Proc. Fla. State Hort. Soc. 129:257–262. 2016.

Nutrient Leaching from Bananas Grown in Sphagnum Peat and Sugarcane Filter Press Mud Based Growing Media During Acclimation

Nicholas Larsen*[1], Kimberly Moore[2], Tim Broschat[2], Samira Daroub[3], and Ann Wilkie[4]

[1]*International Responsible Farming Council, PO Box 282, Pahokee, FL 33476*

[2]*University of Florida/IFAS, Fort Lauderdale Research and Education Center, 3205 College Ave, Davie, FL 33314*

[3]*University of Florida/IFAS, Everglades Research and Education Center, 3200 E. Palm Beach Rd, Belle Glade, FL 33430*

[4]*University of Florida/IFAS, Soil and Water Science, 2610 SW 23rd Terrace, Building 246, Gainesville, FL 32608*

Additional index words. *Musa acuminata*, mill mud, cachaza, alternative substrate

Nutrient leaching is a necessary, but wasteful part of growing nursery plants. Substrate, fertilization, and their interactions affect nutrient leaching. This study was designed to investigate nutrient leaching from tissue culture bananas during the acclimation phase in four different substrates. The growing media mixtures consisted of 90% and 55% sugarcane filter press mud (FP) or sphagnum peat (SP) by volume mixed equal parts of perlite and vermiculite to make up the complement of each mixture. There were 3 fertilization treatments: Osmocote Plus 15–9–12, 3–4 month release incorporated at the rates of 2.4 g/L, 4.8 g/L and 7.2 g/L. The experiment was designed as a completely randomized design factorial with each media x fertilization treatment consisting of three replicates for a total of 36 experimental units. Nitrate leaching was higher in FP treatments. Ammonium leaching was higher in SP treatments. Phosphorus leaching was higher in SP treatments. The lowest level of fertilization in the SP treatments had mean phosphate-phosphorus (PO_4-P) leaching two times as high as the highest mean PO_4-P leached in FP treatments. Potassium leaching in FP treatments was higher than in SP treatments. The high levels of nitrate-nitrogen (NO_3-N) leaching indicate that N fertilization practices when using FP-based media could be adjusted to match the amount of N needed by the plant. The volume of leachate was higher for FP-based substrates. Adopting an evapotranspiration based irrigation regime would decrease mass of nutrients of leached, and would benefit both the grower and the environment.

Nutrient leaching from nursery containers represents both a monetary waste and an environmental liability. Leaching is essential to container production to prevent a build-up of salts and to ensure saturation of the media. Growers must try to limit both the volume of leachate and the nutrient concentration in the leachate.

Bananas (*Musa* spp.) are grown throughout the tropics and subtropics. Use of tissue culture banana plants is widely practiced, and millions of plants are produced each year. These banana plants spend 2-4 months in a container nursery prior to field planting. Substrate choice, fertilization practices, and irrigation practices vary widely depending on the complexity and locale of the banana nursery. Simple recommendations on fertilization, substrate characteristics, and irrigation are outlined by Robinson and Galán Saúco (2009), but very little specific research has been published.

This research seeks to quantify the amount of nitrate-nitrogen (NO_3-N), ammonium-nitrogen (NH_4-N), phosphate-phosphorus (PO_4-P), and potassium (K) leached from container-grown bananas grown in sugarcane filter press mud based or sphagnum peat based substrates at 55% and 90% incorporation fertilized with 3 different rates of fertilizer. The objectives of this research are to determine the effect of substrate, fertilizer rate and their interaction on nutrient leaching. The goal is to find a fertilization rate for each substrate that balances the nutritional needs of the plant with the environmental impact of leaching

Materials and Methods

Tissue culture banana plantlets [*Musa acuminata* (Colla)] cv. 'Williams' were purchased from Sunscape Nursery in Apopka, FL. The plantlets were acclimated to greenhouse conditions under 50% shade and misting for two weeks. Plantlets were graded prior to planting to a uniform height of 4 cm and 6 leaves.

The substrate mixtures consisted of 90% and 55% sugarcane filter press mud (FP) or sphagnum peat (SP) by volume mixed with perlite and vermiculite. The perlite (Specialty Vermiculite, Pompano Beach, FL) and vermiculite (Specialty Vermiculite, Pompano Beach, FL) were mixed in equal parts to make up the

[15]Corresponding author; email: nlarsen@impac.org

complement of each mixture. Media was prepared by mixing the components in their respective volumetric proportions in a concrete mixer. The nutrient analyses (Table 1) of these substrates were performed by saturated media extract at Waters Agricultural Laboratory, Camilla, GA. Contributions of NO_3-N, NH_4-N, P, and K by the substrate were determined by multiplying the concentrations reported by Waters Agricultural Laboratory by the dry weight of 2500 mL of substrate.

There were 3 fertilization treatments: Osmocote Plus 15N–2.6P–10K, 3-4 month-release (Everris, Dublin, OH) incorporated at the rates of 2.4, 4.8, and 7.2 g/L of substrate. These rates correspond to 6, 12, and 18 grams of fertilizer per 16.5 cm x 16.5 cm container (C300S #1 container; Nursery Supplies, Kissimmee, FL). Contributions of NO_3-N, NH_4-N, P, and K from substrate and fertilizer are shown in Table 2.

From 1 to 24 days after planting (DAP), 100 mL of irrigation per container was applied. From 25 to 64 DAP, 200 mL of irrigation per container was applied. At planting, and every 8 days thereafter, a leachate sample was collected using the Pour-Thru method (Cavins et al., 2000). Daily leachate volume was estimated to be the difference between the irrigation amount and gravimetric evapotranspiration as measured in an adjoining irrigation experiment planted on the same day using the same substrates and the 4.8 g/L fertilizer rate. Gravimetric evapotranspiration in the adjoining experiment was calculated by measuring difference in mass of the plant, substrate and container before irrigation and after irrigation to container capacity.

Leachate was prepared for analysis by dilution in 5 mL vials so that concentration could be interpolated on the standard curve. Analysis for NO_3-N, NH_4-N, and PO_4-P were performed by colorimetry with a Seal Autoanalyzer 3 (Seal Analytical, Mequon, WI). Analysis for K was performed by atomic absorption spectrometry with a Perkin Elmer AAnalyst 400 (Perkin Elmer, Waltham MA). Both instruments were located at the University of Florida, Fort Lauderdale Research and Education Center.

Mass of nutrients leached was calculated by multiplying the estimated weekly calculated leachate by the mean of the nutrient concentrations observed at the beginning and end of each leachate period. These masses were then summed to arrive at a total mass leached for each nutrient.

The experiment was designed as a factorial with each media by fertilization treatment consisting of 3 replicates for a total of 36 experimental units. The experimental unit consisted of one banana plant in a container. The experiment was conducted within a pad and fan cooled greenhouse maintained between 20 °C and 30 °C at the Everglades Research and Education Center in Belle Glade, FL. Statistical analysis on total leached mass was performed with JMP Pro 11.0 (SAS Institute, Cary, NC) using a least squares model with substrate, substrate rate, fertilizer rate and their interaction being the effects. Statistical analysis on nutrient concentrations was performed with JMP Pro 11.0 using multivariate analysis of variance (MANOVA) with repeated measures.

Table 1. Analyses of the sugarcane filter press mud (FP) and sphagnum peat (SP) in 90% and 55% by volume mixtures with equal parts perlite and vermiculite. The FP was a 12-month aged sample from a sugar mill in the Everglades Agricultural Area.[z,y]

Measurement	FP55	FP90	SP55	SP90
pH	7.2	7.4	6.5	6.3
Organic Matter[x]	23.82	32.37	26.37	46.63
Bulk Density[w]	0.28	0.35	0.15	0.19
Porosity[v]	72	69	83	79
Air-Filled[v] Porosity	13	10	25	15
Electrical Conductivity[u]	2.09	2.35	0.514	0.501
Nitrate-Nitrogen	204.8	235.9	5.6	7.7
Ammonium-Nitrogen	8.75	12.25	9.8	13.3
Phosphorus	9.56	9.68	4.45	4.92
Potassium	44.73	77.78	18.12	19.39
Calcium	228.3	261.7	28.88	32.78
Magnesium	100.0	117.5	12.06	13.36
Sulfur	73.49	70.17	42.75	35.79
Boron	0.07	0.06	0.16	0.15
Zinc	0.55	0.62	0.17	0.09
Manganese	0.01	0.01	0.17	0.22
Iron	0.02	0.04	0.35	0.28
Copper	0.03	0.04	0.01	0.03

[z]Nutrient values reported as mg/kg.
[y]Chemical analyses performed by Waters Agricultural Laboratory, Camilla, GA, Saturated media extract.
[x]Percent dry weight.
[w]g/cm^3
[v]Percent by volume, measure at planting.
[u]mS/cm

Table 2. Contributions of nitrate-nitrogen, ammonium-nitrogen, phosphorus, and potassium from fertilizer and substrate in containers filled with sugarcane filter press mud (FP) and sphagnum peat (SP) in 90% and 55% by volume mixtures with equal parts perlite and vermiculite. Plants were fertilized with 6, 12, or 18 grams of fertilizer per container.[z]

	Fertilizer	Nitrate-nitrogen			Ammonium-nitrogen			Phosphorus			Potassium		
Substrate	rate	Substrate	Fertilizer	Total	Substrate	Fertilizer	Total	Substrate	Fertilizer	Total	Substrate	Fertilizer	Total
FP55	6	143	396	539	6	504	510	7	156	163	31	600	631
	12	143	792	935	6	1008	1014	7	312	319	31	1200	1231
	18	143	1188	1331	6	1188	1194	7	468	475	31	1800	1831
FP90	6	206	396	602	11	504	515	8	156	164	68	600	668
	12	206	792	998	11	1008	1019	8	312	320	68	1200	1268
	18	206	1188	1394	11	1188	1199	8	468	476	68	1800	1868
SP55	6	2	396	398	4	504	508	2	156	158	7	600	607
	12	2	792	794	4	1008	1012	2	312	314	7	1200	1207
	18	2	1188	1190	4	1188	1192	2	468	470	7	1800	1807
SP90	6	4	396	400	6	504	510	2	156	158	9	600	609
	12	4	792	796	6	1008	1014	2	312	314	9	1200	1209
	18	4	1188	1192	6	1188	1194	2	468	470	9	1800	1809

[z]Reported in mg/container.

Results

Total estimated leachate (Table 3) varied considerably from 2747 mL of H_2O in the SP55 treatments to 4171 mL of H_2O in the FP 55 treatment. The SP55 treatment had one week where leaching would not have been expected to occur due to evapotranspiration that exceeded the 200 mL/day irrigation schedule.

Mass of NO_3-N leached ranged from 992.34 mg/pot in FP55-18g to 52.24 mg/pot in SP90-6g (Table 4). Nitrate leaching was higher in FP treatments. The lowest rates of fertilization in FP treatments leached more NO_3-N than the SP treatments with the highest rates of fertilization.

Mass of NH_4 leached ranged from 595.53 mg/pot in SP90-18g to 5.45 mg/pot in the FP90-6g (Table 4). Ammonium leaching was higher in SP treatments, with only the lowest rates of fertilization in SP treatments having equivalent leaching to the FP treatments.

Mass of N from NO_3-N and NH_4-N ranged from 1003.34 mg/pot in SP90-18g to 96.54 mg/pot in SP55-6g (Table 4). Increased rates of fertilizer were associated with increasing amounts of nitrogen leaching.

Mass of PO_4-P leached ranged from 118.45 mg/pot in SP90-18g to 3.32 mg/pot in FP90-18g (Table 4). Phosphorus leaching was higher in SP treatments. The 6 g treatments of SP were statistically similar to the FP treatments, but still had mean P-PO_4 leaching two times as high as the highest mean PO_4-P leached in FP treatments.

Mass of K leached ranged from 219.21 mg/pot in FP55-18g to 18.75 mg/pot in SP55-6g (Table 4). Potassium leaching in FP treatments was higher than in SP treatments. Potassium leaching tended to increase with increasing fertilization.

Discussion

Nitrate-nitrogen leachate was elevated in the FP in comparison to the SP treatments and concentrations measured early in the crop would be of environmental concern (Fig. 1). Substrate, substrate rate, fertilizer rate, and the interaction of substrate and fertilizer rate were all significant predictors of NO_3-N concentration in leachate (Table 5). The interaction occurs because increasing fertilizer rate did not affect leachate NO_3-N concentrations as much in FP as it did in SP. Days after planting (DAP) also was a significant predictor, as well as its interactions with substrate, substrate rate, fertilizer rate, substrate x substrate rate, and substrate x fertilizer rate. The type of substrate, the rate of substrate, and fertilizer rate affected the rate of release. The interactions appear to be related to a relatively flat NO_3-N leaching rate in the 6 g fertilizer of SP, while the 18 g treatments of FP 55% and FP 90% show a difference in NO_3-N leaching which suggest a saturation of binding sites in the FP 55% treatment that does not occur in the FP 90% treatment. Concentrations in the FP-18 g treatments never were below the 10 mg/L threshold for drinking water. Beeson (1996) reported decreased NO_3-N leachate when yard waste compost consisted of 20% to 40% of the substrate in *Pittosporum tobira variegata* and *Rhododendron indicum* when compared to a 3:1:1 pine bark, sedge peat and sand substrate. These data suggest that the type of composted material may have

Table 3. Estimated weekly leachate from *Musa acuminata* (Colla)] cv 'Williams' bananas grown in containers filled with sugarcane filter press mud (FP) and sphagnum peat (SP) in 90% and 55% by volume mixtures with equal parts perlite and vermiculite. Daily leachate volume was estimated to be the difference between the irrigation amount and gravimetric evapotranspiration as measured in an adjoining irrigation experiment planted on the same day using the same substrates and the 12 g per container fertilizer rate.[z]

	Day 1–8	Day 9–16	Day 17–24	Day 25–32	Day 3–40	Day 41–48	Day 48–56	Day 56–64	Total Leachate
FP55	547	480	432	640	656	464	696	256	4171
FP90	400	600	296	808	608	376	784	152	4024
SP55	547	456	136	656	280	336	0	336	2747
SP90	360	336	296	696	488	648	168	576	3568

[z]Measured in mL H_20 per pot.

Table 4. Nitrate-nitrogen, ammonium nitrogen, total nitrogen, phosphate-phosphorus and potassium leached from *Musa acuminata* (Colla)] cv. 'Williams' bananas grown in containers filled with sugarcane filter press mud (FP) and sphagnum peat (SP) in 90% and 55% (by volume) mixtures with equal parts perlite and vermiculite. Plants were fertilized with 6, 12, or 18 g of fertilizer per container.[z,y]

Substrate	Substrate rate	Fertilizer rate	Nitrate-nitrogen		Ammonium-nitrogen		Total nitrogen		Phosphate-phosphorus		Potassium	
FP	55	6	539.07	CD	6.66	D	545.73	CD	6.33	C	147.25	C
		12	604.76	BC	8.61	D	613.36	CD	8.46	C	142.55	C
		18	992.34	A	11.00	D	1003.34	A	10.15	C	219.21	A
FP	90	6	301.22	E	5.45	D	306.67	E	5.58	C	103.45	D
		12	483.35	D	6.19	D	489.54	D	4.03	C	131.01	C
		18	672.97	B	6.64	D	679.61	BC	3.32	C	185.62	B
SP	55	6	52.24	I	44.21	CD	96.45	F	19.42	C	18.75	F
		12	132.01	H	154.20	C	286.21	E	33.49	BC	57.36	E
		18	206.44	FG	289.02	B	495.46	D	62.52	B	74.25	E
SP	90	6	50.87	I	47.93	CD	98.79	F	25.63	C	19.62	F
		12	142.51	GH	354.91	B	497.42	D	64.25	B	52.11	E
		18	226.53	F	595.53	A	822.06	B	118.45	A	73.51	E

[z]Measured in mg/pot.

[y]Means in the same column followed by different letters are significantly different (Student's *t* test, JMP 11.0; α =0.05)

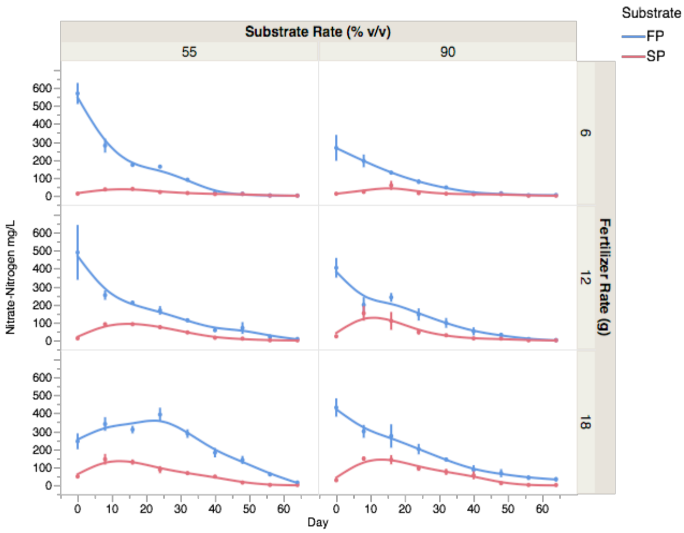

Fig. 1. Nitrate concentrations in leachate from) 'Williams' bananas [*Musa acuminata* (Colla)] grown in containers filled with sugarcane filter press mud (FP) and sphagnum peat (SP) in 90% and 55% (by volume) mixtures with equal parts perlite and vermiculite. Plants were fertilized with 6, 12, or 18 g of fertilizer per container.

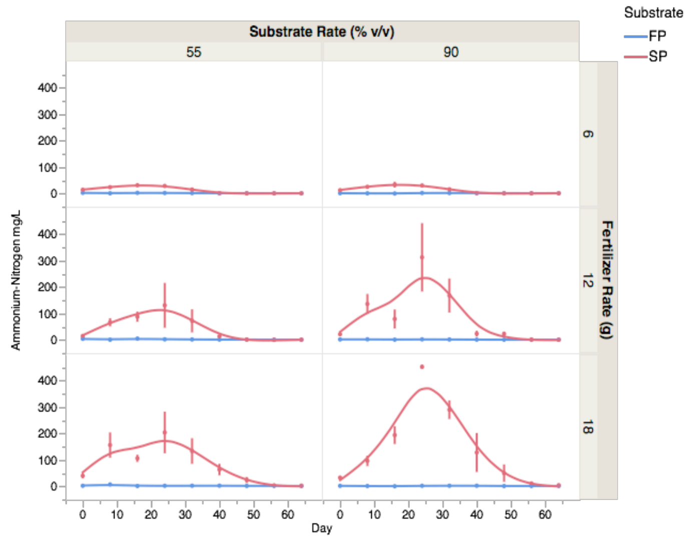

Fig. 2. Ammonium concentrations in leachate from 'Williams' bananas [*Musa acuminata* (Colla)] grown in containers filled with sugarcane filter press mud (FP) and sphagnum peat (SP) in 90% and 55% (by volume) mixtures with equal parts perlite and vermiculite. Plants were fertilized with 6, 12, or 18 g of fertilizer per container.

a large impact on NO_3-N leaching. This is not surprising, as the substrate was determined to have high levels of NO_3-N prior to planting. In agreement with the work of Broschat (1995) on *Spathiphyllum* and *Dypsis lutescens*, NO_3-N concentrations did decrease as the experiment progressed.

Ammonium-nitrogen leachate concentrations were significantly predicted by substrate, substrate rate, fertilizer rate and all their interactions (Table 5). Ammonium-nitrogen leachate concentrations were higher in the SP treatments than in the FP treatments (Fig. 2). There appears to be a strong fertilizer rate signal as the concentrations of NH_4-N increased with increasing rates of fertilizer. At 24 DAP peak NH_4-N concentrations are reached and SP90 has greater amplitude than SP55. The FP treatments have flat NH_4-N leachate concentrations indicating that they are either binding the ammonium or are nitrifying it. The consistently flat release of NH_4-N from the FP treatments versus the fertilizer rate dependent sigmoidal release of NH_4-N from SP explains the interactions. Shober et al. (2010) found that sphagnum-based substrates had high ammonium loads, especially early in the growth phase of *Begonia* x*hybrida*, *Solenostemon scutellarioides*, and *Tagetes patula*. This finding fits well with the current study.

The difference in leaching of N between FP and SP based substrates seems to be in speciation. FP primarily leached NO_3-N, while SP primarily leaches NH_4-N. A major component of FP is the histosols of the Everglades Agricultural Area, which

Table 5. Results of statistical tests involving leachate nutrient concentrations.

	Nitrate-Nitrogen	Ammonium-Nitrogen	Phosphate-Phosphorus	Potassium
Between Subjects				
All	$P < 0.0001$	$P < 0.0001$	$P < 0.0001$	$P < 0.0001$
Substrate	$P < 0.0001$	$P = 0.0003$	$P < 0.0001$	$P < 0.0001$
Substrate Rate	$P = 0.0002$	$P < 0.0028$	$P = 0.0245$	$P < 0.0814$
Fertilizer Rate	$P < 0.0001$	$P < 0.0001$	$P < 0.0001$	$P < 0.0001$
Substrate x Substrate Rate	$P < 0.0001$	$P = 0.0020$	$P = 0.0056$	$P = 0.2395$
Substrate x Fertilizer Rate	$P = 0.0035$	$P < 0.0001$	$P < 0.0001$	$P = 0.6961$
Substrate Rate x Fertilizer Rate	$P = 0.4188$	$P = 0.0278$	$P < 0.1487$	$P = 0.2915$
Substrate x Substrate Rate x Fertilizer Rate	$P = 0.5150$	$P = 0.0251$	$P = 0.0677$	$P = 0.1603$
Within Subjects				
All	$P < 0.0001$	$P < 0.0001$	$P < 0.0001$	$P < 0.0001$
Days after planting (DAP)	$P = 0.0002$	$P = 0.0524$	$P = 0.3981$	$P = 0.1035$
DAP x Substrate	$P < 0.0001$	$P < 0.0001$	$P < 0.0001$	$P < 0.0001$
DAP x Substrate Rate	$P = 0.0014$	$P = 0.1715$	$P = 0.2736$	$P = 0.2208$
DAP x Fertilizer Rate	$P < 0.0001$	$P < 0.0001$	$P = 0.0005$	$P < 0.0001$
DAP x Substrate x Substrate Rate	$P = 0.0047$	$P = 0.0311$	$P = 0.0618$	$P = 0.3096$
DAP x Substrate x Fertilizer Rate	$P = 0.0114$	$P < 0.0001$	$P = 0.0003$	$P = 0.8911$
DAP x Substrate Rate x Fertilizer Rate	$P = 0.1773$	$P = 0.1996$	$P = 0.2989$	$P = 0.6493$
DAP x Substrate x Substrate Rate x Fertilizer Rate	$P = 0.0953$	$P = 0.1263$	$P = 0.2725$	$P = 0.7127$

Table 6. Results of statistical tests involving total mass of nutrients leached

	Nitrate-Nitrogen	Ammonium-Nitrogen	Total Nitrogen	Phosphate-Phosphorus	Potassium
ANOVA	$P < 0.0001$	$P < 0.0001$	$P < 0.0001$	$P < 0.0001$	$P < 0.0001$
Substrate	$P < 0.0001$	$P < 0.0001$	$P = 0.3314$	$P < 0.0001$	$P < 0.0001$
Substrate Rate	$P = 0.2856$	$P < 0.0001$	$P = 0.3848$	$P = 0.0029$	$P = 0.6764$
Fertilizer Rate	$P = 0.0015$	$P < 0.0001$	$P < 0.0001$	$P < 0.0001$	$P = 0.0025$
Substrate x Substrate Rate	$P = 0.0695$	$P < 0.0001$	$P = 0.0015$	$P = 0.0007$	$P = 0.2697$
Substrate x Fertilizer Rate	$P = 0.3797$	$P < 0.0001$	$P = 0.0532$	$P < 0.0001$	$P = 0.9945$
Substrate Rate x Fertilizer Rate	$P = 0.6450$	$P < 0.0001$	$P = 0.0316$	$P < 0.0009$	$P = 0.3478$
Substrate x Substrate Rate x Fertilizer Rate	$P = 0.3820$	$P < 0.0001$	$P = 0.0130$	$P = 0.0004$	$P = 0.4639$

are flocculated out of the sugarcane juice solution with other non-sucrose contaminants. These histosols are highly humified reed-sedge peats. Shober et al. (2010) found that reed-sedge peats had higher leaching of NO_3-N, while sphagnum peats had higher leaching of NH_4-N. At the 12 g fertilization rate N leaching was the same across substrates except for SP55-12 g. There seems to be a contrasting affect in terms of percentage of FP or SP in terms of N leaching. FP55 had numerically higher N leaching than FP90 at each level of fertilization, while SP55 had numerically lower N leaching than SP90 at each level of fertilization. This is likely due to differences in cation exchange capacity (CEC) and the charge of the primary species of nitrogen being leached. Vermiculite, which has an elevated CEC, was 22.5% of the media in the FP55 and SP55 treatments. Vermiculite likely played a positive role in binding NH_4^+ in SP treatments. Lucas (1982) noted that muck soil, which is the primary constituent of FP, has nearly eight times the CEC of sphagnum peat on a volume basis. This could explain why so little NH_4-N was leached from the FP treatments. The change in the shape of the NO_3-N release curves in response to increasing fertilization provides evidence of saturation of NO_3^- binding sites in FP55 (Fig. 1).

Substrate, substrate rate, fertilizer rate, substrate x substrate rate, and substrate x fertilizer rate were significant predictors of leachate PO_4-P concentration (Table 5). Phosphate-P leaching was low in all FP treatments. The findings of lower P leaching in FP-based substrates is intriguing as FP is roughly 2% P, and the FP-based substrates has SME phosphorus readings twice as high as the SP-based substrates. Phosphate-phosphorus leaching was relatively flat throughout the experiment and was not impacted by fertilization in the FP treatments (Fig. 3). This was likely due to precipitation and immobilization of the nutrient. The pH of the FP-based substrates was higher, and calcium (Ca) and magnesium (Mg) levels were 10-fold higher than in the SP-based substrates. The interactions observed are due to differences in PO_4-P leaching in response to the rate of fertilizer and the rate of SP. There was lower PO_4-P leaching in SP 55% treatments than in SP 90% treatments. The amplitude of PO_4-P in SP treatments was affected by fertilization rate and there the release rate of PO_4-P in leachate was higher at each level of fertilization in SP 90% in comparison to SP 55%. This difference indicates that vermiculite might be binding some of the PO_4-P. The SP treatments did show decreasing levels of phosphorus as the experiment progressed, which seems to conflict with the finding of Broschat (1995) that P leaching increased over time. However, that experiment was seven months longer than the current study and involved several fertilization events.

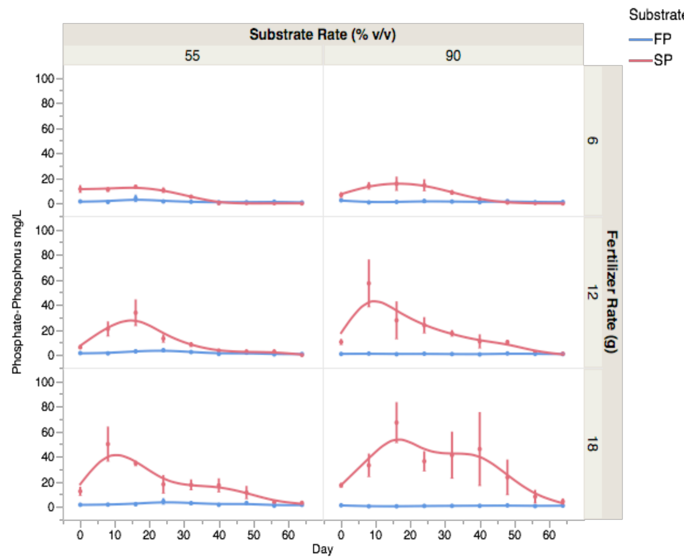

Fig 3. Phosphate concentrations in leachate from 'Williams' bananas [*Musa acuminata* (Colla)] grown in containers filled with sugarcane filter press mud (FP) and sphagnum peat (SP) in 90% and 55% (by volume) mixtures with equal parts perlite and vermiculite. Plants were fertilized with 6, 12, or 18 g of fertilizer per container.

Potassium leaching is generally not considered an environmental hazard; however, it does represent a loss of a resource. Substrate and fertilizer rate were the only significant predictors of K concentration in leachate waters (Table 5). Since K levels in the FP-based substrates were already higher at the beginning of the experiment, it was expected that FP-based substrates would leach more potassium than SP-based substrates (Fig. 4). Also given the large quantities of divalent cations in FP-based media, and its histosol provenance, potassium may have been unable to compete at cation-exchange sites, and stayed in soil solution available to be leached. The change in the shape of the K release curves in response to increasing fertilization provides evidence of saturation of K binding sites at the 18g fertilization rate (Fig. 4).

In conclusion, substrate, substrate rate, fertilization rate, and their interactions affect nutrient leaching. The high levels of NO_3-N leaching indicate that N fertilization practices when using FP-based media could be adjusted to match the amount of N added as fertilizer to the needs of the plant. Phosphorus leaching

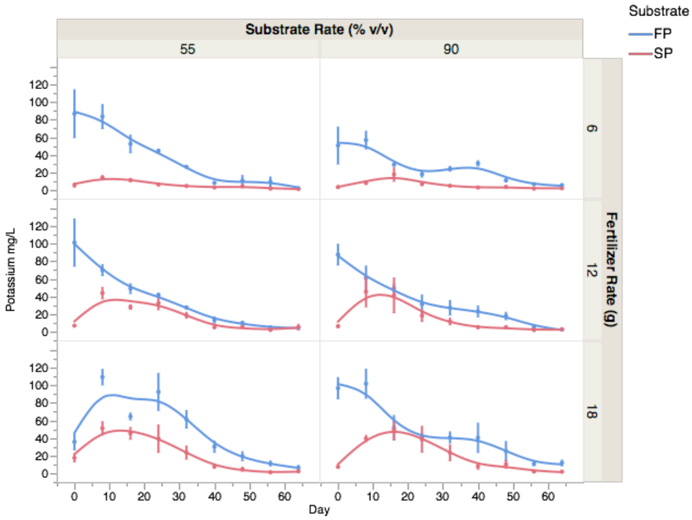

Fig. 4. Potassium concentrations in leachate from 'Williams' bananas [*Musa acuminata* (Colla)] grown in containers filled with sugarcane filter press mud (FP) and sphagnum peat (SP) in 90% and 55% (by volume) mixtures with equal parts perlite and vermiculite. Plants were fertilized with 6, 12, or 18 g of fertilizer per container.

was much lower in FP than in SP. This is important, as FP would likely be used close to its source near the Everglades where P is a nutrient of concern. Adjusting the proportion of vermiculite and perlite incorporated into the substrate could be a nutrient management tool for managing N and P leaching. Potassium leaching was higher in the FP-based media; however, K is not an element of environmental concern. This finding may indicate that K fertilization practices could be altered. Research into the response of tissue culture bananas to the same substrates and fertilization rates showed that the largest plants were produced at the highest rate of fertilization for all substrate x substrate rate combinations, except SP 55%, which had the largest plants in the 12 g fertilization treatment (Larsen et al., 2015). Nitrogen leaching in the SP 55% 12 g treatment was ≈25% as much as in the FP 55% 12 g treatment, although PO_4-P leaching was more than three times that of the FP 55% 12g treatment. In a commercial nursery setting, it may be advisable to collect the early leachate from FP-based media, treat it for pathogens, and then recycle the leachate by fertigation. The volume of leachate was higher for FP-based substrates. Adopting an evapotranspiration based irrigation regime would decrease mass of nutrients leached, and would benefit both the grower and the environment. An environmentally conscious banana nursery operator may wish to consider the environmental impact of substrate choice, rate of vermiculite and perlite incorporation, and fertilization rate. If the process is optimized, marketable banana plants can be produced quickly with minimal risk to the environment.

Literature Cited

Beeson, R.C., 1996. Composted yard waste as a component of container substrates. J. Env. Hort. 14:115–121.

Broschat, T.K. 1995. Nitrate, phosphate, and potassium leaching from container-grown plants fertilized by several methods. HortScience. 30:74–77.

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. North Carolina Agricultural Experiment Station, Horticulture Information Leaflet 590. Raleigh, NC.

Larsen, N.A., K.K. Moore, T.K. Broschat, S. Daroub, and A.C. Wilkie. 2015. Fertilization of tissue-culture bananas grown in sugarcane filter press mud and sphagnum peat based media. Proc. Fla. State Hort. Soc. 128:1–6.

Lucas, R.E. 1982. Organic Soils (Histosols). Formation, distribution, physical and chemical properties and management for crop production. Michigan State University, Res. Rpt. No. 435 (Farm Science).

Robinson, J.C. and V. Galán Sáuco. 2009. Nursery hardening of in-vitro-produced banana plants. Fruits 64:383–392.

Shober, A.L., C. Wiese, G.C. Denny, C.D. Stanley, and B.K. Harbaugh. 2010. Plant performance and nutrient losses during containerized bedding plant production using composted dairy manure solids as a peat substitute in substrate. HortScience 45:1516–1521.