Fertilizer Formulation and Method of Application Influence Bedding Plant Growth and Nitrogen Leaching in Urban Landscapes[1]

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Abstract

Two experiments were conducted to evaluate fertilizer formulation, method of application, and frequency of application on growth of landscape bedding plants and nitrogen (N) leaching. In the first experiment, 'Peppermint Cooler' vinca (*Catharanthus roseus* (L.) G. Don 'Peppermint Cooler'), 'Bonanza Yellow' marigold (*Tagetes patula* L. 'Bonanza Yellow'), and 'Hawaii Blue' ageratum (*Ageratum houstonianum* Mill. 'Hawaii Blue') were planted in raised beds. Four inorganic fertilizer formulations used included 13N–5.6P–10.9K (13–13–13) and 15N–0P–12.6K (15–0–15) granular water soluble (GWS) fertilizers, Osmocote 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 N/m^2 (1 lb N/1000 ft^2) either incorporated into the top 10.2 cm (4 in) pre-plant or topdressed post-plant. Additional treatments included an industry practice of incorporating 13N–5.6P–10.9K (13–13–13) pre-plant and topdressing 17N–3.0P–10.1K (17–7–12) post-plant; and a pre-plant incorporation of an organically-based fertilizer composed of recycled newspaper amended with chicken manure (caged layer manure). In Expt. 2, a similar experimental setup was used with 'Peppermint Cooler' vinca, 'Red Vista' salvia (*Salvia splendens* F. Sellow ex Roem. & Schult. 'Red Vista'), and 'Strata' salvia (*Salvia farinacea* Benth. 'Strata'). Inorganic fertilizers were applied in either single or multiple applications. 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. Three organically-based fertilizers were applied pre-plant and were composed of recycled newspaper amended with either chicken, beef cattle, or dairy cow animal manures. Summarizing across both experiments, plants treated with GWS fertilizers appeared to benefit with improved foliar color from immediate release of nutrients, while those treated with CRFs required at least 4 weeks to achieve dark foliar color. Nutrient leaching below plant roots was greater for GWS compared to CRFs. The industry practice treatment provided some improved plant growth in both experiments; however, it also caused initially high levels of soil-water-N (SWN) in Expt. 1. The organically-based fertilizer resulted in larger, more attractive (higher foliar color ratings) plants than inorganic fertilizers, though it also resulted in the highest levels of SWN compared to all other treatments.

Species used in this study: 'Peppermint Cooler' vinca (*Catharanthus roseus* (L.) G. Don 'Peppermint Cooler'); 'Bonanza Yellow' marigold (*Tagetes patula* L. 'Bonanza Yellow'); 'Hawaii Blue' ageratum (*Ageratum houstonianum* Mill. 'Hawaii Blue'); 'Red Vista' salvia (*Salvia splendens* F. Sellow ex Roem. & Schult. 'Red Vista'); and 'Strata' salvia (*Salvia farinacea* Benth. 'Strata').

Index words: nitrate, lysimeter, multiple application, agricultural waste.

Significance to Nursery Industry

Use of bedding plants in the landscape increased dramatically during the 1990s and has become a major part of landscape services in the United States. However, limited fertilizer research has been conducted in the past 15 to 20 years for bedding plants in the landscape; although, the industry has experienced major changes including multiple croppings of annuals in the same bed, overhead irrigation of most landscape beds, and use of controlled-release fertilizers (CRFs). Concurrent with these changes is a society increasingly concerned about the environment and the impact of urban landscape practices. Our data suggest that CRFs, either 14N–6.0P–11.6K (14–14–14) at 4.9 g N/m^2 or 17N–3.0P–10.1K (17–7–12) at 9.8 g N/m^2 can be used to provide similar or better plant growth and foliar color while minimizing nitrogen (N) leaching, compared to other inorganic fertilizers. An organically-based fertilizer composed of recycled newspaper amended with chicken manure provided superior foliar color and plant growth, however, it also caused excessive N leaching.

Introduction

An important component of successful landscape maintenance programs is proper fertilization, which should supply plants with sufficient mineral nutrients with minimal nutrient loss below plant roots. Landscape fertilizer recommendations in popular and scientific literature are inconsistent from source to source. A common source for landscape fertilization recommendations are state cooperative extension services; however, even these vary from state to state. For example, the Alabama Cooperative Extension Service recommends for herbaceous ornamentals, a single application per year of a complete fertilizer applied at planting at a rate of 4.9 g N/m^2 (1.0 lb N/1000 ft^2) (26). The Florida Cooperative Extension Service recommends a complete, controlled-release fertilizer be incorporated into the soil prior to planting at a rate of 5.9 g N/m^2 (1.2 lb N/1000 ft^2), and that applications be repeated on a monthly basis throughout the grow-

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ing season (4) (resulting in 35.3 g N/m² (7.2 lb N/1000 ft²) per 6 month growing season). The Delaware Cooperative Extension Service recommends topdressing 14.7 g N/m² (3 lb N/1000 ft²) prior to planting, with an additional 9 to 18 g (1 to 2 tablespoons)/plant at first flower (1).

Because of increased public awareness of nonpoint source (NPS) pollution from urban landscapes, and the apparent lack of consistency in recommendations, best management practices (BMPs) for the urban landscape should be developed to guide industry professionals and homeowners in using proper fertilization practices for landscape bedding plants. These practices include determining fertilizer formulation, method of application, and frequency of application that will maximize plant growth and minimize N leaching below plant root zones into ground water. Fertilizer formulations used commonly include granular water soluble (GWS) fertilizers, CRFs, and organic or organically-based fertilizers (17). Methods of application typically used include incorporating fertilizer into the soil or topdressing fertilizer over the soil surface. Varying frequency of application, whether fertilizers are applied in one application or several applications throughout the growing season, is another strategy used by landscape professionals. Waters (24) reported two 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 [*Dendranthema* ×*grandiflora* (Ramat.) (syn. *Chrysanthemum* ×*morifolium* (Kitam.)]. However, Farnham et al. (11) reported no differences between Osmocote (18% N) and conventional fertilization (GWS fertilizers) with respect to floral yield and flower quality for cut-flower production in field-grown carnation (*Dianthus caryophyllus* L.). Everett (10) demonstrated that a combination of 10N–2.2P–7.5K (10–5–9) granular water soluble (GWS) fertilizer with Osmocote (3 to 4 month release) provided the highest yield and largest fruit size of 'Early Cal Wonder' peppers (*Capsicum annuum* L. var annuum), whereas an application of 10N–2.2P–7.5K (10–5–9) GWS provided the lowest yield and smallest fruit size, and Osmocote alone provided intermediate yields. Currently, a combination of GWS and CRFs is utilized by landscape professionals (personal communication with Heather Mann, Color Burst Landscape Co., Birmingham, AL) for fertilization of landscape bedding plants. Effect of fertilizer practices on N leaching from landscape crops is absent from the literature. Work in agronomic crops and turfgrass provides some information. Diez et al. (7) reported almost twice as much leached N from urea compared to two CRFs (Florinad and Multicote). Wadell et al. (23) demonstrated that sulfur coated urea (SCU, a type of CRF) and turkey manure reduced N leaching compared to urea with no adverse affect on potato (*Solanum tuberosum* L.) tuber yield.

A review of application methods, whether topdressed or incorporated, results in conflicting reports. Waters (24) 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). However, Simpson et al. (21) reported that topdress applications produced superior 'Hostess' chrysanthemum compared to incorporation, which they attributed to excessive leaching of incorporated fertilizer.

Guertal (12) compared single preplant applications of sulfur-coated urea and polyolefin resin-coated urea (both considered slow-release N sources) to single or split applications of GWS ammonium nitrate for pepper production. She reported N source did not affect pepper yield or quality and indicated that a single application of slow-release N fertilizers may be an alternative to repeated applications of GWS fertilizers. However, Simpson et al. (21) reported single preplant application of Osmocote 18N–1.7P–5.9K (18–4–7) to be inferior for growth of field-grown chrysanthemum compared to similar applications supplemented with liquid feed.

Organic or organically-based fertilizers are also becoming more popular, especially with urban consumers. A new organically-based fertilizer currently being evaluated consists of recycled paper amended with animal manure (Tascon, Inc., Houston, TX). Research has demonstrated that crop yields can be increased over those obtained from standard fertilization practices by applications of organic compost (14, 16, 27). Recycled paper adds carbon (C) to the soil, increases organic matter content (6), and may improve soil physical properties such as bulk density, soil aeration, porosity, and water infiltration (9). Animal manure provides mineral nutrients for plant growth, increases soil organic matter content, water holding capacity, water infiltration rates, water stable soil aggregates, microbial activity (8), and nutrient storage (9). Others have used manures for providing nutrients to crops such as corn (*Zea mays* L.) (27), cotton (*Gossypium hirsutum* L.) (5), vegetables (19), and ornamentals (2).

Understanding how fertilizer formulation and application practices affect plant growth and N leaching with landscape bedding plants in an urban landscape setting will guide landscape professionals and home owners toward utilizing BMPs for landscape fertilization. Therefore, the objective of this research was to evaluate different fertilizer formulations, methods of application, and frequency of application on growth of landscape bedding plants and N leaching.

Materials and Methods

Experiment 1. Uniform plants [approximately 15 cm (6 in) tall] of 'Peppermint Cooler' vinca (*Catharanthus roseus* 'Peppermint Cooler'), 'Bonanza Yellow' marigold (*Tagetes patula* 'Bonanza Yellow'), and 'Hawaii Blue' ageratum (*Ageratum houstonianum* 'Hawaii Blue') from 48-cell packs 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. 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 tall (0.5 ft) bed press pad, followed by incorporating 3.8 cm (1.5 in) of milled pine bark. 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 cultivar 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 treatment arrangement 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) 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 N/m² (1 lb N/1000 ft²) either incorporated into the top 10.2 cm (4 in) pre-plant or topdressed post-plant. The rate of 4.9 g N/m² (1 lb N/1000 ft²) was chosen based on the recommendation of the Alabama Cooperative Extension Service (26). Additional treatments included applying 17N–3.0P–10.1K (17–7–12) fertilizer at 9.8 g N/m² (2 lb N/1000 ft²), either 1) incorporated or 2) topdressed, to test the hypothesis that a single application of CRF could be applied to provide fertility to two successive crops over a 6 to 9 month period; 3) an industry practice of incorporating 13N–5.6P–10.9K (13–13–13) GWS at 4.9 g N/m² (1 lb N/1000 ft²) pre-plant and topdressing 17N–3.0P–10.1K (17–7–12) CRF at 4.9 g N/m² (1 lb N/1000 ft²) post-plant, and 4) a pre-plant incorporation of an organically-based fertilizer composed of recycled newspaper amended with chicken manure (manure collected from below commercial production of caged layers) applied at the manufacturer (Tascon Inc., Houston, TX) recommended rate [4.9 kg of product/m² (1 lb of product/ft²)]. The product is 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 83.3 g N/m² (17.0 lb N/1000 ft²). Prior to planting, a soil test was performed by the Auburn University Soil Testing Laboratory. Dolomitic lime was applied May 18, 1998, at 2.2 metric tons/ha (1 ton/A), as per the recommendation. On May 23, 1998, treatments requiring incorporation were applied, and plants were planted. Treatments requiring topdressing were applied immediately after planting. Plants were watered after planting and thereafter as needed with overhead irrigation. Foliar color was rated for each cultivar 8, 12, and 20 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 using a Leco CN 2000 (LECO Corp., St. Joseph, MI) C and N analyzer 8 WAP for all cultivars, and 20 WAP for 'Peppermint Cooler' vinca. Growth index [(height + width1 (widest part of plant) + width2 (? width1)) ? 3] of each cultivar were measured 6 and 20 WAP, and shoot dry weights (SDWs) were determined 20 WAP. Soil-water samples were collected 2, 4, 8, 12, and 16 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 inserted vertically into the ground with the ceramic cap being placed at a depth of 25.4 cm (10 in). The hole for the lysimeter was formed using a soil-core remover. A hand pump was used to create a vacuum of 0.06 MPa (8.7 psi) within the lysimeters. Soil-water collected from lysimeters was analyzed using a colorimetric procedure (22) to determine parts per million (ppm) soil-water-N (NO_3^- –N + NH_4^+–N) (SWN). Data were subjected to contrast analysis and analysis of variance (ANOVA), with means separation by Duncan's multiple range test (? = 0.10). Alpha was set to 0.1 due to the variable nature of field experiments, and to avoid making Type II statistical errors (15).

Experiment 2. On May 12, 1999, a treatment sequence similar to Expt. 1 occurred with 'Peppermint Cooler' vinca, 'Red Vista' salvia (*Salvia splendens*), and 'Strata' salvia (*Salvia farinacea*). This experiment was conducted and analyzed similarly to Expt. 1 with the following exceptions. Inorganic fertilizers were applied as either a single application of 4.9 g N/m² (1 lb N/1000 ft²) pre-plant, or in multiple applications with 4.9 g N/m² (1 lb N/1000 ft²) applied pre-plant followed by applications of 2.45 g N/m² (0.5 lb N/1000 ft²) 8 and 12 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. Three different organically-based fertilizers were applied pre-plant and were composed of recycled newspaper amended with animal manures (chicken, beef cattle, or dairy cow). Fertilizers amended with beef cattle or dairy cow manure were adjusted with ammonium sulfate [$(NH_4)_2SO_4$] to achieve C:N ratios of 20:1 and applied at a rate of 2.5 kg product/m² (0.5 lb product/ft²) [equivalent to 41.7 g N/m² (8.5 lb N/1000 ft²)] (manufacturer recommended rate). Fertilizers amended with chicken manure were adjusted in a similar manner to a C:N ratio of either 20:1 or 30:1, and then applied at a rate of either 1.2 or 2.5 kg product/m² (0.25 or 0.5 lb product/ft²) [equivalent to 18.2 or 36.4 g N/m² (3.7 or 7.4 lb N/1000 ft², respectively)]. The industry practice treatment described in Expt. 1 was also included. The following data were collected: foliar color ratings (same scale) at 2, 4, 8, 12, and 16 WAP; foliar N at 16 WAP for 'Peppermint Cooler' vinca only; growth index at 8 and 16 WAP; and SDW at 16 WAP. Lysimeters were installed 45° to the ground surface 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. Soil-water was collected 1, 2, 4, 8, 12, and 16 WAP, and analyzed for SWN expressed in parts per million (ppm).

Results and Discussion

Experiment 1. 'Peppermint Cooler' vinca was the only species in which foliar color was influenced by treatment. At 8 WAP 'Peppermint Cooler' vinca with inorganic fertilizers incorporated had higher foliar color ratings than those which had fertilizers topdressed (Table 1). After 8 WAP, method of application (topdress vs. incorporation) had no effect on foliar color or any other measured parameter throughout this experiment. Others have reported conflicting results as to whether topdressing or incorporating provides superior results (21, 24), while our results indicate it has no effect on plant performance. 'Peppermint Cooler' vinca treated with organically-based fertilizers had the highest foliar color ratings throughout the experiment, however, 20% of these plants died in the first week of the study, probably due to high level of salts released (13). Soluble salt level was determined in soil-water collected from lysimeters (data not reported) and soil-water from plots treated with the organically-based fertilizer had 140% higher salt levels compared to those fertilized with the industry practice, and 300% higher than those fertilized with all other treatments. In addition, throughout the experiment 'Peppermint Cooler' vinca fertilized with CRFs had higher foliar color ratings than those fertilized with GWS fertilizers (Table 1, contrast analyses). At 8 WAP, 'Peppermint Cooler' vinca treated with 14N–6.0P–11.6K (14–14–14) CRF had higher foliar color ratings than plants treated with GWS fertilizers [13N–5.6P–10.9K (13–13–13) and 15N–0P–12.6K (15–0–15)], and similar ratings to the industry practice treatment and 17N–3.0P–10.1K (17–7–12) CRF (9.8 g N/m²), both of which received twice the rate of N at planting. By 20 WAP, 'Peppermint Cooler' vinca treated with 14N–6.0P–11.6K (14–14–14) CRF had ratings similar to

Table 1. Effect of selected fertilizers on foliar color ratings and foliar N of summer annuals (Expt. 1).

Fertilizer	Rate (g N/m²)	Foliar color[z] of 'Peppermint Cooler' vinca 8 WAP[y]	12 WAP	20 WAP	Foliar N (%) 8 WAP[y] 'Hawaii Blue' ageratum	'Bonanza Yellow' marigold	'Peppermint Cooler' Vinca	Foliar N (%) 20 WAP 'Peppermint Cooler' Vinca
13N–5.6P–10.9K GWS[x]	4.9	4.0cd[w]	3.0d	2.7e	3.7b[y]	3.4	2.2c	3.2bc
15N–0P–12.6K GWS	4.9	3.8d	3.1d	2.8de	3.6b	3.5	2.4bc	3.1c
14N–6.0P–11.6K CRF	4.9	4.3b	3.2d	2.9cde	3.7b	3.4	2.4bc	3.2bc
17N–3.0P–10.1K CRF	4.9	4.1bc	3.3d	3.1b	3.6b	3.4	2.5bc	3.3bc
17N–3.0P–10.1K CRF	9.8	4.2bc	3.7c	3.2b	3.7b	3.2	2.7b	3.4ab
Industry practice[v]	9.8	4.0bc	4.0b	3.0bcd	3.4b	3.4	2.9b	3.5ab
Organic-based[u]	4.9[t]	5.0a	4.3a	4.0a	4.1a	3.6	4.5a	3.7a
Contrast[s]								
Topdress vs. incorporation		* (4.0 vs. 4.2)	NS	NS	NS	NS	NS	NS
Inorganic vs. organic		*** (4.1 vs. 5.0)	*** (3.3 vs. 4.3)	*** (2.9 vs. 4.0)	*** (3.6 vs. 4.1)	* (3.4 vs. 3.6)	*** (2.6 vs. 4.5)	** (3.3 vs. 3.7)
Inorganic vs. industry		NS	*** (3.3 vs. 4.0)	NS	NS	NS	* (2.6 vs. 2.9)	* (3.3 vs. 3.5)
CRF vs. GWS		** (4.2 vs. 3.9)	* (3.3 vs. 3.1)	* (3.0 vs. 2.7)	NS	NS	NS	NS

[z]On a scale from 1 to 5 where 1 = severe chlorosis, 2 = moderate chlorosis, 3 = slight chlorosis, 4 = light green, and 5 = dark green.
[y]WAP = weeks after planting.
[x]GWS = granular water soluble fertilizer and CRF = controlled-release fertilizer.
[w]Mean separation within columns by Duncan's Multiple Range test (? = 0.1).
[v]Industry practice treatment: 13N–5.6P–10.9K at 4.9 g N/m² incorporated preplant and 17N–3.0P–10.1K at 4.9 g N/m² topdressed postplant.
[u]Organically-based fertilizer: recycled paper amended with chicken manure.
[t]4.9 kg product/m².
[s]Group means listed below significant contrasts.
NS, *, **, *** = nonsignificant or significant at the 0.1, 0.01, or 0.001 level, respectively.

GWS fertilizers and ratings lower than those treated with 17N–3.0P–10.1K (17–7–12) (4.9 or 9.8 g N/m²). Differences in foliar color over time may be explained in part by N release rates from the fertilizers. N release from GWS fertilizer is immediate, while N release from CRFs is extended over time (product specific). Among CRFs, N release from 14N–6.0P–11.6K (14–14–14) (3 to 4 month release) is initially more rapid than that from 17N–3.0P–10.1K (17–7–12) (12 to 14 month release) which is designed to release nutrients over a longer period of time. Patel and Sharma (20) demonstrated that initially a 3 to 4 month Osmocote formulation had more rapid N release than 8 to 9 month or 12 to 14 month formulations (the referenced experiment used different formulations of Osmocote than those in our study). Additionally, research by Meadows and Fuller (18) reported lower levels of N release from a 3 to 4 month (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.

Among plants fertilized with inorganic fertilizers at 8 WAP, fertilizer formulation did not affect foliar N (Table 1). Across all species, plants treated with organically-based fertilizer had higher foliar N than inorganically fertilized plants (contrast analyses). Foliar N levels of 'Peppermint Cooler' vinca were similar to foliar color data at 8 and 20 WAP, in that plants fertilized with the organically-based fertilizer had the highest foliar color ratings and foliar N levels.

Fertilizer formulation and method of application (data not presented) for inorganic fertilizers had no effect on growth index for any species at either date, however, there were differences between inorganic fertilizers as a whole, organically-based, and industry practice treatment (Table 2, contrast analyses). At 6 WAP, 'Hawaii Blue' ageratum treated with the industry practice treatment were larger than all other plants, while those treated with the organically-based fertilizer were the smallest. By 20 WAP, all plants of 'Hawaii Blue' ageratum were similar in size. All 'Bonanza Yellow' marigolds were similar in size at 6 WAP, and by 20 WAP, had begun to decline and therefore were not measured for growth index. At 6 and 20 WAP, 'Peppermint Cooler' vinca treated with the organically-based or industry practice treatments were larger than those treated with inorganic fertilizers. At 6 WAP 'Peppermint Cooler' vinca treated with GWS fertilizers were larger than those treated with CRFs, however, by 20 WAP plants treated with CRFs were larger. Again, this was likely due to N being immediately available and depleted from GWS fertilizers, while N release from CRFs was initially slow but provided extended release thereafter. Shoot dry weights for 'Hawaii Blue' ageratum and 'Peppermint Cooler' vinca followed a trend similar to growth index data at 20 WAP (data not presented).

At 2 WAP, SWN (NO_3^-–N + NH_4^+–N) from plots treated with the organically-based fertilizer and the industry prac-

Table 2. Effect of selected fertilizers on growth index of summer annuals (Expt. 1).

		Growth index[z] (cm)				
		6 WAP[y]			20 WAP	
Fertilizer	Rate (g N/m²)	'Hawaii Blue' ageratum	'Bonanza Yellow' marigold	'Peppermint Cooler' vinca	'Hawaii Blue' Ageratum	'Peppermint Cooler' vinca
13N–5.6P–10.9K GWS[x]	4.9	30.6bc[w]	34.2	28.6bc	35.9	36.0cd
15N–0P–12.6K GWS	4.9	31.0ab	36.4	28.0bc	35.3	33.7d
14N–6.0P–11.6K CRF	4.9	31.2ab	36.4	27.1c	35.1	36.5cd
17N–3.0P–10.1K CRF	4.9	30.1bc	35.1	26.7c	34.7	37.7c
17N–3.0P–10.1K CRF	9.8	28.7bc	34.5	26.4c	35.3	36.5cd
Industry practice[v]	9.8	32.7a	37.2	29.7ab	37.5	41.2b
Organic-based[u]	4.9[t]	26.6d	33.7	31.1a	35.1	53.0a
Contrast[s]						
Inorganic vs. organic		*** (30.1 vs. 26.6)	NS	** (27.1 vs. 31.1)	NS	*** (35.7 vs. 53.0)
Inorganic vs. industry		* (30.1 vs. 32.7)	NS	* (27.1 vs. 29.7)	NS	** (35.7 vs. 41.2)
CRF vs. GWS		NS	NS	* (26.9 vs. 28.3)	NS	* (37.2 vs. 34.9)

[z]Growth index = (height + width1 + width2) / 3.
[y]WAP = weeks after planting.
[x]GWS = granular water soluble fertilizer and CRF = controlled-release fertilizer.
[w]Mean separation within columns by Duncan's Multiple Range test (? = 0.1).
[v]Industry practice treatment: 13N–5.6P–10.9K at 4.9 g N/m² incorporated preplant and 17N–3.0P–10.1K at 4.9 g N/m² topdressed postplant.
[u]Organically-based fertilizer: recycled paper amended with chicken manure.
[t]4.9 kg product/m².
[s]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 selected fertilizers on soil-water-N (Expt. 1).

		Soil-water-N[z] (ppm)				
Fertilizer	Rate (g N/m²)	2 WAP[y]	4 WAP	8 WAP	12 WAP	16 WAP
13N–5.6P–10.9K GWS[x]	4.9	12.2c[w]	11.9ab	0.3b	0.6	0.0
15N–0P–12.6K GWS	4.9	9.6c	6.2bc	0.5b	0.3	0.0
14N–6.0P–11.6K CRF	4.9	7.2c	4.3c	0.7ab	0.6	0.0
17N–3.0P–10.1K CRF	4.9	8.9c	6.2bc	0.2b	0.6	0.2
17N–3.0P–10.1K CRF	9.8	8.5c	3.7c	0.1b	0.8	0.1
Industry practice[v]	9.8	34.0a	12.9a	0.0b	1.2	0.0
Organic-based[u]	4.9[t]	24.1b	8.3abc	1.6a	0.2	0.0
Contrast[s]						
Inorganic vs. organic		** (9.4 vs. 24.1)	NS	* (0.2 vs. 1.6)	NS	NS
Inorganic vs. industry		*** (9.4 vs. 34.0)	* (6.6 vs. 12.9)	NS	NS	NS
CRF vs. GWS		* (8.1 vs. 9.5)	* (5.3 vs. 9.1)	NS	NS	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]Mean separation within columns by Duncan's Multiple Range test (? = 0.1).
[v]Industry practice treatment: 13N–5.6P–10.9K at 4.9 g N/m² incorporated preplant and 17N–3.0P–10.1K at 4.9 g N/m² topdressed postplant.
[u]Organically-based fertilizer: recycled paper amended with chicken manure.
[t]4.9 kg product/m².
[s]Group means listed below significant contrasts.
NS, *, **, *** = nonsignificant or significant at the 0.1, 0.01, or 0.001 level, respectively.

Table 4. Effect of selected fertilizers on foliar color ratings of summer annuals (Expt. 2).

	Foliar color ratings[z]												
	'Red Vista' salvia				'Peppermint Cooler' vinca					'Strata' salvia			
Fertilizer	2 WAP[y]	4 WAP	8 WAP	12 WAP	2 WAP	4 WAP	8 WAP	12 WAP	16 WAP	2 WAP	4 WAP	8 WAP	12 WAP
Inorganic: 14N–6.0P–11.6K CRF[x]	3.5c[w]	4.6c	4.5a	3.9ab	3.5c	5.0a	4.6ab	4.2a	3.5ab	3.9d	4.7b	4.7ab	3.6a
15N–0P–12.6K GWS	4.4b	4.8abc	4.4a	3.9ab	4.6ab	5.0a	4.3c	3.7bc	3.5ab	4.4c	4.9ab	4.3c	3.6a
17N–3.0P–10.1K CRF	3.1d	4.3d	4.4a	4.1a	2.6d	4.6b	4.5bc	4.0ab	3.7a	3.1e	4.4c	4.4bc	3.7a
Industry practice[v]	4.6ab	4.9ab	4.3a	3.8ab	4.8ab	5.0a	4.3c	3.6bc	3.2bc	4.6bc	4.9ab	4.4bc	3.7a
Organic[u]: Beef cattle	4.9a	5.0a	4.7a	3.3c	5.0a	5.0a	4.8a	3.1d	2.9d	4.9ab	5.0a	4.9a	3.5a
Dairy	4.9a	5.0a	4.4a	3.6bc	4.9a	5.0a	4.7ab	3.5c	3.1cd	5.0a	5.0a	4.7ab	3.6a
Chicken	4.3b	4.7bc	4.3a	3.8ab	4.4b	4.8a	4.6ab	3.6bc	3.1cd	4.4c	4.8ab	4.6bc	3.5a
Chicken 20:1[t]	4.9a	5.0a	4.6a	3.6b	5.0a	5.0a	4.8a	3.6a	3.0b	4.9a	5.0a	4.8a	3.5a
30:1	3.7b	4.4b	4.0b	4.0a	3.8b	4.7b	4.4b	3.6a	3.2a	4.0b	4.6b	4.3b	3.6a
1.2 kg/m²	4.3a	4.6a	4.2b	3.7a	4.4a	4.7b	4.5b	3.5a	3.1a	4.5a	4.7a	4.3b	3.5a
2.5 kg/m²	4.3a	4.7a	4.5a	3.9a	4.3a	4.9a	4.8a	3.8a	3.1a	4.4a	4.9a	4.8a	3.6a
Contrast													
Single vs. multiple applications[s]	NS	NS	NS	NS	NS	NS	NS	* (3.8 vs. 4.1)	* (3.5 vs. 3.7)	NS	NS	NS	NS
Inorganic vs. organic	*** (3.8 vs. 4.5)	** (4.6 vs. 4.8)	NS	* (3.9 vs. 3.7)	*** (3.8 vs. 4.6)	NS	** (4.5 vs. 4.7)	*** (3.9 vs. 3.5)	*** (3.5 vs. 3.0)	*** (3.8 vs. 4.6)	** (4.7 vs. 4.9)	** (4.4 vs. 4.6)	NS
Industry practice vs. inorganic	*** (4.6 vs. 3.7)	** (4.9 vs. 4.6)	NS	NS	*** (4.8 vs. 3.6)	NS	NS	NS	* (3.2 vs. 3.6)	*** (4.6 vs. 3.8)	NS	NS	NS
Industry practice vs. organic	NS	NS	NS	NS	NS	NS	** (4.3 vs. 4.7)	NS	NS	NS	NS	NS	NS
CRF vs. GWS	*** (3.3 vs. 4.4)	*** (4.5 vs. 4.8)	NS	NS	*** (3.1 vs. 4.6)	** (4.8 vs. 5.0)	** (4.6 vs. 4.3)	** (4.1 vs. 3.7)	NS	*** (3.5 vs. 4.4)	* (4.6 vs. 4.9)	* (4.5 vs. 4.3)	NS

[z]On a scale from 1 to 5 where 1 = severe chlorosis, 2 = moderate chlorosis, 3 = slight chlorosis, 4 = light green, and 5 = dark green.

[y]WAP = weeks after planting.

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

[w]Mean separation within columns, separated by lines, using Duncan's multiple range test (? = 0.1).

[v]Industry practice treatment: 13N–5.6P–10.9K at 4.9 g N/m² incorporated preplant and 17N–3.0P–10.1K at 4.9 g N/m² topdressed postplant.

[u]Organically-based fertilizer: recycled paper amended with beef cattle, dairy, or chicken manure.

[t]C:N ratio.

[s]Mulitple applications applied at planting, 8 and 12 WAP.

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

tice treatment were 24 and 34 ppm, respectively (Table 3), and resulted in higher levels of SWN compared to inorganic fertilizers as a whole (262% and 370%, respectively). By 4 WAP, SWN from plots treated with organically-based fertilizer was similar to all other treatments. However, industry practice treated plots still had higher levels of SWN than all other treatments except the organically-based and 13N–5.6P–10.9K (13–13–13) fertilized plots, and was 177% higher than soil-water from inorganically treated plots as a whole. Contrast analysis indicates that plots treated with GWS fertilizers had more SWN than those treated with CRFs through 4 WAP. By 8 WAP, SWN from all treatments was at or near zero, which is likely the result of lower levels of N being released from fertilizers in combination with increased N uptake by larger plants with more expansive root systems.

Experiment 2. Plants of all cultivars treated with the GWS fertilizer initially (2 WAP) had higher foliar color ratings than those treated with CRFs (Table 4). By 8 WAP, plants treated with CRFs had similar or higher ratings compared to those treated with GWS fertilizers. These data concur with Expt. 1 and are likely due to fertilizer release properties discussed previously. Plants in Expt. 2 were slightly chlorotic when planted, indicating N deficiency. If plants had sufficient N when transplanted from flats, foliar color response due to immediate N release from GWS fertilizers may not have been as dramatic. Plants treated with Osmocote 14N–6.0P–11.6K (14–14–14) had higher ratings than plants treated with Osmocote 17N–3.0P–10.1K (17–7–12) through 4 WAP with 'Red Vista' salvia and 'Peppermint Cooler' vinca, and through 8 WAP with 'Strata' salvia. However, ratings for plants treated with 17N–3.0P–10.1K (17–7–12) were similar to those with 14N–6.0P–11.6K (14–14–14) by 8 WAP for 'Red Vista' salvia and 'Peppermint Cooler' vinca, and 12 WAP for 'Strata' salvia; and by 16 WAP foliar color ratings of all cultivars treated with 17N–3.0P–10.1K (17–7–12) were numerically higher (statistically similar) than those treated with 14N–6.0P–11.6K (14–14–14). These results concur with those from Expt. 1 in that 14N–6.0P–11.6K (14–14–14) resulted in similar foliar color to 17N–3.0P–10.1K (17–7–12) early in the experiment, but after 3 months when N was depleted from 14N–6.0P–11.6K (14–14–14), foliar ratings dropped below those of plants treated with 17N–3.0P–10.1K (17–7–12). Multiple applications of inorganic fertilizers made 8 WAP resulted in higher foliar color ratings for 'Peppermint Cooler' vinca 12 and 16 WAP, but had no affect on 'Red Vista' salvia or 'Strata' salvia (contrast analyses, Table 4). Others have reported more consistent plant performance throughout the year when multiple or split applications were made as opposed to a single application (3, 25).

Through 8 WAP, plants of all cultivars treated with organic fertilizers as a whole had similar or higher foliar color ratings than those treated with inorganic fertilizers (Table 4). By 12 WAP, this trend was reversed. Within plants treated with organically-based fertilizers, those amended with chicken manure and adjusted to a C:N ratio of 20:1 had higher foliar color ratings through 8 WAP than those treated with fertilizers adjusted to 30:1, however by 12 WAP this was reversed. Because ammonium sulfate was used to adjust the C:N ratio, it is likely that the higher ratings early in the study were due to higher levels of readily available inorganic N. More readily available inorganic N early in the study from fertilizers adjusted to 20:1 resulted in larger plants which

Table 5. Effect of selected fertilizers on foliar nitrogen (N) of 'Peppermint Cooler' vinca (Expt. 2).

Fertilizer	Foliar N (%) 8 WAP[z]	Foliar N (%) 16 WAP
14N–6.0P–11.6K CRF[y]	3.2bc[x]	2.6bc
15N–0P–12.6K GWS	3.2abc	2.5c
17N–3.0P–10.1K CRF	3.1c	2.9a
Industry standard[w]	3.3abc	2.7ab
Chicken manure + paper	3.5a	2.6bc
Beef cattle manure + paper	3.5ab	2.6bc
Dairy manure + paper	3.2abc	2.7abc
Contrast[v]		
Single vs. multiple applications[u]	NS	NS
Inorganic vs. organic	*** (3.2 vs. 3.4)	NS
Industry practice vs. inorganic	NS	NS
Industry practice vs. organic	NS	NS
CRF vs. GWS	NS	** (2.7 vs. 2.5)

[z]WAP = weeks after planting.

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

[x]Mean separation within columns by Duncan's Multiple Range test(? = 0.1).

[w]Industry practice treatment: 13N–5.6P–10.9K at 4.9 g N/m ^{2} incorporated preplant and 17N–3.0P–10.1K at 4.9 g N/m2 topdressed postplant.

[v]Group means listed below significant contrasts.

[u]Multiple applications applied at planting, 8 and 12 WAP.

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

may have required more nutrients to maintain plant health and dark foliar color. In some instances, chicken manure amended fertilizer applied at 2.5 kg/m^2 (0.5 lb/ft^2) resulted in higher ratings than when applied at 1.2 kg/m^2 (0.25 lb/ft^2), however, this was transient. Foliar color ratings of plants treated with fertilizer amended with beef cattle or dairy manure (adjusted to 20:1) were similar to those of plants fertilized with chicken manure at the same C:N ratio and rate of application. This indicates that the source of the manure component had no effect on foliar color, and C:N ratio of the applied product was the most important factor of those tested.

There were few differences in foliar N due to fertilizer treatment (Table 5). Similar to Expt. 1, at 8 WAP 'Peppermint Cooler' vinca treated with organically-based fertilizers had higher levels of foliar N than those treated with inorganic fertilizers. There were no difference between CRFs and GWS fertilizers with respect to foliar N at 8 WAP, however, by 16 WAP those fertilized with CRFs had higher foliar N. This concurs with foliar color data in that CRFs provided N later in the study while GWS fertilizers failed to provide adequate N towards the end of the study.

Multiple applications of inorganic fertilizer had no affect on growth index of 'Red Vista' salvia or 'Peppermint Cooler' vinca, and multiple applications only increased the size of 'Strata' salvia by 16% at 16 WAP (data not presented). At 8 WAP, plants fertilized with 14N–6.0P–11.6K (14–14–14) or 15N–0P–12.6K (15–0–15) were larger than those fertilized with 17N–3.0P–10.1K (17–7–12) (Table 6). This was likely due to more rapid release of nutrients from 14N–6.0P–11.6K (14–14–14) CRF compared to 17N–3.0P–10.1K (17–7–12)

Table 6. Effect of selected fertilizers on growth index of summer annuals (Expt. 2).

Fertilizer			'Red Vista' salvia		'Peppermint Cooler' vinca		'Strata' salvia	
			8 WAP[z]	16 WAP	8 WAP	16 WAP	8 WAP	16 WAP
Inorganic:	14N–6.0P–11.6K CRF[x]		21.4b[y]	23.3ab	27.9bc	50.4ab	25.0b	36.6a
	15N–0P–12.6K GWS		22.4ab	24.3a	25.5cd	51.4ab	25.5ab	32.7a
	17N–3.0P–10.1K CRF		17.3c	20.4b	23.0d	48.1b	22.1c	32.5a
	Industry practice[w]		23.4ab	26.6a	27.9bc	54.0a	26.0ab	34.9a
Organic[v]:	Beef cattle		24.7a	25.4a	31.5a	53.6ab	28.0a	35.5a
	Dairy		22.8ab	23.4ab	30.0ab	55.3a	26.9ab	35.4a
	Chicken		21.7ab	23.3ab	27.9bc	53.3ab	25.8ab	34.5a
	Chicken	20:1[u]	25.0a	26.9a	32.2a	56.0a	27.7a	34.7a
		30:1	18.4b	19.7b	23.5b	50.7b	23.9b	34.3a
		1.2 kg/m²	22.0a	25.0a	27.2a	55.8a	24.9a	34.5a
		2.5 kg/m²	21.4a	24.0a	28.5a	54.1a	26.6a	35.7a
Contrast								
Single vs. multiple applications[t]			NS	NS	NS	NS	NS	* (31.5 vs. 36.5)
Inorganic vs. organic			* (20.8 vs. 22.4)	NS	*** (25.8 vs. 28.8)	* (50.5 vs. 53.7)	** (24.4 vs. 26.3)	NS
Industry practice vs. inorganic			* (23.4 vs. 20.8)	* (26.6 vs. 23.2)	* (27.9 vs. 25.8)	NS	NS	NS
Industry practice vs. organic			NS	NS	NS	NS	NS	NS
CRF vs. GWS[s]			** (19.4 vs. 22.4)	* (21.8 vs. 24.3)	NS	NS	* (23.6 vs. 25.5)	NS

[z]Growth index = (height + width1 + width2) / 3.

[y]WAP = weeks after planting.

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

[w]Mean separation within columns, separated by lines, using Duncan's multiple range test (? = 0.1).

[v]Industry practice treatment: 13N–5.6P–10.9K at 4.9 g N/m² incorporated preplant and 17N–3.0P–10.1K at 4.9 g N/m² topdressed postplant.

[u]Organically-based fertilizer: recycled paper amended with beef cattle, dairy, or chicken manure.

[t]C:N ratio.

[s]Mulitple applications applied at planting, 8 and 12 WAP.

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

and the immediate release of nutrients from 15N–0P–12.6K (15–0–15). These results agree with Expt. 1 and research cited previously (20). By 16 WAP 'Peppermint Cooler' vinca and 'Strata' salvia treated with 17N–3.0P–10.1K (17–7–12) were similar in size to plants treated with other inorganic fertilizers, however 'Red Vista' salvia fertilized with 17N–3.0P–10.1K (17–7–12) were still smaller than those fertilized with 15N–0P–12.6K (15–0–15).

At 8 WAP, plants that received organically-based fertilizers were larger than those that received inorganic fertilizers (Table 6). At 16 WAP 'Peppermint Cooler' vinca fertilized with organically-based fertilizers were larger; however, 'Red Vista' and 'Strata' salvias fertilized with organically-based fertilizers were similar in size to those fertilized with inorganic fertilizers. For all cultivars and dates except 'Strata' salvia at 16 WAP, plants treated with fertilizer amended with chicken manure adjusted to 20:1 were larger than those treated with fertilizer amended to 30:1. Also, similar to results for foliar color, contrast analysis revealed that plants that received fertilizers amended with beef cattle manure and dairy manure were similar in size to those that received fertilizer amended with chicken manure (20:1). Only C:N ratio of organically-based fertilizers affected the size of plants, manure source and the two rates tested had no effect. SDW data followed a similar trend to growth index (data not presented).

Multiple applications of inorganic fertilizers had no effect on SWN throughout the study (data not presented). Additional N inputs from added fertilizer may have been absorbed more effectively by larger plants with more expansive root systems. Although not statistically evaluated, across all treatments it appeared as though SWN increased from 1 to 4 WAP and then began to decline by 8 WAP (Table 7). This differs from Expt. 1 where SWN for most treatments began to decline after only 2 WAP. In general, through 4 WAP, plots that received organically-based fertilizers had higher levels of SWN than those that received inorganic fertilizers. Plots treated with 15N–0P–12.6K (15–0–15) GWS fertilizer had more SWN than those treated with 14N–6.0P–11.6K (14–14–14) and 17N–3.0P–10.1K (17–7–12) CRFs at 1 WAP and more than those treated with 17N–3.0P–10.1K (17–7–12) at 4 WAP. This was likely a result of immediate release of N from GWS 15N–0P–12.6K (15–0–15) compared to more

Table 7. Effect of selected fertilizers on soil-water-N in soil-water (Expt. 2).

Fertilizer			Soil-water N[z] (ppm) 1 WAP[y]	2 WAP	4 WAP	8 WAP	12 WAP
Inorganic:	14N–6.0P–11.6K CRF[x]		8.4cd[w]	8.9bc	14.4bc	7.3bc	0.0a
	15N–0P–12.6K GWS		11.7ab	12.2bc	19.6ab	10.9ab	0.0a
	17N–3.0P–10.1K CRF		6.3d	7.4c	8.3c	6.4bc	0.3a
	Industry practice[v]		7.2cd	9.5bc	14.9bc	16.3a	0.1a
Organic[u]:	Beef cattle		11.1abc	13.7ab	26.8a	11.2ab	0.0a
	Dairy		13.1a	17.0a	25.2ab	2.6c	0.0a
	Chicken		10.8abc	12.0bc	17.4abc	7.1bc	0.1a
	Chicken	20:1[t]	11.2a	12.3a	27.4a	7.8a	0.1a
		30:1	10.3a	11.6a	9.0b	6.5a	0.1a
		1.2 kg/m^2	9.2a	9.9b	10.9b	6.5a	0.1a
		2.5 kg/m^2	12.0a	14.1a	23.8a	7.7a	0.0a
Contrast							
Single vs. multiple applications[s]			NS	NS	NS	NS	NS
Inorganic vs. organic			* (8.4 vs. 11.1)	** (8.9 vs. 12.9)	** (14.1 vs. 20.1)	NS	NS
Industry practice vs. inorganic			NS	NS	NS	NS	NS
Industry practice vs. organic			NS	NS	NS	NS	NS
CRF vs. GWS			** (7.3 vs. 11.7)	* (8.2 vs. 12.2)	* (11.8 vs. 19.6)	NS	NS

[z]NO_3^-–N + NH_4^+–N.
[y]WAP = weeks after planting.
[x]CRF = controlled-release fertilizer and GWS = granular water soluble fertilizer.
[w]Mean separation within columns, separated by lines, using Duncan's multiple range test (? = 0.1).
[v]Industry practice treatment: 13N–5.6P–10.9K at 4.9 g N/m^2 incorporated preplant and 17N–3.0P–10.1K at 4.9 g N/m^2 topdressed postplant.
[u]Organically-based fertilizer: recycled paper amended with beef cattle, dairy, or chicken manure.
[t]C:N ratio.
[s]Mulitple applications applied at planting, 8 and 12 WAP.
NS, *, **, *** = nonsignificant or significant at the 0.1, 0.01, or 0.001 level, respectively.

gradual release from CRFs. Contrast analysis revealed that similar to Expt. 1, CRFs as a whole resulted in lower levels of SWN than 15N–0P–12.6K (15–0–15) GWS fertilizer. These data agree with other research which reported urea (GWS) caused higher NO_3^- leaching rates than CRFs (Florinad and Multicote) through the first 5 months of the study, and higher leaching rates for CRFs thereafter (7). By 8 WAP, there were no differences in SWN as a result of inorganic fertilizer formulation. Plots fertilized with the industry practice treatment had higher levels of SWN than those fertilized with CRFs. By 12 WAP, SWN was negligible for all treatments.

Data from Expt. 1 indicate that using the organically-based fertilizer may result in larger, more attractive (higher foliar color ratings) plants than the inorganic fertilizers tested. However, initial mortality caused by the organically-based fertilizer and high levels of SWN suggest the product may need additional modification before it is an acceptable alternative to inorganic fertilizers. Among inorganic fertilizers, CRFs appear to be better suited for landscape use because they released less SWN and provided similar or higher quality plants (foliar color and growth index), particularly near the end of the study, compared to GWS fertilizers. The industry practice treatment offered some advantages by providing larger 'Hawaii Blue' ageratum early in the study, better foliar color for 'Peppermint Cooler' vinca 12 WAP, and larger vinca throughout the experiment. These data are in agreement with Everett (10) who reported a combination of CRF and GWS fertilizers provided higher yields and fruit size in pepper than either fertilizer alone. However, this treatment also caused higher levels of SWN through 4 WAP. The treatment consisting of 9.8 g N/m^2 (2 lb N/1000 ft^2) of 17N–3.0P–10.1K (17–7–12) was applied to determine if a single application would sustain plant growth over two successive crops. Because plants receiving this treatment had low foliar color ratings (< 4) by the end of Expt. 1, this treatment would likely be insufficient for supplying nutrients over two successive crops.

Results from Expt. 2 indicate that among inorganic fertilizers, plants treated with 15N–0P–12.6K (15–0–15) GWS appeared to benefit from immediate release of nutrients. Plants treated with CRFs required at least 4 weeks to develop dark green foliage. For each cultivar, this deficiency was more pronounced and the lag time greater for 17N–3.0P–10.1K (17–7–12) than 14N–6.0P–11.6K (14–14–14) CRF. Despite this, nutrient leaching into soil-water was greater for 15N–0P–12.6K (15–0–15) than for CRFs. These data indicate that using CRFs minimizes nutrient leaching compared to other types of fertilizers tested. There is an initial lag response in plant growth and color when using 14N–6.0P–

11.6K (14–14–14) CRF, however, within 4 weeks plants were similar in foliar color and size compared to other types of fertilizer. Initial nutrient release from organically-based fertilizers resulted in larger plants with better foliar color than other types of fertilizers tested, however as nutrients were depleted, plant appearance began to decline. In addition, SWN was higher in these plots compared to inorganically fertilized plots.

Of the fertilizer treatments tested, our data demonstrate that 14N–6.0P–11.6K (14–14–14) CRF (3 to 4 month release) provides for sufficient plant growth and development while minimizing excessive N leaching. Use of adequately fertilized plants at the time of planting is recommended due to slight lag time of N release from this fertilizer. Also, based on foliar color data for 'Peppermint Cooler' vinca, an additional application of this fertilizer at 2.45 g N/m^2 (0.5 lb N/1000 ft^2) should be applied approximately 8 WAP if plants are to remain in the landscape longer than 3 months.

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