to inhibit drainage but also to minimize overland flow potential. During 2010, the field plots were planted in barley.

At the Winchester site, liquid swine manure (LSM) was applied to the field at a rate of 80 m3 ha-1 on October 13, 2010. Prior to LSM application, rhodamine WT (RWT) chemical tracer was mixed with the manure for a targeted RWT concentration of 50 mg L-1. Pumps fitted to each of the road tankers were used to continuously mix the manure throughout the land application. For a period of 36 d following the manure application, YSI 6600 sondes (YSI Inc., Yellow Springs, OH) continuously measured a suite of water quality properties for the tile discharge (including RWT concentrations). To facilitate nutrient analysis, point samples were obtained with ISCO 6712 automatic water samplers (Teledyne ISCO, Lincoln, NE) that were fitted with ISCO 730 Bubbler Flow Modules.

Results & Conclusions:

The results from this work have demonstrated that advanced numerical simulation technology can be used very effectively to help evaluate agricultural water and nutrient management practices. In particular, through a series of comparisons with observational data from field experiments conducted at Winchester Ontario, the HydroGeoSphere (HGS) model has been shown to accurately reproduce the movement of both water and nutrients to tile drains that are under free drainage and controlled drainage management. Furthermore, the HGS modelling was able to help explain some of the complex observations from the field experiments by showing the strong influence of shallow groundwater on tile drain discharge and on the concentration of nutrients in discharge. From the modelling results it was apparent that the higher and flatter water table associated with controlling tile drain discharge actually serves to increase the downward movement of water through the soil profile which can then act to increase the concentration of surface derived nutrients in the tile discharge. In the case of free tile drainage, the lower water table in the vicinity of the tile drain acts to reduce the local downward hydraulic gradients which in turn promotes the upwelling of shallow groundwater to the tile drain.

The modelling also verified results from the field experiments that showed that controlled drainage can be used to mitigate the movement of manure to tile drains immediately following manure application. In some cases, such as when manure is applied to tile drained soils that also have effective natural drainage, the model showed that controlled drainage may be able to almost completely eliminate tile discharge under most weather conditions, which would in turn could greatly reduce the risk that manure application poses to surface water quality in tile drained settings. However, in the situation where tile drain discharge is eliminated, groundwater becomes the principle receptor for manure derived nutrients. As the simulation results indicate, the nutrients that would likely pose the highest risk to groundwater would be the highly mobile species such a nitrate. For total phosphorus and ammonium, the model predicts that under both the controlled and free tile drainage conditions the majority of their mass will be retained in the shallow soil on account of their limited mobility.

In the sand soil that was investigated, implementing controlled drainage during the over-winter period could in some cases be able to almost completely eliminate tile discharge, and the associated nutrient loads that would otherwise be transmitted to surface water. By incorporating winter processes in the model, the results showed that in both the controlled and free drainage scenarios, and in both the clay and sand soils that were considered, nutrient movement during the winter is closely related to the occurrence of melt events, and in the intervals between the melts there was minimal nutrient movement. When winter processes were not included in the modelling approach, the model results did not as accurately reflect the high degree of nutrient concentration variability in the tile discharge that was observed during the field experiments. The inclusion of winter processes within any modelling approach utilized for investigating over-winter nutrient losses in climates such as that of Ontario's can therefore be considered an imperative component.

Contact:

Steven Frey
Senior Scientist, Aquanty
519.279.1080
sfrey@aquanty.com

Steven Frey of Aquanty is researching how liquid manure travels through soil.

#14 Demonstration and evaluation of pond/wetland/ vegetated filter systems to treat beef manure pile and outdoor confinement area runoff

Introduction:

Chris Kinsley demonstrates how this aerobic treatment pond filled with aquatic plants will treat beef manure pile runoff.

Beef farms produce 37 kg of manure per day for each head of cattle (Statistics Canada, 2006). Beef manure is high in organic content and nutrients, making it a very effective fertilizer when properly applied on agricultural land. Animal manure improves soil fertility and the quality of crop growth.

Manure runoff that is washed out due to precipitation can eventually leach into nearby streams and river ways. Manure runoff can occur from improperly stored manure and from the land application of manure itself. The excess of nutrients and contaminants from manure runoff can pose a significant risk to nearby river ecosystems and sources of drinking water. Wetlands are known to be highly effective at removing nutrients from wastewater. The following project characterized the performance of a constructed wetland at removing organic matter, nutrients and bacteria from beef manure runoff.

There were four primary objectives:

Objective 1 – Characterize runoff from a beef operation manure pile and exercise yard during spring runoff and as a function of precipitation events. Develop runoff coefficient and compare with literature values.

Objective 2 – Characterize the performance of a surface flow constructed wetland system to remove organic matter, solids, N, P, and *E.coli* and relate to loading events and season.

Objective 3 – Compare post wetland treatment using a vegetated filter and a flow path to treat and discharge wetland effluent in terms of N, P and *E.coli* attenuation. Recommend an optimum management option for beef operations.

Objective 4 – Establish native wetland plant species within the wetland and pond system (three each of floating and emergent macrophytes), and plant species sequentially in rows and study their growth and competition within the system with respect to nutrient gradient along the system axis. Characterize nutrient uptake/release over the growing season. Lastly, develop recommendations for plant selection and establishment.

Methods:

The treatment of the manure runoff is completed in two stages: Stage one consists of a primary settling pond, a constructed wetland, and a secondary treatment pond. Stage two comprises of a side by side comparison of a vegetated filter and a flow path (ditch).

When precipitation occurs, manure runoff is discharged from the concrete pad. A plastic collection basin was constructed in order to capture and feed the runoff from the edge of the concrete pad into a concrete sump. The sump was constructed to facilitate flow monitoring and composite sampling. The manure runoff is pumped from the concrete sump into the primary treatment pond. The collected runoff is a combination of direct runoff from the concrete pad and precipitation from the road, exercise yard and surrounding areas. Eavestroughs from the barn and lean to building were diverted away from the concrete pad in order to reduce the total volume of water going through the manure pile. Pump runtime data (seconds) from the concrete sump pump is collected. By measuring the flow per unit time (L/second) which the pump produces, manure runoff influent (L) is quantified.

The manure runoff influent is pumped into the first settling pond via a vertical baffle in order to maximize settling and limit channeling through the pond. The primary settling pond is approximately 15m x 10m and was dug to a depth of 1.5m.

Influent then enters the constructed wetland through an overflow weir. The overflow weir spans the entire length of the pond. For the best efficiency of the system, the weir must be completely level, otherwise channeling will develop. The constructed wetland spans approximately 15m x 10m, and was dug to a depth of approximately 0.5m. Once planted, wetlands typically take two to three years to fully establish. From the wetland, the runoff then passes to the second treatment pond. The second treatment pond spans approximately 17m x10m, and was dug to a depth of approximately four metres.

Stage two comprises a side by side comparison of a vegetated filter and vegetated flow path. Stage one effluent is evenly distributed to the vegetated filter by a horizontal baffle. Six zero tension lysimeters were dug in the vegetated filter, which measures approximately 25m x25m at a 2-3% slope. The lysimeters are located at the start, middle and end of the vegetated filter. Two piezometers were also installed at the start and end of the filter respectively. Stage one effluent is also pumped to the beginning of the vegetated flow path. Lysimeters were installed at 0m, 5m, 10m, 20m, and 40m from the start of the flow path. Two additional piezometers were installed at the middle and end of the flowpath.

In order to compare and characterize the performance of the: ponds, wetland, vegetative filter and flow path, the following analyses are to be conducted. Pond and wetland samples are analysed for Biochemical oxygen demand (BOD), Chemical oxygen demand (COD), Ammonia (NH_3), Nitrates (NO_3), Phosphates (OPO_4), Total Kjeldahl Nitrogen (TKN), Total Phosphorus (TP), and Total Suspended Solids (TSS). Lysimeter and piezometer samples were analysed for Ammonia (NH_3), nitrates (NO_3), and (OPO_4).

The TSS from the primary settling pond and secondary settling pond were found to be 240 mg/L and 17 mg/L, respectively. Other analyses: Total Kjeldahl Nitrogen (134 mg/L to 18 mg/L), Ammonia (76.79 mg/L to <0.05 mg/L), and Biochemical Oxygen demand (240 mg/L to 17 mg/L) yielded similar results when comparing the primary and secondary treatment pond. It is possible the secondary treatment pond has become diluted with rainwater and groundwater, which would explain reductions of over 90% for TSS, BOD and NH_3. Samples from the lysimeters and piezometers were analysed for ammonia (NH_3). Lysimeter samples show ammonia concentrations ranging from <0.05 mg/L to 6.6 mg/L. Samples from the piezometers (wells) contained ammonia concentrations under 0.05 mg/L.

Results & Conclusions:

At this time, we cannot conclude the efficacy of the wetland, vegetative filter or flow path. However, at the first thaw in the spring of 2015, sampling of the Pemdale beef manure runoff project will resume. The wetland will be planted with indigenous species of cattails. Grass pasture seeds, of the same strain used by the farmer, will be spread upon the vegetated filter and flow path. The performance of the wetland, vegetative filter and flow path will be evaluated in the coming months and years as the plant species grow and become fully established.

Contact:

Chris Kinsley, Manager
Ontario Rural Wastewater Centre
613.679.2218
ckinsley@uoguelph.ca
http://www.uoguelph.ca/orwc/index.html

Chris Kinsley of the Ontario Rural Wastewater institute is shown with beef cattle in eastern Ontario.

"Wetlands are known to be highly effective at removing nutrients from wastewater."

- Chris Kinsley, University of Guelph Alfred Campus

#15 Cornell soil health assessment as a possible soil quality standard for Ontario

Introduction:

Maintaining and building soil health is an essential component of long-term sustainable agriculture production. Helping Ontario growers improve soil health will have multiple benefits such as higher crop yields, increased resiliency against severe weather events expected with climate change, and perhaps reduced water demand due to improvements in water holding capacity and water infiltration. Although maintaining and building soil health is important to growers, it is not easy to define and measure and it is difficult to interpret the meaning of results. One soil health test available to growers in the USA and Ontario is the Cornell Soil Health Assessment (CSHA). It provides one number indicating soil health (the higher the number, the better the soil health). In 2009-11, OMAFRA Soil Specialists Anne Verhallen and Adam Hayes collected soil samples from long-term research trials in Ontario to evaluate the CSHA. Preliminary results indicate differences between treatments but the opportunity existed to analyze all data together via sophisticated statistical tools to gain meaningful knowledge. Therefore, the goals of our research were to a) evaluate the ability of the CSHA to accurately assess soil health in Ontario and provide information to improve soil health scoring, b) characterize the effect of long-term land management (i.e. tillage, crop rotation, fertilization) on overall soil health. C) to produce a preliminary tool ('look up table') that growers, crop consultants or Ontario-certified laboratories could use to estimate soil health.

"The WAMQI program was designed to allow me, a scientist, to focus on the research with very minimal administrative busy work. In my opinion has led to some really important work which will benefit Ontario's water and soil resources."
- Laura Van Eerd, University of Guelph - Ridgetown Campus

Methods:

Through a previous grant, OMAFRA soil management specialists Anne Verhallen and Adam Hayes collected soil samples from long-term tillage and crop rotation trials at four Ontario sites: Ridgetown, Delhi, Elora, and Ottawa/Woodslee which were processed based on the Cornell Soil Health Assessment. This is a substantial database with two tillage practices (conventional and no-till), four to six crop rotations (monoculture and rotations of cereals, legumes, forages), and four to six replicates. Meta-analysis using principal component analysis of the complete dataset was conducted to gain meaningful results.

Results & Conclusions:

Although the CSHA is a useful method for combining soil characteristics into a measure of soil health, the scoring is based on simply taking the average of all scores. This does not account for the relationship among soil attributes, and by taking the average it may overestimate soil health because eight of the 14 indicators are nutrients. Our study showed relationships among soil attributes at four long-term experiments in Ontario. We developed a weighted scoring system to compute a new overall soil health score ON-CSHA. The ON-CSHA rankings >55 percent are considered good, rankings between 45 and 54 percent are considered fair, and rankings <44 percent are considered as poor soil health. This is the first soil health test for Ontario and an approach for developing soil health tests elsewhere. The ON-CSHA provides a more meaningful overall soil health score. The ON-CSHA scoring system was more sensitive than the CSHA in showing numerical differences for soil health between tillage and crop rotation systems, which may help growers to more clearly see differences in soil health under different management practices. For instance, at Ridgetown the scores were 64 vs. 68 for conventional vs. no-till for the CSHA but scores by the new ON-CSHA were 37 vs. 64. Although both tests showed a statistical difference there was a bigger difference between the numbers with the ON-CSHA. Thus, it is recommended that growers use the ON-CSHA over the CSHA to better identify management practices which improve soil health.

By using the four long-term experiments in Ontario, we were able to critically evaluate how many years of production and crop management affect soil health. Generally, the ON-CSHA individual indicators were greater with long-term no-till compared to conventional tillage. There were no differences among crop rotations at Ottawa and Delhi. At Ridgetown and Elora, crop rotations which included winter wheat or 2-yr-alfalfa tended to have the highest ON-CSHA scores. In 2009 (at the time of sampling), Elora was the only site where red clover was intersown into cereal crops which had higher scores than without red clover. Therefore, to improve soil health, growers should consider adopting no-till and increasing the frequency of alfalfa, winter wheat or intersown red clover in crop rotations.

Laura Van Eerd is working with AAFC and OMAFRA to determine if the Cornell Soil Health Assessment is applicable in Ontario.

Contact:

Laura Van Eerd, Associate Professor, School of Environmental Sciences
University of Guelph Ridgetown Campus
519.674.1500
lvaneerd@uoguelph.ca
http://www.ridgetownc.uoguelph.ca/

#16 Evaluating GreenSeeker and the Kentucky Algorithm for predicting nitrogen requirements in wheat

Introduction:

The objective of this project was to evaluate the Kentucky Algorithm for the GreenSeeker technology on winter wheat in Ontario.

Nitrogen fertilizer is the largest single cost in wheat production in Ontario. Over-application can have negative environmental impacts, while under-fertilization affects yields negatively. Uniform blanket nitrogen (N) applications on a field basis ignore the variability of soils, yield potential, and variability in response to applied N. Normalized difference vegetation index (NDVI) technology (Greenseeker, Optrix, CropSpec, and others) offers one opportunity to improve yields and potentially reduce nitrogen input costs. Using NDVI and "on the go" variable rate nitrogen application technology, nitrogen applications can be more targeted to the varying needs of the crop in any specific part of the field. This has the potential to increase yields in areas where the crop is nitrogen-starved, yet benefit the environment by applying less or no N in areas where the crop has sufficient N supply from the soil. While this technology holds great promise, to date its success has been disappointing. A new algorithm for eastern soft wheat was developed by Dr. Lloyd Murdock of Kentucky State University (Kentucky Algorithm). This project was designed to test the Kentucky Algorithm under Ontario conditions.

"Our agronomy just hasn't caught up to the technology."
- Peter Johnson, OMAFRA

Methods:

Five locations were identified in 2014 to assess GreenSeeker technology using the Kentucky Algorithm. Due to extremely harsh winter conditions and severe winter kill, two of the sites had to be abandoned in the spring of 2014.

Treatments (two replicate field scale)

1. High N rate "reference" strips
2. Variable rate N strips utilizing the GreenSeeker and the Kentucky Algorithm
3. Fixed N rates using the average of the variable rate application as a fixed rate
4. Application rate #3 less 30 pounds N/ac
5. N Stamp strips: small strips of multiple N rates to evaluate for NDVI

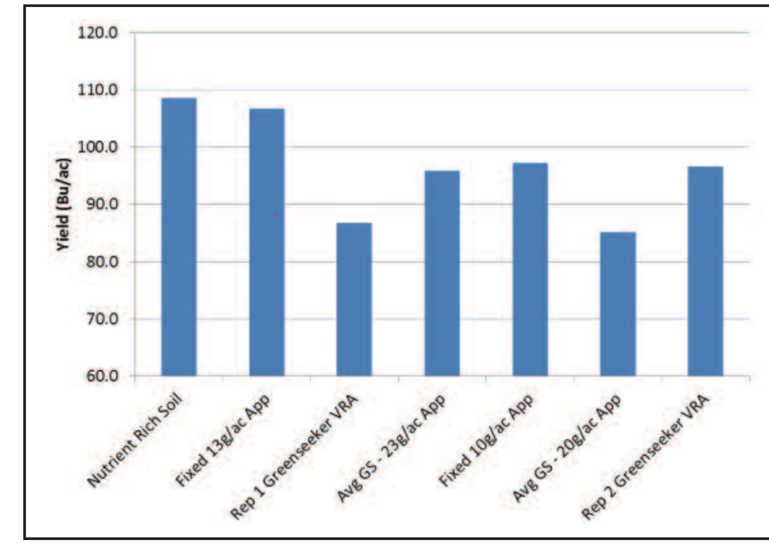
Treatment four was installed to determine if variable rate N application would improve yield over a fixed blanket N application across the field. Treatment 5 was to determine if the total amount of N applied using the GreenSeeker and the Kentucky Algorithm was an appropriate rate, or if N rates predicted needed to be adjusted according to Ontario conditions. Measurements taken included soil tests, leaf greenness (handheld GreenSeeker), leaf disease ratings, lodging scores, yield, grain moisture, protein, thousand kernel weights and residual soil nitrate levels. Aerial imagery was taken of all fields to compare to GreenSeeker NDVI readings, and determine zones for analysis purposes.

Results & Conclusions:

Yield response to the variable rate technology was disappointing. There was no yield gain to using the GreenSeeker and the Kentucky Algorithm. Figure 1 shows the yields of various treatments at the Tebutt field. There is tremendous variability across this field, as shown by the 10 g/ac treatment (30N/ac) out yielding both the 20 and 23 g/ac treatments (60N and 70N respectively) on either side of it. VRA rep 1 is low yielding, but VRA rep 2 (avg application rate 20 g/ac) out yielded the 20 g/ac fixed as the comparable fixed treatment. This shows the potential for VRA technology to apply equal or less N and maintain yield.

Several other key learnings were achieved during this project. Readings from the N rich strip are a key component in utilizing this technology, and are used to set the target NDVI for the balance of the field. At the Hauke location, the N rich strip varied from an NDVI reading of 85 to 89, with an average of 87. When 87 was used as the target NDVI, the algorithm applied significantly more nitrogen than anticipated, or expected to be needed for the field. By reducing the target NDVI to 86, N applications were reduced significantly. This suggests that the slope of the Kentucky Algorithm may be too steep for Ontario conditions, and adjustments may need to be made. Additionally, winterkilled areas within that field had very low NDVI readings (45), and extreme amounts of nitrogen were applied. This indicates that a higher cutoff point is required, where N applications would drop to zero as no amount of N can correct the problem.

Greenseeker Wheat Trial - Tebutt



Fields were also flown with an unmanned aerial vehicle (UAV). The match between the UAV NDVI image and the yield from the Greenseeker strip were very close. This demonstrates that the NDVI map can be generated with on-the-go sensing, or any other method, with application maps generated and utilized for N applications. With the increasing availability of UAVs, this offers another good option to take advantage of the opportunity NDVI offers.

In summary, opportunities exist with this technology. The Kentucky Algorithm and our understanding of NDVI and related N applications in wheat are not yet sufficient to use this on a wide scale. Hopefully further studies in the future will address these opportunities.

Contact:

Nicole Rabe, Land Resource Specialist
Ontario Ministry of Agricultural, Food and Rural Affairs
519.826.3550
Nicole.rabe@ontario.ca
http://www.omafra.gov.on.ca/english/

#17 Improving irrigation scheduling and nitrogen management in sweet potato production

Introduction:

Sweet potatoes that will be sold in grocery stores in North America.

Sweet potatoes have become a significant specialty crop for Ontario in recent years, with approximately 1,300 acres in production. Sweet potatoes are commonly considered to be drought tolerant, and most Ontario growers rarely, if ever, irrigate. However, while sweet potatoes can be produced under very low moisture conditions, several studies in the southern United States have demonstrated significant reductions in yield when soil moisture falls below 50 percent of field capacity at critical stages of plant development. Critical plant development stages identified for sweet potatoes are:

a) storage root initiation (from 0 to 40 days after transplanting)

b) root elongation (40 days after transplanting onwards).

Nitrogen requirements of 50 kg N/ha have recently been established for sweet potato production in Ontario. However, no studies have been conducted under Ontario conditions to determine the optimum fertilizer source and timing of application. Practices vary widely from grower to grower, with some applying all nitrogen fertilizer before planting and others applying the fertilizer in one or more split applications. Split applications of nitrogen fertilizer with applications spread out over time is thought to reduce the risk of nitrogen leaching by reducing the supply of leachable nitrogen at any given time. Splitting applications also reduces the amount of nitrogen present in the soil during the first few weeks after transplanting when plants are small and not taking up large quantities of nitrogen.

Ontario sweet potato yields are typically much lower than those of competitors from the southern United States, largely due to our shorter, cooler growing seasons. Growers have identified increasing yield as a high priority, but have not considered irrigation as a means of doing this, largely because they are not aware of the potential benefits of adequate moisture during critical development periods on yield of sweet potatoes. A better understanding of the impact of irrigation and nitrogen management under Ontario growing conditions could help growers increase yields of marketable roots, thereby increasing profitability and competitiveness.

The objectives of this project were to:

1) Compare the effect of irrigation during different stages of crop development on sweet potato yield;

2) Compare the effect of various nitrogen sources and application timings on yield of sweet potatoes and potential nitrate leaching.

Methods:

A field trial was conducted in 2014 at the Simcoe Research Station. Soil type was a Walsher sandy loam (1.0% organic matter, pH 6.9). Slips of the sweet potato cultivar Covington were purchased from a local grower and planted by hand into 20 cm high hills on June 12. Rows were spaced 1 m apart and plants were spaced 0.3 m apart in the row. Each experimental unit (plot) was 8 m long and 10 m wide in size, consisting of ten 8 m long rows. Plots were separated by a 3 m buffer on all sides to prevent irrigation water from impacting adjacent plots. Treatments consisted of five irrigation timings:

1. a non-irrigated control;
2. early season irrigation for two weeks during root set (7 to 21 days post-transplant – 19 June-3 July, 2014);
3. early season irrigation for 4 weeks during root set (7 to 35 days post-transplant – 19 June-17 July, 2014);
4. late season irrigation only during root elongation (35 days post-transplant to 5.5 weeks prior to harvest, 17 July-21 Aug, 2014);
5. all season irrigation during both root set and root elongation (19 June-21 Aug, 2014).

Treatments were arranged using a randomized complete block design with four replications per treatment. Irrigation was achieved by means of an overhead sprinkler system consisting of Senninger ½˝ Xcel Wobbler Sprinklers fitted with No. 9 (flow rate 1.8 gallons (6.81 L) per minute) nozzles, placed 0.45 m above the soil surface. Soil moisture was monitored to a depth of 18 cm twice a week using a Field Scout TDR 100 portable soil moisture meter. Each time, measurements were taken at three randomly selected points per plot. Irrigation was applied when the average soil moisture of the plots to be irrigated (treatments 1, 2 or 3, depending on the date) was at or below 35% of available water (=14% volumetric water capacity). For each irrigation event, sufficient water was applied to bring the soil at rooting depth up to field capacity (=21% volumetric water capacity). Rooting depth was defined as six inches (15 cm) until July 17th, and then increased to 12 inches (30 cm) thereafter, as roots grew deeper into the soil.

Prior to planting, 109 kg/ha triple super-phosphate (46% P_2O_5), 125 kg/ha muriate of potash (60% K_2O), 250 kg/ha sulphate of potash magnesia (22% K_2O, 20% S, 11% Mg) and 220 kg/ha ammonium nitrate (34% N) was broadcast over the trial area and incorporated. July 16, plots were hilled again to a final height of approximately 25-30 cm. The inside 4 m of the middle two rows of each plot was harvested on 29 September, 2014 using a small one row potato digger. Roots were cured at 29°C for 5 days, then stored at 13°C.

Results & Conclusions:

The first irrigation occurred June 19. Soil moisture dropped below the trigger point (14% VWC) for irrigation on 15 occasions throughout the season resulting in five (no irrigation), six (two week early season), nine (four week early season) and 15 (late season) irrigation events respectively. Irrigation ceased after August 21 to allow time for root skin to toughen prior to harvest. Irrigation treatments did not affect any of the yield categories or total roots per plot. Average weight per root was significantly lower in plots irrigated all season compared to the early season (two week), no irrigation and late season irrigation treatments.

"Further work is needed to test various soil moisture monitoring technologies and identify tools better suited for this crop."
- Cathy Bakker, University of Guelph Simcoe Research Station

This sweet potato has suffered 'cracking' due to insufficient irrigation during the growing season.

Results from 2014 did not indicate a clear benefit of irrigation on sweet potatoes, possibly due to the fact that the growing season was not sufficiently dry to stress this drought-tolerant crop. Soil volumetric water content as measured by the Field Scout TDR was consistently lower than expected during the season and triggered irrigation events more often than anticipated. Plants in plots irrigated all season developed chlorotic symptoms typical of nitrogen deficiency suggesting that nutrients may have been leached out of the root zone. Results suggest that the type of TDR used in this trial may not be appropriate for sweet potatoes or may require calibration when used in a hilled crop. Further work is needed to test various soil moisture monitoring technologies and identify tools better suited for this crop.

Contact:

Cathy Bakker, Research Technician
University of Guelph, Simcoe Research Station
519.426.7127
cbakker@uoguelph.ca
http://www.uoguelph.ca/plant/stations/simcoe

#18 Nitrogen use efficiency in two Ontario legume crops

Introduction:

Laura Van Eerd demonstrates equipment used in determining nitrogen content and soil quality.

There is a need to better understand nitrogen (N) fertilizer requirements for a) edamame, also known as fresh vegetable soybean, a relatively new crop in Ontario for which there are no fertility recommendations and b) snap beans, where nitrogen recommendations were determined in 1962.

By determining the most economical rate of nitrogen fertilizer, growers will be able to optimize inputs while minimizing impacts on the environment like nitrogen loss. There are significant environmental and economic benefits to gaining a better understanding of nitrogen use efficiency in both of these crops. In either crop, unnecessarily high applications of nitrogen fertilizer could potentially compromise the quality of the harvested product, as well as increase the risk of residual nitrogen at the end of the season which can be lost during the fall, winter and spring seasons through greenhouse gas emissions or leaching to groundwater and surface water (through tiles).

Both crops are commonly grown on coarse-sandy loam textured soils which have a high risk of nutrient leaching and contamination of water. Determining the most economic rate of nitrogen fertilizer and estimating the nitrogen budget (inputs at planting and outputs at harvest) for the crops will allow for improved water quality through better nitrogen management. Considering that snap beans and edamame are legume crops, there may be opportunities to significantly reduce nitrogen fertilizer applications and protect water resources. Thus there is a need to evaluate the N fertility requirements in edamame and snap beans.

Objectives:

- Determine yield response to higher rates of nitrogen in snap beans in Ontario.
- Determine the most economic rate of nitrogen (MERN) for edamame in Ontario.
- Determine the impact supplemental nitrogen has on the quality or marketability of edamame and snap beans in Ontario.
- Estimate nitrogen losses in snap beans and edamame in Ontario.

Methods:

There were three trial locations for each crop; Ridgetown, Simcoe, and a grower location in the Rodney area, which represent processing and fresh market growing areas. The experiment was a randomized complete block design with four replications for each crop. Nitrogen fertilizer (34-0-0) was applied at five different rates (0, 20, 40, 60, 80, 120 lb/ac) to six row wide by eight meter long plots of snap beans and edamame. The 0 and 120 lb/ac rates were not necessarily recommended practices but were needed to determine crop response with and without N fertilizer and to predict N losses from the field.

Soil texture and complete soil characterization were determined at 0-15 cm depth in a composite sample approximately 24 soil cores from either each replicate or the entire trial area. Harvest parameters collected included: fresh weight of plants and pods, total number of pods, total yield, and marketable yield. For select N treatments (0, 60, 120 lb/ac), nitrogen dynamics were determined. Residual soil nitrogen levels were assessed pre-plant and post-harvest for N content at the 0-30 and 0-60 cm depth. Soil nitrate-N and ammonium-N were extracted with 2M KCl and concentration determined via auto-analyzer with cadmium reduction method. Dry plant samples of both shoots and pods were ground and nitrogen content determined by LECO CN to calculate uptake and removal values for both crops. With soil and plant nitrogen data, nitrogen losses from the field were predicted.

Results & Conclusions:

Sites that would likely yield an N response were examined. These sites had sandier soils with less organic matter. Although 2014 was a wet, cool season, the later planting dates for edamame and snap beans avoided a lot of the rain.

The current OMAFRA nitrogen recommendation for snap beans is 40 kg ha^{-1}. The research conducted provides no reason to increase the provincial N recommendation. In fact, the research suggests growers could drop their N rate to zero without yield, quality or economic losses. In 2014, there was no evidence to suggest that N fertilizer greatly influences snap bean or edamame quality in the parameters measured. Growers with soybean cyst nematodes should use caution when selecting varieties and avoid Harronomai edamame. For edamame, there was too big of a difference between sites to make an N recommendation as at Simcoe there was no yield or economic response to applied N fertilizer and at Ridgetown the response was linear.

"This research should provide growers with the confidence to reduce nitrogen fertilizer applications in snap bean and edamame crops without yield or quality penalties while saving input costs and minimizing risks of environmental nitrogen loss."

- Laura Van Eerd, University of Guelph Ridgetown Campus

Contact:

Laura Van Eerd, Associate Professor, School of Environmental Sciences
University of Guelph Ridgetown Campus
519.674.1500
lvaneerd@uoguelph.ca
http://www.ridgetownc.uoguelph.ca/

#19 Optimizing Molybdenum levels in sub-irrigation floriculture systems

Introduction:

At certain points in greenhouse production, it is desirable to refresh the nutrient feed solution and dispose of the re-circulated water (in open systems, nutrient solution is discharged continuously). The expansion of the *Ontario Water Resources Act* to allow land application of nutrient feed water (excess nutrient solution from greenhouses) following the guidelines of the *Nutrient Management Act* (NMAN) provides a sustainable solution for disposing of this excess water. However, an Ontario Greenhouse Alliance study revealed that levels of molybdenum (Mo) and boron (B) in floriculture greenhouse nutrient feed water exceeded the allowable rates in the NMAN program, indicating that full application of this solution on land would be limited under the NMAN program.

"Poinsettias grown without molybdenum after potting showed no evidence of molybdenum deficiency."
- Dr. Jeanine West, Flowers Canada

Molybdenum, the least abundant essential micronutrient, is required for plant growth, metabolism of nitrogen and reproduction. This project tested a range of concentrations of Mo in the nutrient feed solution (from the maximum commercially available rate to zero) to determine the lowest, yet optimal level for plant growth, bloom yield, and overall plant quality. The experiment was performed at the Vineland Research and Innovation Centre's greenhouse using Mo-sensitive potted poinsettia plants over the course of one growing cycle (August through December 2014). The use of sensitive plants ensured that the results could be transferred to other flower species.

Objectives:

- Research greenhouse (i.e. laboratory) studies on a sensitive floriculture crop (Poinsettia spp.) grown using a sub-irrigation system to determine minimal Mo application rates without negatively impacting bloom yield and plant quality;
- Correlate tissue levels of Mo with the presence/absence of deficiency symptoms;
- Communicate results to the sector and fertiliser manufacturers/suppliers.

Methods:

Three hundred rooted Poinsettia "Christmas Day" cuttings were generously supplied by a Linwell Gardens, a local commercial greenhouse rooting station, in production week 31. Cuttings had been rooted in peat-based Ellegaard style plugs. Rooted cuttings were planted into 16.5 cm plastic azalea pots filled with Sunshine #1 soilless media courtesy of SunGro Horticulture, on July 31, 2014. During the establishment phase, the following set points were established: D/N heat 22oC, venting at 24oC; shading was triggered based on light and/or temperature (600 W/m2 from 10;00-17;00h or 26oC). Cuttings were pinched to 7/8 nodes two weeks after planting.

The cuttings were fertilized overhead by hand beginning one week after transplanting using Plant Prod 20-8-20 at 100 ppm N with each irrigation (roughly two times per week).

The plants were placed in 12 rows (troughs) of 24 plants each, and three of the four treatments (0%, 50%, 100% Mo) were randomly assigned to each trough with the exception of the 25% Mo treatment. The four treatments were continued until December 5, 2014. The fertilizer solution was applied via sub-irrigation to all plants with the same volumes (i.e. each trough received the same volume of its particular feed solution), with the recirculating feed solution passing by the pots for a period of 20 minutes.


Molybdenum was applied to this still-growing crop during the growing season at varying rates.

Results & Conclusions:

By the end of the trial, there were no visible differences among the rows and treatments, in either colour of leaves or flowers, overall height, apparent bloom yield, and no visible interveinal chlorosis was observed

By comparing overall plant height, and fresh weights of the three plant parts (bracts, leaves and stems), there appeared to be no difference between the 25% Mo treated plants in row eight (embedded in the treatment area) and the two outside rows. While there might be slight differences apparent in the tissue analysis through the growing cycle, there was not enough evidence to show an edge effect.

Based only on heights and fresh weights taken at the December harvest, there were no significant differences among the four treatments. Micronutrient levels of Mo and B will be compared among the four treatments to explore the level of mobility of these elements between plant parts and test our prediction that these elements have intermediate mobility.

Recommendations:

- Significant decreases in the levels of Mo in fertilizer application rates will decrease input costs and appear to have no impact on the production of saleable Poinsettia crops (known to be sensitive to Mo deficiency).
- Both 0% and 25% Mo treatments appeared to have an impact on the level of Mo in the tissue over time (mature leaves only data so far); however, the decrease in mature leaf Mo levels was insufficient to cause deficiency symptoms during the crop cycle. The level of Mo (and Ca, N, and B) in the bracts, as well as the mature tissues from the December harvest might provide clues as to the degree of mobility and ability of the plant to sustain itself beyond the trial period.
- Mo applied through the rooting period (August) might provide sufficient Mo to the plant for the remainder of the growing cycle (September through December), since plants possess some ability to mobilize Mo.
- Other cultivars of poinsettia may have different responses to Mo rates, so it would be valuable to trial various Mo dose rates before changing production practices.
- Decreased levels of Mo in discharge water could result in levels meeting the Provincial Water Quality Objectives and be used for land application under the NMA.
- In open systems, 'waste' nutrient feedwater can be reused on other crops (e.g. outdoor containers) or can be land applied as a beneficial solution under the NMA.
- This research, while not directly applicable to vegetable greenhouse production, will set a precedent for testing similar theories for vegetable Mo requirements.

Contact:

Jeanine West, Water Specialist
Flowers Canada (Ontario) Inc.
519.836.5495
jeanine@fco.ca
http://www.flowerscanadagrowers.com/

#20 Establishing cover crops in growing corn and small grain crops

Introduction:

Alfalfa grows well in wheat.

> *"Corn yields were greatest in all plots when underseeded with rye though the population of rye was the highest."*
> ***- Sam Bradshaw, Ontario Pork***

The goal of the project was to evaluate the use of an air seeder mounted to a liquid manure tanker seeding cover crops into standing corn and wheat. A Veenhuis disk applicator was used in wheat and a Nuhn injector was used in standing corn. Hog manure was applied at approximately 3000 gallons per acre during all of these treatments.

Three different cover crops, red clover, crimson clover and annual ryegrass were evaluated and three different methods of application were used, planting seed ahead, in the trench and behind as manure was applied. Cover crop biomass was counted and weighed at the end of each growing season for corn and wheat and yields of both were tabulated.

Methods:

Wheat: A 27 acre winter wheat field was divided into 34 plots of 0.7 acres each. Three plots had red clover planted ahead of the manure applicator, three plots had red clover planted behind the applicator and three others had red clover planted in the slot made by the disc. Three others had alfalfa planted ahead of the manure applicator, behind the applicator and in the slot made by the disc and three others had Crimson red clover planted ahead of the manure applicator, behind the applicator and in the slot made by the disc. Each plot was replicated in triplicate.

The air seeder was assembled and mounted to the manure tanker and the Veenhuis disk applicator on May 16th. The equipment was made ready and planting started on the afternoon of May 19th. By the evening of May 20th, 15 of the plots had been planted. Seeding continued on May 20th, with two of the three cover crops planted behind the manure disc applicator.

The red clover and the alfalfa were seeded before it rained that afternoon. The field had dried sufficiently to continue seeding on May 26th. The crimson red clover was planted and the machine was again taken into the shop to be reconfigured to plant the last trials which involved planting seed in the applicator disc trench. To accomplish this, the 6 seed delivery hoses were routed to the manure accumulator on the tanker. The red clover and the alfalfa seemed to be planted successfully, but we noticed that 3 of the hoses delivering alfalfa seed to the accumulator were plugged after finishing the plots.

Corn: Manure was applied and cover crops were planted into the standing corn on June 20th using the Wendell Mathis AP precision seeder. The air seeder was reconfigured and seed deflectors were mounted in three different configurations on the Nuhn manure applicator. Seed distributor plates were mounted ahead of the manure applicator, behind the applicator, and behind the manure injection shank. Four different cover crops were sown into growing corn when the corn was approximately 12 – 18 inches high.

We used 4 seed treatments as below – 2 reps of each:

Red clover, 10 lbs/acre

Alfalfa, 10lbs/acre

Crimson clover 15 lbs/acre

Annual ryegrass 15 lbs/acre

Results & Conclusions:

Planting into winter wheat was finished May 26th. As noted by the graph, particular cover crops had an effect on wheat yields.

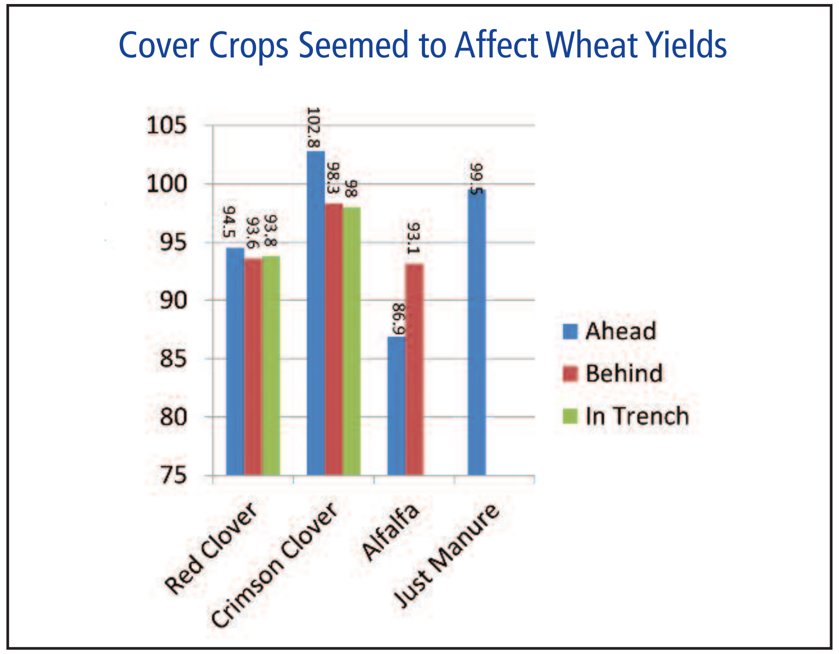
Corn:

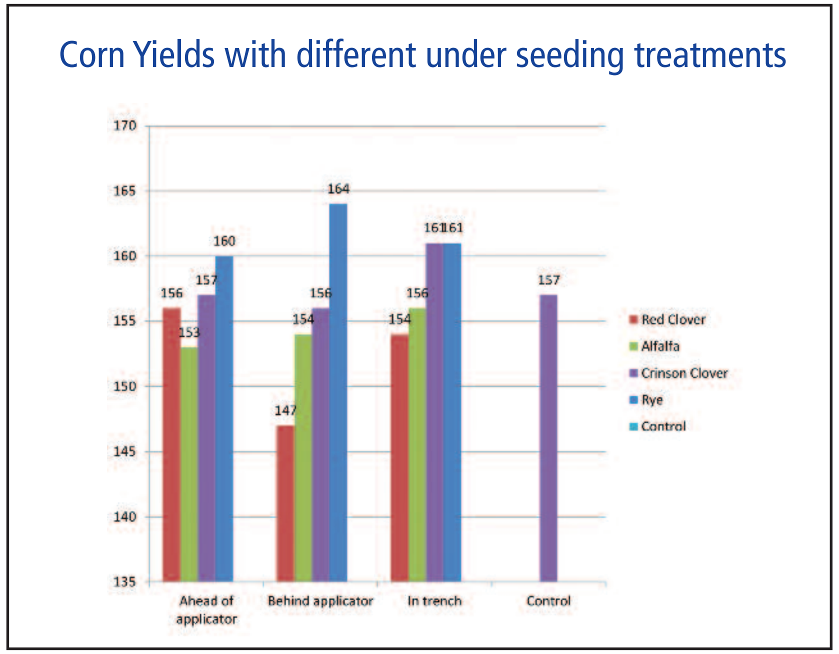
Corn was most successful when planted with rye. Yields were greater undressed to rye than using just manure (control).

Contact:

Sam Bradshaw, Environmental Specialist
Ontario Pork
519.831.2966
Sam.bradshaw@ontariopork.on.ca
http://www.ontariopork.on.ca/

Annual ryegrass planted into growing corn performed quite well and increased corn yields.





#21 Legume cover crops – minimizing nitrogen loss in the fall and supplying N in the next season

Introduction:

Tests are conducted to determine nitrogen content of cover crops.

Cover crops are a significant component of OMAFRA's nutrient management plans and best management practices. Cover crops retain nutrients in the fall. Ideally cover crops retain nutrients over winter and release nutrients to the following crop, thereby minimizing losses and fertilizer needs. The project aimed to build on previous research to better understand the role of three legume cover crops (crimson clover, red clover, and alfalfa) in terms of nitrogen (N) use efficiency and providing cover crop management recommendations.

Methods:

Three legume cover crops were compared with no-cover plots to determine how alfalfa and crimson clover compare to red clover regarding N loss and availability. Red clover is well-used in Ontario, though on occasion it fails to establish and grow. The goal was to know if alfalfa or crimson clover could be used as a substitute. In 2012-13 and 2013-14, the trial was conducted at two sites (Table 1). The experiment was a split-split-plot design with four replications. The cover crop type (red clover, crimson clover, alfalfa and no cover crop control) was the main factor, cover crop seeding rate (3, 6, 12 lb/ac) as the second factor and cover crop termination (fall or spring tillage) as the third factor. The split-split plot size was six field corn rows by 16.4 ft.

The N credit from red clover to corn has been well documented. Therefore, we used red clover as an industry control treatment. The no cover crop control treatment plots were split and pre-plant N fertilizer was applied at either 0, 100 or 200 lb N/ac. The no-cover with and without N allowed for comparison and to determine the N credit.

Soil and plant sampling was conducted at cover crop planting, before late fall tillage (freeze up), before corn planting, during corn season in June (time of side dress), July, August and at corn harvest. Soil from the 0-1 and 1-2 foot depths were collected from all plots and analyzed for nitrate and ammonium. Cover crop plant samples were collected from two ¼ m2 quadrats. Throughout the corn growing season, three to five corn plant samples were collected. Corn grain was mechanically harvested from the middle two rows of each split-split plot. All plant material was weighed and analyzed for N content by combustion.

Table 1. Select soil characteristics at the field sites at Ridgetown in 2012-2014.

Characteristic	R18	L
pH	7.4	6.2
Soil texture	Loam	Sandy Loam
Sand:silt:clay (%)	47:44:09	76:17:07
OM (%)	5.1	3.3
Cation exchange capacity (Meg 100g^{1})	26	6.8
Preplant nutrients (mg kg^{1}) Phosphorus	36	32
Potassium	59	107
Calcium	4634	872
Magnesium	169	119

*All soil parameters were taken from a composite of over ten cores to 15 cm depth.

Results & Conclusions:

Crimson clover: Production recommendations gained from this project for crimson clover, a relatively new legume cover crop in Ontario include:

- Crimson clover should be considered a warm season cover crop, so planting should be delayed until late spring when temperatures are warm.
- Crimson clover is not very competitive compared to red clover or alfalfa; attention to planting is needed to get good growth. Do not use an oat nurse crop and prepare the seed bed without weed and it is best to drill it in.
- Crimson clover does not overwinter well. Fall-planted crimson clover is not recommended for those farmers looking for spring growth. Some plants will survive so be prepared with termination plan in the spring.
- Positive results from farmers in the area have been reported when crimson clover is used in a mix.

Cover crop seeding rate: Cover crops were seeded at three, six and 12 lb/ac. Most cover crop biomass and N content analyses resulted in no differences between the three rates. Visually, it was difficult to distinguish between the six and 12 lb/ac seeding rates but the three lb/ac seeding rate had patch growth. Cover crop seeding rate did have an impact on following corn yield. Thus, balancing seed costs, with the results from this project, a six lb/ac seeding rate is recommended for the cover crop tested (crimson clover, alfalfa and red clover).

Cover crop termination timing: Cover crops were terminated by tillage in the fall (late October) or in the spring (mid-May). The no-cover crop plots were also tilled. Termination timing had no influence on N cycling or corn crop yield. Thus growers should make their management decision on when to control the cover crop according to their goals (minimizing erosion vs. preparing seedbed). To get the most cover crop growth in the fall, it is recommended that termination should not occur before the end of October.

Nitrogen cycling: Nitrogen losses from the field are an agronomic, economic, and environmental concern. In late October, the legume cover crops reduced the amount of soil mineral nitrogen (SMN = nitrate and ammonium) by 8.9 lb/ac compared to the no-cover plots. Thus these cover crops should be used by growers to minimize N available for loss in the non-growing season.

In the following spring there was no difference in SMN between any of the plots. However, there were differences in total plant available nitrogen (PAN) between the two different termination timings. In the spring, there was significant alfalfa and red clover growth and at least 17.8 lb/ac more N accounted for compared to the no-cover plots. Spring-terminated red clover and alfalfa had 33 lb/ac more N compared to the fall-terminated plots of red clover and alfalfa. Thus to maximize N, growers should use red clover or alfalfa with a spring termination.

The amount of N in the system (soil and crop) throughout the corn growing season was measured each month from June-October. Though the legume cover crops can increase the amount of N accounted for in the system, there was little effect on the N dynamics throughout the corn growing season. Total N in the system fluctuated between the months but was not affected by the presence of a cover crop compared to no cover crop nor a difference between cover crop species.

"Planting red clover or alfalfa at a 6 lb ac-1 seeding rate and terminating in the spring prior to corn planting is recommended to lower the risk of nitrogen loss over the winter, increase nitrogen availability in the spring and provide a yield increase to the following corn crop."

- Laura Van Eerd, University of Guelph, Ridgetown Campus

Contact:

Laura Van Eerd, Associate Professor, School of Environmental Sciences
University of Guelph Ridgetown Campus
519.674.1500
lvaneerd@uoguelph.ca
http://www.ridgetownc.uoguelph.ca/

#22

A mobile mapping technology application for Smart Soil Sampling (triple-S) on Ontario farmland

Introduction:

On-farm generated, geospatially-referenced field cropping system datasets have become valuable information assets for Ontario farm management. These precision agricultural databases grow with each annual addition and provide valuable information for crop planning, monitoring and traceability. Sound stewardship practices require crop plans that ensure crops have optimal nutrients and build long-term soil health. A key element to developing optimal crop plans (which include fertilizer recommendations) is the analysis of soil nutrients from collected field samples. With the advent of precision field data sets including yield maps, airborne imagery and detailed elevation data, sampling strategies can be customized to characterize the physiographic zones.

This project focused on development and testing of field record management technology targeted for use on mobile devices. It combined the development of a core mobile app for comprehensive field record keeping and an extension standalone module to augment the soil sample records with a "Smart Soil Sampling" (Triple-S) mobile mapping application.

The Smart Soil Sampling (Triple-S) mobile application will help Ontario farmers and crop consultants build knowledge about the variations of soil characteristics within a field through providing data collection tools that will aid them in the selection of soil sample locations and to record textual and photographic pedology data. The current recommended methodologies for soil sample site selection are to either perform grid based sampling or random samples within each 2.5 acre grid. With the growing base of precision agriculture data there is evidence that crop response varies within a field and these variations can be attributed to differences in topography, drainage, soil texture and other physical and biological factors. Given that much of the variation in crop response can be associated with static physical properties, management zones can be delineated to identify areas within the field that might benefit from customized and target practices such as variations in seed population, hybrid selection, fertility application and chemical-based treatments.

"WRAMQI has been integral partner in making FarmHand™ available to Ontario growers. FarmHand™ provides Ontario growers with a mobile crop management solution tailored for Ontario field crop growers that provides environmental stewardship benefits and improves their net profitability."

- Dave Branson, FieldTraks Solutions

Methods:

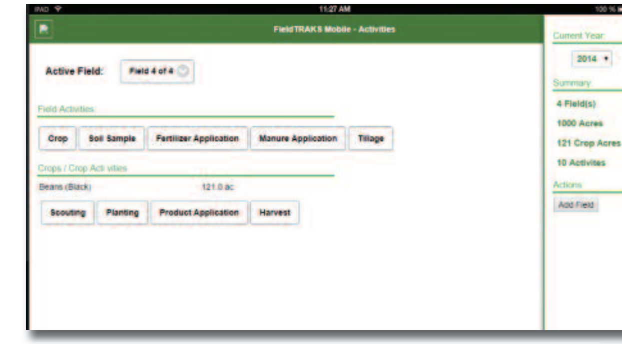
The applications were developed by FieldTRAKS Solutions Inc. using original code algorithms. The application goals identified the functional requirements of each of the applications and such things as how the application would be utilized by end-users and desirable application interface behaviours. One of the key goals of the project was ensure the final applications work on both Android and iOS tablets.

At the outset of the project it was identified that the application(s) would have the following features:

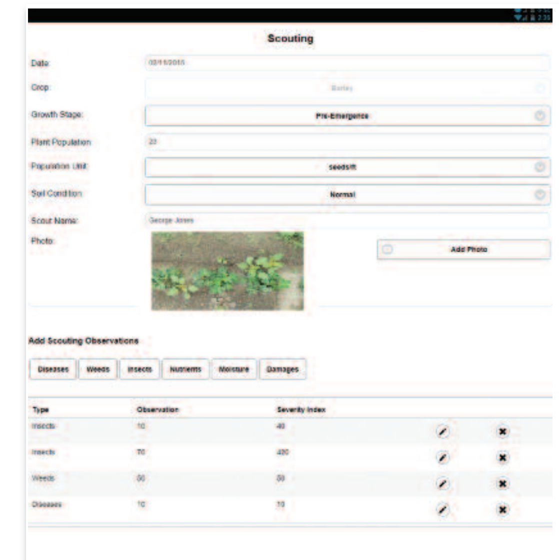
- Record and visualize the boundaries for fields and crop zones in a map window. Fields will be defined as areas that have a physical bounding area that is generally permanent. Crops may be one or more planted areas within a field and will be created each crop year.
- Users would be able to import and display thematic map layers for each field. These will include: Management Zone Map (1), Elevation/Topo Map (1), Yield Maps (multiple), NDVI images (multiple). Supported formats will include .SHP and .KML for vector data and .GRD and .JPG/.JPW for raster. All imported data would be in Lat/Long geographic coordinates (no projection conversions would be provided).
- Users would be able to control which thematic layer is visible and set the transparency for that layer. A second layer can be added for comparison. If a 2nd layer is added, the user will have the ability to control the transparency of that layer and have a horizontal/vertical slider which will hide/reveal the layer beneath.
- Layer controls would Users to alter the graphic display of fields/crops in the map window (e.g., colour by crop type, display field name, acres, etc).
- Map window would have measurement tools for calculating areas and lengths.
- Smart Soil Sampling (Triple–S) would allow the user to capture one or more photos to be tied to the soil sample location. A detailed soil description dialog would be developed with OMAFRA soil scientists to record soil characteristics that could be utilized to in development of fertility plans. Users would be able to import and link PDF & JPG files to soil sample locations (e.g., PDF lab reports, digital photos, etc.).

Following the completion of the initial assessment of application and technology goals, work began on:

1. Development of a prototype concept application and research/testing Javascript UIs using Model-View-View Model patterns and jQuery frameworks to test the proposed application design and deployment to mobile devices.
2. Design of the FarmHand™ data model definition which describes the database content such as the object relationship, activity definitions and the data properties of all objects and activities.
3. Research and testing of image analysis algorithms to support the image overlay processes required for Triple-S. The process developed enables a full-spectrum jpg image to be re-classified into a user-selected number of classes.



This is a view of what the application looks like, allowing the user to select a field and then add activities such as crops planted and disease scouting.



This is what the scouting screen looks like after a crop and scouting parameters are indicated in the application.

4. Storyboard conceptual application interface illustrations for the FarmHand™ app. This process involves using a whiteboard to schematically illustrate each page of the application and document the application behaviours.

Results & Conclusions:

Our plan is to publish the application to the Google Play Store where it will be available for download for a minimal fee. This version will have local storage capabilities and the user would be able to extract their data directly from the device for use in other software systems. In addition to the soil sampling module, it would include a comprehensive grower record-keeping profile and the crop residue measurement module. The business plan to offer a subscription based service where users would have the option of having their data stored in a private cloud database where they could set up sharing with other users. This version should be of interest to agriculture service providers who work with multiple farms and growers who would like to share selected field level data.

Contact:

Dave Branson, CEO
FieldTraks Solutions Inc.
613.489.0550
d.branson@fieldtraks.ca

#23 Advancing sustainable water management for Ontario sod production

Introduction:

In 2014, 26 weather stations in four configurations were installed at 18 sod farms. The 24 remaining stations (undamaged) will be left in the field over winter to monitor soil moisture until freeze-up and to measure soil moisture after the spring thaw. The spring soil moisture readings will assist in verifying the initial values for soil water balance models. The three-level soil moisture sensors, C-Probes, were replaced with a single-level soil moisture Stevens probe.

To address soil moisture sensor malfunctions and to reduce the number of accidents resulting in damage, a new type of soil moisture sensor was installed. The Stevens soil moisture probe replaced the C-Probe soil moisture sensor at eight sites. This probe allows for simultaneous observation of soil moisture and soil temperature. The probe is buried in the ground, with only a data cable exiting the surface. By running the cable underground to the station pole, the risk of instrument damage is greatly reduced. The Stevens probe measures soil moisture and temperature at a depth of 10 cm as it was determined that sod roots typically draw water from within 10 to 20 cm of the surface.

"Overall, the level of participation and enthusiasm from sod growers is a testament to the success of this project."

- Ian Nichols, Win Weather INovations

Methods:

Sensors were installed for the beginning of August. Although measured temperature values are only available at Full weather stations, calculated temperature maximum and minimum estimates are available to all participants. These values are intended to help growers visualize the relationship between evapotranspiration and temperature. The comparatively cool summer temperatures combined with consistent and timely rainfall allowed for less irrigation to be applied during the season.

Evapotranspiration estimation is another very useful tool in helping growers to make decisions about efficient irrigation. For www.turfmonitor.com, evapotranspiration was calculated using the Priestley-Taylor equation with a coefficient of 1.26. This equation allows an estimate of the evapotranspiration when there are a limited number of measured weather parameters, such is the case for the rain only and rain-and-soil moisture stations in this project. Ideally, the amount of evapotranspiration lost will match the amount of water gained by rainfall and irrigation to create a balanced water budget for the sod.

Radar has been used as a supplementary tool for predicting rainfall amounts for the purpose of this project. The turf stations span four different radar bases: Buffalo, Cleveland, Detroit and Fort Drum. Some of the stations are beneath one radar station, whereas others are beneath two or even three where the radars over-lap each other. In cases where the stations are beneath more than one radar, the predicted rainfall values from each radar are averaged.

Results & Conclusions:

During the period of June 16 through September 30, 2014, www.TurfMonitor.com received 10,774 hits. From April 1 to October 31, 2014 there were 20,684 total web hits. The most viewed tools on the website were Daily Rainfall Map.

This project contributed to the enhancement of sustainable water usage and environmental stewardship in Ontario's sod-farming industry. The site-specific weather tools delivered through the TurfMonitor.com website assisted the participating growers in making informed irrigation management decisions. Many features on the website were also openly available, providing both a service to the sod industry as a whole and an educational opportunity for the public.

A new mobile application was developed to assist sod growers in accessing soil moisture levels in their fields. Featuring soil water balance information and a field water check, the mobile app allows growers to view site specific information to assist with determining irrigation requirements. This app features an updated evapotranspiration calculation utilizing crop coefficients to further refine the existing models.

Valuable benchmark data was also collected from several farms, including total amounts of water (rain and irrigation) applied along with soil moisture profiles that illustrate the effectiveness of each water event.

Evapotranspiration calculations are very useful for sod growers because they serve as a 'water balance' for their sod. Growers were able to consult the site-specific evapotranspiration calculations and graphs along with other website tools and weather data when determining required irrigation amounts. Growers should strive to replace only the water that is lost to evapotranspiration. Any water applied above this amount is likely to be unused.

This project also demonstrated the use of radar as a tool for predicting rainfall amounts. The radar estimates were fairly accurate, with some year-to-year variability. Accuracy was found to be highest when comparing total rainfall amounts to total radar-predicted rainfall amounts. Since sod growers are aware of the sometimes imperfect predictions by radar, showing that radar can very often predict rainfall amounts to within 80-98 percent accuracy is a great incentive to use it as a rainfall amount prediction tool. It would be advised that areas that have found to be less accurate than this should use the radar as a supplementary tool to other weather monitoring equipment.

Ian Nichols of Win Weather Innovations stands next to a weather station that monitors variables such as temperature, relative humidity and rainfall.

Active website use indicates a high level of interest in the tools provided and feedback from the participating project sod growers has been positive. Many have expressed interest in continuing participation in future seasons. The growers have said that the tools have helped them to keep an accurate record of rainfall and to estimate when and how much to irrigate in an environmentally and economically conscious manner.

This project has not only benefitted the participants, but has also contributed to the sod industry and Ontario agriculture as a whole. The level of participation and enthusiasm from sod growers is a testament to the success of this project. The project contributed to the improvement of environmental stewardship in Ontario by investigating tools that help make irrigation practices on sod farms more efficient.

Contact:

Ian Nichols, President
Win Weather INovations
519.352.5334
inichols@weatherinnovations.com
www.weatherinnovations.com

#24 New technology water management for Ontario potato production

Introduction:

This soil moisture probe stays in the soil and determines moisture levels at 10cm, 20cm and 30cm.

This project continued a pilot program for Ontario potato growers through the website **www.ONpotatoes.ca**, which provides online tools that facilitate more sustainable water consumption and responsible farming. The website merges data from site-specific weather and environmental monitoring with modeling and online data management to create an interactive web-accessed decision support system that serves all growers.

This project's deliverables comprised an array of enhancements to the website, moving the ONpotatoes.ca program forward to include:

- mobile Web App for accessing crop and site specific evapotranspiration
- mobile-friendly programming and user interface
- radar-predicated rainfall for weather stations

This project provided online tools for Ontario potato growers with the goal of promoting more sustainable and efficient use of water on farms. Weather data was collected through a network of automated observation stations and presented along with analysis and advisories through Weather INnovations' website.

The collection of an entire season's weather data provides opportunities for an analysis of the weather factors over the season in Ontario's potato-growing regions. Graphical interpretations of the data and discussion are provided in this report to help illustrate the weather conditions that shaped this year's potato season.

Methods:

Resulting from data collected over the past seasons, we have developed a new web-based application to assist potato growers in accessing soil moisture information in their fields. Featuring soil water balance information and a field water check, the mobile app allows users to view site specific information to assist with determining irrigation requirements. This app features a crop coefficient evapotranspiration calculation to increase accuracy compared to reference calculations. Station data, if available, drives evapotranspiration calculations. When data is not available, interpolated data from nearby sources is used.

Accessible from mobile devices, via www.ONpotatoes.ca/swb the web app allows users to easily select their field based on current location. After selecting a location, the user can choose to view the soil water balance or a water check of the field.

The water check page allows users to select the date range for the period in question. This date range may include future dates as the app features a five-day forecast for rainfall and evapotranspiration. After specifying a date range, daily rain and evapotranspiration values are presented in graphical and tabular form. Forecasted data, if any, is easily distinguished via shading effects on the graph and orange text in the table. You can use the historical and forecast data to aid in scheduling irrigation events.

The application also offers climatological soil water balance for a selected field. A colour-coded soil water balance chart also provides accumulated rainfall and evapotranspiration values for each five day period. Five day groupings and starting date are controlled by the specified planting date.

Both the water check and soil water balance pages use a crop coefficient curve to determine crop specific evapotranspiration. The crop-coefficient method improves on existing reference evapotranspiration calculations to provide additional accuracy to the models.

The main Ontario potato growing regions span three different radar bases: Buffalo, Cleveland, and Detroit. Some regions are beneath one, two, or even three radar site. In cases where the weather stations are beneath more than one radar site, the predicted rainfall values from each radar base are averaged. Between May 1 and July 31, 2014, radar predicted rainfall was 78.6 % accurate across 14 sites.

This season, soil moisture was monitored at three locations: two stations at Alliston and one station at Grand Bend. Soil moisture was measured at 10 cm, 20 cm, 30 cm, 40 cm, 50 cm, and 60 cm levels. Examining data collected over the 2013 and 2014 growing seasons, it was determined that potatoes use water up to a depth of 30 cm. Therefore, soil moisture charts available on ONpotatoes.ca only display data for the 10 cm, 20 cm, and 30 cm levels.

Typically, individual soil moisture profiles are used to determine how much to irrigate.

Results & Conclusions:

Featuring soil water balance information and a field water check, the mobile application allows growers to view site-specific information to assist with determining irrigation requirements. This application also features an evapotranspiration calculation utilizing crop coefficients.

In terms of extending the website's reach to growers, the project proved very successful. 2014 was the third operational season for ONpotatoes.ca. It was launched in 2012 through research collaboration between the Ontario Potato Board and Weather INnovations Consulting LP (WIN). The improvements made through the support of the WRAMI program contributed to a 14.5% increase in traffic to the website during the main growing season (May 1 – August 31) over the same period in 2013.

ONpotatoes.ca utilized 11 weather monitoring locations managed by WIN. The locations were selected to cover the major potato-growing regions of the Province. For each location, weather data was collected, analyzed, and provided to growers through the website in the forms of interactive maps, graphs and charts.

Given the wet conditions and cool growing season, the project team is satisfied with the results of this initiative to assist in educating producers on the benefits of technologically-enhanced production management on Ontario potato farms.

"Enhancements for next season are currently in development, such as the capability for users to register an account and save their site specific field locations and calculations."

- Ian Nichols, Win Weather INnovations

Contact:

Ian Nichols, President
Win Weather INovations
519.352.5334
inichols@weatherinnovations.com
www.weatherinnovations.com

#25

Visualizing and quantifying sources of nutrients in the agriculturally-dependent Muskrat River watershed

Introduction:

Sampling water in the Muskrat River Watershed provides data necessary to make recommendations for improvements and understand the flow of pollutants.

The Muskrat Lake Watershed occupies 67,836-ha in Renfrew County. It represents a significant drainage area for the City of Pembroke, the Town of Cobden, and large portions of Whitewater Region and surrounding municipalities. Its major tributary is the Snake River, whose basin comprises 58 percent of the total area of the Muskrat Lake Watershed. There is strong evidence of agricultural nutrient pollution in the lower-elevation portions of the Muskrat Lake Watershed. Ontario Ministry of Environment (MOE) data for 2005 and 2012 indicated elevated nitrite/nitrate, phosphorus, E. coli, and total suspended solids in the Snake River. Muskrat Lake itself is highly eutrophic with phosphorus levels averaging 20-45 ppm.

Farming represents an important economic sector within Renfrew County and a long time cultural practice that defines the identity of many in the region. Local farmers employ various tillage, land clearing, and manure application practices. With the vast geographical reach of the Muskrat Lake Watershed, it is to be expected that agricultural practices will in some way intersect with, and have an impact on, the biophysical components of the watershed's various ecosystems. Unlike most parts of Southern Ontario, the Muskrat Lake Watershed lacks a Conservation Authority to provide a coordinated approach to nutrient management and water quality initiatives.

The overall purpose of the project was to document water quality issues in the Muskrat Lake Watershed in relation to current land-use practices. By gathering and analyzing data regarding water quality and quantity, and using spatial tools to classify the landscape and visualize impacts, the project aimed to both address and mitigate agricultural impacts by raising awareness and assisting local farmers to better manage nutrients and minimize three off-site impacts of nutrients on water quality. Specifically, the information gathered would be used to identify and tailor management strategies in the future that would assist farmers in implementing best management practices (BMPs) specific to the geographical, biophysical, and socio-economic characteristics of the area. Future application of the identified BMPs would thus mitigate, or significantly reduce, nutrient and sediment loading in certain key areas of the watershed.

Our goal was to present interpreted, scientifically defensible data in conjunction with the knowledge of local stakeholders (e.g., farmers, waterfront landowners, etc.), as this will be crucial for creating a sustainable long-term set of management strategies that take into account the specific issues faced by the Muskrat Lake Watershed as well as the broader geographical, biophysical, and socio-economic characteristics of Renfrew County. Muskrat Lake is one of the most nutrient enriched lakes in all of Ontario for its size.

Methods:

The project assessed water quality and quantity issues by sampling and analyzing water quality and quantity every week from May 2014 to November 2014 at 28 key sites along the watershed, including three additional sites located on Muskrat Lake. The three additional lake sites were each monitored with HOBO conductivity loggers and sampled every two weeks. Site selection was a collaborative and deliberative effort, decided by our Steering Committee of local experts, including local farmers. We also chose a background site – Black's Creek – on the watershed located above and away from agricultural influence. This site helped to determine what water parameters were occurring naturally in the watershed.

Water quantity was measured using a handheld Acoustic Doppler Velocimeter (Sontek/FlowTracker) and field water quality parameters were measured on-site using a YSI multi-meter probe. Grab samples were collected biweekly and were analyzed for nitrogen, phosphorus, and total suspended solids both internally. Samples sent to the MOE lab were analyzed monthly for a full suite of nutrients, major ions, and metals.

The project provided a unique opportunity to explore the use of advanced geospatial tools, including a partnership with two local companies in the acquisition of infrared, multispectral, and true color 20cm resolution imagery along stretches of Muskrat Lake and the Cobden Wetland using drone technologies. The long term goal of this advanced work will be to categorize the landscape based on tillage practices, provide information on land-use, trends/patterns and further identify hotspots with respect to nutrient and sediment loading.

By collecting aerial video and photos along identical high priority pathways on multiple occasions we were able to perform qualitative analysis of spatial information regarding water quality, quantity, and agricultural practices, providing information on practices and landscape characteristics. They included:

1) Spring aerial video showing some fresh runoff;
2) Summer aerial video and photography;
3) Fall aerial photography.

The side-by-side video and photos provided comparison points between the seasons as well as information on agricultural practices most utilized and/or most likely to cause erosion and runoff of nutrients into surface and ground water. These data and interpretive products provided a foundation to eventually develop recommendations and strategies for BMPs and watershed management.

Results & Conclusions:

There were certain sites that experienced consistently high levels of phosphorous and conductivity throughout the seasons, and some sites that displayed abnormal peaks in phosphorous and conductivity as well as very low levels of dissolved oxygen. Accurate assessment of trend information for all of the stations requires a three-year investment in sampling. Delineation of hot spots has seasonal implications. Sites experience elevated phosphorus concentrations during certain seasons and not all during the same season. Implementation of BMPs needs to take these seasonal fluctuations into account.

Many agricultural properties displayed serious slope and erosion issues wherein sediment travels easily into the watershed. Additionally, inadequate or non-existent buffers were common between crops and water sources, including tile drains and municipal drains. Several observations were of sites that did not present any fencing to separate livestock from the water. Livestock was observed standing in the water on more than one occasion.

The lack of a clearly defined management strategy and Conservation Authority within Renfrew County to tackle the issues and challenges related to water adaptation, water quality, and agricultural impacts demonstrates an obvious gap and necessary need for a series of well-rounded initiatives that provide baseline research, spatial perspectives, and strategies for land-use and water adaptation. These initiatives look to touch on the scientific/environmental side of the issues, as well as the economic and social aspects, by participating in effective stakeholder engagement as well as running cost-effective projects and tailoring management strategies to the specific needs of the region.

This grassed waterway removes pathogens and nutrients.

"This project is a crucial step toward a sustainable, long-term plan for nutrient management and BMPs for farmers living on the Muskrat Lake Watershed"

- Juile Sylvestre, Algonquin College

Contact:

Julie Sylvestre
Project Officer, Algonquin College
613.735.4700
sylvesj@algonquincollege.com
http://www.algonquincollege.com/

#26 Whiteman's Creek water conservation and drought contingency planning

Introduction:

This proactive drought preparedness project addressed the reoccurring issue of low water in the Whiteman's Creek sub watershed, a highly productive agricultural area. The 2014 WAMQI project built on the success of the 2013 WRAMI project, providing the agricultural community with a broader suite of cost effective tools to help satisfy irrigation demand - particularly during drought conditions. The project took place over eight months and all "Permit To Take Water" holders in the sub watershed were notified of the project's commencement to provide a fair opportunity for all irrigators to participate.

The project addressed water conservation assessments through the completion of irrigation assessments and ongoing water use monitoring. The project improved access to off-line irrigation water sources and improved contingency groundwater sources. Four farmers participated in pond renovations through cost-sharing initiatives to create or modify contingency sources. The project demonstrated how soil moisture instruments can help apply the right irrigation amount with the added intention of improving shallow groundwater quality through reduced nutrient leaching. This project also supported Ontario low water response by developing drought resilience.

"The feedback from the irrigators involved in the project for a second year, along with those who joined in 2014, spoke highly of the benefits of the proactive community based project."

- Hajnal Kovacs, Grand River Conservation Authority

Methods:

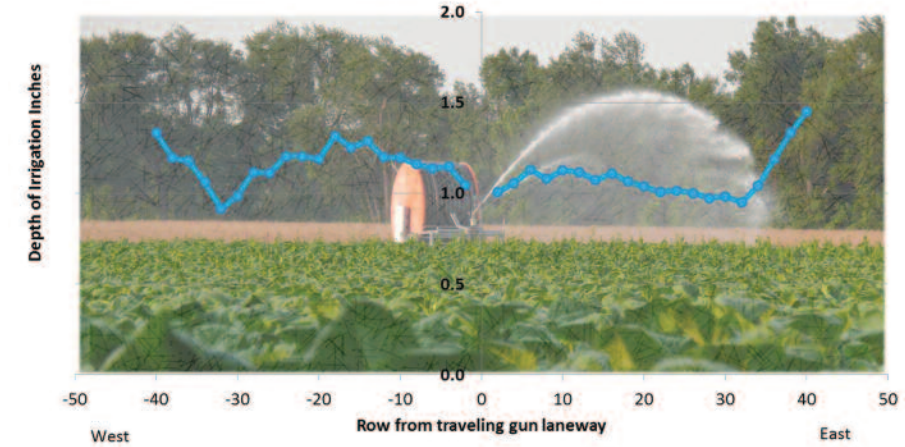
The irrigators in the Whiteman's Creek sub watershed are considered to be responsible water users, especially during irrigation events. Farmers are constantly under the stress of producing quality, high yielding crops with the least amount of inputs to maximize revenue. Pressures are especially high during times of drought. This is why proactive thinking and planning ahead for a drought is beneficial. When a drought occurs, farmers should have plans in place to deal with extreme weather situations.

- Below is a list of the activities undertaken as part of this project:
- Irrigation efficiency assessments and drought contingency planning
- Providing information about best management practices
- Soil moisture recording
- Evapotranspiration recording
- Water quality improvements
- Project information was communicated via several formats including: workshops, social media channels like Twitter and Youtube and field visits.

Results & Conclusions:

The Whiteman's Creek sub watershed is a priority study area because the rich agricultural production and cold water trout fishery in the sub watershed are susceptible to the perennial low water conditions. In preparation for future drought scenarios, staff has worked collaboratively with the community to help landowners establish a successful drought contingency program. In 2014, irrigation contingency planning was linked with the GRCA Rural Water Quality Program and Grand River Fisheries Management Plan; making contingency planning support more sustainable.

Other programs that support water conservation include the Ontario Drinking Water Source Protection Program as per the Clean Water Act, 2006 which aims to protect municipal water supplies. Municipalities and the MOECC collaborate to create Source Protection policies for the vulnerable areas around municipal water sources to manage and/or prohibit activities that endanger water quantity and quality.



This graph represents the depth of water collected in irri-gauges for a travelling gun irrigation system – assuming overlap. (Original graph and photo courtesy of Rebecca Shortt, OMAFRA).

West irrigation pond outlet before (left) and after (center) and an 8' in-line water control structure (right) was installed to utilize a bottom draw mechanism to reduce the water temperature leaving the pond and entering the wetland downstream.

The goals of this project are also reflected in the Grand River Water Management Plan's Integrated Action Plan section C: ensuring water supplies. Item C4 specifically highlights the importance of agricultural water use in the Whiteman's creek area and encourages users to continue long term water conservation best practices to reduce water demand. In C4, the Water Management Plan Project Team recommends that:

a) Irrigation water be sourced from off-line storage ponds and/or groundwater to avoid direct withdrawal from surface water streams during low flow periods;

b) Water use efficiency advice be available to irrigators to ensure that gun irrigation is timed to minimize evaporation and overspray, piping systems are maintained to minimize losses; soil moisture is assessed prior to irrigation events; and ponds are maintained and sized to satisfy the needs of summer irrigation; and

c) Water use information be kept current for all sectors to observe trends in total water use across the watershed.

The feedback from the irrigators involved in the project for a second year, along with those who joined in 2014, spoke highly of the benefits of the proactive community based project. The success of the project can be applied in other sensitive irrigation areas by providing the mentioned resources and agency support to the irrigators. The increased awareness of the agricultural community with our agency's efforts to promote water security continues to build our relationship with the public. We cannot change the fact that water use is essential for life, but when and how we choose to use water, and from what sources, is in our control.

Contact:

James Etienne, Senior Water Resources Engineer
Grand River Conservation Authority
519.621.2763
jetienne@grandriver.ca
http://www.grandriver.ca/

With Thanks

TEXT CONTRIBUTIONS FROM PROJECT PARTICIPANTS

Editor: Micah Shearer-Kudel
Design by: Lynn Chudleigh
OMAFRA Project Manager: Deborah Brooker
Farm & Food Care Ontario Environmental Program Manager: Bruce Kelly

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Farm & Food Care Ontario
100 Stone Road West, Suite 202
Guelph, ON N1G 5L3
519.837.1326
info@farmfoodcare.org www.farmfoodcare.org

PROJECT CHAMPIONS

PROJECT PARTNERS