Impact of Fertilization on Vinca (*Catharanthus roseus* L.) Grown in Binary Mixtures of Sugarcane Filter Press Mud and Vermiculite[1]

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Abstract

Filter press mud (FPM) is a waste product of the sugar manufacturing industry that is primarily composed of soil, finely ground sugarcane (*Saccharum spp.*) stalks, and lime. It is widely used as a soil amendment wherever sugarcane is produced. This study sought to investigate the impact of fertilization with potassium nitrate on the growth of vinca (*Cataranthus roseus* L.) being grown in mixtures of FPM and vermiculite. The purpose of the study was to investigate the nutrient-supplying ability of the FPM-based growing medium. A completely randomized factorial design was installed into 18-count landscape trays, with each cell consisting of a different growing medium by fertilization treatment. While the bulk density of FPM-based growing media tended to be higher than Fafard™ 2, plant growth was not stunted. Electrical conductivity and pH were not deleterious to the plants in any of the FPM treatments. Fertilization increased plant growth and development in all treatments in comparison to non-fertilized controls. The 1:1 FPM and vermiculite mixture by volume had the greatest increase in growth from fertilization while the least change in growth from fertilization occurred with the 100 percent FPM treatment. When using FPM as a growing medium, it appears that the fertilization practices might be decreased to take advantage of the nutrients released by the growing medium.

Index words: cachaza, sugar mill, alternative growing medium, mill mud.

Species used in this study: vinca (*Cataranthus roseus* L.).

Significance to the Horticulture Industry

Growers who might choose to use Filter Press Mud (FPM) need to be aware of its nutrient-supplying ability and its suitability as a growing medium. This paper seeks to quantify the need for fertilization with potassium nitrate over a range of mixtures of FPM with vermiculite. This paper shows that FPM is suitable for growing vinca and that fertilization is required for maximum growth.

Introduction

Filter Press Mud (FPM) is a waste product of the sugar manufacturing industry that is composed of the solids flocculated out of the sugarcane juice by calcium phosphate. These solids include ash from sugarcane, soil, waxes, sugars, and plant residue consisting mostly of stems. The flocculate is mixed with water and pumped out into settling ponds. The ponds fill with FPM, and eventually dry out. During the off-season, the material is removed and applied to agricultural fields, usually in close proximity to the sugarcane mill (Qureshi et al. 2001). One analysis concluded that it would only be profitable to apply FPM to fields with sandy soils within 16 km (10 mi) of the sugarcane mill, and that the optimum rate for yields would be adding a 20 to 25 cm (8 to 10 in) depth of FPM to the soil (El-Hout 2008). Currently, only one sugar mill, in Clewiston, FL, is located in an area with sandy soils.

Some fertilizer components have doubled in price over the past 10 years (USDA 2012). Controlled release fertilizer (CRF) is more expensive than mineral salt fertilizer, leading some researchers to examine alternatives such as pasteurized poultry litter (Broschat 2008). FPM contains many nutrients needed for plant growth, especially nitrogen, phosphorus, and calcium (Stofella and Graetz 1996).

FPM has been evaluated for some horticultural uses, but has not been adopted as a growing medium or amendment by nurserymen in most of the United States. The exception was the Lower Rio Grande Valley of Texas where a commercial facility (Natural Soil Solutions, LLC, Santa Rosa, TX) produced a FPM-based product for ornamental and landscape use. Their product, however, did make use of ash, bagasse, and mulch, which were added to the FPM and co-composted. This company, however, is no longer in business. In Florida, Poole and Conover (1989) found that a FPM-based product with high pH and EC produced *Gardenia jasminoides* Ellis poorly; however, *Dieffenbachia spp.* grew as well in this commercial growing medium as it did in reed-sedge peat and better than it did in pine bark. Soltanzad et al. (1982) reported that plant height and stem diameter of *Chrysanthemum morifolium* Ramat. was higher in plants grown in FPM in comparison with plants grown in sphagnum peat-based media. Plants grown in FPM also produced the numerically most leaves but the difference was not significant. Stofella et al. (1996) found that *Citrus spp.* rootstock seedling growth was improved by FPM addition. Stofella and Graetz (1996) and Berrospe-Ochoa et al. (2012) investigated the use of FPM as a growing medium for the production of tomato (*Lycopersicum esculentum* L.) transplants. Both found no difference in percent germination between FPM and sphagnum peat commercial mixtures; however Stofella and Graetz found that plants grown in FPM were shorter and had fewer roots while Berrospe-Ochoa et al. found the opposite to be true. In these studies, the impact of fertilization on growth of plants grown in FPM growing medium was not addressed.

Vinca was chosen as a suitable test plant based on some preliminary knowledge and testing of the growing medium. FPM is known to hold water, have high levels of phosphorus, and a pH near or above 7.0 (Gilbert et al. 2008; Stofella and Graetz 1996). The objective of this experiment was to deter-

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mine if FPM was capable of supplying a significant portion of the nutrients required for plant growth and development.

Methods and Materials

Vinca growth trial. FPM that was pile aged for over 12 months was mixed with fine vermiculite (Therm-o-rock, Chandler, AZ) in 4 different volumetric ratios of FPM:vermiculite: 9:1, 3:1, 2:1, and 1:1. Initial pour-thru readings of the vermiculite indicated a pH of 9.5 and an EC of 0.1 mS·cm^{-1}. Individual cells (263 mL (16.1 in^3), 7.9 × 5.6 × 8.3 cm (3.12 × 2.2 × 3.3 in)) of a TSS 18 count landscape tray (Landmark Plastic, Akron, OH) were filled with 100% FPM, one of the FPM:vermiculite mixtures, or Fafard™ 2 (57% Sphagnum peat, 20% perlite, 23% vermiculite, Conrad Fafard, Inc, Agawam, MA).

The trays were placed under irrigation one day before planting. Approximately 10 mm (0.4 in) of overhead irrigation was applied daily. The irrigation water had a pH of 7.4 and an EC of 1.0 mS·cm^{-1}. Cell liners (288 OCT plug Tray, Landmark Plastic, Akron OH); cells size 2.1 cm (0.83 in) wide by 2.5 cm (1.0 in) deep, with a rooting volume of 6.7 mL (0.4 in^3) of 'Cooler Coconut' vinca were obtained from Knox Nursery, Winter Garden, FL, and planted on April 11, 2013. Per cell, 100 mL (3.4 oz) of 100 mg·mL^{-1} (13.4 oz·gal^{-1}) N KNO3 was applied to the fertilized treatment units weekly. Observations during growth were made on leaf color and first flowering date. Leaf Color was rated using the uppermost fully developed leaf on a 0 to 5 scale similar to that used by Broschat (2003) where 1 is severe chlorosis/completely white, 3 is moderate chlorosis and 5 is dark green. Leaf color was rated 11, 19, 26, and 39 days after planting.

Plants were harvested May 25, 2013, and data were taken on plant height, number of flowers, number of branches and dry weight. Shoots were cut at the soil surface and dried at 48 C until there was no change in weight.

Starting and ending pH and EC were measured using the pour-thru technique (Cavins et al. 2000) using a Hanna HI 98130 (Hanna Instruments Inc, Woonsocket, RI). Leachate from each substrate by fertilizer combination were combined and then measured. Initial bulk density was measured by drying a 1 L sample of the substrate at 120 C until no weight change occurred, and weighing it. Total porosity was measured by saturating the same sample used to determine bulk density, and weighing it to determine the weight of the water added. A single sample was sent for nutrient analysis of the filter press mud at the Everglades Soils Testing Lab in Belle Glade, FL, to determine available levels of phosphorus (P), potassium (K), calcium (Ca), magnesium (Mg) and Iron (Fe). Phosphorus was measured using a water extraction followed by measurement using the ascorbic acid-molybdenum blue method and a probe colorimeter (Murphy and Riley 1962). Potassium, calcium (Ca), magnesium (Mg) were extracted with 0.5 N acetic acid (Morgan et al. 2009). Iron (Fe) was extracted with 6N hydrochloric acid. Potassium, Ca, Mg, and Fe was measured by atomic absorption spectrometry. The pH was 7.36, the water soluble P was 89.71 mg·kg^{-1}, the acetic acid available K was 217.65 mg·kg^{-1}, Ca was 13,509 mg·kg^{-1}, Mg was 1,989 mg·kg^{-1} and Fe was 5.40 mg·kg^{-1}.

The experiment was designed as a factorial design with six growing media and two rates of fertilization. The experiment was laid out using a completely randomized design with each cell of the tray being a treatment unit with one plant. Each substrate by fertilization treatment was replicated nine times. Statistical analysis was done with JMP 8.0 (SAS Institute, Cary, NC) using a least-squares fit model. Means separations were accomplished with a student's t-test when the model indicated statistical significance.

Nutrient leaching trial. A follow-up study to determine the nutrient release characteristics of FPM was performed using one sample of 12-month aged FPM from the same sugar mill. The sample delivered from the sugar mill was approximately 7.6 m^3 (10.0 yds^3). A 75.7 L (2.67 ft^3) subsample representing shovel loads from different spots on the pile was then used for the experiment. Nitrate-nitrogen (NO_3-N), ammonium-nitrogen (NH_4-N), phosphate-phosphorus (PO_4-P), and potassium (K) release characteristics were determined by packing the FPM into 5.1 cm (2.0 in) by 30 cm (11.8 in) cylindrical PVC containers, and collecting the daily leachate following 2.5 cm (1 in) of irrigation with deionized water. Leachate was filtered to remove particulate matter. The one sample was divided among 3 containers. Every eight days, the volume of composite leachate was measured and a 20 mL subsample was taken and frozen until analysis could be performed. The experiment was conducted for 64 days. Total mass of nutrients leached was calculated by multiplying the concentration of a nutrient in the eight-day composite leachate by the volume leached over eight days. Masses of nutrients collected over the 8 day periods were then summed to arrive at a total mass for the 64 day period.

Leachate was prepared for analysis by dilution in 5 mL vials so that the concentration could be interpolated on the standard curve. Nitrate-nitrogen [U.S. EPA method 353.2 (U.S. EPA 1993b)], NH_4-N [U.S. EPA method 350.1 (U.S. EPA 1993a)], and PO_4-P [U.S. EPA method 365.1 (U.S. EPA 1993c)] analysis were performed by colorimetry with a Seal Autoanalyzer 3 (Seal Analytical, Mequon, WI). Analysis for K was performed by atomic absorption spectrometry with a PerkinElmer AAnalyst 400 (PerkinElmer, Waltham, MA). Both machines were located at the UF/IFAS Fort Lauderdale Research and Education Center.

Results and Discussion

Vinca growth trial. There was little difference in initial or final pH among the treatments. All treatments had pH values in excess of 5.6 (Table 1), which was considered ideal for vinca by Thomas et al. (2012). Electrical conductivity was below the high threshold (1.0 mS·cm^{-1} via 2:1 method or 2.6 mS·cm^{-1} by PourThru) reported for vinca by Kessler (1998). There was little difference in bulk density or porosity among FPM treatments.

Although no growth measurements were taken between planting and harvest, the fertilized treatments appeared larger by April 30, 2013. Leaf color ratings began 11 days after planting (DAP) (Table 2, Fig. 1). There were no differences among the fertilized FPM-containing treatments throughout the trial, with leaf color ratings ranging from 4.0 to 5.0 and generally between 4.8 and 5.0 from 19 DAP to harvest (Table 2). Starting at 19 DAP, plants in the fertilized Fafard™ 2 treatment began lagging behind those in the FPM treatments. At 19 DAP, plants in the unfertilized FPM treatments had lower leaf color ratings than those in the fertilized FPM treatments. Plants in the 50% FPM treatment had a lower rating than the rest of the FPM treatments and remained separated at 26 DAP. However, by harvest day (39 DAP), leaf color was the same in plants for all FPM treatments, fertilized

Table 1. **Physical and chemical[z] characteristics of the growing media composed of sugarcane filter press mud (FPM) and vermiculite used in the vinca growth trial.**

Growing medium[y]	Initial pH	Initial EC (mS·cm⁻¹)	Bulk density (g·cm⁻³)	Total porosity (% by vol)	Final pH (mS·cm⁻¹)		Final EC (mS·cm⁻¹)	
					Not fertilized	Fertilized	Not fertilized	Fertilized
FAFARD™ 2	7.00	0.75	0.17	84	6.87	7.14	0.80	0.97
FPM50	7.40	1.41	0.36	78	7.00	7.15	1.20	1.87
FPM67	7.35	1.57	0.42	57	7.16	6.97	1.09	1.58
FPM75	7.44	1.51	0.41	57	7.21	7.08	0.97	1.29
FPM90	7.22	1.49	0.38	59	7.01	7.21	0.92	0.74
FPM100	7.47	0.57	0.35	57	7.14	6.91	0.84	0.73

[z]Determined by pour-thru method bulking all samples within a treatment.

[y]Fafard™ 2, 57% Sphagnum peat, 20% perlite, 23% vermiculite, Conrad Fafard, Inc, Agawam, MA; FPM100, 100% sugarcane filter press mud; FPM90, 9:1 volumetric mixture of sugarcane filter press mud and vermiculite; FPM75, 3:1 volumetric mixture of sugarcane filter press mud and vermiculite; FPM67, 2:1 volumetric mixture of sugarcane filter press mud and vermiculite; FPM50, 1:1 volumetric mixture of sugarcane filter press mud and vermiculite.

and unfertilized. The relative lag in the unfertilized FPM treatments can likely be explained by differences in nutrient availability as older plants would be expected to have more developed root systems and would be able to extract nutrients from a greater volume of soil (Fig. 1).

Flowering began on April 30, 2013, except in the unfertilized 100% FPM, 75% FPM, and Fafard™ 2 treatments, and by May 25, 2013, all plants had flowered (Table 3). Days to first flower in the unfertilized treatments ranged from 25.4 days in the 67% FPM treatment to 31.4 days in the Fafard™ 2 growing medium (Table 3). In the fertilized treatments, days to flowering ranged from 25.1 days in the 100% FPM treatment to 30.0 days in the Fafard™ 2 growing medium. Despite a trend (Table 3) of unfertilized plants taking slightly longer to flower, the relationship falls just outside of statistical significance ($P = 0.0898$). FPM treatments generally flowered sooner than Fafard™ 2 treatments, and all fertilized FPM treatments grouped together with the fewest days to flower.

Number of flowers at harvest in the unfertilized treatments ranged from 1.4 in the Fafard™ 2 growing medium to 3.3 in the 100% FPM (Table 3). In the fertilized treatments, number of flowers at harvest ranged from 2.3 in the Fafard™ 2 to 5.0 in the 50% FPM. In the unfertilized FPM treatments, mixtures above 67% FPM grouped together, while the 50% FPM treatment grouped with the treatment with the lowest number of flowers, Fafard™ 2. There was no statistical separation between fertilized treatments with greater than 67% FPM and the unfertilized 100% FPM treatment.

Height in the unfertilized treatments ranged from 13.9 cm (5.5 in) in the Fafard™ 2 growing medium to 23.7 cm (9.3 in) in the 75% FPM (Table 3). In the fertilized treatments, height ranged from 17.6 cm (6.9 in) in the Fafard™ 2 growing medium to 26.6 (10.5 in) in the 90% FPM. In the unfertilized FPM treatments, treatments with greater than 67% FPM were grouped together. The same trend held for the fertilized FPM treatments, except that the 50% FPM treatments was also equivalent in height to all FPM treatments except the 90% FPM treatment.

Number of branches in the unfertilized treatments ranged from 0.8 in the Fafard™ 2 growing medium to 10.1 in the 100% FPM (Table 3). Number of branches at harvest in the fertilized treatments ranged from 4.0 in the Fafard™ 2 growing medium to 11.7 in the 75% FPM (Table 3). In the unfertilized FPM treatments, only the 100% FPM one was equivalent in number of branches with the fertilized treatments, and it separated statistically from all but the 75% FPM treatment. All the fertilized FPM treatments grouped together with the most branches.

Shoot dry weight in the unfertilized treatments ranged from 0.3 g (0.01 oz) in the Fafard™ 2 growing medium to 1.2 g (0.04 oz) in the 100% FPM (Table 3). Shoot dry weight in the fertilized treatments ranged from 0.5 g (0.02 oz) in the Fafard™ 2 medium to 2.1 g (0.07 oz) in the 67% FPM. In

Table 2. **Chlorosis ratings[z] (± SE) of the upper most developed leaf for vinca grown in mixtures of sugarcane filter press mud (FPM) and vermiculite.**

Days after planting	11		19		26		39	
Fertilizer	Yes	No	Yes	No	Yes	No	Yes	No
Growing medium[y]								
FAFARD™ 2	3.9 ± 0.1a[x]	3.0 ± 0.2b	3.6 ± 0.2e	2.4 ± 0.2f	3.3 ± 0.3c	3.1 ± 0.3c	3.9 ± 0.3b	3.8 ± 0.3b
FP100	4.0 ± 0.0a	4.0 ± 0.0a	4.9 ± 0.1a	4.4 ± 0.2bc	5.0 ± 0.0a	4.9 ± 0.1a	5.0 ± 0.0a	4.9 ± 0.1a
FPM90	4.0 ± 0.0a	4.0 ± 0.0a	4.9 ± 0.1a	4.2 ± 0.1c	5.0 ± 0.0a	4.9 ± 0.1a	4.9 ± 0.1a	4.9 ± 0.1a
FPM75	4.0 ± 0.0a	4.0 ± 0.0a	5.0 ± 0.0a	4.2 ± 0.1c	4.9 ± 0.1a	5.0 ± 0.0a	5.0 ± 0.0a	4.9 ± 0.1a
FPM67	4.0 ± 0.0a	3.8 ± 0.1a	4.9 ± 0.1a	4.1 ± 0.1cd	4.9 ± 0.1a	4.8 ± 0.1ab	4.8 ± 0.1a	4.8 ± 0.1a
FPM50	4.0 ± 0.0a	3.3 ± 0.2b	4.8 ± 0.1ab	3.8 ± 0.2de	4.9 ± 0.1a	4.3 ± 0.3b	4.8 ± 0.1a	4.8 ± 0.1a

[z]Chlorosis scale; 1 is severe chlorosis, completely white, 3 is moderate chlorosis and 5 is darkest green.

[y]Fafard™ 2, 57% Sphagnum peat, 20% perlite, 23% vermiculite, Conrad Fafard, Inc, Agawam, MA; FPM100, 100% sugarcane filter press mud; FPM90, 9:1 volumetric mixture of sugarcane filter press mud and vermiculite; FPM75, 3:1 volumetric mixture of sugarcane filter press mud and vermiculite; FPM67, 2:1 volumetric mixture of sugarcane filter press mud and vermiculite; FPM50, 1:1 volumetric mixture of sugarcane filter press mud and vermiculite.

[x]Means followed by different letters are significantly different (Student's t, JMP 8.0).

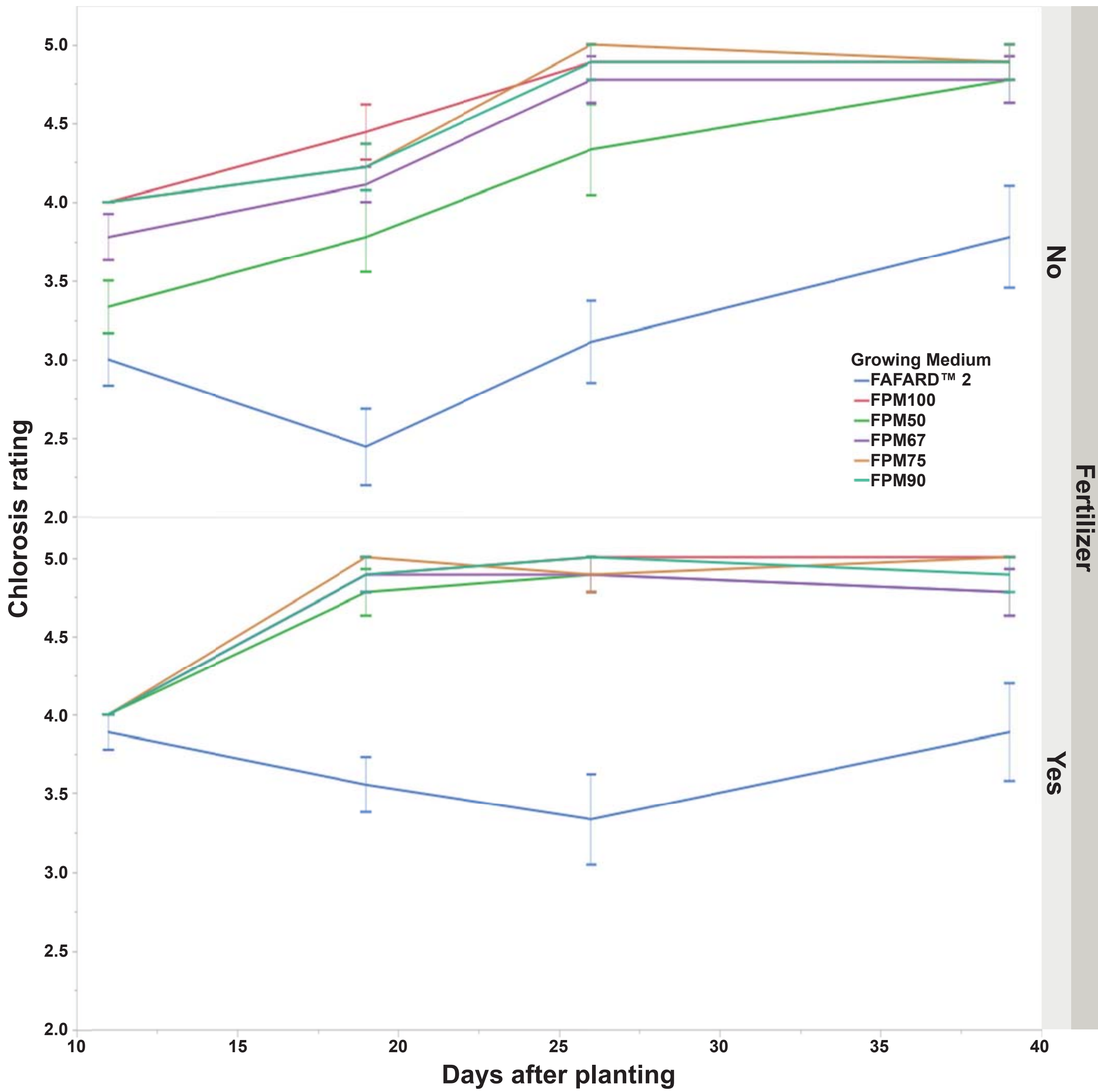

Fig. 1. **Chlorosis ratings of the upper most developed leaf for vinca grown in mixtures of sugarcane filter press mud (FPM) and vermiculite, Each error bar is constructed using 1 standard error from the mean. The chlorosis scale used was: 1 is severe chlorosis/completely white, 3 is moderate chlorosis and 5 is darkest green. Fafard™ 2, 57% Sphagnum peat, 20% perlite, 23% vermiculite, Conrad Fafard, Inc, Agawam, MA; FPM100, 100% sugarcane filter press mud; FPM90, 9:1 volumetric mixture of sugarcane filter press mud and vermiculite; FPM75, 3:1 volumetric mixture of sugarcane filter press mud and vermiculite; FPM67, 2:1 volumetric mixture of sugarcane filter press mud and vermiculite; FPM50, 1:1 volumetric mixture of sugarcane filter press mud and vermiculite.**

the unfertilized FPM treatments, all treatments above 67% FPM were equivalent Plants receiving fertilizer grew better than those that did not receive fertilizer in all growing media except Fafard™ 2, where growth was similar.

ANOVA indicated a significant response for the fit least squares model for all measured variables (Table 4). Growing medium had a significant effect on all variables tested. Fertilizer had a significant effect on all variables except days to flowering. The interaction was significant for number of branches and shoot dry weight. This interaction is likely due to the homogeneity of response in the fertilized FPM treatments versus the separation seen between different FPM treatments in the unfertilized FPM treatments.

Moore (2004) evaluated petunias (*Petunia* × *hybrida* Hort.) and impatiens (*Impatiens walleriana* Hook.) at different rates and types of fertilization and rates of incorporation of compost consisting of biosolids and yard trimmings, and found that both plants were responsive to additions of

Table 3. **Means of growth and development parameters for vinca grown in binary mixtures of sugarcane filter press mud (FPM) and vermiculite.**[z]

Growing medium[y]	Fertilizer	Flowering date	# Flowers	Height (cm)	# Branches	Shoot dry weight (g)
FAFARD™ 2	No	31.4a	1.4e	13.9f	0.8f	0.3e
FAFARD™ 2	Yes	30.0ab	2.3cde	17.6e	4.0e	0.5de
FPM100	No	29.7ab	3.3bc	23.6cd	10.1ab	1.2b
FPM100	Yes	25.1c	4.3ab	26.3ab	11.1a	2.0a
FPM50	No	28.4abc	1.9de	19.5e	4.9de	0.7cd
FPM50	Yes	27.7bc	5.0a	24.2bc	12.1a	2.0a
FPM67	No	25.4c	2.8cd	22.0d	6.8cd	1.0b
FPM67	Yes	25.4c	4.3ab	25.4abc	11.3a	2.1a
FPM75	No	27.8abc	3.0cd	23.7cd	8.2bc	1.0bc
FPM75	Yes	27.7bc	4.3ab	26.1ab	11.7a	2.0a
FPM90	No	26.6bc	2.8cd	23.6cd	6.9cd	0.9bc
FPM90	Yes	25.6c	4.2ab	26.6a	11.4a	2.0a

[z]Means in the same column followed by different letters are significantly different (Student's t, JMP 8.0).
[y]Fafard 2, 57% Sphagnum peat, 20% perlite, 23% vermiculite, Conrad Fafard, Inc, Agawam, MA; FPM100, 100% sugarcane filter press mud; FPM90, 9:1 volumetric mixture of sugarcane filter press mud and vermiculite; FPM75, 3:1 volumetric mixture of sugarcane filter press mud and vermiculite; FPM67, 2:1 volumetric mixture of sugarcane filter press mud and vermiculite; FPM50, 1:1 volumetric mixture of sugarcane filter press mud and vermiculite.

fertilizer. However, if the fertilizer had a more rapid release, then compost incorporation should not be over 30%, but at a slower release rate, up to 60% of the media could be comprised of compost. Perhaps the nutrient release curves of the compost could explain this. High concentrations of nutrients and fertilizer could damage the plant's root system. In the present study, adding 100 mL of 100 mg·L^{-1} KNO_3 did not seem to harm the plant, despite potentially high initial

Table 4. **Results of statistical tests.**[z]

Response		df	F	P
Leaf color	ANOVA	23,408	26.5426	<0.0001
	Effect tests			
	Growing medium	5	70.689	<0.0001
	Fertilizer	1	47.9976	<0.0001
	Days after planting (DAP)	1	170.8851	<0.0001
	Growing medium × Fertilizer	5	2.6831	0.0212
	Growing medium × DAP	5	1.402	0.2224
	Fertilizer × DAP	1	10.5528	0.0013
	Growing medium × Fertilizer × DAP	5	1.4346	0.2107
Days to flower	ANOVA	11,960	2.4	0.01
	Effect tests			
	Growing medium	5	3.9	0.0031
	Fertilizer	1	2.9	0.0898
	Growing medium × Fertilizer	5	0.8	0.5
Number of flowers	ANOVA	11,960	7.5	<0.0001
	Effect tests			
	Growing medium	5	6.0	<0.0001
	Fertilizer	1	43.0	<0.0001
	Growing medium × Fertilizer	5	1.9	0.1
Height	ANOVA	11, 960	24.8	<0.0001
	Effect tests			
	Growing medium	5	43.0	<0.0001
	Fertilizer	1	54.8	<0.0001
	Growing medium × Fertilizer	5	0.6	0.7
Number of branches	ANOVA	11,960	23.1	<0.0001
	Effect tests			
	Growing medium	5	30.7	<0.0001
	Fertilizer	1	83.1	<0.0001
	Growing medium × Fertilizer	5	3.6	0.005
Shoot dry weight	ANOVA	11,960	40.8	<0.0001
	Effect tests			
	Growing medium	5	38.3	<0.0001
	Fertilizer	1	228.8	<0.0001
	Growing medium × Fertilizer	5	5.6	0.0001

[z]Fit Least Squares, JMP 8.0, SAS Institute, Cary, NC.

releases of NO_3-N and K from the growing medium. For the grower using FPM, it will be critical to match plant nutrient needs and nutrient release from both growing medium and fertilizer sources.

Nutrient leaching trial. In the leaching study, which used 100% FPM, an average of 295.4 mg of NO_3-N was leached cumulatively from the 3 containers over 64 days. NH_4-N leaching was much lower at 15.4 mg per container, cumulatively. Despite high levels of phosphorus in FPM, PO_4-P leaching was only 2.0 mg per container, cumulatively. Potassium leaching was 171.6 mg per container, cumulatively. Peak electrical conductivity, nitrate and potassium concentrations occurred after the initial 8 days of leaching and decreased until day 32 after which values were stable. Ammonium and phosphorus concentrations in leaching were stable over the course of the leaching study.

Prior research has examined the nutrient-supplying capacity of composts and bio-solids. Chaney et al. (1980) found that composted sewage sludge, when making up 33% of the soilless media, could supply the needed micronutrients, phosphorus and a portion of the Nitrogen required for growth of *Tagetes erecta*. The leaching study demonstrates the capacity for FPM to supply nitrate and potassium. FPM contained adequate plant-available iron to counteract the deleterious effects of a pH over 7.0 and irrigation water pH above 7.0 such as chlorosis and outbreaks of *Thielaviopsis* reported by Thomas et al. (2012). Phosphorus was also not limiting as plants grew very well without any supplemental phosphorus fertilization.

The plants in unfertilized FPM were more developed than those grown in the fertilized Fafard™ 2 growing medium, indicating that the total nutrient supplying power was greater than a once weekly fertilization of 100 $mg \cdot L^{-1}$ N application of KNO_3. Thomas et al. (2012) indicated that vinca grew more in response to nitrate fertilization as opposed to ammonium fertilization. FPM has the capacity to release high concentrations of NO_3-N initially, while releasing little NH_4-N. Nitrate concentrations during the first 24 days of leaching were in excess of 100 $mg \cdot L^{-1}$ NO_3-N. However, after 32 days concentrations in the leachate of the leaching study were less than 50 $mg \cdot L^{-1}$. Similar results occurred with potassium.

Generally, plants receiving fertilizer grew better than plants that did not. The unfertilized 100% FPM treatment had similar number of flowers and branches as did the fertilized 100% FPM treatment. This indicates that these plants were well-developed, more compact plants, which is a positive. Perhaps a lower or single early dose of fertilizer could give the plants a sufficient boost to flower earlier and develop quicker. Ultimately, further investigation would be required to determine the effects of FPM source, type and rate of fertilizer, and the impact of FPM on nutrient leaching.

Literature Cited

Berrospe-Ochoa, E.A., V.M. Ordaz-Chaparro, M. de la N. Rodríguez-Mendoza, and R. Quintero-Lizaola. 2012. Cachaza como sustrato para la producción de plántula de tomate. Rev. Chapingo Serie Hort. 18:141–156.

Broschat, T.K. 2003. Effectiveness of various iron sources for correcting iron chlorosis in dwarf I*xora*. HortTech. 13:625–627.

Broschat, T.K. 2008. Effectiveness of pasteurized poultry litter as a partial substitute for controlled-release fertilizers in the production of container-grown ornamental plants. HortTech. 18:671–677.

Cavins, T.J., B.E. Whipker, W.C. Fonteno, B. Harden, I. McCall, and J.L. Gibson. 2000. Monitoring and Managing pH and EC Using the PourThru extraction method. NCAES, Horticulture Information Leaflet 590. Raleigh, NC. 17 pp.

Chaney, R.L., J.B. Munns, and H.M. Cathey. 1980. Effectiveness of digested sewage sludge compost in supplying nutrients for soilless potting media. J. Am. Soc. Hort. Sci. 105:485–492.

El-Hout, N.M. 2008. Response of sugarcane to mill mud application on a sandy soil. J. Am. Soc. Sugar. Tech. 28:53–54.

Gilbert, R.A., D.R. Morris, C.R. Rainbolt, J.M. McCray, R.E. Perdomo, B. Eiland, G. Powell, and G. Montes. 2008. Sugarcane response to mill mud, fertilizer, and soybean nutrient sources on a sandy soil. Agronomy Journal 100:845–854.

Kessler, J.R. 1998. Greenhouse production of annual vinca. Alabama Cooperative Extension System. ANR-1119. Auburn, AL. 4 pp.

Moore, K.K. 2004. Growth of bedding plants in substrates amended with compost and fertilized with three different rates of a controlled-release fertilizer product. HortTech. 14:474–478.

Morgan, K.T., J.M. McCray, R.W. Rice, R.A. Gilbert, and L.E. Baucum. 2009. Review of current sugarcane fertilizer recommendations: A report from the UF/IFAS sugarcane fertilizer standards task force. SL 295. EDIS. UF/IFAS. 5 pp.

Murphy, J. and J.P. Riley. 1962. A modified single-solution method for the determination of phosphorus in natural waters. Analytica Chimica Acta 27:31–36.

Poole, R.T. and C.A. Conover. 1989. Growth of dieffenbachia and gardenia in various potting ingredients. Proc. Fla. St. Hort. Soc. 102:286–288.

Qureshi, M.E., M.K. Wegener, and F.M. Mason. 2001. Economics of sugar mill by-products as a source of nutrients in the Australian sugar industry in Mackay. Proc. Soc. Aus. Sugar. Tech. 23:192–198.

Soltanzad, I., L. Bailey, and R. Bingham. 1982. Effects of various soil mixtures on growth of *Chrysanthemum morifolium*. J. Rio Grande Valley Hort. Soc. 35:43–45.

Stofella, P.J. and D.A. Graetz. 1996. Sugarcane filtercake compost influence on tomato emergence, seedling growth, and yields. *In*: The Science of Composting, Part 2, M. DeBertoldi, P. Sequi, B. Lemmes, and T. Papi (Eds.). Blackie Academic and Professional, New York, USA. p. 1351–1356.

Stofella, P.J., Y. Li, D.V. Calvert, and D.A. Graetz. 1996. Soilless growing media amended with sugarcane filtercake for citrus rootstock production. Compost Science and Utilization 4:21–25.

Thomas, P., J. Woodward, F. Stegelin, and B. Pennisi. 2012. A guide for commercial production of vinca. University of Georgia Cooperative Extension. Athens, GA. 28 pp.

USDA. 2012. Agricultural Prices. U.S. Dept. Agr., Washington, DC. 34-39. 50 pp.

U.S. EPA. 1993a. METHOD 350.1 Determination of ammonia nitrogen by semi-automated colorimetry. http://www.flowinjection.com/images/ApplicationFiles/350_1_Ammonia.pdf. Accessed February 29, 2016.

U.S. EPA. 1993b. METHOD 353.2 Determination of nitrate-nitrite nitrogen by semi-automated colorimetry. http://www.flowinjection.com/images/ApplicationFiles/353_2_Nitrate-Nitrite.pdf. Accessed February 29, 2016.

U.S. EPA. 1993c. METHOD 365.1 Determination of phosphorus by semi-automated colorimetry. http://www.flowinjection.com/images/ApplicationFiles/365_1_Phosphorus.pdf. Accessed February 29, 2016.