Pre-plant Nitrogen Rates in Alternative Substrates Affect Production of *Impatiens ×walleriana*©

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SUMMARY

The effect of nitrogen on an alternative forest-based product substrate (FPS) performance was evaluated using rates of Nitroform®, a slow-release urea-based pre-plant fertilizer, and a water-soluble N-P-K starter fertilizer. FPS is manufactured from loblolly pine (*Pinus taeda*) harvested locally within the Southeastern United States. *Impatiens ×walleriana* were grown in 80:20 peat:perlite (by volume) industry standard, 80:20 FPS:peat, or 100% FPS. Nitroform® was incorporated at 0 or 0.59 $kg{\cdot}m^{-3}$ N, and ammonium nitrate was incorporated at 0.06, 0.12, or 0.18 $kg{\cdot}m^{-3}$ N. Nitroform® increased plant size regardless of substrate. Plants grown in 80:20 peat:perlite had higher size indices (SI) than plants in either the 80:20 FPS:peat or 100% FPS regardless of Nitroform® rate. In both FPS substrates, size index increased with increasing N rate, while in the 80:20 peat:perlite substrate, size index decreased with increasing N rate. The results indicate that substrates containing high FPS (up to 100%) have potential in greenhouse substrates with the addition of adequate types and amounts of pre-plant incorporated nitrogen.

INTRODUCTION

Peat-based substrates have been the greenhouse industry standard since their introduction in the 1970's as Cornell peat-lite mixes (Boodley and Sheldrake, 1972; Jackson et al., 2008). Peat moss imports increased from $157 to $312 million from 2000 to 2015 and costs increased from $200 to $271 per ton, respectively (Jasinski 2000; Apodaca, 2015). Due to increased demand for greenhouse media and rising costs of peat (Jasinski 2000), growers are looking for ways to lower their overhead. Approaches include augmenting peat with potentially less costly alternatives such as wood fiber. There was significant research in the last decade on alternative wood fiber substrate components (Fain et al., 2008; Domeno et al., 2010; Gaches et al, 2011, Jackson et al., 2008).

HydraFiber® (Profile® Products LLC, Buffalo, IL) is a wood fiber substrate component currently available in the U.S. Growers and professional blenders are using HydraFiber® at rates of 20– 50% (by volume). Benefits of a manufactured product include product consistency and uniformity, which are crucial for commercial production. Additionally, when substrates are manufactured using resources located near growers, transport costs are reduced, resulting in a more cost-competitive product. Given the abundance of pine trees (*Pinus* spp.) in the Southeastern U.S., wood fiber substrates are a strong candidate for peat alternatives in greenhouse production. Optimum nutrition for FBS has not been determined and is explored in this study.

In this study, we evaluated a forest product based substrate (FPS) made from loblolly pine (*Pinus taeda*), alone and in combination with peat, and starter fertilizer rates in the production of a greenhouse annual. The objective of this study was to evaluate the performance of FPS with various nitrogen treatments and peat amendments.

MATERIALS AND METHODS

The study was conducted at the Paterson Greenhouse Facility, Auburn University, Alabama. Substrates were blended on June 13, 2018. The treatment design was a 3-way factorial with 3 substrates, 2 Nitroform® rates, and 3 starter nitrogen fertilizer rates. Each of the 18 treatments had 12 single-container experimental units having one seedling from a 200-count plug tray. Treatments were arranged in a randomized complete block design. The study was blocked for greenhouse temperature variation, and each block consisted of one experimental unit per treatment in a single row. Substrate treatments in the study were: 80:20 peat:perlite (by volume) the industry standard, 80:20 FPS:peat, or 100% FPS. Raw peat moss was used in the peat-lite blend and in the peat fraction added to the wood fiber substrate. Nitroform® (39-0-0 powdered slow release, Koch Agronomic Services, LLC., Wichita, KS) treatments were at 0 $kg\cdot m^{-3}$ or 0.59 $kg\cdot m^{-3}$. Preplant starter fertilizer treatments were at 0.06-0.03-0.06, 0.12-0.03-0.06, or 0.18-0.03-0.06 $kg\cdot m^{-3}$ N-P-K, respectively. Nitrogen immobilization was expected in wood-based substrates and therefore, required higher fertilizer rates to compensate (Witcher et al., 2009). Water soluble ammonium nitrate, potassium sulphate, and potassium phosphate were blended into the ratios listed above. Pre-plant starter fertilizers were dissolved in 2 L (67.6 oz) of water and applied as a spray to each substrate at mixing. All substrates had the following amendments added at mixing: dolomitic limestone (2.97 $kg\cdot m^{-3}$ for peat-lite, 0.59 $kg\cdot m^{-3}$ for 80:20 FPS:peat, or 0.30 $kg\cdot m^{-3}$ for 100% FPS), 0.59 $kg\cdot m^{-3}$ gypsum, 0.30 $kg\cdot m^{-3}$ Micromax®(ICL Fertilizers, Dublin, OH), and 3.6 $kg\cdot m^{-3}$ Conductor® substrate surfactant (Aquatrols®, Paulsboro, NJ). Limestone varied by substrate based on previous literature (Boyer et al., 2007; Fain et al., 2008; Jackson et al., 2009)

Impatiens ×*walleriana* ‘Xtreme White’ were acquired from Young’s Plant Farm, Inc. (Auburn, AL) on June 25, 2018, transplanted into containers, and watered on June 29, 2018. Containers [Shuttle Container® SS325, 473 cm^3, East Jordan Plastics Inc., East Jordan, Michigan] were filled based on a pre-determined target weight per container calculated from the density of each substrate. Containers were placed in flats and covered with plastic to prevent evaporation until all containers were filled. Visually uniform plugs were chosen randomly from the flats. Holes in the center of each container were dibbled before plugs were transplanted by block. The finished containers were lightly watered and then fertilizer with 150 ppm N 20-10-20 (Greencare, Kanakee, IL). Plants were produced during the experiment using continuous fertilization at 150 ppm N 20-10-20 on greenhouse benches in full sun and irrigated with clear water as needed to address rising EC.

Initial pH and EC were taken using the press method (Scoggins et al., 2001) and fallow containers were brought to saturation using clear water. Mid-study 14 days after planting (DAP) and at termination (28 DAP), pH and EC were collected using the press method and brought to saturation with 150 ppm N 20-10-20. Prior to both press method extractions, shoot tissue was cut at the soil line, bagged per experimental unit, and placed in a forced air-drying oven at 76°C until dry and weighed. For mid-study data collection, four blocks were picked at random from the 12 for destructive harvest. At termination, the remaining eight blocks were harvested for shoot tissue and four of those eight blocks were randomly picked for destructive analysis of pH and EC. The four blocks remaining were used to analyze substrate shrinkage and final water holding capacity (WHC). To determine substrate shrinkage, the void space was measured using 100% fine grade Profile® porous ceramic (Profile® Products LLC, Buffalo, IL), which has a density of 0.6245 $g \cdot cm^{-3}$. The containers were first brought to saturation and weighed (equation, value A). Then a 30 × 30 cm piece of clear 12.7μ thick plastic wrap was loosely centered over the pot, and lightly pressed into the void until the plastic contacted the substrate. Ceramic was added on top of the plastic to fill the void to the top of the container, the container was then reweighed (equation, value B). The ceramic was removed after weighing by grabbing all four corners of the plastic wrap and lifting it out. The saturated containers were placed in a forced air-drying oven at 76°C until dry to determine WHC (Fonteno and Harden, 2003). Shrinkage was calculated using the following formula:

$$\frac{B-A}{0.6245} \times \frac{1}{container\ volume} = \%\ substrate\ shrinkage$$

Throughout the experiment, the date of first bloom was recorded and the days to bloom was then calculated from the date of planting. At termination, a final bloom count was recorded. Size index [SI=(height + width + perpendicular width)/3] was recorded at study termination on all blocks prior to shoots being harvested.

RESULTS

There were interactive treatment effects on size index (Table 1). In the substrate by Nitroform® interaction, plants grown in 80:20 peat:perlite had higher SI's than plants in either the 80:20 FPS:peat or 100% substrates regardless of Nitroform® treatments . In both substrate by Nitroform® and starter N by Nitroform® interactions, plants grown with Nitroform® had higher SI's than those without Nitroform®. SI increased linearly with increasing starter N rate without Nitroform® indicating that starter N rate had a larger effect on plants without Nitroform® than with; however, plants with Nitroform® and the lowest starter N rate were larger than plants without Nitroform® at the highest starter N rate. The addition of Nitroform® to substrates increased SI, regardless of substrates. In the substrate by starter N interaction, both FPS substrates had linear increases in SI with increasing starter N rate, while the 80:20 peat:perlite decreased linearly.

Mid-study shoot dry weight (SDW) showed an interaction among Nitroform® rate, starter N rate, and substrate (Table 2). Plants in 80:20 FPS:peat with and without Nitroform® showed linear increases in dry mass as starter N rate increased, but had no trend in 100% FPS. Plants in 80:20 peat:perlite without Nitroform® displayed a linear decrease as starter N rate increased, but there was no trend in 80:20 peat:perlite containing Nitroform®. Among substrates with and without Nitroform®, 80:20 peat:perlite had significantly higher SDW than either 80:20 FPS:peat or 100% FPS for each rate of starter N. Plants in 80:20 FPS:peat and 100% FPS were not significantly different for each rate of starter N except for the lowest rate of 0.06 N $kg\cdot m^{-3}$ with Nitrogen®, in which 100% FPS plants had significantly higher SDW than 80:20 FPS:peat. Between Nitroform® rates within substrates, 80:20 peat:perlite plants had significantly higher SDW's only at the highest starter N rate containing Nitroform®. Plants at the middle and lowest starter N rates were non-significant between Nitroform® rates. Within 80:20 FPS:peat and 100% FPS, both had significantly higher SDW's in the lowest starter N rate containing Nitroform®.

For final SDW (Table 3), the substrate by starter N rate and Nitroform® by starter N rate interactions were significant. Final SDW increased linearly with increasing starter N rate for both FPS substrates while 80:20 peat:perlite showed no trend. Within each of the starter N rates, 80:20

peat:perlite plants had higher SDW's than either FPS substrates. In the Nitroform® by starter N rate interaction, SDW increased linearly over starter N rate without Nitroform® but there was no trend with Nitroform®. Between Nitroform® rates, plants had a higher SDW at the two lowest starter N rates containing Nitroform® with no trend for the highest starter N rate.

Plants in the peat-lite substrate had the highest bloom count at termination followed by plants in the 80:20 FPS:peat and 100% FPS (data not shown). Bloom count increased linearly with increasing starter N rate across all substrates without Nitroform® but decreased linearly with Nitroform®. Substrate pH was within an acceptable range (4.8–6.4) at 0, 14, and 28 DAP across all treatments (data not shown) and the substrate × Nitroform® × starter N rate interaction was significant at each test date. An increased EC was observed in substrates containing Nitroform®. The 80:20 peat:perlite substrate had much higher EC values (2.3-4.8 $mS \cdot cm^{-1}$) than either FPS substrate (0.9-1.9 $mS \cdot cm^{-1}$). EC stayed high in 80:20 peat:perlite (2.5-.8 $mS \cdot cm^{-1}$) from 0 – 14 DAP. At termination, 80:20 peat:perlite EC had dropped to 1.1 $mS \cdot cm^{-1}$. EC in both FPS substrates remained consistent between 0.9 and 2.5 $mS \cdot cm^{-1}$ throughout the study.

DISCUSSION

Results indicate that substrates high in FPS (up to 100%) have potential as greenhouse substrates with the addition of adequate forms and amounts of pre-plant nitrogen. Previous research documented nitrogen loss issues in substrates containing higher amounts of wood fiber. Nitrogen immobilization and microbial respiration were recorded by Boyer et al. (2012) in which a high wood fiber content substrate, clean chip residual (CCR), was incubated in sealed glass and carbon mineralization measured to determine the amount of microbial respiration. Boyer concluded that respiration increased with increasing nitrogen; the more finely processed the wood substrate, the more microbial respiration occurred; and CCR had the lowest available nitrogen. N-immobilization was documented in pine tree substrate (PTS) in earlier studies by Jackson and Wright (2007). Nitrogen drawdown index (NDI) and substrate CO_2 efflux were recorded to determine the extent of N-immobilization. The authors determined that PTS CO_2 efflux rate was five times as high as peat and twice as high as pine bark. Additionally, NDI results showed that 68% of PTS's available substrate N was immobilized compared to 13% in peat. Therefore, future studies should evaluate N-immobilization in FPS using one or more of these procedures. Further studies should also evaluate higher rates of nitrogen, as well as varying formulations and delivery methods to overcome the effects of N-immobilization on crop production.

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Table 1. Effects of substrate and nitrogen on size index of *Impatiens* ×*walleriana*.[zy]

	Substrate			
Nitroform N kg·m^{-3}	80:20 peat:perlite	80:20 FPS[x]:peat	100% FPS	
0	18.6bA[wv]	14.3bB	15.0bB	
0.59	19.5aA	16.8aB	15.8aC	
Starter N kg·m^{-3}	80:20 peat:perlite	80:20 FPS:peat	100% FPS	
0.06	19.3A	15.2B	14.4B	
0.12	19.1A	15.4B	15.5B	
0.18	18.7A	16.1B	16.3B	
sign.[u]	NS	L*	L***	
	Starter N kg·m^{-3}			
Nitroform N kg·m^{-3}	0.06	0.12	0.18	sign.
0	15.3b	15.7b	16.9ns	L***
0.59	17.3a	17.6a	17.2	NS

[z] The substrate by Nitroform®, substrate by fertilizer, and fertilizer by Nitroform® interactions were significant at $P < 0.05$.

[y] Size Index in cm [(height + width + perpendicular width)/3].

[x] Forest-product substrate (FPS)

[w] Least squares means comparisons between Nitroform rates (lower case letters in columns) using F-tests at $P < 0.05$.
ns = not significant.

[v] Least squares means comparisons among substrates (upper case letters in rows) using the simulated method at $P < 0.05$.

[u] Not significant (NS) or significant (Sign.) linear (L) trends using qualitative-quantitative regression models at $P < 0.05$ (*) or 0.001 (***).

Table 2. Effects of substrate and nitrogen on shoot dry weight at 14 days after planting of *Impatiens* ×*walleriana*.[zy]

	Nitroform N kg·m^{-3}					
	0			0.59		
Starter N kg·m^{-3}	80:20 peat:perlite	80:20 FPS[x]:peat	100% FPS	80:20 peat:perlite	80:20 FPS:peat	100% FPS
0.06	0.543aNS[wv]	0.173bB	0.183bB	0.513a	0.253cA	0.358bA
0.12	0.533aNS	0.175bNS	0.238bNS	0.478a	0.245b	0.295b
0.18	0.418aB	0.275bNS	0.260bNS	0.545aA	0.338b	0.298b
sign.[u]	L**	L*	NS	NS	L*	NS

[z] The substrate by Nitroform by fertilizer interaction was significant at $P < 0.05$.

[y] Plant shoot dry weight in grams.

[x] Forest-product substrate (FPS)

[w] Least squares means comparisons among substrates within Nitroform rates (lower case letters in rows) using the simulated method at $P < 0.05$.

[v] Least squares means comparisons between Nitroform rates within substrates (upper case letters in rows) using F-tests at $P < 0.05$. NS = not significant.

[u] Not significant (NS) or significant (Sign.) linear (L) trends using qualitative-quantitative regression models at $P < 0.05$ (*) or 0.01 (**).

Table 3. Effects of substrate and nitrogen on shoot dry weight 28 days after planting of *Impatiens* ×*walleriana*.[zy]

	Substrate				NitroForm N kg·m^{-3}	
Starter N kg·m^{-3}	80:20 peat:perlite	80:20 FPS[x]:Peat	100% FPS	Starter N kg·m^{-3}	0	0.59
0.06	3.91aNS[w]	1.78b	1.85b	0.06	2.04b[v]	2.99a
0.12	4.10a	1.79b	2.03b	0.12	2.28b	3.00a
0.18	3.79a	2.25b	2.34b	0.18	2.83ns	2.76
sign.[u]	NS	L**	L***		L***	NS

[z] The substrate by fertilizer and Nitroform by fertilizer interactions were significant at $P < 0.05$.

[y] Plant shoot dry weight in grams.

[x] Forest-product substrate (FPS)

[w] Least squares means comparisons among substrates (lower case letters in rows) using the simulated method at $P < 0.05$.

[v] Least squares means comparisons between Nitroform rates (lower case letters in rows) using F-tests at $P < 0.05$. ns = not significant.

[u] Not significant (NS) or significant (Sign.) linear (L) trends using qualitative-quantitative regression models at $P < 0.01$ (**) or 0.001 (***).