Fertilization Methods Affect Growth, Color and Nitrogen Leaching of Winter Annuals in Landscape Beds[1]

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Abstract

Two experiments were conducted to evaluate fertilizer formulations, methods of application, and frequency of application on growth of winter-grown landscape bedding plants and N leaching. In Expt. 1, 'Majestic Giants White' pansy (*Viola ×wittrockiana* Gams.) and 'Telstar Purple' dianthus (*Dianthus chinensis* L.) were planted in raised beds. Four inorganic fertilizer formulations were applied at 4.9 g/m^2 N (1 lb N/1000 ft^2) either incorporated pre-plant or topdressed post-plant. Additional treatments included an industry practice (IP) of incorporating a granular water soluble (GWS) fertilizer pre-plant and topdressing a controlled release fertilizer (CRF) post-plant, and a pre-plant incorporation of an organically-based fertilizer (OBF) composed of recycled newspaper amended with chicken manure. In Expt. 2, similar treatments were applied to the following species: 'Bingo Blue with Blotch' pansy, 'Telstar Crimson Picotee' dianthus, and 'Tall Red' snapdragon (*Antirrhinum majus* L.). Across both studies, CRFs generally improved foliar color and plant size compared to GWS fertilizers, while reducing total-N in soil-water in some instances. The IP treatment provided superior foliar color and larger plants compared to other inorganically fertilized plants, while causing no more or less total-N in soil-water leaching below plant roots. Response to the OBF differed among the two experiments. The OBF resulted in adequate foliar color and plant size and reduced total-N recovered from soil-water in Expt. 1. However, it generally provided superior foliar color and size compared to all other treatments in Expt. 2, but also caused elevated levels of total-N in soil-water.

Species used: 'Majestic Giants White' and 'Bingo Blue with Blotch' pansy (*Viola ×wittrockiana* Gams.); 'Telstar Purple' and 'Telstar Crimson Picotee' dianthus (*Dianthus chinensis* L.); 'Tall Red' snapdragon (*Antirrhinum majus* L.).

Index words: nitrate, nitrogen, multiple application, winter annual, organic and agricultural waste, bedding plants, leachate.

Significance to Industry

Use of bedding plants in the winter is common in regions of the country where mild winters allow for their growth. Little or no research has been conducted to provide fertilizer recommendations for winter-grown landscape bedding plants. Our data indicate that method of application, topdressed or incorporated, has little or no effect on plant growth and nitrogen (N) leaching. Applying fertilizers in multiple applications improved plant foliar color, foliar N (except snapdragon), and growth index, but did not increase the amount of total-N recovered in soil-water. Controlled-release fertilizers (CRFs) generally improved foliar color and plant size compared to granular water-soluble (GWS) fertilizers, while reducing total-N recovered from soil-water in some instances. A common industry practice of incorporating a GWS fertilizer [13N–5.6P–10.9K (13–13–13) at 4.9 g/m^2 N (1 lb N/1000 ft^2)] and topdressing a CRF [17N–3.0P–10.1K (17–7–12) at 4.9 g/m^2 N (1 lb N/1000 ft^2)] provided superior foliar color and larger plants compared to other inorganically fertilized plants. Response to the organically-based fertilizer (OBF) was different between the two experiments. While the organically based fertilizer resulted in adequate foliar color and plant size in Expt. 1, it generally provided superior foliar color and size compared to all other treatments in Expt. 2.

Introduction

Year-round maintenance of landscape beds with seasonal color is common in regions where mild winters allow for bedding plant growth. Fertilization is an important component of landscape bed management, and fertilization practices should be implemented that maximize plant growth and/or appearance while minimizing N leaching away from plant roots. Crops hardy for use in southern winter landscapes include: pansy (*Viola ticolor* and *V*. ×*wittrockiana* Gams.), carnation (*Dianthus caryophyllus* L.), chrysanthemum [*Dendranthema* ×*grandiflora* (Ramat.) (syn. *Chrysanthemum* ×*morifolium* (Kitam.)], snapdragon (*Antirrhinum majus* L.), and ornamental kale (*Brassica oleracea* L. Acephala Group). Because there are few crops hardy for winter landscape use compared to summer, little or no research based fertilizer recommendations are available for winter crops. Recommendations in popular literature are most reliable from state extension services, but even these are vague (19). Research-based fertilizer recommendations are predominantly results of studies on field production of carnation, chrysanthemum, and snapdragon for the cut-flower industry.

Landscape professionals should better understand the impact of landscape fertilization practices on growth and performance of winter annuals, and how these practices impact N leaching. For this, research is needed that examines how fertilizer formulation, method of application, and frequency of application affects plant growth and N leaching out of plant root-zones and into ground water. Fertilizer formulations commonly used include granular water soluble (GWS) fertilizers, controlled-release fertilizers (CRFs), and organic or organically-based fertilizers (OBFs). Waters (20) reported two

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surface applications of Osmocote 14N–2.6P–10K (14–6–12) CRF was equal to weekly applications of a water soluble fertilizer for growth of 'Iceberg' chrysanthemum. Similarly, Raulston and Geraldson (15) reported that a single application of Osmocote 14N–6.0P–11.6K (14–14–14) applied at planting provided higher stem weights of 'Snow Crystal' and 'Iceland' chrysanthemum compared to either 6N–3.5P–6.6K (6–8–8) GWS or 20N–8.6P–16.6K (20–20–20) liquid feed fertilizer. However, Farnham et al. (6) reported no differences between Osmocote (18% N) and conventional fertilization (overhead liquid feed) with respect to floral yield and quality-of-flower for cut-flower production in field-grown carnation.

Organic or organically-based fertilizers are also becoming more popular, especially with urban consumers. Composting organic wastes to generate fertilizers has been accepted as a viable process (3). A new noncomposted organically-based fertilizer currently being evaluated consists of recycled paper amended with animal manure (Tascon, Inc., Houston, TX). Breakdown of noncomposted organic products occurs in the soil as microorganisms consume the product and return carbon (C) and N back to the soil's organic fraction (3). Agronomic research has demonstrated that application of noncomposted recycled paper amended with chicken manure improved cotton (*Gossypium hirsutum* L.) yields 54 to 60% when compared to standard cultural practices (2). The same fertilizer treatment increased corn (*Zea mays* L.) grain yields 40% over standard cultural practices (11).

Methods of application that are commonly used include incorporating fertilizer into the soil or topdressing fertilizer over the soil surface. In a container study, Simpson et al. (18) reported that topdress applications produced superior 'Hostess' chrysanthemum compared to incorporation, which they attributed to excessive leaching of incorporated fertilizer.

Varying frequency of application, whether fertilizers are applied in a single or multiple applications throughout the growing season, is another strategy used by landscape professionals. Support for use of multiple applications is strong. Hood et al. (7) reported uptake of nutrients by snapdragon is high at the stage of visible bud to anthesis, and suggests that supplemental fertilizer during this stage of growth would be beneficial. Similarly, Kazimirova (9) demonstrated that nutrient uptake by carnation was greatest during full bloom and seed development and N requirement was high throughout growth, thus suggesting that sufficient available N throughout the plant's life cycle is necessary for optimum growth and flowering. Work by Simpson et al. (18) supports this suggestion by demonstrating that a single preplant application of Osmocote 18N–1.7P–5.9K (18–4–7) to be inferior for growth of field-grown chrysanthemum to similar applications supplemented with liquid feed. However, Waters (20) demonstrated that a single application of incorporated Osmocote 14N–2.6P–10K (14–6–12) provided superior results with 'Iceberg' chrysanthemum compared to two topdress applications of Osmocote 14N–2.6P–10K (14–6–12). Raulston and Geraldson (15) reported no difference in growth of 'Iceland' and 'Yellow Shasta' chrysanthemum but higher foliar N (percent of dry weight) when fertilized with a single application of Osmocote 14N–6.0P–11.6K (14–14–14) applied at planting compared to the same rate of 6N–3.5P–6.6K (6–8–8) GWS applied in ten equal weekly applications. Because of increased use of bedding plants during winter months, and lack of research based fertilizer recommendations in the literature, our objective was to evaluate landscape fertilization practices for use in winter-grown landscape bedding plants.

Materials and Methods

Experiment 1. Both experiments were conducted at the Auburn University Experiment Station in Auburn, AL. Uniform plants (approximately 13 cm (5 in) tall) from 48 cell-packs of 'Majestic Giants White' pansy (*Viola ×wittrockiana*) and 'Telstar Purple' dianthus (*Dianthus chinensis* L.) were planted in a Marvyn sandy loam soil (78.6% sand, 17.1% silt, and 4.3% clay) in raised beds simulating an urban landscape. Plants used in both experiments were produced without the use of chemical plant growth regulators. Raised beds [0.9 m (3 ft) wide] were developed using a Kenco bed maker (Kenco Corp., Ligonier Valley, PA) with a 0.9 m (3 ft) wide × 0.2 m (0.5 ft) tall bed mold. Beds were divided into plots 0.9 m (3 ft) × 2.7 m (9 ft) with 0.3 m (1 ft) between plots. In each plot, nine plants per species were planted 0.3 m (1 ft) on center in a 3 plant × 3 plant grid. The experimental design was a randomized complete block in a 4 × 2 factorial arrangement of treatments with four inorganic fertilizer formulations and two methods of application. The four inorganic fertilizer formulations used included 13N–5.6P–10.9K (13–13–13) and 15N–0P–12.6K (15–0–15) GWS fertilizers, Osmocote (Scotts Co., Marysville, OH) 14N–6.0P–11.6K (14–14–14) (3 to 4 month release) controlled-release fertilizer (CRF), and Osmocote 17N–3.0P–10.1K (17–7–12) (12 to 14 month release) CRF. Each fertilizer was applied at a rate of 4.9 g/m^2 N (1 lb N/1000 ft^2). Fertilizers were applied using one of two application methods: either incorporated into the top 10.2 cm (4 in) pre-plant (after beds were formed) using a roto-tiller, or topdressed post-plant. For purposes of this experiment, the above listed fertilizers will be collectively referred to as 'inorganic fertilizers'. The rate of 4.9 g/m^2 N (1 lb N/1000 ft^2) was chosen based on a recommendation of the Alabama Cooperative Extension Service (21). Additional treatments (randomized with the 4 × 2 factorial described above) included application of 17N–3.0P–10.1K (17–7–12) fertilizer at 9.8 g/m^2 N (2 lb N/1000 ft^2) which was applied May 23, 1998, prior to the previous summer landscape bedding crop, either 1) incorporated or 2) topdressed, to test the hypothesis that a single application of CRF could be applied to provide fertility for two successive crops over a 6 to 9 month period; 3) an industry practice (IP) of incorporating 13N–5.6P–10.9K (13–13–13) at 4.9 g/m^2 N (1 lb N/1000 ft^2) pre-plant and topdressing 17N–3.0P–10.1K (17–7–12) at 4.9 g/m^2 N (1 lb N/1000 ft^2) post-plant, and 4) pre-plant incorporation of an organically-based fertilizer (OBF) composed of recycled newspaper amended with chicken manure (caged layer manure) applied at the manufacturer (Tascon, Inc.) recommended rate [2.5 kg/m^2 product(0.5 lb product/ft^2)]. The product was manufactured by mixing recycled paper (41%), caged layer manure (37%), gypsum (11%), ammonium sulfate [$(NH_4)_2SO_4$] (8%), potassium chloride (KCl) (1%), and triple super phosphate (2%). The final fertilizer product was adjusted to a C:N ratio of 20:1 using $(NH_4)_2SO_4$. Analysis of the product prior to application revealed it contained 1.5% organic N and 1.7% inorganic N, therefore the amount of inorganic N applied was 41.7 g/m^2 N (8.5 lb N/1000 ft^2). Prior to planting, a soil test was performed by the Auburn University Soil Testing Laboratory. On October 30, 1998, treatments requiring incorporation were applied, then plants were installed. Treatments requiring topdressing were applied immediately after planting. Plants were watered after planting and thereafter with overhead irrigation to supplement rainfall so that approximately 2.5 cm (1 in) of precipitation occurred each week. Foliar color was visually rated for each species 6, 14, 18, and 22 weeks after planting (WAP) on a scale of 1 to 5 where 1 = severe chlorosis, 2 = moderate chlorosis, 3 = slight chlorosis, 4 = light green, and 5 = dark green. Foliar color ratings of 4 and higher were considered acceptable. Foliar N (percent of dry weight) was determined for each species 22 WAP using a Leco CN 2000 (Leco Corp., St. Joseph, MI). Growth index [(height + width1 (widest part of plant) + width2 (perpendicular to width1)) ÷ 3] of each species were measured 14 and 22 WAP, and shoot dry weights (SDW) were determined 22 WAP. Soil-water samples were collected 1, 2, 4, 6, 10, 14, 18, and 22 WAP using suction-cup lysimeters 0.6 m (2 ft) long and 5.1 cm (2 in) in diameter with a ceramic cap 7.6 cm (3 in) long and 5.1 cm (2 in) wide. Lysimeters were installed 45º to the ground to minimize preferential water flow down the side of the lysimeter. A mud slurry using soil from the hole was poured back into the hole before insertion of the lysimeter to ensure soil contact with the ceramic cap. A hand pump was used to create a vacuum of 0.06 MPa (8.7 psi) within the lysimeters 24 hours prior to sampling. Soil-water collected from lysimeters was analyzed using a colorimetric procedure (17) to determine total-N (NO_3^- – N + NH_4^+ – N) (mg/liter). Data were subjected to contrast analysis and analysis of variance (ANOVA), with means separation by Duncan's multiple range test (α = 0.1). Alpha was set to 0.1 due to the variable nature of field experiments, and to avoid making Type II statistical errors (12).

Experiment 2. On November 11, 1999, a treatment sequence similar to Expt. 1 occurred with 'Bingo Blue with Blotch' pansy, 'Telstar Crimson Picotee' dianthus, and 'Tall Red' snapdragon. This experiment was conducted similarly to Expt. 1 with the following exceptions. Inorganic fertilizers were applied as either a single application of 4.9 g/m^2 N (1 lb N/1000 ft^2) pre-plant, or in multiple applications with 4.9 g/m^2 N (1 lb N/1000 ft^2) applied pre-plant followed by applications of 2.5 g/m^2 N (0.5 lb N/1000 ft^2) 14 and 18 WAP. Inorganic fertilizers included 15N–0P–12.6K (15–0–15) GWS fertilizer, Osmocote 14N–6.0P–11.6K (14–14–14) CRF, and Osmocote 17N–3.0P–10.1K (17–7–12) CRF. For purposes of this experiment, the above listed fertilizers, applied in a single or multiple applications, will be referred to collectively as inorganic fertilizers. The OBF described in Expt. 1 was applied either in a single application pre-plant at a rate of 2.5 kg/m^2 product (0.5 lb product/ft^2) [equivalent to 41.7 g/m^2 N (8.5 lb N/1000 ft^2; manufacturer recommended rate)], as a single application preplant at the same rate supplemented with additional applications of 1.2 kg/m^2 product (0.25 lb product/ft^2) at 14 and 18 WAP, or as a single application preplant with supplemental foliar applications of 1% urea at a rate of 0.6 liters/m^2 (0.13 gal/yd^2) at 14 and 18 WAP. The IP treatment described in Expt. 1 was also included. The following data were collected: foliar color ratings (same scale) at 1, 2, 4, 8, 12, and 16 WAP; foliar N at 16 WAP for each species; growth index at 16 and 22 WAP; and SDW at 22 WAP for all species. Soil-water was collected using suction-cup lysimeters 1, 2, 4, 8, 12, 14, 16, and 20 WAP, and analyzed for total-N (mg/L).

Results and Discussion

Experiment 1. Method of application, whether topdressed or incorporated, had no effect on foliar color, foliar N, or growth for either species (contrast statements, Tables 1 and 2). This concurs with similar work conducted during summer months (1). All plants were uniformly chlorotic at planting (foliar color rating of 3). At 6 WAP, plants treated with GWS fertilizers had higher foliar color ratings than those treated with CRFs (Table 1, contrast statements). By 14 WAP, plants treated with CRFs had higher foliar color ratings than those treated with GWS fertilizers. Pansy fertilized with 14N–6.0P–11.6K (14–14–14) (3 to 4 month release) and 17N–3.0P–10.1K (17–7–12) (9 to 12 month release) CRFs had similar foliar color through 18 WAP, but those treated with 17N–3.0P–10.1K (17–7–12) had higher foliar color thereafter. Differences in foliar color over time may be explained in part by N release rates of the fertilizers. N release from GWS fertilizer is immediate, while N release from CRFs is extended over time (product specific). Among CRFs, Patel and Sharma (14) demonstrated a 3 to 4 month Osmocote formulation initially had more rapid N release than 8 to 9 month or 12 to 14 month formulations. Additionally, research by Meadows and Fuller (13) reported lower levels of N release from a 3 to 4 month [19N–2.6P–10.1K(19–6–12)] Osmocote formulation compared to a 12 to 14 month [17N–3.0P–10.1K (17–7–12)] formulation beyond 105 days after application.

Throughout the experiment plants fertilized with the IP fertilizer had higher foliar color ratings than those fertilized with other inorganic fertilizers (Table 1, contrast statements) and the OBF (except 18 WAP). Pansy fertilized with the IP fertilizer responded by 6 WAP with excellent foliar color (4.9) and higher foliar color ratings than those fertilized with CRFs. However, by 14 WAP and thereafter pansy fertilized with 17N–3.0P–10.1K (17–7–12) had similar foliar color to those fertilized with the IP treatment. Pansy fertilized with the IP treatment benefitted from immediate availability of N from the GWS component and extended release of N from the CRF component. These results concur with Everett (4) who attributed yield differences in pepper (*Capsicum annuum* L. var. annuum) to excessive leaching of the GWS fertilizer and poor dissolution of Osmocote, while the combination treatment provided nutrients throughout the growing season. Foliar color of pansy fertilized with the OBF was adequate throughout the study (4.2 to 4.3).

Fertilizer treatment had little effect on foliar N of either species. Pansy fertilized with 17N–3.0P–10.1K (17–7–12) had higher foliar N than all other treatments, and pansy fertilized with CRFs had higher foliar N than those fertilized with GWS fertilizers (Table 1). Raulston and Geraldson (15) obtained similar results in that chrysanthemum fertilized with 14N–6.0P–11.6K (14–14–14) CRF had higher foliar N than those fertilized with 6N–3.5P–6.6K (6–8–8) GWS fertilizer. Dianthus fertilized with the OBF had higher foliar N than those fertilized with inorganic fertilizers. Despite statistical significance, differences in each case were small.

Differences in growth between treatments were small, therefore comparisons were made between groups of treatments using contrast statements. At 14 WAP, CRFs resulted in larger pansies than GWS fertilizers, but smaller dianthus (Table 2, contrast statements). By 22 WAP, plants of both

Table 1. Effect of fertilizer treatment on foliar color of pansy and foliar N (%) of pansy and dianthus planted and fertilized October 30, 1998 (Expt. 1).

Fertilizer	N rate (kg/m²)	Foliar color[z] of 'Majestic Giants White' pansy				Foliar N (%)	
		6 WAP[y]	14 WAP	18 WAP	22 WAP	'Majestic Giants White' pansy	'Telstar Purple' dianthus
13N–5.6P–10.9K GWS[x]	4.9	4.4bc[w]	3.8c	3.4c	3.7d	2.4b	3.1a
15N–0P–12.6K GWS	4.9	4.6b	3.8c	3.7b	3.7d	2.4b	2.9b
14N–6.0P–11.6K CRF	4.9	4.3c	4.5ab	4.4a	4.0c	2.3b	2.7b
17N–3.0P–10.1K CRF	4.9	4.2cd	4.4ab	4.4a	4.6a	2.6a	3.2a
Pre-17N–3.0P–10.1K CRF[v]	9.8	4.1d	3.9c	3.5bc	3.9c	2.5b	3.0a
IP[u]	9.8	4.9a	4.6a	4.3a	4.6a	2.4b	2.8b
OBF[t]	4.9[s]	4.2cd	4.3b	4.3a	4.3b	2.4b	3.1a
Contrast[r]							
Topdress vs. incorporation		NS	NS	NS	NS	NS	NS
Inorganic vs. OBF		NS	* (4.0 vs. 4.3)	*** (3.9 vs. 4.3)	** (4.0 vs. 4.3)	NS	* (3.0 vs. 3.1)
Inorganic vs. IP		*** (4.2 vs. 4.9)	*** (4.0 vs. 4.6)	** (3.9 vs. 4.3)	*** (4.0 vs. 4.6)	NS	* (3.0 vs. 2.8)
CRF vs. GWS		** (4.3 vs. 4.5)	*** (4.4 vs. 3.8)	*** (4.4 vs. 3.5)	*** (4.3 vs. 3.7)	* (2.5 vs. 2.4)	NS

[z]Foliar color ratings on a scale from 1 to 5 where 1 = severe chlorosis, 3 = slight chlorosis, and 5 = dark green foliar color.
[y]WAP = weeks after planting.
[x]GWS = granular water soluble fertilizer and CRF = controlled release fertilizer.
[w]Means separation within columns using Duncan's multiple range test ($\alpha = 0.1$).
[v]Fertilizer applied May 23 of the same year, prior to previous crop.
[u]IP = industry practice treatment: 13N–5.6P–10.9K at 4.9 g/m² N incorporated and 17N–3.0P–10.1K at 4.9 g/m² N topdressed.
[t]OBF = organically-based feritilzer: recycled paper amended with chicken manure.
[s]4.9 kg/m² product.
[r]Group means listed below significant contrasts.
NS, *, **, *** = nonsignificant or significant at the 0.1, 0.01, or 0.001 level, respectively.

Table 2. Effect of fertilizer treatment on growth index[z] of winter annuals planted and fertilized October 30, 1998 (Expt.1).

Fertilizer	N rate (kg/m²)	'Majestic Giants White' pansy		'Testar Purple' dianthus	
		14 WAP[y]	22 WAP	14 WAP	22 WAP
13N–5.6P–10.9K GWS[x]	4.9	15.3cd[w]	19.9cd	17.6b	23.3d
15N–0P–12.6K GWS	4.9	15.2cd	20.7bcd	17.6b	24.8cd
14N–6.0P–11.6K CRF	4.9	16.7b	22.0b	17.8b	25.7bc
17N–3.0P–10.1K CRF	4.9	15.7bc	22.0b	15.8c	24.6cd
Pre-17N–3.0P–10.1K CRF[v]	9.8	14.2d	19.3d	15.5c	24.2cd
IP[u]	9.8	20.3a	23.9a	20.1a	27.0ab
OBF[t]	4.9[s]	15.2cd	21.4bc	17.2b	27.6a
Contrast[r]					
Topdress vs. incorporation		NS	NS	NS	NS
Inorganic vs. OBF		NS	NS	NS	*** (24.2 vs. 27.6)
Inorganic vs. IP		*** (15.2 vs. 20.3)	** (20.7 vs. 23.9)	*** (16.8 vs. 20.1)	** (24.2 vs. 27.0)
CRF vs. GWS		* (16.2 vs. 15.2)	** (22.0 vs. 20.3)	* (16.8 vs. 17.6)	* (25.2 vs. 24.1)

[z]Growth indices calculated by: (height + width + width) ÷ 3.
[y]WAP = weeks after planting.
[x]GWS = granular water soluble fertilizer and CRF = controlled release fertilizer.
[w]Means separation within columns using Duncan's multiple range test ($\alpha = 0.1$).
[v]Fertilizer applied May 23 of the same year, prior to previous crop.
[u]IP = industry practice treatment: 13N–5.6P–10.9K at 4.9 g/m² N incorporated and 17N–3.0P–10.1K at 4.9 g/m² N topdressed.
[t]OBF = organically-based feritilzer: recycled paper amended with chicken manure.
[s]4.9 kg/m² product.
[r]Group means listed below significant contrasts.
NS, *, **, *** = nonsignificant or significant at the 0.1, 0.01, or 0.001 level, respectively.

Table 3. **Effect of fertilizer treatment on total-N[z] (mg/liter) in soil-water collected from plots containing winter annuals that were planted and fertilized October 30, 1998 (Expt. 1).**

Fertilizer	N rate (kg/m^2)	1 WAP[y]	2 WAP	4 WAP	6 WAP	10 WAP	14 WAP
13N–5.6P–10.9K GWS[x]	4.9	12.5ab[w]	11.2a	13.2abc	12.3bc	17.0a	2.9a
15N–0P–12.6K GWS	4.9	13.4a	11.8a	12.2bc	16.3a	16.9a	3.3a
14N–6.0P–11.6K CRF	4.9	11.4abc	10.7a	12.5bc	11.4c	9.5b	3.2a
17N–3.0P–10.1K CRF	4.9	13.1abc	10.8a	15.1ab	14.9ab	13.6ab	3.8a
Pre - 17N–3.0P–10.1K CRF[v]	9.8	10.9bc	9.9ab	13.9ab	13.6abc	9.7b	4.2a
IP[u]	9.8	12.6ab	8.6b	16.2a	16.2a	7.0b	2.7a
OBF[t]	4.9[s]	9.7c	9.1b	9.7c	11.2c	11.5ab	2.6a
Contrast[r]							
Topdress vs. incorporation	NS	NS	* (13.7 vs. 11.6)	NS	NS	NS	
Inorganic vs. OBF	* (12.0 vs. 9.7)	* (10.6 vs. 9.1)	* (12.9 vs. 9.7)	NS	NS	NS	
Inorganic vs. IP	NS	** (10.6 vs. 8.6)	NS	NS	NS	NS	
CRF vs. GWS	* (11.6 vs. 13.0)	NS	NS	NS	* (11.5 vs. 17.0)	NS	

[z]$NO_3^- – N + NH_4^+ – N$.
[y]WAP = weeks after planting.
[x]GWS = granular water soluble fertilizer and CRF = controlled release fertilizer.
[w]Means separation within columns using Duncan's multiple range test ($\alpha = 0.1$).
[v]Fertilizer applied May 23 of the same year, prior to previous crop.
[u]IP = industry practice treatment: 13N–5.6P–10.9K at 4.9 g/m^2 N incorporated and 17N–3.0P–10.1K at 4.9 g/m^2 N topdressed.
[t]OBF = organically-based feritlizer: recycled paper amended with chicken manure.
[s]4.9 kg/m^2 product.
[r]Group means listed below significant contrasts.
NS, *, **, *** = nonsignificant or significant at the 0.1, 0.01, or 0.001 level, respectively.

species fertilized with CRFs were larger than those fertilized with GWS fertilizers. Pansy and dianthus treated with the IP fertilizer were larger than inorganically fertilized plants at 14 and 22 WAP. Plants of both species fertilized with the OBF were of similar size compared to those fertilized with inorganic fertilizers, and smaller than those fertilized with the IP treatment, except at 22 WAP when dianthus were similar in size.

Across all treatments, total-N in soil-water was high (greater than 10 mg/liter) through 6 WAP, but had dropped to low levels (about 3 mg/liter) by 14 WAP (Table 3) and was negligible at 18 WAP (data not presented). This differs from similar studies conducted during the summer where total-N in soil-water was not detectable by 8 WAP (1). Higher levels are likely due to infrequent irrigation during the winter experiment, resulting in less N leached than during the summer. Additionally, N release from CRFs is temperature dependent in that higher temperatures result in more rapid N release (8, 10), thus N would likely be released slower and over a longer period of time during cooler months. Topdressing fertilizer led to higher levels of total-N in soil-water compared to incorporation only at 4 WAP, though this effect was transient. Comparing across formulations with contrast statements, CRFs resulted in less total-N in soil-water at 1 and 10 WAP compared to GWS fertilizers. OBFs resulted in lower levels of total-N in soil-water compared to inorganic fertilizers through 4 WAP. This differs from similar studies conducted in summer months where the OBF led to high levels of total-N in soil-water. Ammonium sulfate is added to the OBF in the manufacturing process, and warm soil conditions throughout the summer likely caused higher rates of nitrification by soil bacteria than during winter months (16). Because nitrate anions are leached more readily in mineral soils than ammonium cations, more total-N recovered in soil-water might be expected during summer months.

A treatment was included to test the hypothesis that a single preplant application of 17N–3.0P–10.1K (17–7–12) CRF (12 to 14 month release) could be applied to support two successive crops (Tables 1 through 3). Plants in this experiment were the second successive crop supported by the treatment. This resulted in reduced foliar color and plant size in pansy compared to other CRF treatments; however, pansy foliar color in this treatment was higher than those receiving GWS fertilizers. Dianthus in this treatment were similar in size to other CRF treatments. These results concur with those of Farnham (5) who reported an Osmocote 18N–2.6P–10.0K (18–6–12) application intended to supply nutrients for two years resulted in fewer blooms harvested from 'White Sim' carnation during the second year. Total-N in soil-water recovered from this treatment was negligible by the end of the prior experiment (crop), so it was surprising that total-N in soil-water recovered from this treatment was similar to other treatments in this experiment. This might be explained by several factors. Plants in the prior study were large with more expansive root systems toward the end of the study (1), and thus may have efficiently intercepted N released from the fertilizer, while small plants with confined root systems installed at the initiation of this study would be inefficient at

Table 4. Effect of fertilizer treatment on foliar color[z] of winter annuals (Expt. 2).

	'Big Blue with Blotch' pansy							'Telstar Crimson Picotee' dianthus						
Fertilizer	**1 WAP[y]**	**2 WAP**	**4 WAP**	**8 WAP**	**12 WAP**	**16 WAP**	**20 WAP**	**1 WAP**	**2 WAP**	**4 WAP**	**8 WAP**	**12 WAP**	**16 WAP**
15N–0P–12.6K GWS	3.9b	4.5b	4.6b	3.7b	3.5c	4.3c	4.1b	4.1c	4.7b	4.8a	4.0b	3.8b	4.4b
14N–6.0P–11.6K CRF[x]	2.9c[w]	3.5c	3.9c	4.5a	4.7a	4.5b	3.8b	3.3d	3.8c	4.3b	4.5a	4.7a	4.7a
17N–3.0P–10.1K CRF	3.0c	3.3c	3.6d	3.7b	4.2b	4.3c	4.1b	3.3d	3.5d	4.0c	4.2b	4.5a	4.8a
IP[v]	3.9b	4.7ab	4.9a	4.8a	4.5b	4.4bc	3.9b	4.3b	4.9ab	5.0a	4.8a	4.4a	4.7a
OBF[u]	4.4a	4.8a	4.9a	4.7a	4.9a	4.9a	4.6a	4.9a	5.0a	5.0a	4.8a	4.7a	5.0a
Contrast[t]													
Single vs. multiple apps.	—	—	—	—	—	*** (4.2 vs. 4.6)	*** (3.8 vs. 4.2)	—	—	—	—	—	*** (4.4 vs. 4.9)
Inorganic vs. IP	*** (3.2 vs. 3.9)	*** (3.7 vs. 4.7)	*** (4.0 vs. 4.9)	*** (4.0 vs. 4.8)	* (4.2 vs. 4.5)	NS	NS	*** (3.6 vs. 4.3)	*** (4.0 vs. 4.9)	*** (4.4 vs. 5.0)	** (4.2 vs. 4.8)	* (4.3 vs. 4.4)	NS
Inorganic vs. OBF	*** (3.2 vs. 4.4)	*** (3.7 vs. 4.8)	*** (4.0 vs. 4.9)	*** (4.0 vs. 4.7)	*** (4.2 vs. 4.9)	*** (4.4 vs. 4.9)	*** (4.0 vs. 4.6)	*** (3.6 vs. 4.9)	*** (4.0 vs. 5.0)	*** (4.4 vs. 5.0)	*** (4.2 vs. 4.8)	*** (4.3 vs. 4.7)	*** (4.7 vs. 5.0)
CRF vs. GWS	*** (2.9 vs. 3.9)	*** (3.4 vs. 4.5)	*** (3.7 vs. 4.6)	** (4.1 vs. 3.7)	*** (4.5 vs. 3.5)	* (4.4 vs. 4.3)	NS	*** (3.1 vs. 4.1)	*** (3.7 vs. 4.7)	*** (4.1 vs. 4.8)	** (4.4 vs. 4.0)	*** (4.6 vs. 3.8)	* (4.8 vs. 4.4)

[z]Foliar color ratings on a scale from 1 to 5 where 1 = severe chlorosis, 3 = slight chlorosis, and 5 = dark green foliar color.

[y]WAP = weeks after planting.

[x]GWS = granular water soluble fertilizer and CRF = controlled release fertilizer.

[w]Means separation within columns using Duncan's multiple range test ($\alpha = 0.1$).

[v]IP = industry practice treatment: 13N–5.6P–10.9K at 4.9 g/m^2 N incorporated and 17N–3.0P–10.1K at 4.9 g/m^2 N topdressed.

[u]OBF = organically-based feritlizer: recycled paper amended with chicken manure.

[t]Group means listed below significant contrasts.

NS, *, **, *** = nonsignificant or significant at the 0.1, 0.01, or 0.001 level, respectively.

Table 5. Effect of fertilizer treatment on growth indices[z] of winter annuals (Expt. 2).

	'Big Blue with Blotch' pansy		'Telstar Crimson Picotee' dianthus		'Tall Red' snapdragon	
Fertilizer	16 WAP[y]	22 WAP	16 WAP	22 WAP	16 WAP	22 WAP
15N–0P–12.6K GWS	7.6c	16.3c	11.3b	23.9b	14.5b	28.8bc
14N–6.0P–11.6K CRF[x]	12.3a[w]	20.8b	12.8a	24.7b	15.0b	28.3cd
17N–3.0P–10.1K CRF	10.2b	18.1c	11.3b	23.7b	13.6c	25.9d
IP[v]	12.8a	22.5b	13.0a	25.3b	16.3a	31.3ab
OBF[u]	12.4a	25.7a	13.9a	28.2a	15.2b	33.1a
Contrast[t]						
Single vs. multiple apps.	*	***	**	***	NS	***
	(9.5 vs. 10.6)	(16.8 vs. 20.0)	(11.0 vs. 12.6)	(22.5 vs. 25.7)		(25.6 vs. 29.7)
Inorganic vs. IP	***	***	*	**	***	**
	(10.0 vs. 12.8)	(18.4 vs. 22.6)	(11.8 vs. 13.0)	(24.1 vs. 25.3)	(14.4 vs. 16.3)	(27.7 vs. 31.3)
Inorganic vs. OBF	***	***	***	***	*	***
	(10.0 vs. 12.4)	(18.4 vs. 25.7)	(11.8 vs. 13.9)	(24.1 vs. 28.2)	(14.4 vs. 15.2)	(27.7 vs. 33.1)
CRF vs. GWS	***	***	NS	NS	NS	NS
	(11.2 vs. 7.6)	(19.5 vs. 16.3)				

[z]Growth indices calculated by: (height + width + width) ÷ 3.

[y]WAP = weeks after planting.

[x]GWS = granular water soluble fertilizer and CRF = controlled release fertilizer.

[w]Means separation within columns using Duncan's multiple range test (α = 0.1).

[v]IP = industry practice treatment: 13N–5.6P–10.9K at 4.9 g/m^2 N incorporated and 17N–3.0P–10.1K at 4.9 g/m^2 N topdressed.

[u]OBF = organically-based feritlizer: recycled paper amended with chicken manure.

[t]Group means listed below significant contrasts.

NS, *, **, *** = nonsignificant or significant at the 0.1, 0.01, or 0.001 level, respectively.

intercepting and absorbing N released from the fertilizer. In addition, Osmocote prills intact may have been broken apart when beds were roto-tilled, thus releasing more nutrients.

Experiment 2. Occurrence of interactions between fertilizer formulation and frequency of application (single vs. multiple application) was transient for all measured parameters throughout the experiment, therefore, only main effects are presented and discussed. Plants were uniformly chlorotic when planted (foliar color rating of 2). Pansy and dianthus treated with GWS fertilizer had higher foliar color ratings compared to CRFs until 8, but lower foliar color ratings thereafter (Table 4, contrast statements). This concurs with Expt. 1 in that GWS provided better foliar color early in the study, but lower foliar color in the middle and latter parts of the experiment. Foliar color ratings of plants fertilized with 14N–6.0P–11.6K (14–14–14) were higher than those fertilized with 17N–3.0P–10.1K (17–7–12) from 4 through 16 WAP for pansy and 2 through 8 WAP for dianthus. This differs from Expt. 1 where the two fertilizers provided similar foliar color for pansy throughout the study until the 14N–6.0P–11.6K (14–14–14) was depleted at 22 WAP. Both species fertilized with the IP treatment had superior foliar color compared to inorganically fertilized plants through 12 WAP, and similar thereafter. This concurs with Expt. 1 and results from Everett (4). Plants fertilized with the OBF had high foliar color ratings throughout the experiment, and these plants responded most rapidly with improved foliar color compared to color at planting. Snapdragon treated with the OBF were wilted through 1 WAP and to a lesser extent at 2 WAP. Soluble salts measured in soil-water collected from plots fertilized with the OBFs were 430% and 575% higher compared to all other treatments at 1 and 2 WAP, respectively (data not presented). Lu (11) reported application of a similar OBF increased extractable potassium (K), phosphorus (P), copper (Cu), and zinc (Zn) by 40 to 62%, compared to applications of recycled newsprint amended with other inorganic N sources. Increased levels of soluble salts caused plant mortality in a similar study conducted the previous summer (1), and might explain wilting observed in this study. Supplemental applications of OBF or foliar urea had no effect on pansy or dianthus foliar color (Table 4). In contrast, multiple applications of inorganic fertilizers provided higher foliar color ratings for pansy and dianthus 16 WAP and thereafter for pansy. This supports suggestions made by Kazimirova (9) that supplemental fertilizer applications would benefit growth and development of dianthus, and they concur with results from Simpson (18) that a single application of fertilizer is inferior to similar applications supplemented with liquid feed.

Response of foliar N to fertilizer treatment varied with species. Multiple applications of inorganic fertilizer resulted in higher levels of foliar N in pansy and dianthus at the end of the experiment compared to a single application at planting, though differences for both species were small (data not presented). Pansy receiving the OBF supplemented with either a second application of the fertilizer or foliar urea had higher foliar N than those only receiving a single application at planting, and higher than all other inorganically fertilized plants. Dianthus fertilized with inorganic fertilizers had higher foliar N ratings than those fertilized with the IP treatment. And dianthus fertilized with CRFs had higher foliar N than those fertilized with 15N–0P–12.6K (15–0–15) GWS. Snapdragon fertilized with a single application of the OBF had lower foliar N than all other treatments.

Multiple applications of inorganic fertilizers resulted in larger winter annuals compared to a single application throughout the experiment (except snapdragon at 16 WAP) (Table 5). Pansy fertilized with CRFs were larger than those fertilized with GWS fertilizer at 16 and 22 WAP. The 14N–6.0P–11.6K (14–14–14) CRF resulted in larger pansy (both

Table 6. Effect of fertilizer treatment on total-N[z] (mg/liter) in soil water (Expt. 2).

Fertilizer	1 WAP[y]	2 WAP	4 WAP	8 WAP	12 WAP	14 WAP	16 WAP	20 WAP
15N–0P–12.6K GWS	16.4ab	19.7b	17.9b	2.3b	3.6ab	3.2b	1.3b	0.4b
14N–6.0P–11.6K CRF[x]	12.5b[w]	12.6bc	9.5c	2.5b	3.8ab	4.2b	2.0b	4.7a
17N–3.0P–10.1K CRF	12.9b	9.0c	6.4c	2.0b	3.6ab	3.0b	3.1ab	0.4b
IP[v]	13.7b	20.7b	16.2b	3.2b	2.4b	6.0ab	1.8b	1.3b
OBF[u]	21.3a	32.7a	24.8a	8.7a	6.2a	7.9a	1.2b	0.5b
OBF + OBF	—	—	—	—	—	—	6.2a	1.3b
OBF + urea	—	—	—	—	—	—	4.4ab	0.9b
Contrast[t]								
Single vs. multiple apps.	NS	NS	NS	NS	NS	NS	NS	* (2.8 vs. 0.9)
Inorganic vs. IP	NS	NS	NS	NS	NS	NS	NS	NS
Inorganic vs. OBF	** (13.9 vs. 21.3)	*** (13.7 vs. 32.7)	*** (11.3 vs. 24.8)	*** (2.3 vs. 8.7)	** (3.7 vs. 6.2)	*** (3.5 vs. 7.9)	NS	NS
CRF vs. GWS	NS	* (10.8 vs. 19.7)	*** (8.0 vs. 17.9)	NS	NS	NS	NS	* (2.6 vs. 0.4)

[z]$NO_3^- - N + NH_4^+ - N$.

[y]WAP = weeks after planting.

[x]GWS = granular water soluble fertilizer and CRF = controlled release fertilizer.

[w]Means separation within columns using Duncan's multiple range test ($\alpha = 0.1$).

[v]IP = industry practice treatment: 13N–5.6P–10.9K at 4.9 g/m^2 N incorporated and 17N–3.0P–10.1K at 4.9 g/m^2 N topdressed.

[u]OBF = organically-based feritlizer: recycled paper amended with chicken manure.

[t]Group means listed below significant contrasts.

NS, *, **, *** = nonsignificant or significant at the 0.1, 0.01, or 0.001 level, respectively.

dates), dianthus (16 WAP) and snapdragon (16 WAP). All species treated with the IP and OBF were as large or larger than all other treatments throughout the study.

Using contrast statements to compare across formulations, CRFs resulted in less total-N in soil-water than GWS fertilizers at 2 and 4 WAP, though higher levels at 20 WAP (Table 6). OBFs resulted in higher levels of total-N in soil-water through 14 WAP, and a supplemental application of the product at 14 WAP resulted in higher levels of total-N than a single application made at planting. This is in contrast to the first study where the OBF caused lower levels of total-N through 8 WAP. Although not compared statistically, it appeared that foliar color of plants receiving the OBF were higher than similarly treated plants in Expt.1. Further research is required to determine how nutrients are released from this product in order to provide more consistent results.

In summary, our data indicate that method of application, whether topdressed or incorporated, has no effect on plant growth and little effect on N leaching. Fertilizers applied in multiple applications improved plant foliar color, foliar N (except snapdragon), and growth index, but did not increase the amount of a total-N recovered in soil-water. Across both studies, CRFs generally improved foliar color and plant size compared to GWS fertilizers, while reducing total-N in soil-water in some instances. The IP treatment provided superior foliar color and larger plants compared to other inorganically fertilized plants, while not affecting total-N in soil-water leaching below plant roots. Response to the OBF differed among the two experiments. While the OBF resulted in adequate foliar color and plant size and reduced total-N recovered from soil-water in Expt. 1, it generally provided superior foliar color and size compared to all other treatments in Expt. 2, but also caused elevated levels of total-N in soil-water. Manufacturing, storage conditions, or application of this product may need modification to achieve more consistent results, nonetheless, it appears to have potential for use in winter landscapes.

The authors believe further work is necessary to fully develop best management practices for fertilization in winter landscapes. Nonetheless, based on results of this study we recommend that a combination of a GWS and CRF similar to our IP treatment to provide optimal plant growth from the time of planting throughout the life of the crop, without contributing significant N leached below plant root zones.

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