Agriculture et Agroalimentaire Canada | Agriculture and Agri-Food Canada

AgriInnovation Program Stream B

2017-18 Annual Performance Report

Improving nitrogen and phosphorus use efficiency of potted chrysanthemums grown in a sub irrigation system

Name of Recipient: Canadian Ornamental Horticulture Alliance	
Project Title: Canadian Ornamental Horticulture Research and Innovation Cluster	
Project Number: AIP-CL20	Period Covered by Report: 2017-04-01 to 2018-03-31
Activity #: COHA 07 Name of Activity: Improving nitrogen and phosphorus use efficiency of potted chrysanthemums grown in a sub irrigation system	Principal Investigator: Barry J. Shelp, University of Guelph

Innovation Items	Results Achieved	Provide a description (2-3 paragraphs) for each item produced and describe its importance to the target group or sector. Explain any variance between results achieved and targets. Use plain language.
# of new/improved practices	1	Regardless of the irrigation system used in greenhouse floricultural operations, nutrient delivery should be optimized so that a lower level of fertilizer is used over the crop cycle, thereby minimizing fertilizer costs and minimizing potential environmental impacts. Approximately 5 years ago, we began to investigate and implement a novel and innovative approach, wherein a constant lower level of nutrients was delivered during vegetative growth only, and this lower level was optimized so that reproductive growth was primarily sustained by the mobilization of previously-acquired nutrients, rather than current supply from the root system. We chose sub-irrigated chrysanthemum, a popular potted plant to test the innovative approach . To date, we conducted a combination of research and commercial greenhouse trials on the delivery of nitrogen and phosphorus, the most important environmental contaminants, as well as sulphur and potassium, measuring commercial yields, constructing nutrient budgets as a function of crop development, and assessing plant nutrient status using a mix of leaf analysis and visual diagnosis. With these nutrients, we found that the supply over the crop cycle can be reduced by as much as 75-87.5% compared to the current industry standards. If these trends hold for the remaining macronutrients (i.e., magnesium, calcium), as well as the various micronutrients, our strategy could transform the production of greenhouse floricultural crops in general, and offer opportunities for the development of new commercial fertilizer formulations for low-input sustainable production. In summary, 1 new practice was identified which supports the improved production of potted chrysanthemums.

Innovation Items	Results Achieved	Provide a description (2-3 paragraphs) for each item produced and describe its importance to the target group or sector. Explain any variance between results achieved and targets. Use plain language.
		In the near-term, the target audiences are individual growers, fertilizer companies, provincial extension personnel, industry consultants, government and university researchers, and members of the general public, who are interested in improving greenhouse floriculture production methods, reducing nutrient usage and discharge, and environmental risk. In the longer-term, our target audience will also include undergraduate and diploma students studying greenhouse management, who could learn the most updated production methods, thereby enhancing employment opportunities.

Information Items	Results Achieved	Provide the complete citation for each item. Please see Annex A for examples.
# of peer reviewed publications	1	Shelp, B.J., Solntseva, I., Sutton, W.J., Lum, G.B., Kessel, C. (2017) Optimizing supply and timing of nitrogen application for subirrigated potted chrysanthemums. Canadian Journal of Plant Science 97(1):17-19. doi.org/10.1139/CJPS-2016-0162
# of information items	2	• COHA Description of Cluster Two research projects, 2016, http://www.coha-acho.ca/wordpress/?page_id=216 • COHA Description of Cluster Two research projects, 2017, http://www.flowerscanadagrowers.com/research/presentations-from-fcos-research-conference-2017?preview=true
# of information events	3	• Sutton, W. (presenter), Solntseva, I., Lum, G.B, Shelp, B.J. Improving nitrogen use efficiency of potted chrysanthemums grown in a subirrigation system. Canadian Society of Plant Biologists, Annual Meeting, Queen's University, Kingston, ON (2016/06/19) • Shelp, B.J. (presenter) Optimizing supply and timing of nitrogen application for subirrigated potted chrysanthemums. 2017 FCO Research Conference, Grimsby, ON (2017/02/01) • Sutton, W. (presenter) Optimizing N + P for sub-irrigated chrysanthemums. Canadian Greenhouse Conference. Niagara Falls, ON (2017/10/05)
		Provide the # of attendees
# of individuals attending information events		• 250 attendees (CSPB conference) • 80 attendees (FCO Research Conference) • 85 attendees (CGC)
		Provide the # of attendees who intended to adopt new information or technology
# of individuals attending		• Adoption rate unknown

information event who intend to adopt new innovation		

2. Executive Summary

Key Highlights -

Greenhouse floriculture operations pose significant environmental risk due to the extensive use of fertilizer inputs and the generation of nutrient-rich waste feedwater and leachate. Drip irrigation is the preferred method for reducing water and nutrient usage, although some leaching of nutrient-rich feedwater from the pots is always required to prevent nutrient accumulation in the pot medium. Sub-irrigation systems can effectively eliminate leachate, as well as feedwater via its recycling and reuse. It may be desirable however, to refresh the feedwater at times and either discharge or treat the recirculated feedwater. With both irrigation systems, it would be better to optimize nutrient delivery so that a lower level of fertilizer could be used over the crop cycle.

Current commercial guidelines for delivery of soluble fertilizer to greenhouse-grown, potted chrysanthemums include nitrogen (N) supplied continuously at a minimum concentration of approximately 18.5-21.4 mM (N) in the feedwater over the growth cycle or decreased in a step-wise decrease after the commencement of flowering. Depending upon the commercial fertilizer source, 21.4 mM N is approximately equivalent to 2.42-4.82 mM phosphorus (P) and 6.91-10.2 mM potassium (K).

Our previous research at the University of Guelph shows that complete removal of the feedwater N supply, as well as other nutrients, from potted disbudded plants of 'Yellow Favor' chrysanthemum when flowering begins, promotes sufficient movement of N from previously-produced plant parts to satisfy the N requirements of the developing flower. With new funding from the Canadian Ornamental Horticulture Research and Innovation Cluster (COHRIC), we conducted a research greenhouse experiment in 2015-16, which demonstrated that the supply of N to debudded 'Olympia' and Covington' chrysanthemums could also be reduced by approximately 50% prior to flowering, with only slight effects, if any, on plant and flower quality. Furthermore, the amount of N absorbed by the plant was not markedly affected by the decreasing N supply, indicating that the efficiency of N uptake was improved. In 2016-17, the same delivery strategy (i.e., low constant level until flowering, followed by removal of the supply) was used in two separate research greenhouse experiments to demonstrate that P supplied over the crop cycle of disbudded 'Olympia' and Covington' chrysanthemums could be reduced by as much as 75% without adverse effects on plant or flower yield and quality. With funding from the Ontario Ministry of Agriculture, Food and Rural Affairs (OMAFRA), we also conducted two separate research greenhouse experiments in 2016-18, which established that the sulphur (S) supply during the vegetative phase could be reduced over the crop cycle by as much as 87.5% of typical recommendations without negative effects (Sutton et al., unpublished data). Finally, a commercial trial was conducted in 2017-18 as part of our COHRIC-funded program. It established that a constant low level of N/P/K (5.35/0.95/4.10 mM, respectively) during the vegetative phase only resulted in acceptable plant and flower quality in four pinched chrysanthemum cultivars, and tissue nutrient levels during the crop cycle were within published industry and OMAFRA standards.

Overall, these findings indicate that the mobile nutrients N, P, S and K can be used much more judiciously over the crop cycle than is currently recommended, without negative impacts on plant quality. Further research is required to optimize delivery of the remaining macronutrients (i.e., calcium, magnesium), as well as micronutrients (i.e., iron, manganese, zinc, copper, boron, molybdenum), some are which are considered to be highly immobile in plants (i.e., calcium, manganese). The supply of soluble nutrients during vegetative growth only would be an innovative strategy for reducing the levels of fertilizer required by chrysanthemum and other ornamentals grown with sub-irrigation or another system such as drip-irrigation. Consequently, there would be less nutrient usage and cost and a smaller volume of less concentrated nutrient-rich feedwater for treatment and (or) approved discharge, if and when it is not recycled, and the impacts of floricultural operations on the environment should be reduced.

Success Story -

Over the past year, we worked with the team at Schenck Farms and Greenhouses in St. Catharines, Ontario, to assess the response of commercially-grown, sub-irrigated, pinched plants of four different cultivars (i.e., 'Olympia', 'Covington', 'Milton Orange', 'Kingsville Yellow') to a constant low level of the mobile nutrients N, P and K. Approximately 50% of the industry guidelines for N, P and K was supplied continuously over the crop cycle as the control treatment (T1 = 10.7/1.9/8.2 mM N/P/K), and as part of a double-pronged treatment strategy involving supply during vegetative growth and then removal during reproductive growth (T2). Also, 5.35/0.95/4.10 mM N/P/K was supplied during vegetative growth only (T3), enabling us to further refine the optimal nutrient delivery strategy.

Plant yield and flower quality of the potted plants at commercial harvest were of acceptable yield and quality even when levels of the mobile macronutrients N, P and K were reduced by 75% over the crop cycle. Furthermore, the tissue nutrient levels during the crop cycle were consistent with the published scientific literature, as well as recommendations from OMAFRA (N/P/K at 4.0–6.5/ 0.2–1.2/1.0–10.0% DM, respectively). These findings indicate that growers could potentially reduce their N, P and K use by 75% over the entire crop cycle. This research provides new knowledge of fertilizer timing and supply to subirrigated ornamental crops such as chrysanthemum, which could help in reducing unnecessary nutrient usage and minimizing environmental risks associated with the management of spent nutrient feedwater.

3. Objectives/Outcomes (technical language is acceptable for this section)

Greenhouse floriculture operations can pose significant environmental risk due to the large input of fertilizers to the different crops, in part because leaching and run-off of nutrients such as nitrogen (N) and phosphorous (P) pollute surface and ground waters. Subirrigation systems, which recirculate water and nutrients, are gaining popularity as environmentally friendly strategies for managing the nutrition of potted chrysanthemum, as well as many other popular ornamental potted plant crops grown in the greenhouse. However, subirrigation can result in the retention of nutrients and soluble salts in the growing medium, which can pose problems for the grower, especially for long-term crops. Therefore, it would be better to optimize nutrient delivery so that a lower level of fertilizer could be used over the crop cycle. The goal of the proposed work is to optimize the timing and application rates of soluble N and P to important commercial cultivars of subirrigated chrysanthemum. This knowledge will be used to provide greenhouse flower growers with chrysanthemum fertility recommendations that utilize reduced total N and P amounts without negative impacts on quality. The result will minimize environmental impacts while permitting the production of a high quality product, thereby ensuring that Canadian horticulture remains competitive. The work is being conducted in both research and commercial greenhouses.

Objective

To optimize the timing and application rates of soluble N and P to important commercial cultivars of subirrigated chrysanthemum.

Deliverables/Output and Approach/Methodology

1. **Apr 1, 2015 – March 31, 2016**
   Determine the optimum nitrate-N (NO_3-N level that can be supplied continuously in the subirrigation nutrient solution over a 5-week period only, and yet ensure the production of high quality Chrysanthemum plants and flowers several weeks later. Experiment 1 will investigate the plant and flower responses of four commercial cultivars to N starvation under high light conditions after a period of N supply at three levels, provided over a period of 5 weeks.
2. **Apr 1, 2016 – March 31, 2017**
   Determine the optimal P level that can be supplied continuously in the subirrigation nutrient solution over a 5-week period only, and yet ensure the production of high quality Chrysanthemum plants and flowers several weeks later. Experiments 2 and 3 will investigate the plant and flower response of the same four cultivars as in Experiment 1, to P starvation under both high and low light regimes, after a period of P supply at three levels, in combination with the optimum N supply, provided over a period of 5 weeks.
3. **Apr 1, 2017 – Dec 31, 2017**
   Validate the research results in a commercial greenhouse setting in St. Catharines, Ontario. Experiment 4 will investigate the plant and flower responses of the same four commercial cultivars as above, using the "optimum research N and P regime".

Results and Discussion

Initially, the research greenhouse facility at the University of Guelph was upgraded so that nutrient and light regimes can be controlled automatically, and the analytical procedures for extracting and determining nitrogen and nitrate levels in the shoot and flower of chrysanthemum were established.

Recently, we published a refereed journal paper demonstrating that the N utilization efficiency of subirrigated potted chrysanthemum (‘Yellow Favor’) is improved by interruption of the N supply at flower emergence (essentially the mid-point of the crop cycle), thereby promoting the mobilization of nitrate, as well as reduced N, from above-ground tissues, particularly stems and petioles, for reduction and /or transport to support flower development. In our first experiment here (2015-16), we further optimized the use of N by disbudded chrysanthemums during the vegetative growth phase. A balanced split-plot experiment was conducted under research greenhouse conditions with N treatment (18.5, 12.3 and 9.25 mM N) as the main plot and cultivar (‘Olympia’ and ‘Covington’) as the sub-plot, and the main plots were arranged as a randomized complete block design of two blocks. KCl and $CaCl_2$ were used to maintain the macronutrient supply. Morphological characteristics were only slightly affected, if at all, at commercial harvest and visible symptoms of N deficiency were absent. However, N uptake efficiency improved in both cultivars with decreasing N supply. These findings suggest that marketable chrysanthemums can be grown with subirrigation using only one-quarter of the N supply currently recommended.

In 2016-17, the second and third experiments were conducted in a research greenhouse with high (natural) and low (LED) light, respectively. The design was a balanced split-plot with P treatment as main plot and cultivar as sub-plot; the main plots were arranged in a RCBD with four blocks. Two cultivars (‘Olympia’, ‘Covington’) were provided with four P treatments (2.6 mM for 10 wks (control); 2.6, 1,95 and 1.3 mM P for 5 weeks, providing 50%, 37.5% and 25% of the control rate, respectively; all treatments received 18.5 mM N and KCl to balance K). There were 20 plants (disbudded) per treatment rep, and 10 plants per treatment replicate were harvested at both 5 and 10 wks for evaluation of visual symptoms, plant characteristics and P partitioning (lower leaves, lower stem + petioles, upper leaves, upper stem + petioles, single flower). Two plants were combined for total P and inorganic P analyses (i.e., 5 biological reps per treatment rep). The design of these experiments enabled construction of a P budget for the plant during flower development, in addition to an assessment of final nutrient composition. Regardless of the P treatment and cultivar, there were no visual symptoms of P deficiency on the lower leaves. Furthermore, the dry matter yields of both ‘Olympia’ and ‘Covington’ were not influenced by the P supply, indicating that the P use efficiency (PUE) increased dramatically as a function of decreasing P supply. Thus, the judicious use of P (i.e., 25% of current commercial supply recommendations) improved PUE with no negative effects on plant and flower quality.

In our final year (2017-18), we validated these research results in a commercial greenhouse setting in St. Catharines, Ontario. We conducted a single experiment under high light (natural) with four cultivars (i.e., ‘Olympia’, ‘Covington’, ‘Milton Orange’, Kingsville Yellow’) and three fertilizer (N/P/K) regimens: T_1 = 10.70/1.90/8.20 mM over the entire growth cycle; T_2 = 10.70/1.90/8.20 mM during vegetative growth, followed by water during reproductive growth; and T_3 = 5.35/0.95/4.10 mM during vegetative growth, followed by water during reproductive growth. T_1 was prepared using a commercial fertilizer, and T_1 and T_2 were supplemented with analytical-grade chemical stocks from various sources to balance as much as is practical, the composition of the remaining macronutrients, as well as the micronutrients, among the three fertilizer regimens. The fertilizer regimens were randomly assigned among three adjacent ebb-and-flow flood benches. At both ends of each bench, 100 pinched plants of all four chrysanthemum cultivar were arranged randomly, and at various times thereafter (3, 4, 5 and 8 weeks), 20 recently-matured leaves were randomly collected from 50 plants for nutrient analysis. Shoots of the remaining 50 plants were harvested (10 plants per biological replicate) at the end of the crop cycle (greater than 90% of all flowers were open at harvest, $\leq$ 50% of the flowers were fully open) to rapidly assess visual symptoms and plant characteristics. For comparison of dry mass (DM) yields among treatments, data from the 10 biological replicates were pooled for calculation of mean ± SE. This experimental design allowed assessment of tissue nutrient levels over the crop cycle much as the individual grower would typically do. Surprisingly, The DM yields of T3 plants for all four cultivars were reduced by only 7-12% compared to the T2 plants, even though the N/P/K supply over the crop cycle was reduced by a further 50%, and this did not result in any visible symptoms of nutrient deficiency. While these findings were generally associated with lower tissue levels of N, P and K than in the T2 plants over the entire crop cycle, all levels were within the range recommended in the scientific literature and by OMAFRA. Thus, it appears that the lowest supply of feedwater N/P/K tested in this study (5.35/0.95/4.10 mM, respectively) produced potted chrysanthemums with acceptable quality, findings in agreement with, or even better than our previous study of the N and P nutrition of subirrigated chrysanthemums in a research setting.

Ph.D or Master Students Recruited to Work on the Project

A Master's student did enroll in our graduate program at the University of Guelph in January 2015. Unfortunately, he withdrew from the program a week later because of personal commitments that would continuously interfere with his studies. It was therefore necessary to hire a part-time research associate (Dr. Irina Solntseva) shortly thereafter so that the proposed research on N and P could proceed as planned. This research associate was employed on a part-time basis for the remainder of the project. Students were hired on a part-time basis to assist with the preparation of samples for nutrient analysis (Queen's University undergraduate student Adam MacEachern , summer 2015), and with the harvest, visual assessment of plant materials and analysis of orthophosphate (University of Guelph Master's student William Sutton, summer & fall 2017). William Sutton was also offered the opportunity to present our latest findings on "Optimizing N + P for Sub-irrigated Chrysanthemums" at the Canadian Greenhouse Conference in fall 2017, even though his thesis research is focused on sulphur; this should better prepare him for a career in the floricultural industry .

4. Issues

With respect to Experiment Four, a visit to Schenck Farms and Greenhouses revealed that the ebb-and-flow flood benches were much longer than expected (i.e., half the length of the greenhouse), precluding the economical use of a multiple block design for Deliverable #3. Consequently, we used a single block design only, with a higher number of cultivars and plants at each end of the three treatment benches, and sampled half the plants for final visual and physical characterization, and the other half for leaf nutrient analysis on a bi-weekly basis (as is typically done by the commercial grower for diagnostic purposes), rather than nutrient partitioning between the flower and the remaining shoot (as was done in the research experiments). Overall, this strategy minimized the efforts that would have been required to grind the many individual plant parts, as well the costs associated with analysis of nitrogen, phosphorus and potassium by Agri-Food Laboratory. Furthermore, the use of leaf diagnostics and a larger number of cultivars better represents the wider industry. This will ensure that the results are applicable and can be extended to other sub-irrigated crops in the future.

5. Lessons Learned:

With the modified experimental design for Experiment Four (i.e. use of four cultivars, rather that two; one block design, rather than multiple block design; nutrient analysis of fourth leaf, rather partitioning between the flower and remaining shoot) there is less statistical rigor than the original design. However, it efficiently used the grower's greenhouse space, provided valuable nutrient information for diagnostic purposes, and ensured that the research was completed in the remaining time.

6. Future Related Opportunities:

Our initial research has indicated that the entire macronutrient (i.e., N, P, K, S, magnesium, calcium) and micronutrient (i.e., manganese, iron, zinc, boron, copper, molybdenum) supply can be eliminated from sub-irrigated potted chrysanthemums at the end of the vegetative phase of the crop cycle (approximately 5 weeks) without any adverse impact on plant or flower yield and quality at commercial maturity (approximately 10 weeks). In this project, we demonstrated, using a combination of research and commercial trials, that the N, P, K and S supplies during the vegetative phase can be reduced to 50% or less of the typical commercial recommendations without negative effects. We believe that our innovative delivery system can be immediately adopted by the floriculture industry to reduce the level of N, P, S and K fertilizer that is being used over the crop cycle. It is our intention to communicate this message at upcoming meetings of growers and in industry and scientific publications.

In the near-term, further research could broaden and clarify the general application of our novel optimized nutrient management strategy in three ways: from four to 12 nutrients, including both macronutrients and micronutrients; from one to two irrigation systems (i.e., sub-irrigation and drip-irrigation); and, from research to commercial environments. In the longer term, further research could investigate the impact of our novel nutrient delivery strategy on: pest abundance/diversity and shelf life of indoor-grown chrysanthemums; other indoor-grown floricultural crops; outdoor-grown floricultural crops, and other agriculturally-important indoor crops such as vegetable crop and cannabis.

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