The influence of slow-release fertilizers on potted chrysanthemum growth and nutrient consumption

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ABSTRACT

In a two-year vegetation experiment, the effects of fertilizer with two slow nutrient releasing mechanisms on the growth of outdoor grown potted chrysanthemums (Multiflora group *Chrysanthemum × grandiflorum*) as well as on their uptake of the nutrients N, P, K, were studied. In this experiment, coated fertilizer with a controlled nutrient release effect (CRF) – Basacote 6M and fertilizer with a slow soluble nutrients (SRF) – Lovogreen NPK were tested. In the control variant, Kristalon Blue fertilizer was regularly applied in a solution form. From this experiment, the suitability of a onetime application of a slow nutrient – releasing fertilizer to potted chrysanthemums was ascertained. The fertilizers with a slow nutrient release effect were shown to ensure better plant growth during vegetation as well as a higher biomass weight and nutrient consumption level. From the onset of vegetation, the highest rates of biomass growth and nutrient consumption by plants were evident in the (CRF) – Basacote 6M fertilizer treatment.

Keywords: *Chrysanthemum × grandiflorum* (Ramat.) Kitamura; nutrient; controlled-release fertilizer; nitrogen; growth response

Chrysanthemums are among the most important blooming plants grown all year round (Macz et al. 2001). Chrysanthemums take up nitrogen at an even rate from the time of planting to the flowering stage, after which time nitrogen uptake decreases (Yoon et al. 2000). Nitrogen is essential for the creation of biomass as well as for the biosynthesis of enzymes in chrysanthemum leaves (Liu et al. 2010). Optimal plant growth is evident when ammonium nitrogen is used at a rate of 50% of the total amount of applied nitrogen (Muniz et al. 2009). In chrysanthemum, the need for phosphorus is significantly lower than of nitrogen (Li et al. 2009). Potassium requirements are high, and its presence in the plant favorably affects growth and flower colouring (Vaněk et al. 2012). The mechanism of slow release or controlled-release fertilizers (CRF) enables an increase in the effectiveness of the utilization of nutrients from fertilizer when growing potted plants (Arrobas et al. 2011). Controlled-release fertilizer is based on the granules coated with many different materials as acryl amid copolymer (Abraham and Pillai 1996), wax resin (Guertal 2009), natural rubber, polyvinyl chloride, and polylactic acid (Hanafi et al. 2002). The granules contain primarily NPK nutrients. If they come into contact with moist soil, the nutrients are predominantly released through the membrane with the help of molecular diffusion. The rate of release is dependent on pH levels, temperature (Basu et al. 2010), as well as on coating thickness (Tlustoš et al. 1994). A higher rate of nutrient release takes place in an alkaline environment at higher temperatures (Basu et al. 2010). Fertilizers with slow soluble components (SRF) are based on condensed aldehyde products

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and carbamides of various molecular weights and solubilities. Compounds of slow nitrogen-release fertilizers are primarily used for lawncare (Jahns and Kaltwaseer 2000). The rate of nitrogen release is influenced by soil conditions. A higher nitrogen release rate occurs at higher substrate temperatures (Fan et al. 2010). If the use of slow nutrient – release fertilizers meets the requirements of individual plants, the plants can then more effectively utilize nutrients from these fertilizers, which in turn decrease planting costs. One application can cover several applications of water soluble fertilizers (Guertal 2009). Fertilizers with slow release mechanisms can probably meet the higher nutrient needs of chrysanthemums better than water soluble fertilizers. They also have a better impact on the yield, flowering (Zhu et al. 2009), and a higher uptake of major nutrients (Song et al. 2011). Another advantage of these fertilizers is a higher root growth rate when compared to water soluble fertilizers (Voogt et al. 2006). The goal of this experiment was to study the effects of fertilizers with various slow nutrient releasing mechanisms (CRF and SRF) on the nutrient uptake and growth of outdoor grown potted chrysanthemums.

MATERIAL AND METHODS

In a two year experiment, potted chrysanthemums of the 'Multiflora' group [*Chrysanthemum* × *grandiflorum* (Ramat.) Kitamura, species no. 148] were grown outdoor at flower garden in the city of Ústí nad Labem (Czech Republic). The commercially produced compost was used deliberately for planting; it is characterized by high content of basic nutrient, especially potassium. A compost analysis determining pH values, soluble salt content, and available contents of P, K, were carried out using the Mehlich III method (Mehlich 1984). The pH value was determined in leachate of 0.2 mol/L KCl 10:25 (v/w) and the soluble salt content was measured in demineralized water leachate 1:10 (v/w). Individual forms of nitrogen were determined using the colorimetric method on a Skalar San System (Skalar, Breda, the Netherland). The determinated values of compost are means of two vegetation periods. Pre plant fertilization was carried out using Basacote 6M coated slow-release fertilizer containing 16% N, 3.52% P, 9.96% K, 1.8% Mg with micronutrients, and NPK slow soluble fertilizer containing 20% N, 3.52% P, 6.64% K, 1.8% Mg; 6% of the nitrogen content in the SRF was made of ureaform, 9% was ammonia nitrogen form and 5% was presented by amid nitrogen form. As a control treatment, a onetime per week fertilization with Kristal Blue fertilizer containing 19% N, 2.64% P, 16.6% K, and 1.8% Mg with micronutrients was chosen. Young chrysanthemums were planted on the 16th of June, 2006 and 2007. A pot with a 15 cm upper brim diameter was used. Plants of medium-large size were purposely chosen. Three experimental treatments were realized, and a total of 1.5 L of moist substrate was added to each pot. Each treatment represented 12 plants. In the first treatment, 18.75 g/pot of CRF was applied into the substrate. In the second treatment, 15 g/pot of SRF was applied into the substrate. In the control treatment, no fertilizer was added to the substrate: the plants were fertilized once a week using Kristalon blue fertilizer at a measured amount of 500 mL per pot, at a concentration of 0.2%. The initial fertilization was 14 days after planting. The plants were totally fertilized eight times. The fertilizer doses were chosen with regard to the possibility of nutrient release. Table 1 shows the amount of nutrients applied to each pot by the individual fertilizers.

The experiment was terminated on the 7th October, 2006 and 2007. During vegetation, three plant samples were taken from each treatment. The first sample was taken during the plant vegetation period, 41 days after planting. The other samples were taken during the generative plant phase; the second sample was taken 68 days after planting during the budding phase. The third sample taking was carried out 97 days after planting during the full blooming stage. The roots and aboveground mass were separated. The aboveground portion was cut away at the root junction, and the fresh mass was then weighed in its natural state. The roots were washed in demineralized water, and left on filter paper to slightly dry for 60 min. The total plant N content was set after biomass wet digestion with concentrated H_2SO_4 using a digestion system 20-1015 Digester and subsequently determined by the Kjeltec Auto 1030 analyzer (Tecator, Höganäs, Sweden). In order to determine the presence of other nutrients, samples of plant material were dry digested at a temperature of 500°C. The element content in the prepared mineralizates was determined by flame atomic absorption spectrometry on a Varian 280FS (Varian 280FS, Varian, Australia) (K), and optical emission

Table 1. The mean pH and electrical conductivity (EC) values, N, P, K, Mg and dry matter contents of used substrate, and the amount of applied nutrients by individual fertilizers

	pH_{KCl}	EC (mS/cm)	N	P	K	Mg	Dry matter (%)
			(mg/L)				
Basic characteristics of the substrate	6.6	0.655	NH_4^+ 96.5 NO_3^- 175	69.4	2 653	152	46
	treatment		N	P	K	Mg	
			(mg/pot)				
Amount of applied nutrients	1 – control		1520	211	1328	144	
	2 – CRF		3000	660	1867	225	
	3 – SRF		3000	528	996	180	

CRF – controlled-release fertilizer; SRF – slow soluble fertilizer

spectrometry with induction coupled plasma on a Varian VistaPro (Varian, VistaPro, Australia) (P); both devices were provided by Varian Australia (Varian, Victoria, Australia). The total average yields of dry biomass and nutrient content for each experimental variant were statistically evaluated using a Statistica program (Tulsa, USA).

RESULTS AND DISCUSSION

A sufficient amount of available nutrients in substrate ensured a proper biomass production, as well as a sufficient plant weight and quality of flowers, mainly in treatments with slow-release fertilizers; this concurs with studies carried out by Zhu et al. (2009). Although the nitrogen doses for CRF and SRF treatments were consistent, a higher supply of other nutrients in treatment 2 meant statistically inconclusive growth of aboveground biomass and roots in the second sampling period. The total average dry biomass weight of the aboveground mass and plant roots in individual vegetation samples is displayed in Figure 1.

The highest dry biomass weight of the aboveground plants for all treatments was determined during the full blooming stage. The highest plant root weight for all treatments was ensured during the budding stage. The lowest dry biomass weight was evident in the control treatment, in which the plants were continually fertilized in solution form. Although the plants in treatment 1 were regularly fertilized during the growth phase, this fertilization did not ensure an adequate supply of nutrients to the plants probably because the experiment simulated practical conditions and thus

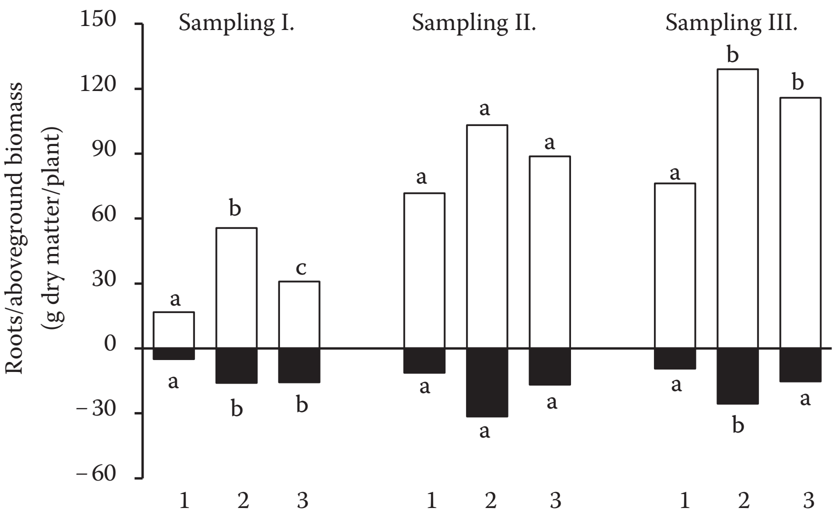

Figure 1. Aboveground and root weight of chrysanthemum. Treatment: 1 – control; 2 – controlled-release fertilizer; 3 – slow soluble fertilizer; □ leaves; ■ roots; a, b – the values labelled by the same letter did not significantly differ at $P < 0.05$

Table 2. Nutrient content in dry aboveground biomass and roots of chrysanthemum plants

Variant	Aboveground mass			Roots		
	sampling I.	sampling II.	sampling III.	sampling I.	sampling II.	sampling III.
Nitrogen (%)						
1 – control	3.65	3.49	3.57	1.53	1.59	1.57
2 – CRF	3.57	3.42	3.33	1.41	2.15	2.04
3 – SRF	3.47	3.53	3.59	1.33	1.37	1.34
Phosphorus (%)						
1 – control	0.56	0.50	0.50	0.35	0.38	0.33
2 – CRF	0.58	0.58	0.49	0.28	0.25	0.28
3 – SRF	0.73	0.70	0.65	0.29	0.30	0.34
Potassium (%)						
1 – control	4.88	4.74	4.81	2.82	2.91	2.74
2 – CRF	4.07	4.30	5.05	1.59	1.51	1.53
3 – SRF	3.16	3.83	3.90	1.24	1.33	1.29

CRF – controlled-release fertilizer; SRF – slow soluble fertilizer

the nutrients were allowed to release. Conversely, the highest dry biomass weight for individual samples was evident in treatment 2, in which all CRF fertilizer was added to the substrate before planting. SRF dissolved more slowly than CRF, primarily at the start of the experiment and during the first sampling representing lower yield of aboveground biomass. Greatest, mainly significant, biomass was also produced by roots at CRF treatment compared to control; differences between CRF and SRF were insignificant. Greater root biomass production at treatments with slow-release fertilizers corresponds with the results made by Voogt et al. (2006): one-time application leads to a greater production of root biomass than does regular supplementary fertilization. The nutrient content in aboveground dry biomass as well as in chrysanthemum roots is given in Table 2.

The nutrient contents showed relatively high stability among sampling periods (Table 2). Neither

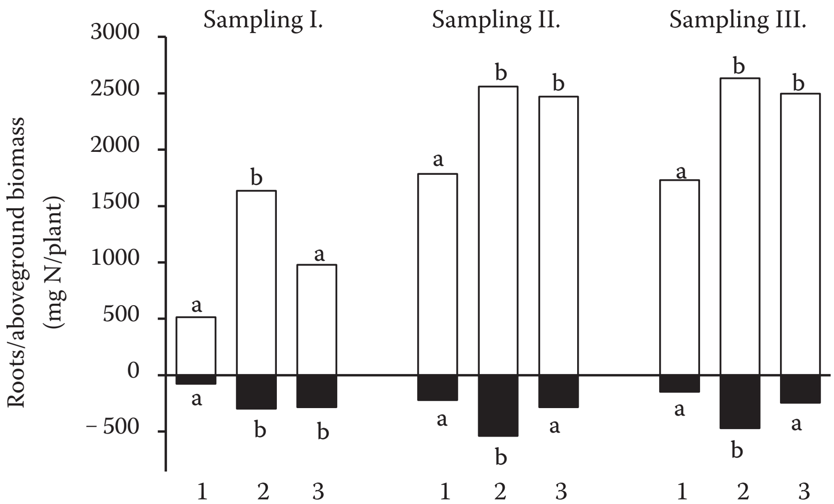

Figure 2. Nitrogen uptake by aboveground biomass and roots of chrysanthemum. Treatment: 1 – control; 2 – controlled-release fertilizer; 3 – slow soluble fertilizer; □ leaves; ■ roots; a, b – the values labelled by the same letter did not significantly differ at $P < 0.05$

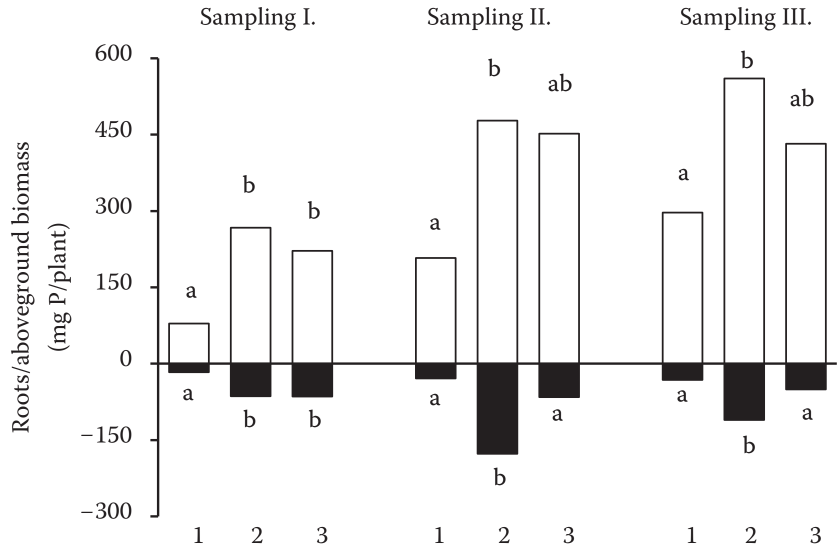

Figure 3. Phosphorus uptake by aboveground biomass and roots of chrysanthemum. Treatment: 1 – control; 2 – controlled-release fertilizer; 3 – slow soluble fertilizer; □ leaves; ■ roots; a, b – the values labelled by the same letter did not significantly differ at $P < 0.05$

significant increase nor decrease of nutrient content was observed for all observed elements meaning that their supply by both fast and slow-release fertilizers did not make any significant difference within growing period. Aboveground biomass took up higher contents of N, P and K. Total nitrogen content in shoots and in roots did not correspond with the application rate at control and treatments with slow-release fertilizers and showed similar contents at all three treatments. Phosphorus showed a slightly different pattern. The highest content was found in shoots at SRF treatment due to easy P solubility in this fertilizer, coating of CRF fertilizer partly limited P availability causing lower content at all three samplings. Opposite results were found for potassium, lower K content in shoots as well in roots at SRF treatment was done by twice lower application rate in this treatment compare to CRF. Equally applied low rate of P and K in solution led to highest nutrient contents in roots and medium high in shoots of chrysanthemum. Figures 2–4 display average uptake of nitrogen, phosphorous, potassium by the aboveground mass and roots of chrysanthemum. CRF and SRF treat-

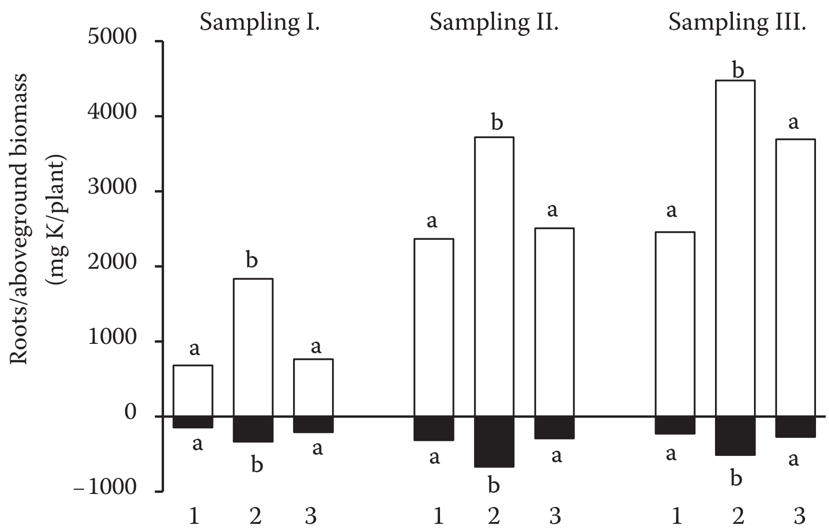

Figure 4. Potassium uptake by aboveground biomass and roots of chrysanthemum. Treatment: 1 – control; 2 – controlled-release fertilizer; 3 – slow soluble fertilizer; □ leaves; ■ roots; a, b – the values labelled by the same letter did not significantly differ at $P < 0.05$

ments ensured the highest nitrogen, phosphorous, and potassium total uptake by chrysanthemums; such results were not evident with water-soluble fertilizer, according to Song et al. (2011).

Plant nitrogen uptake closely correlated with biomass growth, mainly during the initial growth phase. The highest uptake was determined in treatment 2, in which CRF was added to the substrate. Although the nitrogen levels for variants 2 and 3 were the same, it became evident that nitrogen was released more rapidly in CRF than in SRF. The faster nitrogen release rate in CRF indicated a significantly higher N uptake during the initial growing phase, in turn resulting in the highest biomass weight. Conversely, the lowest N uptake was determined in treatment 1, in which the plants were continually fertilized by nitrogen in solution. Nitrogen uptake was increased by chrysanthemums in all treatments with biomass growth during the first two samplings. In the full bloom stage, N uptake stagnated or slightly decreased, which was also indicated by Yoon et al. (2000).

The increase in nitrogen uptake reflected the amount of available nutrients, and partially the transfer of nitrogen from the roots to the aboveground biomass. The root nitrogen content reacted more sensitively, in CRF treatment significantly higher uptake corresponded to the highest nitrogen content as well root biomass. In other treatments root nitrogen uptake corresponded closely to aboveground biomass growth. The highest uptake was evident during the budding phase, after which the rate stagnated or decreased. This confirmed nitrogen redistribution in the plants in the late stages of growth (Yoon et al. 2000).

Phosphorus uptake by chrysanthemums was, in general, several times lower than nitrogen uptake by plants; this was also confirmed by Li et al. (2009). The highest rate of phosphorus uptake by the aboveground biomass of plants in all samples was determined in treatment 2, while the highest amount of P was added to soil and highest biomass yield was determined. The lowest phosphorus uptake was determined in treatment 1, while the plants were continuously fertilized with low rate of P. In treatment with CRF added to the substrate, the phosphorus uptake peaked during the budding stage, and it did not increase further. Similarly in the case of nitrogen, phosphorus uptake was more affected by amount of biomass than nutrient content either in the aboveground mass of plants or in the roots. Phosphorus uptake peaked during the budding stage in all treatments. The highest amount of applied phosphorus in CRF treatment was evident in the highest root uptake, mainly during the budding stage and in full bloom.

Potassium uptake was in general the highest in treatment 2, where CRF with the highest level of provided nutrients was added to the substrate. The lowest potassium uptake was determined in treatment 1, low uptake at the mentioned treatment well corresponded with biomass yield not with applied amount of K. The gradual increase in potassium uptake by chrysanthemum aboveground biomass peaked during the full blooming stage in all treatments. The high mobility of the applied potassium corresponded to its content in plants (Table 2), but was not responsible for total K uptake. The application of potassium in CRF influenced the accumulation of potassium gradually, which climaxed during the blooming stage. The lower K dose at SRF treatment showed insignificantly higher uptake at sampling II. and III. in shoots in comparison to control, differences in K uptake at control and treatment 3 were negligible for roots. The total amount of potassium in plant roots was significantly lower than in the aboveground biomass. The highest levels of potassium in roots were determined during the budding phase, after which they stagnated. The experimental results showed the fertilizer with controlled slow nutrients release, Basacote 6M, had the highest effect on the plant yield and nutrient uptake. This was because of the nitrogen content throughout the whole fertilizer cover, thanks to which the nutrients were released slowly during the whole vegetation period. As opposed to that, NPK fertilizer released ammonium and amide nitrogen forms at the beginning of the vegetation and thus these can be partly leached. The remaining urea form of total nitrogen content was not able to supply such amount of nutrients as Basacote 6M did.

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