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Authors: Shelp, Barry J., Flaherty, Edward J., Sutton, William J., Schenck, Lou M., and Aalbers, Jamie

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Canadian Science Publishing

SHORT COMMUNICATION

Commercial validation of a modified method for delivering low nitrogen, phosphorus, and potassium inputs to greenhouse-grown subirrigated pot chrysanthemums[1]

Barry J. Shelp, Edward J. Flaherty, William J. Sutton, Lou M. Schenck, and Jamie Aalbers

Abstract: Subirrigation systems are popular for reducing nutrient usage in indoor floricultural production. Two open subirrigation experiments were conducted in a commercial setting using multiple chrysanthemum cultivars and up to 75% less N–P–K than industry standards. The lowest N–P–K levels supplied in the nutrient solution (in mmol·L^{-1}: 5.4 N, 0.71–0.97 P, 1.9–4.1 K) up to bud break, were associated with acceptable leaf N–P–K levels [4.5–5.4% dry matter (DM), 0.23–0.60% DM, and 3.3–5.6% DM, respectively]. These findings validate our modified delivery practice and the use of lower N–P–K inputs in the production of subirrigated pot chrysanthemums.

Key words: chrysanthemum, nitrogen, phosphorus, potassium, subirrigation.

Résumé : Les systèmes d'irrigation souterraine ont la cote, car ils permettent de réduire la quantité d'oligoéléments employée pour la production de fleurs en serre. Les auteurs ont procédé à deux expériences ouvertes d'irrigation souterraine dans un établissement commercial en recourant à de nombreux cultivars de chrysanthème et jusqu'à 75 % moins de N–P–K que la norme dans l'industrie. La concentration de N–P–K la plus faible fournie par la solution nutritive (en mmol par litre : 5,4 de N, 0,71 à 0,97 de P, 1,9 à 4,1 de K) jusqu'au débourrement a été associée à une concentration acceptable de N–P–K dans les feuilles (respectivement de 4,5 à 5,4 %, de 0,23 à 0,60 % et de 3,3 à 5,6 % de la matière sèche). Ces résultats confirment le bien-fondé de la nouvelle méthode de fertilisation et l'usage d'une moins grande quantité de N–P–K pour la production de chrysanthèmes en pot, irrigués de façon souterraine. [Traduit par la Rédaction]

Mots-clés : chrysanthème, azote, phosphore, potassium, irrigation souterraine.

Introduction

Subirrigation is popular in indoor floricultural production. In open systems, the nutrient solution is discharged continuously; whereas in closed systems, the nutrient solution is recycled, thereby reducing nutrient usage and the risks of contaminating water resources with nitrogen (N), phosphorus (P), boron, and molybdenum (Ontario Ministry of the Environment 2012; MacDonald et al. 2013; Ferrarezi et al. 2015). The recirculated nutrient solution must be refreshed occasionally and eventually discharged or treated in accordance with applicable environmental legislation. Therefore, the objective of our research is to reduce nutrient delivery where possible so that even less fertilizer is used.

Green Leaf Plants (2015) summarized the general fertilizer practices for cultivating greenhouse pot chrysanthemums: a complete soluble N–P–K fertilizer such as 20–10–20 at 21.4–28.5 mmol·L^{-1} N with micronutrient amendments; and, with subirrigation in particular, the fertilization rate is often 25%–50% less and reduced or eliminated during the final 2–3 wk of the crop. Guidelines are not given for the other macronutrients (i.e., sulphur, calcium, and magnesium), likely because

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B.J. Shelp, E.J. Flaherty, and W.J. Sutton. Department of Plant Agriculture, University of Guelph, 50 Stone Road E., Guelph, ON N1G 2W1, Canada.

L.M. Schenck and J. Aalbers. Schenck Farms & Greenhouses, 1396 S. Service Road, St. Catharines, ON L2R 6P9, Canada.

Corresponding author: Barry Shelp (email: bshelp@uoguelph.ca).

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they are supplied in excess as counter ions in the fertilizer and in the limestone or dolomite used for pH adjustment of the pot medium.

Over the past decade, we modified the nutrient delivery practice to improve the macronutrient use efficiency of subirrigated pot chrysanthemums grown under research greenhouse conditions. Entire macro- and micronutrient supplies were removed during reproductive growth, and approximately 50%–75% or less of the N–P–K levels in Sonneveld's solution (in mmol·L^{-1}: 18.5 N, 2.6 P, 6.0 K; Sonneveld and Kreij 1987) was provided during vegetative growth, together with the essential micronutrients (MacDonald et al. 2014; Shelp et al. 2017, 2020*a*, 2020*b*). There were no visible signs of N–P–K deficiency, and the plant/flower yields and quality were unaffected.

Here, two experiments were conducted in a commercial setting with multiple chrysanthemum cultivars using approximately 75% less N–P–K than industry standards, up to bud break. These findings advance the development of our modified, low-input delivery practice and validate the use of lower macronutrient inputs in the production of subirrigated pot chrysanthemums.

Materials and Methods

Plant growth conditions

Unrooted chrysanthemum (Olympia White, Covington Yellow, Kingsville Yellow, Milton Orange, or Newport Bronze) cuttings were purchased from Syngenta Flowers Inc. (Gilroy, CA) and dipped in a mixture of Stim-Root liquid (0.1% indole butyric acid) and B9 (0.25% daminozide) (Plant Products, Brampton, ON, Canada) and stored overnight in a cooler at 4 °C. The cuttings were individually planted into 10-cm plastic pots filled with a peat moss and perlite mix (90:10 by volume) amended with Schenck Pre-mix No. 1 [10–75–15 hydrated lime : dolomitic lime : extra fine vermiculite (*v*/*v*); 5.0 kg·m^{-3} soil mix] and Schenck Pre-mix No. 2 [nitrate-N, 1.2%; available phosphoric acid (P_2O_5), 2.7%; soluble potash (K_2O), 4.2%; calcium, 13.5%; magnesium, 3.5%; sulphur, 10.2%; iron, 0.17%; 2.0 kg·m^{-3} soil mix) to give a pH of 6.0, and placed on a misting bench in a naturally-lit greenhouse (43.177°N, 79.292°W). After 14 d, the rooted cuttings received fertilizer solution at 21.4 mmol·L^{-1} N (Peters Professional 17–3–17® Peat-Lite Neutral Cal-Mag, ICL Specialty Fertilizers, OH; designated as Schenck No. 1) or 7.1 mmol·L^{-1} N (Fusion Plant Products 17–5–17, Plant Products, Ancaster, ON, Canada; designated as Schenck No. 2) every 2 d and thereafter until day 21.

The rooted cuttings were pinched and moved to ebb-and-flow flood benches (1.8 m × 22.9 m rolling benches, with 0.9 m walkway when rolled apart) located in a naturally-lit greenhouse set at 20–22 °C day and night temperatures with ambient humidity during the two study periods (Schenck No. 1: 12 June–10 Aug. 2017; Schenck No. 2: 27 July–29 Sept. 2020). Automated blackout curtains were used to impose a dark period from 1800 to 0800 h and automated shade curtains were applied from 1200 to 1700 h. Irrigation events were triggered by an accumulated vapour deficit of 165 000 kPa so that frequency varied with environmental conditions. Complete stock solutions were prepared at 100× concentration and then diluted with potable water using a Dosatron injector before flooding and draining (approximately 20 min duration) the bench with 650 L of solution per irrigation event. Stock tanks were refilled as necessary (approximately once per week).

Experimental design

For the Schenck No. 1 study period, three N–P–K delivery regimens were tested (in mmol·L^{-1}): 10.7VR ≡ 10.7 N, 1.9 P, 8.2 K over the entire crop cycle; 10.7V ≡ 10.7 N, 1.9 P, 8.2 K up to bud break, followed by potable water during the remainder of the crop cycle; and 5.4V ≡ 5.4 N, 0.97 P, 4.1 K up to bud break (6 wk), followed by potable water during the reminder of the crop cycle. Peter's Professional 17–3–17® Peat-Lite Neutral Cal-Mag was the source of N–P–K, and analytical-grade chemical stocks were used to balance the remaining nutrients between the two fertilizer rates. For the Schenck No. 2 study period, three N–P–K delivery regimens were used: 7.1VR ≡ 7.1:0.94:2.6 over the entire crop cycle; 7.1V ≡ 7.1:0.94:2.6 up to bud break, followed by potable water during the remainder of the crop cycle; and 5.4V ≡ 5.4:0.71:1.9 up to bud break, followed by potable water during the reminder of the crop cycle. Fusion Plant Products 17–5–17 was the only source of the nutrients, so that the adjustments in the fertilizer rate were accompanied by corresponding changes in the other nutrients. With both Schenck No. 1 and No. 2, sulphur was provided in the pot medium only.

The delivery regimens in each experiment were randomly assigned among three adjacent flood benches, and plants of all cultivars were arranged randomly at both ends of each bench. With Schenck No. 1, a recently matured leaf (the diagnostic leaf) was collected at 3, 4, 5, and 8 wk from 20 individual plants and pooled for nutrient analysis. Shoots of the remaining experimental plants were harvested at the end of the crop cycle when up to 90% of all flowers were open, but less than 50% of the flowers were fully open. Dry mass (DM) yields represent the mean of 10 biological replicates, with each replicate containing 10 plants. With Schenck No. 2, a recently matured leaf was collected at 5 wk from 30 individual plants and pooled for nutrient analysis; data represent the mean of two replicates. At harvest, 30%–80% of all flowers were open, and 10%–50% of the flowers were fully open, depending upon the cultivar. Dry mass yields were calculated as the mean of four biological replicates, with each replicate containing five plants.

Postharvest sample preparation and nutrient analysis

Pooled dried leaf samples were individually ground to a fine powder using a Waring 7011G blender (Waring

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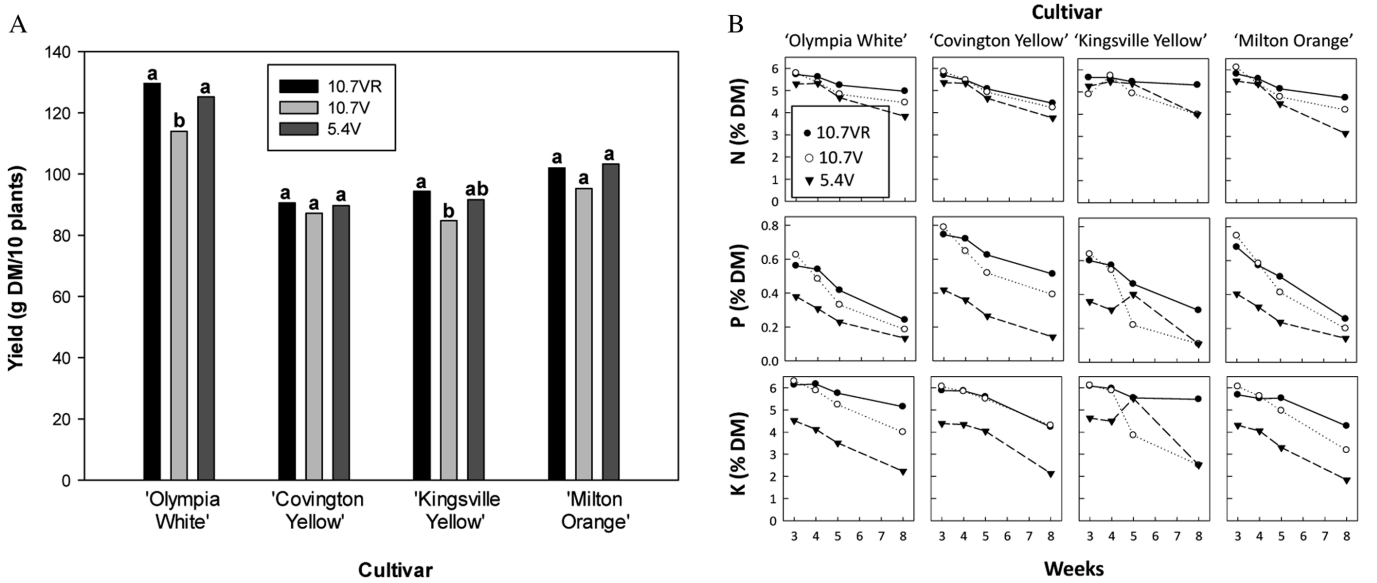
Fig. 1. Yields and leaf N–P–K levels of chrysanthemum cultivars grown with three N–P–K delivery regimens (Schenck No. 1). This experiment used (in mmol·L^{-1}): 10.7VR ≡ 10.7 N, 1.9 P, 8.2 K over the entire crop cycle; 10.7V ≡ 10.7 N, 1.9 P, 8.2 K up to bud break (i.e., 6 wk), followed by potable water during the remainder of the crop cycle; and 5.4V ≡ 5.4 N, 0.97 P, 4.1 K up to bud break, followed by potable water during the reminder of the crop cycle. Yield data represent the mean of 10 biological replicates, each replicate containing 10 plants. Bars within a cultivar not sharing the same letter are significantly different. Leaf-nutrient data represent the pooled sample from 20 individual plants.



Commercial, Torrington, CO). Analysis of N, P, and K was conducted by the Agriculture and Food Laboratory at the University of Guelph. For total N, the ground leaf samples were combusted in a sealed system, and the nitrogenous compounds released were reduced to N_2 gas, which was measured by a thermal conductivity cell using a LECO FP-428 elemental analyzer according to the manufacturer's instructions (LECO instruction/operations manual for the FP-428 Nitrogen and Protein Determinator version 2.4). For analysis of total P and K, the ground leaf samples were microwave acid-digested and diluted to an appropriate volume with nanopure water before measurement by an inductively coupled plasma – mass spectrometry method developed and validated in-house (based on USEPA Method 6020 Inductively Coupled Plasma – Mass Spectrometry).

Statistical analysis

All statistical analyses were conducted using a completely randomized model with the Proc Glimmix method at $\alpha = 0.05$ level (SAS version 9.4, SAS Institute Inc., Cary, NC). Normality and homogeneity of variance were confirmed before further statistical analyses were performed. Variance was separated into fixed effects (nutrient regimen and cultivar), random residual variation, and all interactions between the fixed effects. Analyses of variance (ANOVA) were performed and when effects were significant ($p \leq 0.05$), the means were compared with each other using Tukey's honest significant difference (HSD) test.

Results

Visible signs of nutrient deficiency were absent in both experiments (Supplementary Figs. S1A and S1B[2]). Regardless of the experiment and cultivar, the lowest fertilizer rate supplied over the vegetative stage only did not significantly decrease the DM yield, compared with the highest fertilizer rate, supplied over the vegetative stage only or over both vegetative and reproductive stages (Figs. 1A and 2A). The diagnostic leaf of all cultivars generally exhibited decreasing trends in leaf N, P, and K levels as a function of plant development (Fig. 1B). Nevertheless, the N, P, and K levels at bud break ranged from 4.5% to 5.4% DM, 0.23% to 0.60% DM, and 3.3% to 5.6% DM, respectively, with the lowest delivery regimen across all cultivars in the two experiments (Figs. 1B and 2B).

Discussion

Many fertilizer formulations are available for cultivating greenhouse pot chrysanthemums. The Sonneveld solution (in mmol·L^{-1}: 18.5 N, 2.6 P, 6.0 K) was developed for flowers and vegetables (Sonneveld and Kreij 1987). Common commercial fertilizers such as Fusion Plant

[2]Supplementary data are available with the article at https://doi.org/10.1139/cjps-2020-0294.

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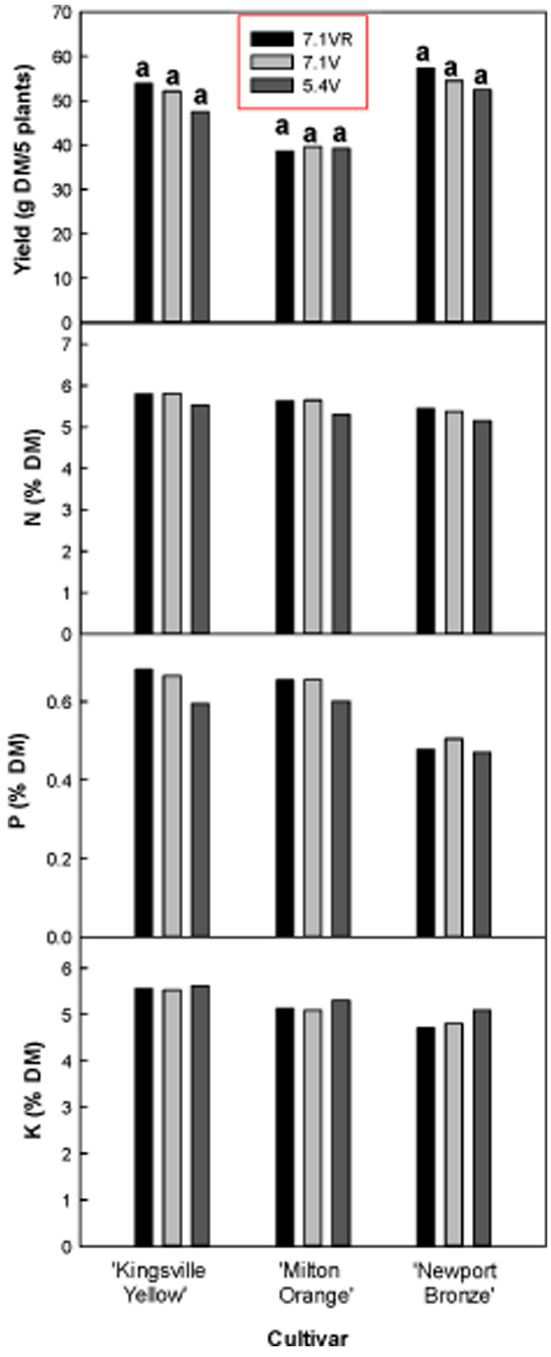
Fig. 2. Yields and leaf N–P–K levels of chrysanthemum cultivars grown with three N–P–K delivery regimens (Schenck No. 2). This experiment used (in mmol·L^{-1}): 7.1VR ≡ 7.1 N, 0.94 P, 2.6 K over the entire crop cycle; 7.1V ≡ 7.1 N, 0.94 P, 2.6 K up to bud break (i.e., 6 wk), followed by potable water during the remainder of the crop cycle; and 5.4V ≡ 5.4 N, 0.71 P, 1.9 K up to bud break, followed by potable water during the reminder of the crop cycle. Yield data represent the mean of four biological replicates, each replicate containing five plants. Bars within a cultivar not sharing the same letter are significantly different. Leaf-nutrient data represent the mean of two replicates, each containing the pooled sample from 30 individual plants at 5 wk; therefore, ANOVA was not applicable.



Products 17–5–17 (in mmol·L^{-1}: 20.4 N, 2.7 P, 7.3 K) and Peter's Professional 17–3–17® Peat-Lite Neutral Cal-Mag (in mmol·L^{-1}: 21.4 N, 1.7 P, 7.7 K) contain similar levels of N–P–K as the Sonneveld solution. Our early research on the nutrition of greenhouse-grown pot chrysanthemums used Sonneveld's solution as the industry standard, and confirmed that the production of market-quality plants and flowers is unaffected by removing entire nutrient supplies at bud break, and by supplying N and P levels as low as 9.3 and 1.3 mmol·L^{-1}, respectively, during vegetative growth (Shelp et al. 2017, 2020*b*). We also demonstrated that N–P–K levels (in mmol·L^{-1}) as low as 4.3 N, 0.65 P, and 2.3 K produces market-quality plants with acceptable leaf N–P–K levels of 4.0%–5.5% DM, 0.61%–0.75% DM, and 4.2%–5.2% DM, respectively (Shelp et al. 2020*a*; B.J. Shelp, unpublished data).

In this paper, commercial greenhouse experiments demonstrated that the lowest levels of N–P–K supplied (in mmol·L^{-1}: 5.4 N, 0.71–0.97 P, 1.9–4.1 K) are associated with leaf N–P–K levels of 4.5%–5.4% DM, 0.23%–0.60% DM, and 3.3%–5.6% DM, respectively. This is in general agreement with sufficiency levels for N, P, and K provided in extension literature [Ontario Ministry of Agriculture, Food and Rural Affairs (2014): 4%–6% DM N, 0.2%–1.2% DM P, and 1.0%–10% DM K; Hill Laboratories (2019): 3.5%–5.0% N, 0.23%–0.70% DM P, and 3.5%–5.0% DM K].

The plant/flower quality at harvest was excellent across the range of N–P–K supplies used here, regardless of the delivery regimen. Indeed, many non-experimental plants were cultivated during both study periods in the open space on the ebb-and-flow benches and sold to commercial vendors. Thus, even though the lowest N–P–K supplies during vegetative growth were 75% of the industry standards, growth was not restricted. These findings indicate that the macronutrient use efficiencies (which can be defined as milligram shoot DM/concentration of macronutrient supply) improved approximately fourfold with decreasing macronutrient supplies. Based on our previous research on the N, P, and sulphur nutrition of chrysanthemums, the primary mechanism for sustaining plant shoot growth with decreasing N–P–K supplies was likely enhanced acquisition or uptake efficiency, but given our experimental methodology, it was not possible here to quantify the relative importance of acquisition and internal utilization efficiencies (Shelp et al. 2017, 2020*a*, 2020*b*; Sutton et al. 2019).

As these commercial experiments confirmed, macronutrient delivery to modern chrysanthemum cultivars can be reduced in the subirrigation solution by approximately 75% during vegetative growth, compared with common fertilizer formulations, and then removed entirely during reproductive growth. In the open subirrigation system used here, the supply of Fusion

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Plant Products 17–5–17 fertilizer over the entire crop cycle at 21.4 mmol·L^{-1} N would cost approximately $126 000 to produce four chrysanthemum crops annually in 1 ha of greenhouse space. Removal of the fertilizer supply at bud break would reduce the fertilizer cost to $76 000, and reduction of the fertilizer supply from 21.4 to 5.4 mmol·L^{-1} N prior to bud break would further reduce the cost to $19 000. A closed subirrigation system would have less total savings as less fertilizer is used due to recycling (Shelp et al. 2020*b*), but the same concept applies — reducing fertilizer rate results in proportional cost savings. The volume of concentrated nutrient-rich nutrient solution for management, and environmental contamination would also be decreased with our modified delivery practice. Future research will focus on the use of essential micronutrients, especially boron and molybdenum.

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Conflict of Interest Statement

The authors declare no competing interests.

Author Contributions

B.J.S. conceived the idea, supervised the work, and wrote the manuscript. E.J.F., W.J.S, and J.A conducted the experiments; E.J.F. conducted the statistical analyses. L.M.S. provided the greenhouse and plant resources. All authors read, edited, and approved the final manuscript.

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