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Evaluation of Petunia Growth Characteristics in Response to Application of a Novel Poultry-derived Fertilizer

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Abstract. **Multiple processes have been developed to reduce the negative effects of raw poultry litter application in soils by altering the physical and chemical nature into a more suitable plant nutrient product. This investigation focused on a novel aerobic digestion process using a proprietary method from Cleaned & Green (C&G) to extend the nutrient release time of fertilizer while eliminating potential pathogens. Physical and chemical characteristics were assessed on C&G fertilizer by conducting plant assays and physical testing. Petunias were grown to evaluate plant growth responses. Substrate pH and electrical conductivity (EC) were evaluated, and plant growth index, dry weight, and foliar analysis were recorded. Increasing application rates resulted in increased EC concentrations and less plant growth 2 weeks after planting. C&G replicates grown at Auburn, AL, had EC values 2 weeks after planting of 0.33, 1.43, 3.18, and 5.20 mS·cm^{-1} for 0, 0.44, 0.89, and 1.78 kg·m^{-3} N, respectively. Plants in Mobile, AL, behaved in a similar manner. Growth indices indicated that the control had the smallest size, while plants given C&G and a blended fertilizer (nutrient-even combination of C&G and a synthetic fertilizer) at 0.44 kg·m^{-3} N were the largest. Initial results suggest that the C&G fertilizer may be used similarly to a rapid-release synthetic fertilizer without the potential environmental burdens imposed by raw poultry litter applications.**

The application of controlled-release fertilizers (CRFs) is a common nutrient management strategy in North American container production of ornamental plants (Alam et al. 2009). Controlled-release fertilizers consist of a synthetic polymer coating that encases water-soluble nutrients, slowly releasing as water and temperature break down the product. Dependent on coating thickness and environmental parameters, CRFs can last from 3 to 14 months (Pasian 2013). Before the popularization of CRFs, the industry relied on conventional water-soluble fertilizers, which often have low nutrient use efficiency (Lawrencia et al. 2021; Wu 2011). These conventional fertilizers were problematic due to nutrient leaching, volatilization, and toxicity damage (Gil-Ortiz et al. 2020; Lawrencia et al. 2021). The reliance on CRFs has led to the development of species-specific recommendations to supply adequate nutrition to commonly grown crops like hydrangeas and boxwood (Clark and Zheng 2015).

The use of CRFs is not limited to the nursery industry; they are also recommended within the landscaping industry to follow best management practices (Chen et al. 2011). Even with species-specific CRFs, plants have complex nutritional requirements that change with age and season. To meet such requirements, growers can mix CRFs of different release periods or use CRFs in conjunction with a water-soluble rapid-release fertilizer (Yeager et al. 2010). Dependence on CRFs has increased due to environmental protection legislation introduced over previous decades, particularly focused on decreasing water eutrophication. The widespread adoption of CRFs is considered a best management practice that limits environmental pollution, by reducing excess nutrients within aquatic habitats (Mack et al. 2019).

Despite the benefits of CRFs, recent legislation focusing on single-use plastics in European countries has the potential to affect the industry by attempting to reduce reliance on mineral fertilizers in favor of organic-based ones (European Parliament and the Council of 5 2019). The far-reaching law allows for the use of synthetic polymers during a transitional period, after which nonbiodegradable products shall be banned and water retention (European Parliament and the Council of 5 2019). The German fertilizer ordinance takes this a step further, limiting the size and duration of use for synthetic polymers in fertilizers (Till 2017). In the United States, no federal single-use plastic bans exist, and the states that have passed such bans have not focused on fertilizers or agriculture (National Conference of State Legislatures 2021; Usman et al. 2022).

Slow-release fertilizers (SRFs) are an alternative to CRFs, lacking a synthetic coating and being dependent on microbial breakdown to mediate nutrient release (Morgan et al. 2009). Polymer products derived from cellulose have already begun to replace some single-use plastic products, and there is growing interest in the expanded use of bioplastics (RameshKumar et al. 2020). However, in areas dense in animal production, research into alternative sources lies in animal wastes (Dadrasnia et al. 2021; Hossain et al. 2021; Li et al. 2021; Mironiuk et al. 2023; Steiger et al. 2024). Recently, one product composed of recycled eggshells, wheat, and chitosan was developed as a granular product that can adsorb orthophosphate when wet and released at a later time, acting like a renewable source of nutrients (Steiger et al. 2024). Biochar, a carbon-rich, solid product produced from organic material that has undergone a pyrolysis process, has been heavily researched for slow-release characteristics (Bhatt et al. 2023; Yu et al. 2019).

Poultry litter is commonly disposed by application to agricultural fields as fertilizer. However, improper application can result in undesirable leaching of nutrients into the environment as a near-even N–P–K ratio can result in an overapplication of phosphorus (Gaskin et al. 2013). Through the process of aerobic digestion, raw poultry litter (PL) is converted into granular fertilizer through repeated processes of acidification and ammonification. The final product of the process is a generally stable, odor-free material (Martín et al. 2018; Shammas and Wang 2007). One such product is the novel PL-derived fertilizer produced by Cleaned & Green (Birmingham, AL, USA). Unlike polymer-coated CRFs, the Cleaned & Green (C&G) product is carbon-based and produced from excess poultry waste. Based on nutrient release tests, C&G is an intermediate between water-soluble synthetic fertilizers and SRFs (Linquist et al., data not shown). C&G fertilizer functions like a water-soluble synthetic, but with an extended nutrient release. Similar to an SRF, C&G fertilizer relies, in part, on microbial activity to help initiate release. Furthermore, C&G contains a blend of micronutrients rarely included in general fertilizer mixes. However, the suitability of C&G for crop production requires quantification. Therefore, the objective of this study is to grow a variety of crops using both C&G and potential market-available products to determine suitable uses for this novel fertilizer.

Materials and Methods

On 20 Mar 2024, petunias (*Petunia ×hybrida* 'Supertunia Vista Bubblegum') were transplanted into 1.98 L containers (15.24 cm standard; Dillen Products, Middlefield, OH, USA) filled with a pine bark:peat (3:1 v/v) amended substrate. Fertilizer treatments included the following: Synthetic (Syn), C&G, Blend (Syn + C&G), PL, and a control receiving no fertilization. Fertilizer treatments were applied at three rates: 0.44, 0.89, and 1.78 $kg \cdot m^{-3}$ N. The fertilizer mixes included 1% phosphorus and 1.5% potassium. Each treatment–rate combination included six replicants. All non-C&G treatments received micronutrients and lime (Tracer Micronutrient Mix; Harrell's, Lakeland, FL, USA) for equitable growing conditions. Raw PL was collected on two dates: first in March 2023 and then in March 2024, with Mobile, AL, receiving the 2023 material and Auburn, AL, receiving the 2024 material. This did not affect the C&G treatments as the source material for both locations was of the same source and date. Replicants were grown inside a greenhouse, receiving daily hand irrigation of 125 ml of water applied at the plant base for the duration of the study. The study was repeated in two locations: Auburn, AL, and Mobile, AL. Auburn irrigation water contained ~0.16 $mg \cdot kg^{-1}$ P, 2.34 $mg \cdot kg^{-1}$ K, 5.99 $mg \cdot kg^{-1}$ S, 0.15 $mg \cdot kg^{-1}$ Zn, 0.14 $mg \cdot kg^{-1}$ Cu, 14.21 $mg \cdot kg^{-1}$ Ca, 4.02 $mg \cdot kg^{-1}$ Mg, 6.68 $mg \cdot kg^{-1}$ Na, and < 0.02 $mg \cdot kg^{-1}$ B, Mn, Fe, and Al (Bartley et al. 2023). Climate conditions were monitored in both locations. Average outdoor temperatures in Auburn were 17.2 ± 4.13 °C with greenhouse temperatures set to maintain a minimum of 18.3 °C and a maximum of 25.6 °C. Average greenhouse temperatures in Mobile were 22.0 ± 6.0 °C.

Electrical conductivity (EC) and pH were collected once a week, beginning on day 0, using the pour through method (Wright 1986). Plant growth indices were recorded at weeks 2 and 4. Growth indices were calculated by multiplying plant height and two canopy widths. Representative plants were photographed at weeks 2 and 4 for visual comparison. Chlorophyll contents were measured using a Spad-502 Plus (Konica Minolta, Tokyo, Japan) in week 4. Fresh weight, dry weight, and foliar nutrient concentrations were recorded after the destructive harvest during week 4. Plants were cut at the substrate level, and fresh weights were recorded. Plant material was air-dried for 1 week at 60 °C before recording dry weights. A total of 5 g of leaf tissue from each replicant was reserved for tissue nutrient analysis. For treatments that failed to produce 5 g individually, a single representative sample was submitted for the entire treatment. For tissue analysis, all vegetative and floral growth was submitted.

Foliar testing was conducted by the Auburn Soil, Water, and Forage Laboratory (Auburn, AL, USA) for foliar concentrations of N, P, and K. Nutrient concentrations were considered deficient at the following concentrations: N (3.85%), P (0.47%), and K (3.13%) (Gibson et al. 2008). All other nutrients followed standards set by the Plant Analysis Handbook III (Bryson et al. 2014).

Statistical analysis. Plant tissue nutrition data were analyzed via PROC REG procedure of SAS 9.4 (SAS Institute Inc., Cary, NC, USA). Effects of fertilizer, rate, and the fertilizer × rate interaction on dry weight and foliar nutrient concentrations were analyzed via analysis of variance with the PROC GLIMMIX procedure. Means were separated using Tukey's honestly significant difference at a 5% α level.

Results and Discussion

EC and pH. Both locations, Auburn and Mobile, exhibited a similar downward trend of EC over time. In Auburn, initial mean EC levels recorded a high of 6.12 ± 0.76 $mS \cdot cm^{-1}$ for all fertilizer applications and dramatically dropped to 2.78 ± 4.6 $mS \cdot cm^{-1}$ within the first 2 weeks (Fig. 1A). By the conclusion of the study, treatments recorded mean EC readings at 1.22 ± 0.21 $mS \cdot cm^{-1}$. Notably, Syn was the only fertilizer to record a final mean EC level below 1 $mS \cdot cm^{-1}$. In the control, initial EC levels were 0.61 ± 0.05 $mS \cdot cm^{-1}$ and dropped to 0.18 ± 0.01 $mS \cdot cm^{-1}$. Initial EC levels were above the desired level and decreased to an acceptable level within 2 weeks. In Mobile, initial mean EC levels were 4.72 ± 3.22 $mS \cdot cm^{-1}$ for all fertilizer applications and dropped considerably to 0.9 ± 0.05 $mS \cdot cm^{-1}$ within the first 2 weeks (Fig. 1B). By the conclusion of the study, treatments recorded mean EC readings at 0.32 ± 0.05 $mS \cdot cm^{-1}$. Notably, all treatments recorded a final mean EC level below 1 $mS \cdot cm^{-1}$. In the control, initial EC levels were 0.28 ± 0.05 $mS \cdot cm^{-1}$ and dropped to 0.14 ± 0.01 $mS \cdot cm^{-1}$. Initial EC levels for Mobile plants were similarly above desirable levels but experienced a more rapid drop-off, falling below desired levels within the same time.

No significant differences in leachate pH were observed between locations, so pH will be discussed together. Over 4 weeks, pH exhibited an increasing trend over time. For continuity purposes, the remainder of the discussion on pH shall focus on the 0.89 $kg \cdot m^{-3}$ N rate similar to EC. At Auburn, the initial mean pH for all fertilizer applications was 5.7 ± 0.3 and increased to 6.1 ± 0.06 by week 2 (Fig. 2A). By the conclusion of the study, treatments recorded a mean pH of 6.0 ± 0.3. Notably, Syn and PL increased to respective pH levels of 6.5 ± 0.42 and 6.0 ± 0.2, while C&G and Blend began at 5.6 ± 0.15 and 5.8 ± 0.05, increased, and returned to their original pH levels. In the control, initial pH levels were 6.3 ± 0.09 and increased to a final pH of 6.5 ± 0.06. From initiation to conclusion, all treatment pH levels fell within an acceptable range of 5.2 to 6.8 for optimum nutrient uptake. In Mobile, the initial mean pH for all fertilizer applications was 4.9 ± 0.38 and increased to 6.5 ± 0.17 by week 2 (Fig. 2B). By the conclusion of the study, treatments recorded a mean pH of 6.9 ± 0.09. In comparison with the Auburn study, all fertilizer treatments increased from their original pH levels by ~2 units. In the control, initial pH levels were 5.8 ± 0.05 and increased to a final pH of 6.9 ± 0.04. In comparison with Auburn, initial pH levels at Mobile were below acceptable ranges and rose into the recommended range before finishing the study higher than the optimum maximum pH (Van Iersel 2020).

Fresh and dry weights. A significant difference in dry weight was observed between the two locations and by treatment × location interactions (Table 1). Petunia dry weight was affected by rate, fertilizer type, and the interaction between rate and fertilizer type ($P < 0.0001$). The locations will be discussed separately due to differing trends. There were similar observations between fresh weights and dry weights (Table 2). In Auburn, plants grown in C&G and PL at 0.44 $kg \cdot m^{-3}$ N had the greatest petunia weights. Across all treatments, application rates of 0.44 $kg \cdot m^{-3}$ N had a greater size than 0.89 or 1.78 $kg \cdot m^{-3}$ N. Despite this, plants grown in Syn at 0.44 $kg \cdot m^{-3}$ N were only of marginally greater biomass than plants grown in Blend or C&G and 0.89 $kg \cdot m^{-3}$ N and were smaller than plants grown in PL at 0.89 $kg \cdot m^{-3}$ N. Increased mortality was observed in plants grown in Syn and Blend fertilizers applied at 1.78 $kg \cdot m^{-3}$ N, with Syn experiencing a 50% mortality rate. Petunias receiving PL at 1.78 $kg \cdot m^{-3}$ N did not

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The datasets generated during and/or analyzed during the current study are available from the corresponding author on reasonable request.
During the preparation of this work the author(s) used ChatGPT in order to improve readability and the language of the work. After using this tool/service, the author(s) reviewed and edited the content to ensure accuracy and clarity and take(s) full responsibility for the content of this publication.
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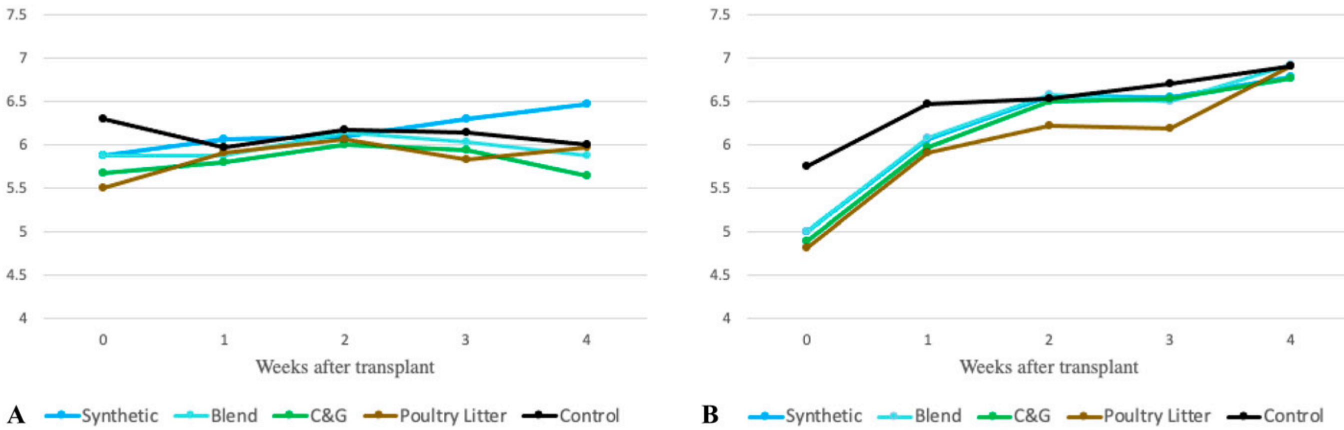

Fig. 1. pH measurements for petunias grown at the 0.89 kg·m^{-3} N rate. (**A**) Auburn measurements. (**B**) Mobile measurements. Lines present the averages of three measurements collected per treatment on a weekly basis. Treatments include synthetic, a blend of C&G and Synthetic, C&G alone, poultry litter, and a control receiving no additional fertilizer. Micronutrients (Mg, S, Cu, Fe, Mn, Mo, and Zn; rate: 0.89 kg·m^{-3}) and lime (rate: 2.96 kg·m^{-3}) were applied to all treatments. C&G = Cleaned and Green, a poultry litter–derived product.

have increased mortality but did experience stunting in growth. Petunias receiving 1.78 kg·m^{-3} N C&G demonstrated improved vitality, not losing any specimens. However, treatments applied at 1.78 kg·m^{-3} N consistently had less growth after 4 weeks, with plants grown in Syn have the least amount of growth, excluding the control. Visually, petunias fertilized with 1.78 kg·m^{-3} N PL exhibited overfertilization and stunting beginning at week 2 and remained stunted through the study conclusion. No other treatments exhibited visual nutritional deficiency.

In Mobile, plants grown in Blend, closely followed by C&G, at 0.44 kg·m^{-3} N had the greatest biomass (Table 3). Across all treatments, plants grown in applications of 0.44 kg·m^{-3} N were of greater size than plants grown in 0.89 kg·m^{-3} N or 1.78 kg·m^{-3} N. Despite this, plants grown in Syn at 0.44 kg·m^{-3} N were only marginally of greater biomass than Blend and PL and had less growth than plants grown in C&G at 0.89 kg·m^{-3} N. No increased mortality was observed in treatments applied at 1.78 kg·m^{-3} N, but treatments, excluding C&G, did experience a general stunting. Unlike petunias grown at Auburn, petunias supplied with PL resulted in plants 31% and 67% of greater mass than plants than Syn and Blend, respectively. Petunias receiving 1.78 kg·m^{-3} N C&G demonstrated improved vitality, performing comparably to C&G at 0.89 kg·m^{-3} N. Except for Blend at 0.44 kg·m^{-3} N, C&G consistently outperformed other treatments, regardless of rate. Visually, all petunias receiving fertilization appeared nutritionally sufficient through the study conclusion.

Except for PL applied at 0.44 kg·m^{-3} N, petunias in Mobile were consistently of greater biomass than petunias in Auburn. However, in both Auburn and Mobile, plants grown at the PL 1.78 kg·m^{-3} N rate were the plants with the least growth at 121% and 40%, respectively, smaller than the 0.44 kg·m^{-3} N rate. In Auburn, plants grown in C&G and Blend were of comparable weight, while Syn consistently underperformed, suggesting that C&G nutrient release is preferential for growing petunias. In

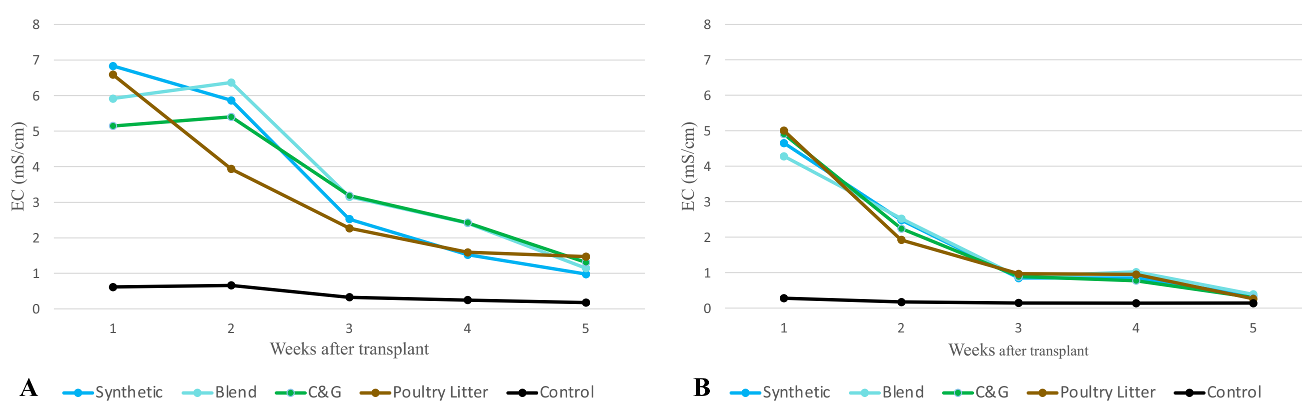

Fig. 2. Electrical conductivity (EC) measurements for petunias, which had an application of 0.89 kg·m^{-3} N. (**A**) Auburn measurements. (**B**) Mobile measurements. Lines present averages of three measurements collected per treatment on a weekly basis. Treatments include synthetic, a blend of C&G and synthetic, C&G alone, poultry litter, and a control receiving no additional fertilizer. Micronutrients (Mg, S, Cu, Fe, Mn, Mo, and Zn; rate: 0.89 kg·m^{-3}) and lime (rate: 2.96 kg·m^{-3}) were applied to all treatments. C&G = Cleaned and Green, a poultry litter–derived product.

Table 1. Analysis of variance for the effects of fertilizer treatments on the development of *Petunia ×hybrida* 'Supertunia Vista Bubblegum' for the studied traits.[i]

		P values						
Source of variation	*df*	Fresh weight	Dry weight	Growth index	Chlorophyl content	Foliar N	Foliar P	Foliar K
A: Fertilizer	12	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001
B: Rate	3	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	NS
C: Location	1	<0.0001	<0.0001	<0.0001	0.0076	NS	NS	0.0196
A × B	12	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001
A × C	12	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001
B × C	3	0.0002	0.0085	NS	0.0201	<0.0001	<0.0001	NS

[i] Treatment effects were analyzed using PROC Glimmix in SAS 9.4 (SAS Institute, Cary, NC, USA). df = degrees of freedom, NS = not significant.

Table 2. Fertilizer type and rate effects on petunia (*Petunia* ×*hybrida* 'Supertunia Vista Bubblegum') fresh and dry weights produced in Auburn, AL, USA.

Fertilizer type	Rate (kg·m^{-3} N)	Fresh weight (%)	Dry weight (%)
	0.44	22.9 bcd[i]	2.9 bcd
Synthetic[ii]	0.89	15.3 def	1.7 def
	1.78	3.8 fg	0.5 f
	0.44	30.5 abc	4.2 ab
Blend[iii]	0.89	19.5 cd	2.6 cde
	1.78	4.5 fg	0.7 f
	0.44	31.6 ab	4.4 a
C&G[iv]	0.89	17.4 de	2.5 cde
	1.78	8.3 efg	1.2 ef
	0.44	39.7 a	4.7 a
Poultry litter[v]	0.89	30.4 abc	3.3 abc
	1.78	5.7 fg	0.8 f
Control[vi]	—	3.1 g	0.5 f

[i] The data were analyzed using a one-way analysis of variance, and subsequent means were compared using the Tukey's honestly significant difference ($P \leq 0.05$). Means within a column with the same letter do not significantly differ from each other. — = no other additions were made to the control plants, C&G = Cleaned and Green.

[ii] Synthetic fertilizer was a custom blend comprised of ammonium sulfate, triple superphosphate P, potash. The amounts of N, P, and K applied to each plant were 4.22, 0.28, and 0.28 g, respectively.

[iii] Blend fertilizer was comprised of synthetic and C&G blended together at a N ratio of 1:1.

[iv] C&G is a poultry litter–based fertilizer product enhanced through a proprietary process. Its composition is 11.5N–1P–1.5K–14S.

[v] Poultry litter was collected at the Miller Poultry Science Center in Auburn, AL, on 17 Apr 2023. Its composition is 1.3N–1P–1.5K.

[vi] Control plants received only the nutrients Mg, S, Cu, Fe, Mn, Mo, and Zn (Harrell's profertilizer) at a rate of 0.48 mg/container.

Mobile, all fertilizer types performed similarly at rates of 0.44 and 0.89 kg·m^{-3} N. However, plants grown in C&G were significantly of greater biomass than petunias of other fertilizer types at 1.78 kg·m^{-3} N.

Growth indices. A significant difference in growth indices at week 2 were observed between the two locations. There were no significant interactions observed between location × treatment ($P = 0.3149$) or location × rate ($P = 0.2681$). Location ($P = 0.0003$) and rate ($P = 0.0010$) affected petunia growth indices but not fertilizer type ($P = 0.0556$). In Auburn, there were significant differences observed between fertilizer and rates ($P < 0.0001$). The Blend at the 0.44 kg·m^{-3} N rate had the largest average volume of 1172.4 cm^3, followed by PL at the same rate, 1097.9 cm^3 (Table 4, Fig. 3A). Following this, plants grown in the 0.44 kg·m^{-3} N C&G and all treatments grown at 0.89 kg·m^{-3} N had comparable volumes. The plants grown in Syn at the 0.44 kg·m^{-3} N rate were only larger than the control and 1.78 kg·m^{-3} N rate. The control and treatments at the 1.78 kg·m^{-3} N rate had the least growth, all with comparable-sized plants. In Mobile, petunia growth indices were affected by fertilizer type ($P < 0.0001$) and rate ($P = 0.0001$). Excluding the control, the only difference reported was between the 0.44 kg·m^{-3} N rate and 1.78 kg·m^{-3} N rates for Syn and Blend. The average size of plants treated with 0.44 kg·m^{-3} N, regardless of fertilizer type, was 1786.9 cm^3, and the average sizes of Syn and Blend plants were 801.7 and 774.5 cm^3, respectively (Table 5, Fig. 3B).

Week 4 plant growth indices trended similarly to petunia weights. Volumes experienced a significant difference by location ($P < 0.0001$). Petunias were affected by fertilizer type ($P < 0.0001$), rate ($P < 0.0001$), treatment × location interaction ($P < 0.0001$), and a rate × location interaction ($P < 0.0085$). In Auburn, there were significant differences observed by fertilizer type and rate ($P < 0.0001$). The 0.44 kg·m^{-3} N rate had the largest plants, with plants grown in Blend being the overall largest plants, followed by PL and C&G (Fig. 3C). The plants grown in the 0.44 kg·m^{-3} N rate of Syn were comparable to plants grown in the 0.89 kg·m^{-3} N fertilizer applications of Blend and C&G. However, plants grown in Syn at 0.89 kg·m^{-3} N had the least growth for petunias at that application rate. C&G petunias were larger than other treatments at application rates of 0.44 and 0.89 kg·m^{-3} N. The control plants were larger plants than Blend or Syn plants at the 1.78 kg·m^{-3} N rate. In Mobile, there were significant differences observed between treatments and rates ($P < 0.0001$). The plants grown at the 0.44 kg·m^{-3} N rate with C&G had the greatest volume (Fig. 3D). The plants with the least growth were grown in the control and 1.78 kg·m^{-3} N of Blend or Syn. There were few differences among all other treatments.

Petunias grown in Mobile were consistently larger plants than those in Auburn at both week 2 and week 4. Discrepancies in plant growth at 1.78 kg·m^{-3} N PL can be attributed to the age of the PL (Figs. 4 and 5). The PL used at Auburn had been recently collected, while the PL used in Mobile was significantly older material. The age of composted material has been observed to stunt plant growth (Gouin 1998). Greater degrees of stunting have been observed in 30-d-old compost compared with 90-d-old compost in other floriculture crops (Purman and Gouin 1992). However, in both Auburn and Mobile, the 1.78 kg·m^{-3} N PL rate plants had the least growth at 67.8% and 71.2%, respectively, the size of the 0.44 kg·m^{-3} N rate. In Auburn, C&G and Blend petunias were of comparable size. Syn fertilizer consistently underperformed Blend and C&G, suggesting that C&G nutrient release is preferential for growing petunias. In Mobile, all three treatments performed similarly at the rates of 0.44 and 0.89 kg·m^{-3} N. However, at 1.78 kg·m^{-3} N, C&G petunias were significantly larger

Table 3. Fertilizer type and rate effects on petunia (*Petunia* ×*hybrida* 'Supertunia Vista Bubblegum') fresh and dry weights produced in Mobile, AL, USA.

Fertilizer type	Rate (kg·m^{-3} N)	Fresh weight (%)	Dry weight (%)
	0.44	29.5 bc[i]	4.1 bc
Synthetic[ii]	0.89	30.2 abc	3.6 bcd
	1.78	6.1 d	1.9 efg
	0.44	36.7 abc	5.6 a
Blend[iii]	0.89	33.9 abc	4.0 bc
	1.78	12.0 d	1.3 fg
	0.44	38.5 ab	5.0 ab
C&G[iv]	0.89	39.2 ab	4.4 abc
	1.78	37.7 ab	4.3 abc
	0.44	26.5 c	3.3 cde
Poultry litter[v]	0.89	41.1 a	3.6 bcd
	1.78	26.5 c	2.4 def
Control[vi]	—	4.8 d	0.6 f

[i] The data were analyzed using a one-way analysis of variance, and subsequent means were compared using the Tukey's honestly significant difference ($P \leq 0.05$). Means within a column with the same letter do not significantly differ from each other. — = no other additions were made to the control plants, C&G = Cleaned and Green.

[ii] Synthetic fertilizer was a custom blend comprised of ammonium sulfate, triple superphosphate P, potash. The amounts of N, P, and K applied to each plant were 4.22, 0.28, and 0.28 g, respectively.

[iii] Blend fertilizer was comprised of synthetic and C&G blended together at a N ratio of 1:1.

[iv] C&G is a poultry litter–based fertilizer product enhanced through a proprietary process. Its composition is 11.5N–1P–1.5K–14S.

[v] Poultry litter was collected at the Miller Poultry Science Center in Auburn, AL, on 17 Apr 2023. Its composition is 1.3–1–1.5.

[vi] Control plants received only the nutrients Mg, S, Cu, Fe, Mn, Mo, and Zn (Harrell's profertilizer) at a rate of 0.48 mg/container.

Table 4. Fertilizer type and rate effects on petunia (*Petunia* ×*hybrida* 'Supertunia Vista Bubblegum') volumes and chlorophyll content produced in Auburn, AL, USA.

Fertilizer type	Rate (kg·m^{-3} N)	Growth indices (cm^3) Week 2	Growth indices (cm^3) Week 4	Chlorophyll content
	0.44	590 cde[i]	6795 bc	53.3 ab
Synthetic[ii]	0.89	657 b-e	3655 cde	45.4 bcd
	1.78	479 e	317 e	24.6 e
	0.44	1172 a	12605 a	54.5 ab
Blend[iii]	0.89	897 a-e	6287 bcd	55.0 ab
	1.78	540 e	508 e	38.4 cde
	0.44	1087 abc	10559 ab	55.3 ab
C&G[iv]	0.89	874 a-e	6837 bc	58.2 a
	1.78	579 de	1717 de	50.4 abc
	0.44	1097 ab	10747 ab	47.0 bcd
Poultry litter[v]	0.89	1055 a-d	8354 ab	50.0 abc
	1.78	744 a-e	839 e	36.5 de
Control[vi]	—	469 e	597 e	24.8 e

[i] The data were analyzed using a one-way analysis of variance and subsequent means were compared using the Tukey's honestly significant difference ($P \leq 0.05$). Means within a column with the same letter do not significantly differ from each other. — = no other additions were made to the control plants, C&G = Cleaned and Green.
[ii] Synthetic fertilizer was a custom blend comprised of ammonium sulfate, triple superphosphate P, potash. The amounts of N, P, and K applied to each plant were 4.22, 0.28, and 0.28 g, respectively.
[iii] Blend fertilizer was comprised of Synthetic and C&G blended together at a N ratio of 1:1.
[iv] C&G is a poultry litter–based fertilizer product enhanced through a proprietary process. Its composition is 11.5N–1P–1.5K–14S.
[v] Poultry litter was collected at the Miller Poultry Science Center in Auburn, AL, on 17 Apr 2023. Its composition is 1.3N–1P–1.5K.
[vi] Control plants received only the nutrients Mg, S, Cu, Fe, Mn, Mo, and Zn (Harrell's profertilizer) at a rate of 0.48 mg/container.

petunias than Blend or Syn, at 464% and 1224%, respectively.

Stunting occurred at fertilizer applications of 1.78 kg·m^{-3} N. The 4-week petunia trial did not allow stunted plants an opportunity to recover. The trials also differed in which fertilizer type and rate resulted in the largest plants. Poultry litter supplied at 1.78 kg·m^{-3} N recorded the lowest amount of growth. In Auburn, the application of fresh PL may have attributed to greater stunting compared with Mobile (Kithome et al. 1999; Steiner et al. 2010). Finally, optimum growing conditions for petunias occur around 26 °C (Warner 2010). The elevated temperatures experienced for the Mobile location were, on average, closer to the optimum temperature than in Auburn, further promoting growth across treatments.

Foliar nutrient concentrations. Foliar N concentrations were affected by a fertilizer × location interaction ($P < 0.0001$) and a rate × location interaction ($P < 0.0001$). Foliar N concentrations were affected by fertilizer type ($P < 0.0001$) and rate ($P < 0.0001$) but not location ($P = 0.9084$). In Auburn, all fertilizer types supplied at 0.89 and 1.78 kg·m^{-3} N recorded plants sufficient in N. The highest concentrations of foliar N resulted from applications of 1.78 kg·m^{-3} N PL, 1.78 kg·m^{-3} N C&G, and 0.89 kg·m^{-3} N Syn at 6.49%, 6.17% ± 0.53%, and 6.17%, respectively (Table 6). Plants grown with synthetic applied at 0.44 kg·m^{-3} N had a foliar N concentration of 3.84% ± 0.30%. Plants grown with the Blend, PL, and C&G applied at 0.44 kg·m^{-3} N were of comparable foliar N concentrations between 2.37% and 2.9%. All fertilized petunias had nominally higher foliar N than the control. Although PL applied at 0.44 kg·m^{-3} N recorded the petunias of greatest weight, its foliar N concentration was the lowest of any fertilizer and rate combination.

In Mobile, all treatment combinations had sufficient foliar N with the exception of control, 0.44 kg·m^{-3} N Blend, 0.44 kg·m^{-3} N, and 0.89 kg·m^{-3} N PL (Table 7). Petunias fertilized with C&G and Syn at the 1.78 kg·m^{-3} N had the highest foliar concentrations of N: 6.13% ± 0.4% and 5.85% ± 0.35%, respectively (Table 3). All other treatment combinations had comparable foliar N concentrations between 5.74% and 4.01%. Although plants

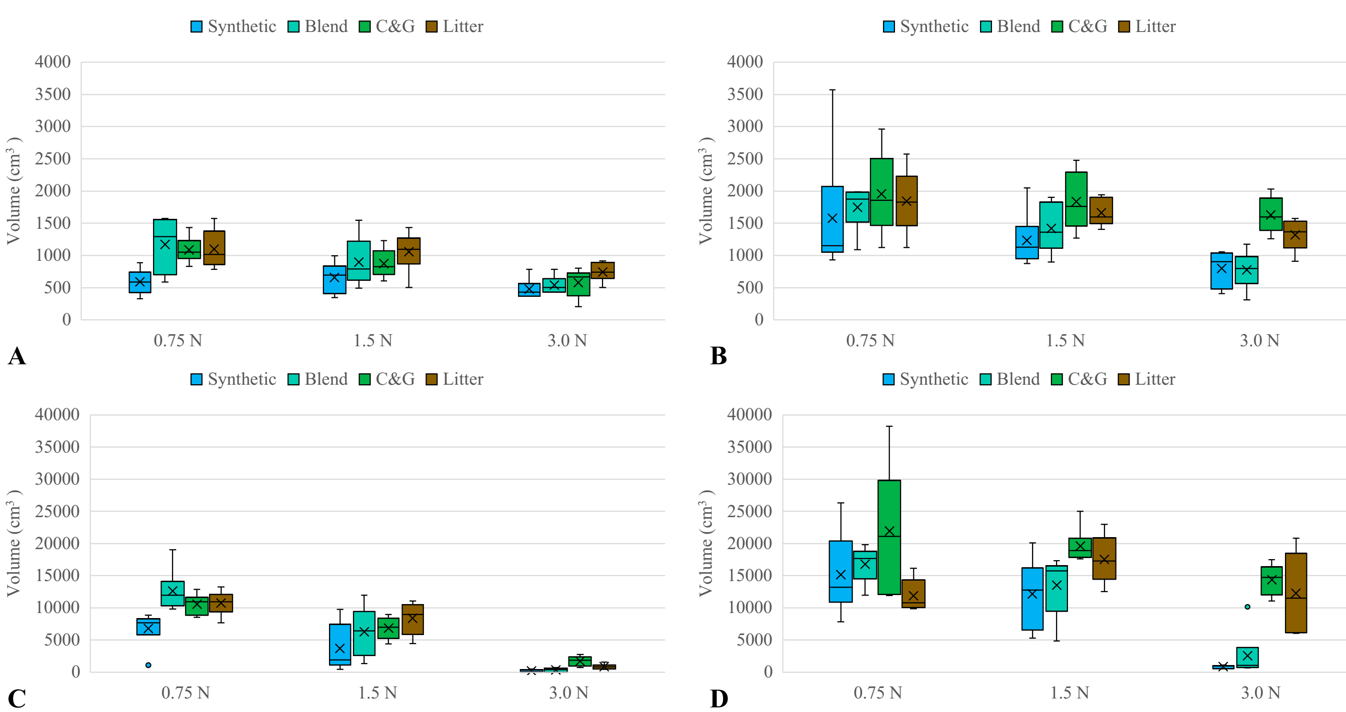

Fig. 3. (**A**, **B**) Two-week volumes for 0.89 kg·m^{-3} N. (**A**) Auburn measurements. (**B**) Mobile measurements. (**C**, **D**) Four-week volumes for 0.89 kg·m^{-3} N. (**C**) Auburn measurements. (**D**) Mobile measurements. Plants are grouped according to rate of application. Treatments include synthetic, a blend of C&G and synthetic, C&G alone, poultry litter, and a control receiving no additional fertilizer. Micronutrients (Mg, S, Cu, Fe, Mn, Mo, and Zn; rate: 0.89 kg·m^{-3}) and lime (rate: 2.96 kg·m^{-3}) were applied to all treatments. C&G = Cleaned and Green, a poultry litter–derived product.

Table 5. Fertilizer type and rate effects on petunia (*Petunia* ×*hybrida* 'Supertunia Vista Bubblegum') volumes and chlorophyll content produced in Mobile, AL, USA.

Fertilizer type	Rate ($kg \cdot m^{-3}$ N)	Growth indices (cm^3) Week 2	Week 4	Chlorophyl content
	0.44	1577 abc[i]	10755 abc	45.2 ab
Synthetic[ii]	0.89	1234 a-d	7892 be	45.4 ab
	1.78	801 bcd	657 e	28.5 de
	0.44	1774 ab	14710 ab	48.0 ab
Blend[iii]	0.89	1417 abc	9898 a-d	48.4 ab
	1.78	774 cd	1736 de	35.5 cd
	0.44	1954 a	16238 a	45.7 ab
C&G[iv]	0.89	1836 a	13237 abc	49.4 a
	1.78	1626 abc	8042 b-e	46.5 ab
	0.44	1840 a	11315 abc	35.8 cd
Poultry litter[v]	0.89	1660 abc	12950 abc	40.7 bc
	1.78	1319 a-d	6557 cde	45.5 ab
Control[vi]	—	460 d	1827 de	25.4 e

[i] The data were analyzed using a one-way analysis of variance and subsequent means were compared using the Tukey's honestly significant difference ($P \leq 0.05$). Means within a column with the same letter do not significantly differ from each other. — = no other additions were made to the control plants, C&G = Cleaned and Green.

[ii] Synthetic fertilizer was a custom blend comprised of ammonium sulfate, triple superphosphate P, potash. The amounts of N, P, and K applied to each plant were 4.22, 0.28, and 0.28 g, respectively.

[iii] Blend fertilizer was comprised of synthetic and C&G blended together at a N ratio of 1:1.

[iv] C&G is a poultry litter–based fertilizer product enhanced through a proprietary process. Its composition is 11.5N–1P–1.5K–14S.

[v] Poultry litter was collected at the Miller Poultry Science Center in Auburn, AL, on 17 Apr 2023. Its composition is 1.3N–1P–1.5K.

[vi] Control plants received only the nutrients Mg, S, Cu, Fe, Mn, Mo, and Zn (Harrell's profertilizer) at a rate of 0.48 mg/container.

grown in PL at the 0.44 $kg \cdot m^{-3}$ N rate had the greatest weight, foliar N was the lowest. Petunias supplied with C&G at 0.44 $kg \cdot m^{-3}$ N had higher foliar N concentrations than PL at 0.44 and 0.89 $kg \cdot m^{-3}$ N by 12% and 50%, respectively. Poultry litter applied at 0.44 $kg \cdot m^{-3}$ N had 59% higher foliar N than the control.

Petunias grown in Auburn recorded higher foliar N concentrations than those grown in Mobile. While both locations used litter from the same source, the petunias grown in Mobile used leftover material from 2023, while petunias grown in Auburn received fresh material collected in Mar 2024. The average PL-fertilized petunia grown in Auburn had foliar N concentrations 63% higher than those grown in Mobile. As PL ages, nitrogen is lost through ammonia volatilization, reducing N availability (Kithome et al. 1999; Steiner et al. 2010). Nitrogen application has a greater effect on plant growth than P or K. However, insufficient application of either P or K may affect N uptake (Alvarado-Camarillo et al. 2018; Kim and Li 2016).

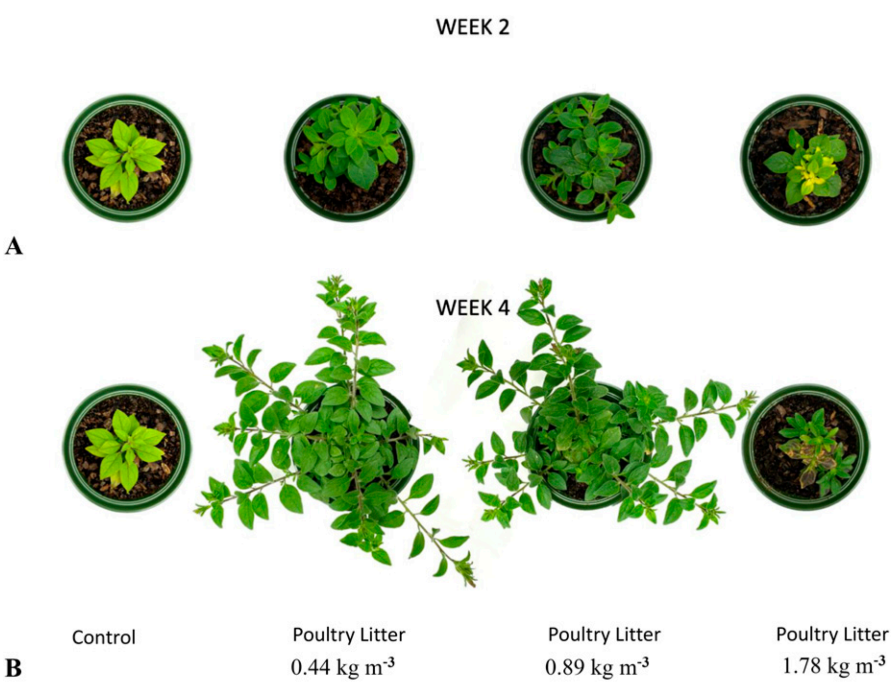

Fig. 4. Overhead view of petunias receiving poultry litter at the rates 0, 0.44, 0.89, and 1.78 $kg \cdot m^{-3}$ N grown in Auburn. (**A**) Two-week overhead view. (**B**) Four-week overhead view. Micronutrients (Mg, S, Cu, Fe, Mn, Mo, and Zn; rate: 0.89 $kg \cdot m^{-3}$) and lime (rate: 2.96 $kg \cdot m^{-3}$) were applied to all treatments.

Foliar P concentrations were affected by fertilizer × location ($P < 0.0001$) and rate × location interactions ($P < 0.0001$). Foliar P concentrations were affected by nutrient source ($P < 0.0001$) and rate ($P < 0.0001$) but not by location ($P = 0.6877$). In Auburn, petunias given PL applied at 0.89 $kg \cdot m^{-3}$ N contained the highest foliar concentrations of P at 0.58% ± 0.1% (Table 6). With few exceptions, fertilizers applied at 0.89 $kg \cdot m^{-3}$ N and 1.78 $kg \cdot m^{-3}$ N contained comparable foliar P at 0.45% ± 0.04%. The only fertilizer and rate combinations that resulted in sufficient foliar P concentrations were 0.44 $kg \cdot m^{-3}$ N PL, 0.89 $kg \cdot m^{-3}$ N Syn, 1.78 $kg \cdot m^{-3}$ N C&G, and 1.78 $kg \cdot m^{-3}$ N Blend. Petunias fertilized at a rate of 0.44 $kg \cdot m^{-3}$ N contained the next lowest foliar P concentrations, averaging 0.19% ± 0.03% across all fertilizer types. Although not statistically significant, 0.44 $kg \cdot m^{-3}$ N C&G foliar P concentrations were 23% and 33% higher than Syn and Blend, respectively.

In Mobile, petunias fertilized with PL at 1.78 $kg \cdot m^{-3}$ N contained the highest concentrations of P at 0.56% ± 0.2%. Petunias fertilized with 0.89 and 1.78 $kg \cdot m^{-3}$ N C&G, 0.44 and 0.89 $kg \cdot m^{-3}$ N PL, 1.78 $kg \cdot m^{-3}$ N Syn, and 1.78 $kg \cdot m^{-3}$ N Blend contained comparable foliar P concentrations between 0.41% and 0.52%. However, PL at the 0.89 $kg \cdot m^{-3}$ N rate and C&G at the 1.78 $kg \cdot m^{-3}$ N rate were the only treatment combinations that resulted in sufficient foliar P concentrations for greenhouse petunias. With few exceptions, petunias fertilized at the 0.44 $kg \cdot m^{-3}$ N rate contained the lowest foliar P concentrations ranging from 0.17% ± 0.02% to 0.33% ± 0.14%. Blend at the 0.89 $kg \cdot m^{-3}$ N rate had similar foliar P concentrations to petunias fertilized at 0.44 $kg \cdot m^{-3}$ N but was nominally higher. Although similar, foliar P concentrations in petunias receiving 0.44 $kg \cdot m^{-3}$ N C&G were nominally higher than Syn and Blend at similar rates: 23% and 25%, respectively. Soilless substrates have a limited capacity for retaining P, with liming agents further reducing soluble P in peat and pine bark (Argo and Biernbaum 1996; Bartley et al. 2023; Whipker 2014). In addition to insufficient application, substrate absorption characteristics may have contributed to deficient foliar P concentrations. However, only the control appeared visibly deficient, suggesting that the recommended foliar P concentrations may be higher than what is required for market-quality plant health. Previous studies have recorded quality crops using low-P fertilizers (Winsor 1968). Furthermore, plants receiving lower P rates have exhibited higher rates of P efficiency with limited effects on flowering (Kim and Li 2016).

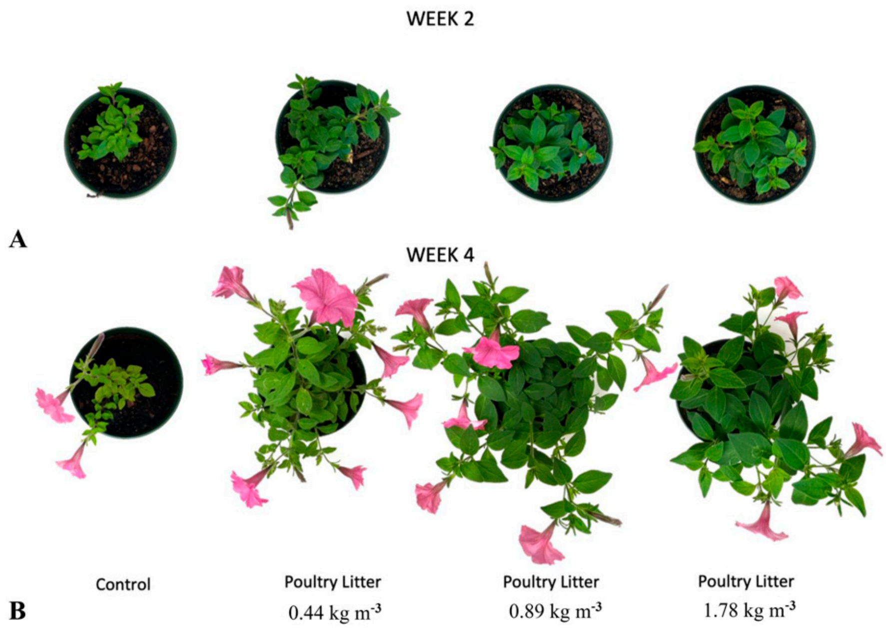

Fig. 5. Overhead view of petunias receiving poultry litter at the rates 0, 0.44, 0.89, and 1.78 kg·m^{-3} N grown in Mobile. (**A**) Two-week overhead view. (**B**) Four-week overhead view. Micronutrients (Mg, S, Cu, Fe, Mn, Mo, and Zn; rate: 0.89 kg·m^{-3}) and lime (rate: 2.96 kg·m^{-3}) were applied to all treatments.

Foliar K concentrations were affected by fertilizer × location ($P < 0.0001$) and fertilizer × rate interactions ($P < 0.0001$). Concentrations were affected by fertilizer type ($P < 0.0001$) and location ($P = 0.0196$), but not rate ($P = 0.9158$). Foliar K concentrations between the Auburn and Mobile locations trended similarly, with petunias fertilized with PL containing the highest concentrations of P, and only PL applications resulted in sufficient foliar K concentrations. In Auburn, few differences in foliar K concentrations were recorded between Syn, Blend, and C&G fertilizers. However, petunias receiving 0.89 kg·m^{-3} N contained 47.8% more foliar K than petunias receiving 0.44 kg·m^{-3} N. Although similar to other fertilizer combinations, foliar K concentrations were nominally lowest for C&G applied at 0.44 kg·m^{-3} N at 1.42% ± 0.12%.

In Mobile, few statistical differences in foliar K concentrations were recorded across Syn, Blend, and C&G treatments. Foliar K concentrations were highest in petunias fertilized with PL at 0.44 and 0.89 kg·m^{-3} N. Following these treatments, C&G at the 1.78 kg·m^{-3} N rate and the control. There were no differences in remaining treatments with foliar K being the lowest for Syn at the rate the 0.89 kg·m^{-3} N at 1.99% ± 0.51%. Notably, between locations, petunias grown in Mobile contained, on average, 25% more K than petunias grown in Auburn. Despite treatments falling short of sufficiency in K concentrations, petunias were of marketable quality. Similar research has similarly resulted in marketable petunias and other bedding plants with foliar K concentrations below recommended levels (Alvarado-Camarillo et al. 2018; Burnett et al. 2016). While K was low in foliar concentration in many petunias, foliar Mg was sufficient. Furthermore, while K has an antagonistic relationship with Mg, the effect is not mutual and is not a limiting factor in plant uptake of K (Xie et al. 2021). Rather than competitive effects, the low foliar K concentrations observed in this study were likely the result of the underapplication of K in the fertilizer treatments.

Few differences were observed in foliar concentrations of Ca, Mg, and other micronutrients (Bryson et al. 2014). All treatments were deficient in Ca, ranging in foliar concentrations from 0.56% to 0.91%. All treatments, except PL for the 0.44 and 0.89 kg·m^{-3} N rates, satisfied the minimum sufficiency requirement of 0.33% in Mg (Bryson et al. 2014). All treatment combinations had Mg foliar concentrations ranging from 0.31% to 0.52%. For boron (B), only PL and Syn applied at rates of 0.89 and 1.78 kg·m^{-3} N, and Blend applied at rates of 1.78 kg·m^{-3} N met the foliar tissue analysis sufficiency requirement of 18 mg·kg^{-1} for petunias. All other treatment combinations resulted in B foliar concentrations ranging from 12 to 17 mg·kg^{-1}. All fertilizer and rate applications resulted in manganese sufficiency levels of 44 mg·kg^{-1}, ranging from 68 to 169 mg·kg^{-1}. Except for C&G at 0.44 kg·m^{-3} N, all fertilizer treatments resulted in foliar concentrations exceeding the zinc sufficiency level of 33 mg·kg^{-1} and ranged from 27 to 104 mg·kg^{-1}. Excessive Zn may result in decreased leaf area, chlorosis, and eventually necrosis (Fukao et al. 2011; Glińska et al. 2016). All fertilizer treatments, except for C&G and Blend applied at 0.44 kg·m^{-3} N, met the iron sufficiency level of 84 mg·kg^{-1}, ranging from 71 to 130 mg·kg^{-1}. Additional micronutrients applied to petunias receiving Syn, Blend, and PL resulted in comparable foliar micronutrient ranges to petunias given C&G, and no visual deficiency was prevalent for the nutrients. Plants fertilized with C&G were of similar foliar micronutrient concentrations as applying Syn with a micronutrient fertilizer. These results suggest that C&G, applied alone or incorporated in a blend, has the potential to supply micronutrient for short-term, container-grown crops.

Chlorophyll content. Chlorophyll content was different between location ($P < 0.0001$) and treatment × location ($P < 0.0001$). Between Auburn and Mobile replications, petunia chlorophyll concentrations were affected by treatment ($P < 0.0001$) and rate ($P < 0.0001$). Petunia chlorophyll content in Auburn was, on average, 9.4% higher than in Mobile. Such discrepancy could be the result of differences in time or weather during data collection. Despite these differences, both locations exhibited similar trends in response to fertilizer treatments. The highest chlorophyll content resulted from applications of 0.89 kg·m^{-3} N C&G at both locations. In petunias, Soil Plant Analysis Development (SPAD) readings below 40 indicate nutrient deficiency (Smith et al. 2004). At both locations, Syn and Blend applied at 1.78 kg·m^{-3} N and the control fell below this threshold. Additionally, in Auburn, PL at 1.78 kg·m^{-3} N and, in Mobile, the PL at 0.89 kg·m^{-3} N also fell below this threshold (Tables 4 and 5). All other treatments can be considered sufficient with few differences recorded. Correlations between chlorophyll content and N concentration have been recorded (Fontes and Ronchi 2002; Jiang et al. 2017; Ulissi et al. 2011). In Auburn, the high levels of N, particularly in PL, applied may have induced toxicity, limiting growth, and causing yellowing leaves. In Mobile, petunias lacked the degree of damage observed in Auburn, although both treatments at 1.78 kg·m^{-3} N experienced similar declines in volume and weight, suggesting similar trends (Tables 2 and 3).

Conclusions

Overall, C&G, both as a stand-alone and blended nutrient source, has shown positive effects on plant growth. It was less volatile than the ammonium sulfate blend of synthetic fertilizer used in these assays, resulting in fewer plant fatalities. In the event of fertilizer overapplication, plants supplied with C&G rebounded quicker than synthetic fertilizers. Fertilizing with C&G resulted in petunias having similar foliar micronutrient concentrations as those treated with Syn and a micronutrient fertilizer, suggesting that C&G, whether applied alone or blended, has the potential to replace micronutrient fertilizers for short-term (4 weeks), container-grown crops. Application rates of 0.89 kg·m^{-3} N rate and lower are preferable for petunia production. Applications above the 0.89 kg·m^{-3} N rate may result in plants of lessened growth.

The Cleaned & Green product has the potential to be a commercial alternative to current synthetic fertilizers in greenhouse production. This novel, litter-based product has the greatest potential in short-duration production systems in which irrigation and leachate fractions can be carefully controlled. The fertilizer has the potential as a starter fertilizer for longer-duration

Table 6. Fertilizer type and rate effects on petunia (*Petunia ×hybrida* 'Supertunia Vista Bubblegum') tissue macronutrient concentrations produced in Auburn, AL, USA.

Fertilizer type	Rate (kg·m^{-3} N)	Nitrogen (%)	Phosphorus (%)	Potassium (%)
	0.44	3.84 cd[i]	0.18 d	1.76 d
Synthetic[ii]	0.89	6.17 a	0.48 abc	1.87 d
	1.78	5.71 ab	0.45 abc	2.29 d
	0.44	2.90 de	0.16 d	1.46 d
Blend[iii]	0.89	4.93 abc	0.30 dc	1.82 d
	1.78	5.76 ab	0.48 abc	2.28 d
	0.44	2.87 de	0.23 d	1.42 d
C&G[iv]	0.89	5.09 abc	0.37 bc	1.67 d
	1.78	6.17 a	0.49 ab	2.26 d
	0.44	2.37 e	0.46 abc	3.95 bc
Poultry litter[v]	0.89	4.05 bcd	0.58 a	4.79 ab
	1.78	6.49 a	0.46 abc	5.60 a
Control[vi]	—	1.25 e	0.16 d	2.62 cd

[i] The data were analyzed using a one-way analysis of variance and subsequent means were compared using the Tukey's honestly significant difference ($P \leq 0.05$). Means within a column with the same letter do not significantly differ from each other. — = no other additions were made to the control plants, C&G = Cleaned and Green.
[ii] Synthetic fertilizer was a custom blend comprised of ammonium sulfate, triple superphosphate P, potash. The amounts of N, P, and K applied to each plant were 4.22, 0.28, and 0.28 g, respectively.
[iii] Blend fertilizer was comprised of synthetic and C&G blended together at a N ratio of 1:1.
[iv] C&G is a poultry litter–based fertilizer product enhanced through a proprietary process. Its composition is 11.5N–1P–1.5K–14S.
[v] Poultry litter was collected at the Miller Poultry Science Center in Auburn, AL, on 17 Apr 2023. Its composition is 1.3N–1P–1.5K.
[vi] Control plants received only the nutrients Mg, S, Cu, Fe, Mn, Mo, and Zn (Harrell's profertilizer) at a rate of 0.48 mg/container.

Table 7. Fertilizer type and rate effects on petunia (*Petunia ×hybrida* 'Supertunia Vista Bubblegum') tissue macronutrient concentrations produced in Mobile, AL, USA.

Fertilizer type	Rate (kg·m^{-3} N)	Nitrogen (%)	Phosphorus (%)	Potassium (%)
	0.44	4.01 cde[i]	0.18 e	2.46 c
Synthetic[ii]	0.89	5.74 ab	0.33 cde	2.93 bc
	1.78	5.85 a	0.45 abc	2.00 c
	0.44	4.02 cde	0.35 b-d	2.71 c
Blend[iii]	0.89	5.66 ab	0.18 e	2.72 c
	1.78	5.33 abc	0.42 a-d	2.43 c
	0.44	3.18 def	0.23 de	2.39 c
C&G[iv]	0.89	5.06 abc	0.41 a-d	2.44 c
	1.78	6.13 a	0.52 ab	3.11 abc
	0.44	1.93 fg	0.4 a-d	6.15 ab
Poultry litter[v]	0.89	2.81 efg	0.49 abc	6.19 a
	1.78	4.45 bcd	0.56 a	5.01 abc
Control[vi]	—	1.05 g	0.20 de	2.98 abc

[i] The data were analyzed using a one-way analysis of variance and subsequent means were compared using the Tukey's honestly significant difference ($P \leq 0.05$). Means within a column with the same letter do not significantly differ from each other.
[ii] Synthetic fertilizer was a custom blend comprised of ammonium sulfate, triple superphosphate P, potash. The amounts of N, P, and K applied to each plant were 4.22, 0.28, and 0.28 g, respectively.
[iii] Blend fertilizer was comprised of synthetic and C&G blended together at a N ratio of 1:1.
[iv] C&G is a poultry litter–based fertilizer product enhanced through a proprietary process. Its composition is 11.5N–1P–1.5K–14S.
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[vi] Control plants received only the nutrients Mg, S, Cu, Fe, Mn, Mo, and Zn (Harrell's profertilizer) at a rate of 0.48 mg/container.

crops. At this time, use as the primary fertilizer source for outdoor container production is not recommended.

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