Evaluation of Processed Corncob and *Paulownia tomentosa* as Substrate Components in Horticulture Crop Production

by

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Abstract

The main components in soilless substrates for greenhouse and nursery production include pine bark, peatmoss, and perlite. There have been recent concerns with peatmoss because of availability, and the environmental impact harvesting has on natural peat bogs. There have also been concerns with perlite because of the fine particle dust that is associated with its dry state. These concerns have led researchers to look at alternatives that will be able to provide the same function with less environmental and health concerns. The first study evaluated the use of corncob as an alternative to perlite in the production of greenhouse annuals. Results from physical properties analysis showed that container capacity decreased with increasing percentages of corncob. Growth index and shoot dry weights showed a reduction in growth with an increase in percentage of corncob for all species, similar results were seen in root ratings and bloom counts. Results from this experiment suggest that a possible reason for reduction in growth could be the availability of essential nutrients. A second study was addressed to evaluate the effect of nitrogen fertilizer rates on corncob-amended substrates in the production of *Petunia ×hybrida*. Peatmoss was combined with soaked corncob, un-soaked corncob, or perlite at an 80:20 (v:v) ratio and mixed with 0.9 (2), 1.8 (4), 2.72 (6), or 3.6 kg·m^{-3} (8 lbs·yd^{-3}) of slow-release fertilizer. Results showed a higher container capacity and total porosity for substrates containing corncob. Electrical conductivity readings decreased over time for all treatments. Shoot dry weights and growth index increased with an increase in fertilizer rates across all treatments for both experiments. Petunias grown in non-soaked and soaked corncob substrates at the highest rate were similar to perlite at fertilizer rates of 1.8 (4), 2.72 (6), or 3.6 kg·m^{-3} (8lbs·yd^{-3}). Results from this study showed that an increase in fertilizer had a positive effect on the growth of petunias in a corncob amended substrate. The third study looked at the effects of corncob as a substrate component in the production of container grown perennials. Container capacity and air space of corncob-amended substrates were equal to their perlite amended counterpart. Results from bulk densities indicated that substrates containing corncob were higher than all substrates containing perlite. Results at 30 and 60 days after planting (DAP) of pH for lantana and miscanthus showed substrates with corncob to have a higher pH than perlite substrates. While at 90 DAP there were no differences across all treatments and species; electrical conductivity followed similar trends. Shoot dry weights of salvia and lantana showed a reduction in growth at 35 DAP, but by 90 DAP there were no differences with miscanthus corncob substrates at 10% and 30% were lower in shoot dry weights compared to its PL counterpart, while at 90 days all treatments were equal except for 30% corncob. In conclusion, growth of lantana, salvia, and miscanthus in corncob amended substrates were similar compared to its perlite counterpart at 90 DAP. Results from this study show that corncob might be a viable alternative to perlite. Because of the environmental issues and the availability of peatmoss, a fourth study was conducted to look at the effects of *Paulownia tomentosa* (PT) as a substrate component in annual production. Results showed substrates containing higher amounts of paulownia had greater air space than substrates containing less amounts of paulownia. Substrate container capacity was greater in the low percentages of paulownia. All substrates containing paulownia had a higher total porosity than the perlite standard (PS). Substrate pH at 14, 21, and 28 DAP was highest for treatments containing 60% to 100% PT. Initial substrate EC was greatest for the PS and the 20% PT substrate, however by 35 DAP, substrate EC was similar among all treatments. Petunia growth index was 63 to 400% greater for plants grown in the PS compared to other treatments. Dianthus tended to respond better to PT as a substrate component than petunia, although dianthus growth index followed a similar trend with GI being 26 to 135% greater in the PS treatment compared to all others. With one exception, all other growth parameters followed similar trends on both species with plants grown in PS having the greatest bloom counts, root ratings, and shoot-dry weights of all treatments.

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I. Literature Review

Introduction

Container grown plants are a major component in the greenhouse industry and provide growers with the ability to grow plants with both uniformity and cost efficiency. Until the 1960s, topsoil was the primary component of rooting substrates for growing container plants. Topsoil became increasingly difficult to find in good condition and was often found to have unneeded nutrients as well as poor drainage and pathogens (2). To address problems with topsoil based substrates alternatives known as soilless substrates were developed. The University of California and Cornell University are often credited with the initial development of soilless substrates. Soilless substrates developed by Cornell University contained a mixture of peatmoss, vermiculite, and perlite with different ratios of the components for the desired crop (2). The base mix of the University of California material consisted of inorganic material, such as sand, perlite, and organic material such as peat, rich hulls, sawdust, and bark (1).

Over the past several years, peatmoss and other components of soilless substrate mixes have become more scarce and expensive, creating a need for alternative substrates with lower cost and easier access than peat based materials. Most peat moss used in the United States is derived from Canada or Europe. The rise in transportation cost associated with importing peat can negatively affect growers (5). Alternatives to peat have been evaluated over the past 30 years. Some of the most successful alternative to peat are pinebark (23), parboiled rice hulls (21), *Wholetree* (17), coconut coir dust (11) and pine wood substrates (20). Alternatives to perlite are being considered, not only because of local availability and cost but also because of reported dangers associated with the expanded perlite dust. Dust that is associated with the dry state of perlite is considered an irritant of the eye and lung (6) and is classified as a nuisance dust. Early studies on the pulmonary function in perlite workers showed that there was no evidence of pneumoconiosis but control of the dust to keep levels below nuisance range was recommended as essential (8).

Chung-Li et al., (6) looked at the effects of expanded perlite exposure with reactive airway dysfunction syndrome. Twenty-four factory workers were followed for six months after an accidental spill at a Taiwan factory. One staff member at the factory that was exposed to the spill and inhaled the particle dust began to develop sore throat, persistent cough, and chest tightness. Workers who responded to help with the cleanup began to complain of eye and throat irritation even though they were wearing masks.

Perlite alternatives. Alternatives to perlite are ground automobile tires (3), expanded polystyrene (7), parboiled rice hulls (12), calcinized clay (28), ground bovine (13), and vermiculite (2). Perlite is an indigenous volcanic rock that is mined and then crushed and heated to 871C (1600F) (24). Perlite is often used in the soilless mixes with peatmoss to provide air space and total porosity, which can often be limited because of the fine particles of peatmoss. Perlite can be a major problem in the greenhouse industry because of the fine particle dust associated with it that can be classified as a nuisance or irritant. These problems have led researchers to look for organic and non-organic alternatives to perlite (2, 3, 7, 12, 13, 28).

Organic Alternatives. Two organic alternatives to perlite are parboiled rice hulls and ground bovine. Evans and Gachukia (12) looked at the growth of annual species in substrates containing perlite or parboiled fresh rice hulls (PFH). Fourteen substrates were formulated by blending perlite or PFH at 10, 15, 20, 25, 30, 35, and 40% (v:v) with sphagnum peatmoss. Substrates were then potted and planted with tomato, marigold, vinca, impatiens, geraniums, or pansies.

Results from the dry root weight of vinca and geranium showed no difference between substrates of peat:PFH and peat:perlite. Dry root weights of impatiens, marigolds, and pansies were found to have different weights in PFH substrates when compared to perlite at certain ratios. Dry root weights in tomatoes were higher in PFH substrates than those grown in perlite substrates. These results concluded that dry root and dry shoots weights of plants grown in perlite and PFH substrates were not significantly different. They also reported that the use of PFH as a perlite alternative could have a positive effect on production cost, without reducing the plant growth (12).

Evans and Gachukia (14) also looked at the effects PFH and peat substrates had on physical properties compared to perlite and peat based substrate. A possible alternative to perlite not only needs to have minimal effects on the chemical properties of the substrate, but it also needs to be similar in physical properties when compared to perlite. Since the effects of PFH on physical properties were never looked at, the objective of this study was to answer those questions.

Results indicated total pore space (TPS) of a perlite substrate ranged from 71.5% to 79.4% while a substrate containing PFH ranged from 82.1% to 86.7%. Results showing that PFH had higher TPS than perlite substrates with some instances being up to

15% greater. An increase in percentage of perlite up to 60% showed a decrease in the amount of TPS, while an increase in the amount of PFH showed a increase in TPS up to 50%. Air space was higher in PFH substrates when compared to its perlite substrate counterpart. Water holding capacity was similar in comparison of both perlite and PFH. PFH held more water at lower percentages, but as PFH increased, similar results to perlite were seen. Overall results showed that an increase in PFH provided a greater increase in air space and water holding capacity than its perlite counterpart. These results suggested that PFH would play a similar role to perlite, but with less PFH needed to provide the same amount of airspace and water holding capacity (14).

Ground bovine (GB), a waste product of the meat processing industry, was evaluated as a low cost organic alternative to perlite (13). Peat based substrates were mixed with GB (two grades of bone were used, large and small) or perlite at rates of 10, 20, 30, and 40% (v:v). Bulk density and container capacity was higher in 10 and 20% large and small GB than perlite. Substrates with small bone at 30 and 40% had similar air space (AS) to perlite while AS of substrates with large GB at the same ratios were higher. Conclusions from the physical properties showed that AS of large GB at the higher ratios were greater than small GB and perlite substrates. Substrates mixed with GB showed an increase of pH and EC over time, which resulted in a high mortality rate in geranium and vinca. Along with the high pH and EC, another explanation for the quick death was the release of mineral elements into the substrate as the GB softened. The high mortality rate of the annuals revealed limitations of GB compared to perlite in the production of greenhouse annuals.

Inorganic Alternatives. There have been several different inorganic alternatives used to substitute for perlite. Noland et al., (27) evaluated the chemical and physical effects of pumice compared to perlite as a substrate amendment. When pumice and perlite were compared they had similar physiochemical properties. Plants grown with pumice grew equally to those in a perlite amended substrate (27). In a study by Pickens et al., (28), clay that was calcinized at high temperatures was used as a perlite alternative when combined with peat. Data was collected on impatiens and verbenas in hanging baskets. The baskets were scaled on a 1 to 5 scale of marketability, and the calcinized clay had the highest marketability rate in verbenas with no difference in impatiens between perlite and calcinized clay. The study reported that peat mixes amended with 15% of calcinized clay had the highest root density and the highest shoot weight (28).

Bowman et al., (3) used ground automobile tires as a perlite alternative in the production of chrysanthemum. Ground rubber was obtained from automobile tire waste and was mixed with sand and sawdust in two grades: coarse and fine. Container substrates that were amended with the coarse tire resulted in a lower total porosity and container capacity and a higher air space. Substrates amended with the fine grade had only a minimal effect on the physical properties. When the substrates amended with ground rubber were compared to the control, the chrysanthemum transplants grew slower and showed signs of stress. Final shoots were also shorter in the substrates amended with the ground rubber. Substrates that contained the ground rubber resulted in a larger amount of zinc in the tissue, suggesting that plants grown in these substrates might develop a toxicity problem.

A similar study was conducted by Newman et al., (26), evaluating the growth of germaniums in substrates amended with waste tire components. The waste used in this study was ground rubber and ground rubber fibers from inside the tire. Container substrates were mixed with rubber or fiber, vermiculite and peat compared to a control of vermiculite, peat, and rockwool (v:v). Plants grown with substrates containing 25% percent ground rubber showed equal flower and size to the control. Plants grown in 50% rubber were smaller, lighter, and had fewer flowers than plants grown in the control. Confirming what was reported in previous studies, plants grown in rubber or fiber had high elevated levels of Zn in the foliar tissue. Plants grown in 50% rubber or fiber had the highest traces of Zn.

The percent and size of the ground rubber did not affect the pH and EC of the substrate compared to the control. Substrates containing fibers showed no effect on the cation exchange capacity (CEC) and showed potential to have higher water holding capacity than substrates with rubber. The tire waste used in this study was obtained in an unprocessed form and contained large amounts rubber dust. The Zn was attributed to the dust, therefore if the dust could be removed, the fiber and rubber could be a viable amendment (26).

Expanded polystyrene was used as a substrate amendment as a replacement of perlite in a study by Cole and Dunn (7). Expanded polystyrene, a waste product of the polystyrene industry can be used at a lower cost than perlite. In comparing substrates containing perlite to polystyrene, pH increased when the amount of perlite increased while no increase in pH was found in the polystyrene. Substrates containing polystyrene showed a decrease in EC as the concentration increased. When the concentration of perlite and polystyrene increased the air space was found to increase, but no major difference was found in total porosity and water holding capacity.

A study by Prasad (29), on physical properties of peat mixes suggests that the addition of polystyrene to peat will provide increased air space and decreased available water content. Polystyrene also has an effect of decreasing the total porosity and bulk density of a substrate as the percentage of polystyrene is increased (29). The use of polystyrene and peat mixes are suggested if using small pots placed under an irrigation system and polystyrene may require more frequent watering.

Peat alternatives

Peat has begun to be problematic when using it in a soilless substrate mix. The harvesting of peat can be a problem because it destroys and upsets the natural environment of the peat bogs. The United States does not have many natural bogs so peat is often harvested in other countries and imported which can raise transportation costs. Because of this problem and many other factors, research has been conducted to identify alternatives to peat for use in the greenhouse industry (9).

Coir dust is produced from the left over material of coconut fiber and is commonly called waste-grade coir. Coir waste can be processed through several screens to remove the fibers, what is left is coir dust (11). Research has shown that coir dust can be used effectively in the production of tropical plants and is now being used as an alternative to peat in greenhouse production.

A study by Evans and Stamps (11), showed the effectiveness of using coir dust as a peat alternative in bedding plant production. Substrates were mixed with 20, 40, 60, and 80% of peat or coir dust and perlite. The mixes were planted with marigolds, petunias and geraniums. Results showed that substrates with 20% coir had greater air space than peat at the same rate but had lower water holding capacity than peat. Overall substrate mixes with coir dust showed a greater water holding capacity than peat. Marigolds grown in 20 to 40% peat had a delayed flower time compared to substrates that containing coir dust. Petunias grown in coir dust had taller growth and greater shoot fresh weights than petunias in peat based substrates. Results from this study showed that coir dust can be a good alternative to peat in the production of peat based substrates (11).

WholeTree. The use of wood fibers and other parts of the tree have been looked at as peat alternatives. One alternative to peat using wood fibers is *WholeTree* substrates; this differs from other tree fibers used because this process uses the entire tree (15). *WholeTree* is a manufactured amendment instead of being a by-product like some wood fiber substrates (16). *WholeTree* can be a beneficial alternative to peat because it is a raw material that is locally available, thereby decreasing transportation costs. *WholeTree* is also beneficial compared to other wood fibers because it is manufactured, which will allow for more uniformity and the ability to alter the product into a required size (17).

A study by Fain et al., (16) compared growth of marigolds and petunias potted in *WholeTree* substrates made from three species of pines. Each of the *WholeTree* substrates consisted of 100, 80, and 50 % *WholeTree* mixed with peat, and each was compared to a 80:10:10 peat:vermiculite:perlite control. Physical properties of substrates showed no difference in total porosity, however container capacity was higher in peat based substrates, showing peat has higher water holding capacity than *WholeTree*. Air space was higher in the substrates that contained larger amounts of *WholeTree*, suggesting that the particle size of the *WholeTree* is larger than peat giving it more air space.

At study termination there was no difference in the bloom counts of marigolds, but petunias that were grown in peat-lite mixes had twice as many blooms as all other substrates. Differences were seen in the growth index of marigolds from plants grown in *WholeTree* mixes compared to that of the peat mixes, but all were considered marketable. Results at study termination showed that substrates containing *WholeTree* had a higher pH than peat mixes and all had similar EC at study termination. Results from this study showed that *WholeTree* could be a possible alternative to peat in greenhouse grown substrates (16).

In a similar study by Gaches et al., (19) two experiments were conducted to compare *WholeTree* and chipped pine logs to industry standard peat in greenhouse grown annuals. Mixes consisted of 1:1 *WholeTree* or chipped pine logs and peat. Substrates were mixed and potted with either impatiens or vincas and placed in a polycarbonate greenhouse. *WholeTree* and chipped pine logs were also chipped and placed in polypropylene bags in the sun and allowed to age before planting. Results showed that growth index, root ratings and bloom count were all similar between both species. Chipped pine longs differed slightly from the *WholeTree* mixes in shoot dry weight, which had 6.5% greater weights than that of *WholeTree*. Plant response showed no differences in pH and EC between the two-substrate types.

In a second experiment (19) substrates of chipped pine logs used to grow vinca had higher pH at 7 and 28 DAP, and similar results were seen in the impatiens at 21 DAP where substrates with chipped pine logs had a higher pH than the *WholeTree* substrate. Vincas grown in both substrates had similar shrinkage, growth index and bloom counts. Impatiens differed in *WholeTree*, which had a greater bloom count and higher root ratings

(19). Results from this experiment showed that chipped pine logs and *WholeTree* could be used as an alternative for each other with no major changes in plant growth and responses.

Pine wood substrates. Research on pine wood substrates has shown that it can be an alternative to current soilless substrates mixes of peat and pine bark (4). Pine wood substrates are similar to that of *WholeTree* but differ because pine wood substrates use de-limbed trees while *WholeTree* substrates include all limbs and foliage (15).

Research by Wright and Browder (31) showed the effects of using chipped pine logs as an alternative to pine bark. Three substrates of chipped pine chips, chipped pine bark and a mix of chipped pine bark and chipped pine logs were potted and planted with three plant species of Japanese holly, azalea and marigold. Shoot dry weights of azalea and marigolds were higher in the 100% pine bark and 75:25 (v:v) pine chips: pine bark than 100% pine chips, while there was no difference in the shoot dry weights of Japanese hollies. Pine chips had a larger particle size distribution than pine bark but there was no difference in container capacity between the substrates. Available water was not different, showing that pine chips were able to supply the same amount of water to the plant as pine bark would. Throughout the study, EC was measured in the substrates with EC of pine chips lower than pine bark each week. The reason for low EC is because the pine chips have a lower cation exchange capacity than pine bark, based on a report in a later study (32).

A study by Jackson and Wright (20) looked at the fertilizer rates needed for growth of Japanese hollies in pine tree substrates and pine bark substrates and chrysanthemums grown in pine tree substrates and peat based substrates. Increase in EC rates occurred with the increase in fertilizer rate. In the production of the Japanese hollies, higher rates of fertilizers were needed for pine wood substrates than that of pine bark. The reason for the higher rate of fertilizer needed is thought to be because of the lower cation exchange capacity of the pine wood substrate.

Similar results occurred in the growth of chrysanthemums. Shoot dry weights and growth index were the highest in the peat substrates at 200mg/L N. Pine wood substrates required up to 300mg/L N to reach their maximum shoot dry weight and growth index compared to 200mg/L N in peat based substrates. The explanation for this was similar to the pine wood substrates compared to pine bark, with pine wood substrates having a lower cation exchange capacity and N immobilization than peat substrates (20).

Murphy et al. (25) looked at the effects of hardwood-amended substrates in the growth of *Petunia grandiflora*, *Catharanthus roseus*, and *Impatiens walleriana*. Substrate treatments included a 75:25 (v:v) peat:perlite, remaining treatments were 75:25 and 50:50 (v:v) peat:sweet gum, peat:hickory, peat:red cedar and peat:wholetree. Results showed that pH levels at all dates were within the BMP recommended ranges. Electrical conductivity was initially high but was similar among treatments at study termination. Flower counts of petunia, vinca and impatiens in red cedar were similar to the greenhouse standard. Plants grown in red cedar preformed just as well as the greenhouse standard throughout the study. Growth parameters of crops grown in hickory and sweet gum were significantly lower than the greenhouse standard and therefore were not recommended for annual crop production (25).

Rice hulls, a by-product of the rice industry, has been evaluated as an organic alternative to peat moss and pine bark in container grown substrates. A study performed by Laiche and Nash (22) showed the effects of mixing rice hulls with a clay aggregate to form a soilless substrate for container grown annuals. Rice hulls that were either milled or composted were mixed with sand or arkalite (clay aggregate) and potted with azaleas, Japanese hollies, and junipers. Results showed hydraulic conductivity of the substrates was very high in the beginning and steadily decreased over time. Growth rates showed that fresh and composted rice hulls can be used as an alternative to pine bark in container grown plants (22).

Kämpf and Jung (21) looked at carbonized rice hulls as a peat alternative in horticulture substrates. Six different mixes of substrates containing peat, peat:rice hulls, peat:sand, and peat:sand:rice hulls were planted with bedding plants that included lobularia, marigolds, tomatoes, and pansies. The best results for marigold growth was in substrates containing rice hulls and peat at 1:1 (v:v) or 2:1 (v:v). Plant weight, height, and number of leaves were greater in substrates with rice hulls for marigolds. Lobularia showed similar results to marigolds but had a larger amount of leaves on the plant when grown in substrates with rice hulls. Similar results occurred in the tomato and pansies also. Results from this experiment showed that a mixture of carbonized rice hulls into a horticulture substrate was effective in the production of bedding plants and can be an effective substrate component (21).

Dueitt and Newman (10) looked at the effects of using aged and fresh rice hulls as a peatmoss alternative in the production of marigolds and statice. Results showed that the addition of rice hulls did not modify the pore space of the substrate. Media that was amended with fresh rice hulls initially had higher AS than media with aged rice hulls. By the end of the study, these results were reversed, likely due to the shrinkage of the rice hulls over time. At study termination, media containing fresh rice hulls had greater water holding capacity than the control media. These results showed that the use of rice hulls could be a successful alternative to peat moss in the growth of selected cut flowers (10).

Statement of Research Objectives

This study will be conducted to determine if corncob can be a successful replacement for PL in greenhouse crops. Successful results will occur if plants grown in corncob amended substrates have similar or greater GI, BC, RR, and SDW than annuals grown in a perlite amended media. Also, chemical components of pH will need to be in the 5.0-7.0 range with minimal variability and EC will need to be in the 0.5 to 1.5 (dS/cm) range. Results from porometer data will need to be in the same range as the peat-lite mixes of Cornell University, which has TP in the 85-88 (% vol), AS 9-10 (% vol), and BD of 0.14 (g/cm^3) (18).

Complications could result in this experiment from amending the substrate with corncob. Currently, no studies have looked at the effects of corncob as a horticulture product, therefore little is known regarding the effects corncob has on greenhouse crops. Possible complications could result from chemical components of the substrate. Chemical problems could induce a drop or increase in the pH and EC of the substrate over time; low CEC resulting in the corncob tying up nutrients and not allowing them to be available to the crop. Corncob substrates may also have a higher potential to hold more water than the PL substrates resulting in plants staying wetter than desired.

Currently about 10% of corncobs nationally are used for domestic products. Some of these products include the use of corncob as an abrasive material, chemical and pesticide absorbent and animal bedding (30). If the location of the corncob can be found near horticultural producers, this would result in a lower transportation cost compared to PL in some regions. The use of corncob also has the potential of providing a healthier working environment for the growers compared to using PL. Success of corncob as a substrate component will be if the product can provide successful physical and chemical properties and a crop of marketable state, without the human health risks when using PL.

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II. Processed Corncob as an Alternative to Perlite in the Production of Greenhouse Grown Annuals

Abstract

This study evaluated the use of processed corncob as an alternative to perlite in the production of greenhouse annuals. Corncob or perlite was added to peatmoss at rates of 10%, 20%, or 30% by volume. Containers were filled and planted with three plugs of *Petunia ×hybrida*, *Impatiens walleriana* or *Tagetes erecta.* Results from physical properties analysis showed that container capacity decreased with increasing percentages of corncob. There were differences in air space of corncob amended substrates when compared to perlite amended substrates in Experiment 1, while Experiment 2 showed slightly different results with air space in corncob and perlite amended substrates to be similar at equal percentages. Growth index and shoot dry weights for plants grown in both experiments were reduced with an increase in percentage of corncob for all species. Similar results were seen in root rating and bloom counts. Results from this experiment show that reduced growth was found in annuals grown in corncob amended substrates compared to its perlite counterpart.

Index words: processed corncob, perlite, peatmoss, alternative substrate, greenhouse annuals.

Species used in the study: *Petunia ×hybrida* 'Dreams Rose', *Impatiens walleriana* 'Extreme Orange' and *Tagetes erecta* 'Antigua Orange'.

Significance to the Industry

Perlite (PL) is a component in most soilless substrates for greenhouse annual production. Significant cost is associated with the production of the lightweight component. Along with the high cost, a fine particle dust is associated with perlite that is known to be an eye and lung irritant (3). A possible new alternative to perlite is the use of processed corncobs. Processed corncob is a product of the United States and has potential to be regionally available and more carbon neutral compared to perlite. Corncobs are more consistent in size, which could eliminate the quantity needed to achieve proper air space. Because of these advantages, corncob has the possibility of being a successful alternative to the use of perlite in production of greenhouse annuals.

Introduction

Topsoil was used in container plants in greenhouse and nursery production until the 1960s when soilless medias were developed. One of the pioneers was Cornell University with their introduction of the peat-lite mixes. The peat-lite mix was a combination of peatmoss, used for its fine particles to hold in water, and perlite and vermiculite used to aerate the media creating air spaces (1). Peatmoss is derived from the decomposition of mosses, sedges, and sphagnums under acidic and wet conditions (2). Perlite is an igneous glassy rock that is mined and heated to 871C (1600F) to remove all water and expand the rock (8). During the production of perlite to its dry state, a very fine particle dust can be produced that is considered to be a lung and eye irritant (3).

The problems with perlite have influenced researchers to look for alternatives that can provide the same air space, without the nuisance of the dust. Some of these alternatives have included pumice, parboiled fresh rice hulls, and expanded polystyrene. Pumice is a natural occurring mineral that comes from aluminum silicate, potassium, and sodium oxides, and is often developed from volcanic eruptions. When compared to perlite, pumice has similar chemical and physical characteristics (9).

Parboiled fresh rice hulls, a by-product of the rice milling industry, has also been evaluated as an alternative to perlite. Parboiled fresh rice hulls and perlite were mixed with peat at rates of 10%, 15%, 20%, 25%, 30%, and 35%. In the growth of impatiens, marigolds, vincas, and geraniums, there were no differences among treatments for root-dry weight and shoot-dry-weight (5).

Cole and Dunn (4) examined the uses of polystyrene beads as a perlite alternative. Polystyrene beads collected as a waste product of polystyrene industries were cheaper than perlite in transportation cost. Plants grown with polystyrene beads produced the same amount of roots when compared to a perlite mix (4).

A potential new alternative to perlite is processed corncobs. Corncobs are often left over from the harvesting of corn seed with four main parts of the corncob that are processed and used commercially. The three outer parts of the corncob are the beeswing, the chaff, and the woody ring. Which are all considered to be the most absorbent part of the corncob and are often pelletized and used for absorbent tasks including spills of chemical waste, oil, grease, animal bedding, litter and a sweeping compound. The inner part of the corncob is the pith, which is often used as an abrasive material for tasks such as sand blasting, metal finishing, polishing, and carriers for pesticides (11).

Processed corncob is a waste by-product of the feed and seed industry that requires less energy to produce than perlite. Because it is a by-product there will be no rise in the feed and seed market price because of short demand. Corncob is a product of the United States and does not have to be imported which could allow a lower transportation cost compared to perlite or peat. The purpose of this study was to evaluate the effects of corncob as a substrate component in the production of container grown annuals compared to substrates containing the industry standard perlite.

Materials and Methods

Two experiments were installed (January 11, 2011, April 14, 2011) at the Paterson Greenhouse Complex at Auburn University. Peatmoss (P) was mixed with either processed corncob (C) (The Andersons Inc. Maumee, OH) or perlite (PL) at rates of 10%, 20%, and 30%. Treatments were 90:10 P:C (v:v) 80:20 P:C (v:v) 70:30 P:C (v:v) 90:10 P:PL (v:v) 80:20 P:PL (v:v) 70:30 P:PL (v:v). Substrates were amended with 1.36 $kg\cdot mg^{-3}$ (3.0 $lbs\cdot yd^{-3}$) of 7N-0.86P-8.3K nutrient charge (7-2-10, GreenCare Fertlizers, Kanakakee, IL), 2.97 $kg\cdot mg^{-3}$ (5 $lbs\cdot yd^{-3}$) of dolomitic lime and 0.68 $kg\cdot mg^{-3}$ (1.5 $lbs\cdot yd^{-3}$) of Micromax (The Scotts Company, Marysville, OH). 1.56 L (1.65 qt) containers (EU105T5, ITM Horticultural Products, Middlefield, OH) were filled to capacity tapped and re-filled to capacity. Three 2 cm^3 (0.7 in^3) plugs grown in 200 cell flats (Young's Plant Farm, Auburn, AL) of either petunia (*Petunia ×hybrida* ‘Dreams Rose’) impatiens (*Impatiens walleriana* ‘Extreme Orange’), or marigold (*Tagetes erecta* ‘Antigua Orange’) were planted in each container. Containers were placed on raised benches in a twin wall polycarbonate greenhouse and hand watered as needed. Plants were liquid fed beginning 10 days after planting utilizing at 200 ppm of N (20N-4.3P-16.6K liquid fertilizer, 20-10-20, SDT Industries, Inc. Winnsboro, LA). Data loggers were installed to capture greenhouse temperatures for the durations of the study. Greenhouse temperature daily average highs and lows were at 25/18C (77/65F).

Initial substrate physical properties including total porosity (TP), container capacity (CC), air space (AS), and bulk density (BD) were determined using the North Carolina State University porometer method (6). Leachates were collected using the Virginia Tech Pour Through Method (12) and analyzed for pH and electrical conductivity (EC) at 0, 14, 21, 28, and 35 days after planting. At 35 DAP all plants were measured for growth index (GI) [(height + width+ perpendicular width)/three (cm)] and bloom count (open flowers and unopened buds showing color) (BC). Roots were visually inspected and rated on a scale of 0 to 5 with 0 indicating no roots present at the container substrate interface and 5 indicating roots visible at all portions of the container substrate interface. At 35 DAP, petunia and impatiens shoots were removed at the substrate surface and oven dried at 70C (158F) for 72 hours and weighed.

Containers were arranged in a randomized complete block with 12 single pot replicates. Each plant species was treated as a separate experiment. Data was subjected to analysis of variance using the general linear models procedure, and multiple comparisons of means conducted using Tukey's Studentized Range Test (Version 9.1; SAS Institute, Cary, NC).

Results and Discussion

Experiment 1. Physical properties analysis (Table 1) indicated similarities for TP of corncob substrates compared to its equal perlite counterpart, except for 90:10 (v:v) were perlite had greater TP than corncob. Among treatments 10% corncob had the highest CC, while CC of 20% and 30% C were similar. Container capacity of perlite substrates were greater than their corncob counterpart. Air space was similar for all perlite treatments, while 20% and 30% corncob had the highest AS. Corncob substrates containing 20% and 30% C had the highest BD, and were greater than 10% corncob and all perlite treatments had similar BD.

The pH of corncob substrates at 0 DAP (Table 2, 3, 4) was similar to corresponding substrates with perlite, except for 30% perlite which was different from 30% corncob. At 21, 28, and 35 DAP leachates from corncob substrates were higher in pH than all substrates containing perlite for all species. Leachates from petunias at termination had similar pH across all treatments except for 10% corncob which was lower (Table 2). Initial EC results indicated corncob substrates had higher EC levels than substrates with perlite. However at 21, 35, 42, 49, and 56 DAP there were no differences in EC across all substrates for petunias and marigolds (Table 2, 4).

Growth index for all species were the highest in perlite amended substrates with growth being up to 70% greater than some treatments of corncob (Table 5). Impatiens and marigolds had higher BC in 10% corncob amended substrates than all other treatments containing corncob, while all substrates with corncob had lower BC than PL amended substrates. Shoot-dry weights and RR followed similar trends with substrates containing perlite to be of greater value than its counterpart containing corncob across all species.

Experiment 2. Physical properties analysis (Table 6) showed that TP was highest in 10% and 20% perlite amended substrates, with substrates containing 10% and 30% corncob similar. Container capacity with 10% and 20% perlite was highest with 10% corncob being similar. Airspace was different than what we saw in Experiment 1, with substrates containing corncob being equal to their perlite counterpart, except for 10% corncob, which had less AS than 10% perlite. Similar to the first experiment, BD increased with increasing percentages of corncob.

The pH of corncob substrates at 0 DAP was higher than substrates containing perlite except for 30% perlite, which was similar to 30% corncob. These results differ from Experiment 1 where there was no difference between leachates from corncob and perlite at 0 DAP. Results of impatiens and marigolds (Tables 8 and 9) at 21, 28, and 35 DAP showed that leachates from corncob substrates at 20% and 30% had higher pH than all substrates containing perlite for all species. Leachates from petunias at termination (Table 7) had similar pH across all treatments except for 20% corncob, which was lower, similar to results found in Experiment 1. Initial EC results showed an increase with increasing corncob in substrates. Results at 14, 21, 28, and 35 DAP showed no difference across all substrates for all species, similar to results in Experiment 1 (Tables 7, 8, 9).

Growth index (Table 10) for all species was again the highest in perlite amended substrates with growth being over 50% greater than some treatments grown with corncob. Impatiens had higher BC in 10% corncob than all other treatments containing corncob, while all substrates with corncob had lower BC than PL substrates, similar to Experiment 1. Shoot-dry weights and RR followed similar trends to Experiment 1 with all substrates containing perlite to be of greater value than its counterpart containing corncob across all species.

Results from this study showed that physical properties analysis of corncob amended substrates resulted in equal or greater AS and BD than perlite substrates. Results from the growth parameters showed a reduction in growth with increasing percentage of corncob. One possible explanation for the reduction in growth could be the nutrient availability in the corncob amended substrates. Results from previous literature suggest that corncob can be a rich source of carbon for soil microorganisms that can deplete available nitrogen in the media (9, 7). Future studies on nutrient management when using corncob as a substrate component is warranted.

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Table 1. Physical properties of corncob and perlite amended amended substrates (Experiment 1).[z]

Substrates	Air[y] space	Container[x] capacity	Total[w] porosity	Bulk[v] density
	(% vol)	(% vol)	(% vol)	(g/cm^3)
90:10 Peat:corncob	9.4b[u]	75.6b	85.1b	0.18b
80:20 Peat:corncob	12.9a	68.5c	81.4c	0.23a
70:30 Peat:corncob	13.3a	69.4c	82.7bc	0.24a
90:10 Peat:perlite	6.4c	83.2a	89.6a	0.13c
80:20 Peat:perlite	6.8c	77.4b	84.2bc	0.15bc
70:30 Peat:perlite	7.8bc	77.9b	85.7b	0.17bc

[z] Analysis performed using the NCSU porometer.

[y] Air space is volume of water drained from the sample ÷ volume of the sample × 100.

[x] Container capacity is (wet weight - oven dry weight) ÷ volume of the sample × 100.

[w] Total porsity is (wet weight - dry weight + drainage) ÷ volume of the sample × 100.

[v] Bulk density after forced air drying at 105C (221F) for 48 h.

[u] Tukey's Studentized Range Test ($P \leq 0.05$, $n = 3$).

Table 2. Effects of substrate on pH and electrical conductivity of greenhouse-grown *Petunia ×hybrida* (Experiment 1).

Substrates	0 DAP[z]		14 DAP		21 DAP		28 DAP		35 DAP		42 DAP		49 DAP		56 DAP	
	pH	EC[y]	pH	EC	pH	EC	pH	EC	pH	EC	pH	EC	pH	EC	pH	EC
90:10 Peat:corncob	4.05 ab[x]	5.26 a	5.33 b	3.67 b	5.35 a	3.87 ab	5.28 a	4.12 a	5.17 a	2.72 a	5.54 a	1.31 a	5.38 a	1.71 a	4.55 b	1.32 a
80:20 Peat:corncob	3.88 c	6.25 a	5.73 a	4.11 ab	5.40 a	3.98 ab	5.18 ab	3.62 a	5.45 a	2.31 a	5.28 ab	1.72 a	5.45 a	1.88 a	5.64 a	1.28 a
70:30 Peat:corncob	4.03 bc	5.44 a	5.62 a	4.31 ab	5.54 a	2.81 b	5.34 a	2.89 a	5.52 a	2.43 a	5.56 a	1.54 a	5.63 a	1.87 a	5.85 ab	1.61 a
90:10 Peat:perlite	3.90 bc	3.12 b	4.14 d	4.79 ab	5.25 a	4.25 ab	4.45 c	4.42 a	4.25 b	2.12 a	4.54 bc	0.88 a	4.36 b	0.90 a	4.5 d	0.95 a
80:20 Peat:perlite	3.95 bc	3.36 b	4.36 cd	5.72 a	4.27 b	4.94 a	4.43 c	4.28 a	4.51 b	2.09 a	4.49 c	1.32 a	4.81 b	1.46 a	4.69 cd	0.95 a
70:30 Peat:perlite	4.20 a	3.07 b	4.60 c	4.68 ab	4.55 b	4.55 a	4.77 bc	4.95 a	4.65 b	2.14 a	5.02 ab	1.37 a	4.66 b	2.39 a	4.86 c	0.98 a

[z] Days after planting.

[y] Electrical conductivity (dS/cm) of substrate solution using the pour-through method.

[x] Tukey's Studentized Range Test ($P \leq 0.05$, n = 4).

Table 3. Effects of substrate on pH and electrical conductivity of greenhouse-grown *Impatiens walleriana* (Experiment 1).

Substrates	0 DAP[z]		14 DAP		21 DAP		28 DAP		35 DAP		42 DAP		49 DAP		56 DAP	
	pH	EC[y]	pH	EC	pH	EC	pH	EC	pH	EC	pH	EC	pH	EC	pH	EC
90:10 Peat:corncob	4.05 ab[x]	5.26 a	4.89 abc	6.22 ab	5.14 b	3.49 a	5.27 b	2.90 c	5.22 a	2.30 b	5.30 ab	1.29 a	5.03 bc	2.84 a	5.73 ab	1.21 ab
80:20 Peat:corncob	3.88 c	6.25 a	5.36 ab	6.95 a	5.34 ab	4.04 a	5.47 a	2.77 c	5.22 a	2.66 ab	5.43 a	1.74 a	5.55 ab	1.99 bc	5.53 b	1.38 a
70:30 Peat:corncob	4.03 bc	5.44 a	5.57 a	4.71 b	5.50 a	3.88 a	5.43 a	4.15 bc	5.43 a	2.42 ab	5.43 a	1.55 a	5.60 a	2.49 ab	5.94 a	1.32 a
90:10 Peat:perlite	3.90 bc	3.12 b	4.05 d	4.94 b	4.09 d	4.58 a	4.18 e	4.01 bc	4.28 b	3.23 ab	4.50 c	1.24 a	4.57 c	0.85 d	4.61 c	0.62 c
80:20 Peat:perlite	3.95 bc	3.36 b	4.55 cd	6.00 ab	4.30 d	4.16 a	4.44 d	6.18 a	4.33 b	3.52 a	4.61 c	1.91 a	4.87 c	1.29 cd	4.64 c	0.82 bc
70:30 Peat:perlite	4.20 a	3.07 b	4.70 bcd	4.98 b	4.63 c	4.10 a	4.59 c	4.85 ab	4.66 b	3.12 ab	4.84 bc	1.33 a	4.91 c	1.41 cd	4.89 c	0.71 c

[z] Days after planting.

[y] Electrical conductivity (dS/cm) of substrate solution using the pour-through method.

[x] Tukey's Studentized Range Test ($P \leq 0.05$, n = 4).

Table 4. Effects of substrate on pH and electrical conductivity of greenhouse-grown *Tagetes erecta* (Experiment 1).

Substrates	0 DAP[z]		14 DAP		21 DAP		28 DAP		35 DAP		42 DAP		49 DAP		56 DAP	
	pH	EC[y]	pH	EC	pH	EC	pH	EC	pH	EC	pH	EC	pH	EC	pH	EC
90:10 Peat:corncob	4.05 ab[x]	5.26 a	4.99 bc	5.82 ab	5.18 a	4.66 a	5.21 b	2.98 ab	5.31 b	2.03 b	3.36 a	2.01 a	5.30 ab	1.44 a	5.83 a	0.90 a
80:20 Peat:corncob	3.88 c	6.25 a	5.35 ab	5.63 a	5.49 a	5.07 a	5.75 a	2.04 b	5.26 b	2.30 b	5.19 ab	1.93 a	5.79 a	2.07 a	5.59 a	0.96 a
70:30 Peat:corncob	4.03 bc	5.44 a	5.61 a	5.22 ab	5.38 a	3.87 a	5.55 ab	2.97 ab	5.72 a	1.87 b	5.34 a	1.74 a	5.63 ab	1.86 a	5.73 ab	1.26 a
90:10 Peat:perlite	3.90 bc	3.12 b	4.22 e	4.53 b	4.22 c	4.42 a	4.44 c	3.08 ab	4.47 d	1.92 b	4.30 c	1.77 a	4.52 d	1.29 a	4.56 c	0.82 a
80:20 Peat:perlite	3.95 bc	3.36 b	4.29 e	6.03 a	4.43 bc	4.90 a	4.57 c	4.37 a	4.48 d	3.59 a	4.78 bc	1.88 a	4.81 cd	2.32 a	4.59 c	1.56 a
70:30 Peat:perlite	4.20 a	3.07 b	4.69 cd	4.48 b	4.72 b	3.89 a	4.79 c	3.23 ab	4.84 c	1.90 b	4.84 ab	1.70 a	5.04 bc	1.40 a	5.15 b	0.98 a

[z] Days after planting.

[y] Electrical conductivity (dS/cm) of substrate solution using the pour-through method.

[x] Tukey's Studentized Range Test ($P \leq 0.05$, $n = 4$).

Table 5. Substrates effect on growth of greenhouse-grown *Petunia*×*hybrida*, *Impatiens walleriana*, and *Tagetes erecta* (Experiment 1).

Substrates	GI[z]	BC[y]	SDW[x]	RR[w]
	Petunia ×hybrida			
90:10 Peat:corncob	10.6b[u]	4.0b	1.59b	1.5b
80:20 Peat:corncob	9.0c	2.8b	0.9c	1.1b
70:30 Peat:corncob	6.8d	1.4b	0.41c	1.1b
90:10 Peat:perlite	27.5a	18.9a	8.86a	4.9a
80:20 Peat:perlite	27.7a	31.8a	8.84a	4.5a
70:30 Peat:perlite	28.3a	18.4a	9.39a	4.5a
	Impatiens walleriana			
90:10 Peat:corncob	13.1b	21.1b	0.69c	1.3c
80:20 Peat:corncob	9.0c	8.0c	0.36c	1.0c
70:30 Peat:corncob	5.7d	4.9c	0.21c	1.0c
90:10 Peat:perlite	21.4a	50.0a	5.31a	4.1ab
80:20 Peat:perlite	22.0a	57.1a	5.21a	4.4a
70:30 Peat:perlite	21.8a	49.3a	3.63a	3.6b
	Tagetes erecta			
90:10 Peat:corncob	14.7b	3.4a	1.65c	1.9b
80:20 Peat:corncob	12.9b	1.9c	0.89d	1.9b
70:30 Peat:corncob	11.7b	0.0c	0.31d	1.1c
90:10 Peat:perlite	23.2a	3.3a	7.63ab	3.2a
80:20 Peat:perlite	17.5ab	3.7a	7.28b	3.1a
70:30 Peat:perlite	19.0ab	3.4a	8.06a	3.0a

[z] Growth index = [(height + width1 + width2)/3] (n = 12).

[y] Bloom count = number of blooms or buds showing color at 35 days after potting (n = 12).

[x] Shoot dry weight measured in grams (n = 8).

[w] Root rating 0-5 scale (0 = no visible roots and 5 = roots visable on the entire container substrate interface) (n = 8).

[u] Tukey's Studentized Range Test ($P \leq 0.05$).

Table 6. Physical properties of corncob and perlite amended amended substrates (Experiment 2).[z]

Substrates	Air[y] space	Container[x] capacity	Total[w] porosity	Bulk[v] density
	(% vol)	(% vol)	(% vol)	(g/cm^3)
90:10 Peat:corncob	7.1b[u]	77.2a	84.3ab	0.75c
80:20 Peat:corncob	10.3ab	71.7b	81.9b	0.78b
70:30 Peat:corncob	14.5a	69.5bc	84.0ab	0.81a
90:10 Peat:perlite	12.1ab	75.8a	87.9a	0.70d
80:20 Peat:perlite	10.9ab	75.6a	86.5a	0.71d
70:30 Peat:perlite	13.1a	68.9c	82.0b	0.73cd

[z] Analysis performed using the NCSU porometer.

[y] Air space is volume of water drained from the sample ÷ volume of the sample × 100.

[x] Container capacity is (wet weight - oven dry weight) ÷ volume of the sample × 100.

[w] Total porsity is (wet weight - dry weight + drainage) ÷ volume of the sample × 100.

[v] Bulk density after forced air drying at 105C (221F) for 48 h.

[u] Tukey's Studentized Range Test ($P \leq 0.05$, n = 3).

Table 7. Effects of substrate on pH and electrical conductivity of greenhouse-grown *Petunia ×hybrida* (Experiment 2).

Substrates	0 DAP[z]		14 DAP		21 DAP		28 DAP		35 DAP	
	pH	EC[y]	pH	EC	pH	EC	pH	EC	pH	EC
90:10 Peat:corncob	4.48ab[x]	3.16bc	4.77c	5.29a	4.76b	4.73ab	4.88ab	3.87a	4.82ab	2.84a
80:20 Peat:corncob	4.53a	4.36b	5.29b	4.51a	5.75a	5.65a	5.46a	3.66a	5.24ab	2.27a
70:30 Peat:corncob	4.49ab	5.64a	5.67a	3.56a	5.51a	3.69ab	5.33a	4.10a	5.74a	2.29a
90:10 Peat:perlite	4.04d	3.55bc	4.43de	4.00a	4.56b	3.30b	4.39b	1.86a	5.36ab	0.84b
80:20 Peat:perlite	4.22cd	3.12c	4.38e	4.13a	4.64b	3.54b	4.40b	2.94a	4.56b	0.99b
70:30 Peat:perlite	4.29bc	3.76bc	4.63cd	4.51a	4.86b	4.06ab	4.65b	2.41a	4.90ab	0.75b

[z] Days after planting.

[y] Electrical conductivity (dS/cm) of substrate solution using the pour-through method.

[x] Tukey's Studentized Range Test ($P \leq 0.05$, $n = 4$).

Table 8. Effects of substrate on pH and electrical conductivity of greenhouse-grown *Impatiens walleriana* (Experiment 2).

Substrates	0 DAP[z]		14 DAP		21 DAP		28 DAP		35 DAP		42 DAP	
	pH	EC[y]	pH	EC	pH	EC	pH	EC	pH	EC	pH	EC
90:10 Peat:corncob	4.48ab[x]	3.16bc	4.77b	5.29a	5.47a	4.93a	4.70b	4.53ab	4.90bc	2.64ab	4.70bc	2.72abc
80:20 Peat:corncob	4.53a	4.36b	5.28a	4.51a	5.40a	3.84a	5.04a	5.40a	5.40ab	2.04ab	5.05ab	3.39a
70:30 Peat:corncob	4.49ab	5.64a	5.49a	3.56a	5.68a	3.56a	5.20a	5.11ab	5.59a	2.80a	5.28a	2.97ab
90:10 Peat:perlite	4.04d	3.55bc	4.34d	4.00a	4.48b	3.93a	4.33c	3.18b	4.53cd	1.17b	4.15d	1.45bc
80:20 Peat:perlite	4.22cd	3.12c	4.42cd	4.13a	4.51b	3.33a	4.33c	2.24b	4.35d	1.70ab	4.26d	1.30c
70:30 Peat:perlite	4.29bc	3.76bc	4.64bc	4.52a	4.72ab	5.63a	4.58bc	3.65ab	4.52cd	2.70ab	4.40cd	1.42c

[z] Days after planting.

[y] Electrical conductivity (dS/cm) of substrate solution using the pour-through method.

[x] Tukey's Studentized Range Test ($P \leq 0.05$, $n = 4$).

Table 9. Effects of substrate on pH and electrical conductivity of greenhouse-grown *Tagetes erecta* (Experiment 2).

Substrates	0 DAP[z]		14 DAP		21 DAP		28 DAP		35 DAP	
	pH	EC[y]	pH	EC	pH	EC	pH	EC	pH	EC
90:10 Peat:corncob	4.48ab[x]	3.16bc	5.02a	3.72b	4.89bc	4.31ab	4.98ab	3.42ab	4.77cd	1.82a
80:20 Peat:corncob	4.53a	4.36b	5.21a	4.20b	5.42ab	3.66ab	5.30a	4.23ab	5.47b	2.42a
70:30 Peat:corncob	4.49ab	5.64a	5.32a	4.09b	5.71a	3.10b	5.45a	3.97ab	5.85a	2.08a
90:10 Peat:perlite	4.04d	3.55bc	4.39b	5.30ab	4.61c	4.48ab	4.44bc	2.66ab	4.52d	1.36ab
80:20 Peat:perlite	4.22cd	3.12c	4.40b	4.53ab	4.41c	3.85ab	4.40c	1.85b	4.62d	0.66b
70:30 Peat:perlite	4.29bc	3.76bc	4.58b	5.95a	4.64c	5.52a	4.62bc	4.84a	5.00c	0.56b

[z] Days after planting.

[y] Electrical conductivity (dS/cm) of substrate solution using the pour-through method.

[x] Tukey's Studentized Range Test ($P \leq 0.05$, $n = 4$).

Table 10. Substrates effect on growth of greenhouse-grown *Petunia×hybrida, Impatiens walleriana,* and *Tagetes erecta* (Experiment 2).

Substrate	GI[z]	BC[y]	SDW[x]	RR[w]
		Petunia ×hybrida		
90:10 Peat:Corncob	13.9b[u]	4.9b	2.6b	3.6b
80:20 Peat:Corncob	11.2bc	3.4bc	1.7bc	2.8c
70:30 Peat:Corncob	9.3c	2.6c	1.0c	1.6d
90:10 Peat:Perlite	32.1a	23.7a	11.2a	4.4a
80:20 Peat:Perlite	34.3a	22.4a	11.5a	4.8a
70:30 Peat:Perlite	32.0a	23.5a	12.1a	4.8a
		Impatiens walleriana		
90:10 Peat:Corncob	13.8b	8.0b	2.6 b	2.0b
80:20 Peat:Corncob	8.6c	3.5b	1.1c	1.9b
70:30 Peat:Corncob	6.5d	2.0b	0.6c	1.1c
90:10 Peat:Perlite	25.4a	43.3a	10.2a	4.1a
80:20 Peat:Perlite	25.5a	45.0a	9.9a	4.3a
70:30 Peat:Perlite	25.7a	46.7a	9.9a	4.4a
		Tagetes erecta		
90:10 Peat:Corncob	12.8b	7.6b	2.0b	2.1b
80:20 Peat:Corncob	10.2c	5.0bc	0.9c	1.5bc
70:30 Peat:Corncob	8.3d	3.1c	0.5c	1.0c
90:10 Peat:Perlite	19.1a	12.1a	8.2a	4.4a
80:20 Peat:Perlite	20.4a	14.7a	8.4a	4.8a
70:30 Peat:Perlite	19.2a	12.8a	8.3a	4.0a

[z] Growth index = [(height + width1 + width2)/3] (n = 12).

[y] Bloom count = number of blooms or buds showing color at 35 days after potting (n = 12).

[x] Shoot dry weight measured in grams (n = 8).

[w] Root ratings 0-5 scale (0 = no visible roots and 5 = roots visable on the entire container substrate interface) (n = 8).

[u] Tukey's Studentized Range Test ($P \leq 0.05$).

III. Effects of Fertilizer Rate on Production of *Petunia ×hybrida* in Corncob Amended Substrates

Abstract

This study evaluated the effect of nitrogen fertilizer rates on corncob-amended substrates in the production of *Petunia ×hybrida*. Peatmoss was combined with soaked corncob, non-soaked corncob, or perlite at an 80:20 (v:v) ratio and mixed with 0.9 (2), 1.8 (4), 2.72 (6), or 3.6 $kg \cdot m^{-3}$ ($8 lbs \cdot yd^{-3}$) of 13N-2.6P-13.8K slow-release fertilizer (13-6-16, Harrell's, Lakeland, FL). Physical properties and growth parameters were evaluated in a controlled experiment. Experiment 1 results showed a higher container capacity (CC) and total porosity (TP) for substrates containing corncob, with similar results seen in Experiment 2 in relation to CC. Both experiments had similar results in electrical conductivity readings with a decrease in readings over time. Shoot-dry weights (SDW) and growth index (GI) showed an increase in growth with increase in fertilizer rate for both experiments. Petunias grown in un-soaked and soaked corncob substrates at the highest rate were similar to plants grown in perlite at 1.8 $kg \cdot m^{-3}$ ($4 lbs \cdot yd^{-3}$), 2.72 $kg \cdot m^{-3}$ ($6 lbs \cdot yd^{-3}$), and 3.6 $kg \cdot m^{-3}$ ($8 lbs \cdot yd^{-3}$) for Experiment 2. This study shows that corncob can be a viable alternative to perlite, and that additional studies need to be conducted to determine the best nutrient management practices when utilizing corncobs as a substrate component.

Index words: alternative substrate, greenhouse production, perlite alternative, peatmoss, corncob, substrate.

Species used in this study: *Petunia ×hybrida* ‘Rambling Sugar Plum’.

Significance to the Industry

Perlite (PL) is a component in most soilless greenhouse substrates. Perlite takes significant energy to produce and transport and, the dust associated with it is known to be an eye and lung irritant. A possible new alternative to perlite is the use of processed corncobs. Corncob, a waste byproduct, requires less energy to produce than perlite, and has the potential to be regionally available. Previous research has found a reduction of growth in greenhouse annuals with the addition of corncob as a substrate component. Results from this study indicated similar physical properties of substrates containing corncob compared to perlite. Growth results indicated that additional fertilizer would be needed to achieve similar results to substrates containing perlite in production of greenhouse grown annuals.

Introduction

In the production of greenhouse crops, soilless substrates are often used as the growing media, and the major components often include peatmoss and perlite (1, 2). These components are often mixed at different rates to reach the desired physical properties of the selected crops. Perlite remains a popular substrate component because of its ability to add air space to peat-based substrates without increasing bulk density. Perlite is an inorganic rock that is mined and heated to 871.1C (1600F) to remove all water and expand the rock (8). This process can produce a fine particle dust that has been shown to cause eye and lung irritation (3).

Alternatives to perlite have been evaluated to provide the same function but with a more worker-friendly environment. Alternatives include: rice hulls, HydRocks®, expanded polystyrene and pumice (4, 5, 7, 10). Evans and Gachukia (5) evaluated growth of greenhouse crops in substrates containing peat, mixed with perlite or rice hulls at different ratios and planted with annuals. Results from the dry root weight of vinca and geraniums showed no difference between substrates of peat:rice hulls and peat:perlite. Dry root weights of impatiens, marigolds, and pansies were different when grown in rice hull substrates compared to perlite at certain ratios. The use of rice hulls as a perlite alternative could have a positive effect on the cost of production, without reducing the growth of the greenhouse crop (5). Noland et al., (7) evaluated the chemical and physical effects of pumice compared to perlite as a substrate amendment. When pumice and perlite were compared they had similar physoichemical properties. Plants grown with pumice grew equally to those in a perlite amended substrate (7).

Another potential alternative to the use of perlite is processed corncob, a readily available domestic product (11). One concern with the use of corncobs is the possibility of nutrient unavailability (9). The objective of this study was to evaluate the effect of fertilizer rate on corncob-amended substrates in the growth of *Petunia ×hybrida.*

Materials and Methods

Two experiments were installed (June 6, 2011, August 22, 2011) at the Paterson Greenhouse Complex at Auburn University. Two types of corncob were used for this study: corncobs that were non-soaked (NS), and corncobs that were soaked in tap water (S) (Corncob was placed in containers and filled with tap water. After 24 hours water was drained and corncob was spread on a greenhouse bench and allowed to air dry for 72 hours) Based on previous studies, we chose to pre-wet the corncob to remove possible residual nutrients and allow the corncob to imbibe water (our corncob source had been heat-dried during processing). Each type of corncob was blended with peat moss at a ratio of 80:20 peat:corncob (NS) (v:v) and 80:20 peat:corncob (S) (v:v); compared to an

80:20 peat:perlite (PL) (v:v) standard. Each substrate was amended with 1.13 kg·mg^{-3} (3 lbs·yd^{-3}) of dolomitic limestone, and 0.68 kg·mg^{-3} (1.5 lbs·yd^{-3}) of Micromax (The Scotts Company, Marysville OH). A 13N-2.6P-13.8K controlled release fertilizer (13-6-16, Harrell's, Lakeland, FL) was added to each substrate at rates of 0.9 (2), 1.8 (4), 2.72 (6), or 3.6 kg·m^{-3} (8lbs·yd^{-3}). 1.22 L (1.33 qt) containers (shuttle pot SP 525, East Jordan Plastics, INC, East Jordan MI.) were filled with substrates and planted with 2 cm^3 (0.7 in^3) plugs (200 cell flat) of *Petunia ×hybrida* 'Rambling Sugar Plum'. Containers were placed on a raised bench in a twin wall polycarbonate greenhouse under full sun and hand watered as needed. Data loggers were installed to capture actual greenhouse temperatures for the durations of the study. Greenhouse temperature daily average highs and lows were at 30/22C (86/72F). Initial substrate physical properties analysis including total porosity (TP), container capacity (CC), air space (AS), and bulk density (BD) were determined using the North Carolina State University porometer method (6). Leachates were collected using the Virginia Tech Pour Through Method and analyzed pH and electrical conductivity at 0, 14, 21, 28, and 35 days after planting (11). At termination all plants were measured for growth index (GI) [(height + width+ perpendicular width)/three (cm)] and bloom count (open flowers and unopened buds showing color) (BC). Roots were visually inspected and rated on a scale of 0 to 5 with 0 indicating no roots present at the container substrate interface and 5 indicating roots visible at all portions of the container substrate interface. At termination, petunia and impatiens shoots were removed at the substrate surface and oven dried at 70C (158F) for 72 hours and weighed.

The experimental was arranged in a 3×4 factorial with 3 substrate treatments and 4 fertilizer treatments. Substrate containers were arranged in a randomized complete block design (RCB) with 12 single pot replicates. Data was subjected to analysis of variance using the general linear models procedure, and a multiple comparison of means was conducted using Tukey's Honest Significant Difference Test. (Version 9.2: SAS Institute, Cary, NC). Fertilizer rate was tested for a linear or quadratic response using single degree of freedom orthogonal contrast (Version 9.2: SAS Institute, Cary, NC).

Results and Discussion

Experiment 1. Physical properties analysis (Table 1) indicated differences in TP and CC of corncob-amended substrates compared to the PL standard, with corncob-amended substrates being higher in both TP and CC. Air space was higher for NS corncob compared to the PL standard, while S corncob showed no difference in AS when compared to PL. One reason for S corncob to have a slightly lower AS than NS could be the expanding of the corncob slightly after soaking in water.

Leachates results at 0 DAP revealed a pH level lower than the recommended range for petunias of 5.5 to 6.2, with no difference found between substrates (Table 2). Leachates from 14 DAP showed pH for NS corncob to be higher than those of S and PL among all fertilizer rates. Results showed a decrease in EC readings over time but there was no difference among the different substrates at 7, 14, 21, and 35 DAP for EC.

Shoot-dry weights (Table 3) of petunias increased with increasing fertilizer rate for all substrates, with GI following a similar trend. Bloom counts were highest at the 3.6 $kg \cdot m^{-3}$ ($8lbs \cdot yd^{-3}$) fertilizer rate of peat:perlite. Soaked and NS corncobs had similar BC at 0.9 $kg \cdot m^{-3}$ (2 $lbs \cdot yd^{-3}$) and 1.8 kg·m-3 (4 $lbs \cdot yd^{-3}$). There were differences for BC in 2.72 $kg \cdot m^{-3}$ (6 $lbs \cdot yd^{-3}$) and 3.6 $kg \cdot m^{-3}$ ($8lbs \cdot yd^{-3}$) with BC in S corncob being 40% greater in 2.72 $kg \cdot m^{-3}$ (6 $lbs \cdot yd^{-3}$), and 50% greater in 3.6 $kg \cdot m^{-3}$ ($8lbs \cdot yd^{-3}$) than BC in

NS corncob. Root ratings for petunias grown in S corncob at fertilizer rates of 2.72 kg·m^{-3} (6 lbs·yd^{-3}) and 3.6 kg·m^{-3} (8lbs·yd^{-3}) and NS corncob at 3.6 kg·m^{-3} (8lbs·yd^{-3}) were similar to plants in PL at fertilizer rates of 0.9 kg·m^{-3} (2 lbs·yd^{-3}) , 1.8 kg·m-3 (4 lbs·yd^{-3}) , and 2.72 kg·m^{-3} (6 lbs·yd^{-3}). Soaked and NS corncob also showed a linear increase in RR with an increasing fertilizer rate.

Experiment 2. Physical properties analysis (Table 4) revealed the substrate of S corncob and PL was higher in CC than the substrate amended with NS corncob. Experiment 2 was different in comparison to Experiment 1 in TP with no difference in substrates containing corncob than those containing perlite. Air space was similar between all substrates, different from results in Experiment 1, and these results could explain why there was no difference in TP for Experiment 2.

The initial pH (0 DAP) was lower than the recommended range for petunias of 5.5 to 6.2, with no differences between substrates (Table 5). At 14 DAP pH of leachates for NS corncob was higher than leachates from S and PL at fertilizer rates of 0.9 kg·m^{-3} (2 lbs·yd^{-3}) and 1.8 kg·m^{-3} (4 lbs·yd^{-3}). At 21, 28, and 35 DAP there was no difference pH with the majority of the readings under the recommended range for petunias. Electrical conductivity decreased over time but with 14, 21, 28, and 35 DAP resulting in no difference among the different substrates. At 0, 14, and 21 DAP there was a linear increase in EC with increase in fertilizer rate, with the exception of S corncob at 21 DAP which showed no difference.

Shoot dry weights of petunias increased with increasing fertilizer rate for all substrates, with GI following a similar trend (Table 6). Plants grown in substrates of both

S and NS corncob at 3.6 kg·m^{-3} (8lbs·yd^{-3}) had similar SDW to perlite at 0.9 kg·m^{-3} (2 lbs·yd^{-3}) of fertilizer.

Growth index for petunias grown in S corncob at the rate of 3.6 kg·m^{-3} (8lbs·yd^{-3}) were similar to GI of petunias in perlite at 1.8 kg·m^{-3} (4 lbs·yd^{-3}), 2.72 kg·m^{-3} (6 lbs·yd^{-3}), and 3.6 kg·m^{-3} (8lbs·yd^{-3}) (Table 6). Bloom counts were highest numerically at the 1.8 kg·m^{-3} (4 lbs·yd^{-3}) fertilizer rate PL, and found to be similar to all other substrates containing PL. Plants grown in Soaked and NS corncobs had similar BC at the 0.9 kg·m^{-3} (2 lbs·yd^{-3}) rate, this differed slightly from Experiment 1 where BC was not similar at the 1.8 kg·m^{-3} (4 lbs·yd^{-3}) rate of fertilizer. There were differences for BC in 1.8 kg·m^{-3} (4 lbs·yd^{-3}), 2.72 kg·m^{-3} (6 lbs·yd^{-3}), and 3.6 kg·m^{-3} (8lbs·yd^{-3}) with S cob being 70% greater at 1.8 kg·m^{-3} (4 lbs·yd^{-3}), 60% greater in 2.72 kg·m^{-3} (6 lbs·yd^{-3}), and 50% greater in 3.6 kg·m^{-3} (8lbs·yd^{-3}) than substrates containing NS corncob (Table 6). Root ratings for S corncob at rates 1.8 kg·m^{-3} (4 lbs·yd^{-3}), 2.72 kg·m^{-3} (6 lbs·yd^{-3}), and 3.6 kg·m^{-3} (8lbs·yd^{-3}), and NS corncob at 3.6 kg·m^{-3} (8lbs·yd^{-3}) were similar to PL at all fertilizer rates, showing similar results to RR in Experiment 1. All substrates showed a linear increase in RR with increasing fertilizer rate.

Results of this study indicated that an increase in fertilizer had a positive effect on the growth of petunias in corncob-amended substrates. Petunias in PL had greater SDW growth than petunias grown in NS and S corncob at their equal counterpart. Petunias in substrates with S corncob at 3.6 kg·m^{-3} (8lbs·yd^{-3}) fertilizer rate in both experiments were similar to results in the peat-lite mix at 2.72 kg·m^{-3} (6 lbs·yd^{-3}) with respect to GI, BC, and RR in Experiment 2, suggesting that pre-soaking the corncob before mixing could also have an effect on the growth of petunias.

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Table 1. Physical properties of corncob and perlite amended substrates (Experiment 1).[z]

	Air[y] space	Container[x] capacity	Total[w] porosity	Bulk[v] density
Substrates	---------------- (% vol)		----------------	($g \cdot cm^{-3}$)
Peat:corncob(us)[u]	13.5a[r]	76.6a	90.1a	0.13a
Peat:corncob(s)[t]	12.4ab	77.6a	90.0a	0.11b
Peat-lite[s]	11.2b	75.1b	86.3b	0.09c

[z] Analysis performed using the NCSU porometer.

[y] Air space is volume of water drained from the sample ÷ volume of the sample × 100.

[x] Container capacity is (wet weight - oven dry weight) ÷ volume of the sample × 100.

[w] Total porsity is (wet weight - dry weight + drainage) ÷ volume of the sample × 100.

[v] Bulk density after forced air drying at 105C (221F) for 48 h.

[u] Peat:Corncob(us) = 80:20 peat:corncob (v:v) us = unsoaked.

[t] Peat:Corncob(s) = 80:20 peat:corncob (v:v) s = soaked.

[s] Peat-lite = 80:20 peat:perlite (v:v).

[r] Tukey's Studentized Range Test ($P \leq 0.05$, n = 3).

Table 2. Fertlizer rate effect on pH and electrical conductivty of *Petunia ×hybrida* in corncob and perlite amended substrates (Experiment 1)**.**

		0 DAP[z]		7 DAP		14 DAP		21 DAP		28 DAP		35 DAP	
Substrate	**Rate (lbs)[y]**	**pH**	**EC[x]**	**pH**	**EC**	**pH**	**EC**	**pH**	**EC**	**pH**	**EC**	**pH**	**EC**
Peat:corncob(us)[w]	2	4.14	3.52	4.68	4.12	5.58	2.29	5.41	2.21	5.44	1.96	5.15	2.05
Peat:corncob(us)	4	3.85	3.01	5.06	4.66	5.41	2.64	5.12	2.94	5.18	1.99	5.28	1.88
Peat:corncob(us)	6	3.84	2.48	5.34	3.99	5.18	2.65	5.53	2.42	5.40	2.56	5.31	2.51
Peat:corncob(us)	8	3.93	4.39	5.06	5.09	5.16	2.76	5.08	2.77	5.30	1.62	5.12	2.14
Peat:corncob(s)[v]	2	3.89	3.09	4.49	3.77	4.37	2.61	4.64	2.49	4.54	1.59	4.81	1.02
Peat:corncob(s)	4	3.81	2.83	3.28	3.97	4.53	2.72	4.51	2.57	4.69	1.11	4.82	0.79
Peat:corncob(s)	6	3.97	4.51	4.24	5.72	4.30	3.02	4.36	2.43	4.77	0.86	4.75	0.80
Peat:corncob(s)	8	3.89	3.54	4.25	7.90	4.03	4.48	4.29	1.86	4.45	1.14	4.31	1.76
Peat-lite[u]	2	3.82	3.72	4.23	4.39	3.88	2.50	3.89	2.41	4.43	0.46	4.52	1.67
Peat-lite	4	3.90	4.31	4.06	6.01	3.98	2.67	3.86	2.48	4.14	0.67	4.24	0.69
Peat-lite	6	3.83	3.93	4.21	6.11	4.10	3.28	3.80	2.87	3.88	1.13	4.11	1.10
Peat-lite	8	3.78	4.38	4.12	4.12	4.11	5.38	2.80	2.30	3.85	1.42	4.33	0.82
	HSD[t]	***0.18***	***1.36***	***1.69***	***2.81***	***0.53***	***2.47***	***1.47***	***2.50***	***0.61***	***1.05***	***0.44***	***2.00***
Fertlizer Rate Response													
Peat:cornccob(us)		L**[s]Q***	L*Q***	NS	NS	L**	L**	NS	NS	NS	Q**	NS	NS
Peat:corncob(s)		NS	NS	NS	L***	L**Q*	NS	NS	NS	NS	NS	L**Q*	NS
Peat-lite		NS	NS	NS	Q**	NS	L**	L*	NS	L**	L**	Q**	NS

[z] Days after planting.

[y] Lbs·yd^{-3} of 13N-2.6P-13.8P slow release fertlizer (13-6-16, Harrell's, Lakeland, FL).

[x] Electrical conductivity (dS/cm) of substrate solution using the pourthrough method.

[w] Peat:corncob(us) = 80:20 peat:corncob (v:v) us = unsoaked.

[v] Peat:corncob(s) = 80:20 peat:corncob (v:v) s = soaked.

[u] Peat-lite = 80:20 peat:perlite (v:v).

[t] Tukey's Honest Significant Difference Test (P ≤ 0.05, n = 4).

[s] Non Significant (NS), Linear (L) or Quadratic (Q) response at P ≤ 0.05 (*), 0.01 (**) or 0.001 (***).

Table 3. Fertilizer rate effect on growth of *Petunia ×hybrida* in corncob and perlite amended substrates (Experiment 1).

		Growth Parameters			
Substrates	**Rate (lbs[z])**	**GI[y]**	**BC[x]**	**RR[w]**	**SDW[v]**
Peat:corncob(us)[w]	2	7.7	2.3	1.9	1.0
Peat:corncob(us)	4	13.0	8.1	2.6	3.8
Peat:corncob(us)	6	25.4	21.5	3.1	3.0
Peat:corncob(us)	8	28.8	35.3	3.4	5.4
Peat:corncob(s)[v]	2	13.6	5.6	2.4	1.4
Peat:corncob(s)	4	21.3	16.9	3.1	2.8
Peat:corncob(s)	6	32.4	49.7	3.4	6.4
Peat:corncob(s)	8	36.4	66.1	3.6	9.6
Peat-lite[u]	2	29.9	43.7	4.0	7.0
Peat-lite	4	37.8	53.4	4.0	10.4
Peat-lite	6	41.1	76.7	4.3	14.5
Peat-lite	8	44.3	90.4	4.6	16.9
	HSD[r]	***5.8***	***12.3***	***1.0***	***3.8***
		Fertilizer Rate Response			
Peat:corncob(us)		L***[q]	L***	L***	L**
Peat:corncob(s)		L***	L***	L***	L***
Peat-lite		L***	L***	L**	L***

[y] Lbs·yd^{-3} of 13N-2.6P-13.8P slow release fertlizer (13-6-16, Harrell's, Lakeland, FL).

[y] Growth index = [(height + width1 + width2)/3] ($P \leq 0.05$, n = 12).

[x] Bloom count = number of blooms showing color at 35 DAP ($P \leq 0.05$, n = 12).

[w] Root ratings 0-5 scale ($P \leq 0.05$, n = 8).

[v] Shoot dry weight measured in grams. ($P \leq 0.05$, n = 8).

[u] Peat:corncob(us) = 80:20 peat:corncob (v:v) us = unsoaked.

[t] Peat:corncob(s) = 80:20 peat:corncob (v:v) s = soaked.

[s] Peat-lite = 80:20 peat:perlite (v:v).

[r] Tukeys Honest Significant Difference Test ($P \leq 0.05$, n = 8).

[q] Linear (L) response at $P \leq 0.05$ (*), 0.01 (**) or 0.001 (***).

Table 4. Physical properties of corncob and perlite amended substrates (Experiment 2).[z]

Substrates	Air[y] space	Container[x] capacity	Total[w] porosity	Bulk[v] density
	-----------------	(% vol)	----------------	(g/cm^3)
Peat:corncob(us)[u]	12.4a[r]	75.8b	88.3a	0.14a
Peat:corncob(s)[t]	11.5a	77.9a	89.4a	0.12b
Peat-lite[s]	10.9a	78.0a	88.9a	0.12b

[z] Analysis performed using the NCSU porometer.

[y] Air space is volume of water drained from the sample ÷ volume of the sample × 100.

[x] Container capacity is (wet weight - oven dry weight) ÷ volume of the sample × 100.

[w] Total porsity is (wet weight - dry weight + drainage) ÷ volume of the sample × 100.

[v] Bulk density after forced air drying at 105C (221F) for 48 h.

[u] Peat:corncob(us) = 80:20 peat:corncob (v:v) us = unsoaked.

[t] Peat:corncob(s) = 80:20 peat:corncob (v:v) s = soaked.

[s] Peat-lite = 80:20 peat:perlite (v:v).

[r] Tukey's Studentized Range Test ($P \leq 0.05$, $n = 3$).

Table 5. Fertlizer rate effect on pH and electrical conductivty of Petunia ×hybrida in corncob and perlite amended substrates (Experiment 2).

		0 DAP^{z}		14 DAP		21 DAP		28 DAP		35 DAP	
Substrate	**Rate (lbs)^{y}**	**pH**	**EC^{x}**	**pH**	**EC**	**pH**	**EC**	**pH**	**EC**	**pH**	**EC**
Peat:corncob(us)^{w}	2	3.87	4.15	4.79	4.08	5.05	2.65	5.30	2.25	5.04	2.40
Peat:corncob(us)	4	3.89	4.42	4.87	3.71	4.95	2.89	5.32	2.64	5.02	3.57
Peat:corncob(us)	6	3.94	5.75	4.52	5.09	4.93	3.93	5.23	3.56	4.93	2.81
Peat:corncob(us)	8	3.82	6.49	4.53	5.68	4.72	4.65	5.34	3.19	4.79	4.36
Peat:corncob(s)^{v}	2	3.97	2.38	4.44	2.34	4.72	1.96	5.01	1.36	4.82	1.31
Peat:corncob(s)	4	4.01	3.32	4.25	3.80	5.50	2.12	5.00	2.26	4.56	2.03
Peat:corncob(s)	6	4.04	3.94	4.11	3.97	4.62	2.43	4.97	2.18	4.41	2.74
Peat:corncob(s)	8	3.97	4.20	4.00	4.02	4.34	2.87	5.14	1.48	4.41	2.36
Peat-lite^{u}	2	4.33	2.47	4.23	3.15	4.86	2.04	4.69	1.85	4.81	0.52
Peat-lite	4	4.04	3.11	4.44	4.35	4.68	3.71	4.80	1.95	4.95	1.52
Peat-lite	6	3.98	3.82	4.35	6.50	4.58	4.67	4.55	3.67	4.36	2.61
Peat-lite	8	3.85	4.68	4.19	8.81	4.50	6.19	4.84	4.11	3.97	3.76
	HSD^{t}	***0.42***	***1.15***	***0.28***	***2.34***	***1.13***	***2.76***	***0.60***	***2.20***	***1.02***	***2.13***
						Fertlizer Rate Response					
Peat:corncob(us)		L**^{s}Q***	L*Q***	L**	L**	NS	NS	NS	Q**	NS	NS
Peat:corncob(s)		NS	NS	L**Q*	NS	NS	NS	NS	NS	L**Q*	NS
Peat-lite		NS	NS	NS	L**	L*	NS	L**	L**	Q**	NS

^{z}Days after planting.

^{y}Llbs·yd^{-3} of 13N-2.6P-13.8P slow release fertlizer (13-6-16, Harrell's, Lakeland, FL).

^{x}Electrical conductivity (dS/cm) of substrate solution using the pourthrough method.

^{w}Peat:corncob(us) = 80:20 peat:corncob (v:v) us = unsoaked.

^{v}Peat:corncob(s) = 80:20 peat:corncob (v:v) s = soaked.

^{u}Peat-lite = 80:20 peat:perlite (v:v).

^{t}Tukey's Honest Significant Differnce Test ($P \leq 0.05$, n = 4).

^{s}Non Significant (NS), Linear (L) or Quadratic (Q) response at $P \leq 0.05$ (*), 0.01 (**) or 0.001 (***).

Table 6. Fertilizer rate effect on growth of *Petunia ×hybrida* in corncob and perlite amended substrates (Experiment 2).

		Growth Parameters			
Substrates	**Rate (lbs[z])**	**GI[y]**	**BC[x]**	**RR[w]**	**SDW[v]**
Peat:corncob(us)[w]	2	6.8	0.1	1.0	0.2
Peat:corncob(us)	4	12.3	1.6	1.9	0.7
Peat:corncob(us)	6	17.3	3.5	2.8	1.4
Peat:corncob(us)	8	23.1	8.3	3.6	3.5
Peat:corncob(s)[v]	2	11.4	1.5	2.4	0.5
Peat:corncob(s)	4	19.5	6.0	3.4	1.9
Peat:corncob(s)	6	23.9	7.8	3.3	3.0
Peat:corncob(s)	8	26.8	13.3	4.6	4.5
Peat-lite[u]	2	23.4	9.5	3.1	4.9
Peat-lite	4	28.5	15.3	3.9	7.5
Peat-lite	6	29.4	12.1	4.0	8.6
Peat-lite	8	27.9	13.1	4.3	9.0
	HSD[r]	***4.2***	***3.0***	***0.9***	***1.8***
		Fertilizer Rate Response			
Peat:corncob(us)		L***[q]	L***Q*	L***	L***Q*
Peat:corncob(s)		L***Q**	L***	L***	L***
Peat-lite		L***Q***	L***Q***	L***	L***Q**

[y] Llbs·yd^{-3} of 13N-2.6P-13.8P slow release fertlizer (13-6-16, Harrell's, Lakeland, FL).

[y] Growth index = [(height + width1 + width2)/3] ($P \leq 0.05$, n = 12).

[x] Bloom count = number of blooms showing color at 35 DAP ($P \leq 0.05$, n = 12).

[w] Root ratings 0-5 scale ($P \leq 0.05$, n = 8).

[v] Shoot dry weight measured in grams. ($P \leq 0.05$, n = 8).

[u] Peat:corncob(us) = 80:20 peat:corncob (v:v) us = unsoaked.

[t] Peat:corncob(s) = 80:20 peat:corncob (v:v) s = soaked.

[s] Peat-lite = 80:20 peat:perlite (v:v).

[r] Tukey's Honest Significant Differnce Test ($P \leq 0.05$, n = 8).

[q] Linear (L) response at $P \leq 0.05$ (*), 0.01 (**) or 0.001 (***).

IV. Processed Corncob as an Alternative to Perlite in the Production of Container Grown Perennials

Abstract

This study evaluated processed corncob as an alternative to perlite in container perennial production. A 80:20 pine bark:peatmoss (v:v) substrate was mixed with processed corncob, or perlite, at 10%, 20%, or 30%. Physical properties and growth parameters were evaluated in a controlled experiment. Container capacity and air space of corncob-amended substrates were equal to their perlite amended counterpart. Results for bulk density showed that substrates containing corncob were higher than all substrates containing perlite. Results at 30 and 60 days after planting (DAP) for lantana and miscanthus showed substrates with corncob to have higher pH than perlite substrates; however, at 90 DAP there were no differences across all treatments and species. At termination there were no differences in electrical conductivity across all treatments and species. Lantana growth index were similar in corncob compared to its perlite counterparts at 35 and 90 DAP. Shoot dry weights of salvia and lantana showed a reduction in growth with an increase of corncob at 35 DAP, but at 90 DAP there were no differences compared to its perlite counterpart. Shoot dry weights of miscanthus results showed corncob substrates at 10% and 30% CC had lower shoot dry weights than its perlite counterpart at 35 DAP. However, at 90 DAP all shoot dry weights were similar except for 30% corncob, which was lower than 30% perlite. In conclusion, growth of lantana, salvia and miscanthus in corncob amended substrates was equal compared to its

perlite counterpart at 90 DAP. Results from this study indicates that corncob might be a viable alternative to perlite in production of container grown perennials.

Index words: alternative substrate, container production, perlite alternatives, peatmoss, corncob substrate, perennials.

Species used in this study: *Lantana camara* ‘Pink Caprice’, *Salvia guaranitica* ‘Black and Blue’, *Miscanthus sinensis* ‘Rigoletto’.

Significance to the Industry

Perlite (PL) is a component in most soilless greenhouse substrates. Perlite takes significant energy to produce and transport and, the dust associated with it is known to be an eye and lung irritant. A possible new alternative to perlite is the use of processed corncobs. Corncob, a waste byproduct, requires less energy to produce than perlite, and has the potential to be regionally available. A reduction in growth was seen in the first 35 days after planting, similar to previous results seen in reduction of growth with addition of corncob in short term annual crops. However at 90 days after planting no differences were seen in the growth of crops in corncob and perlite amended substrates. These results suggest corncob can be a successful alternative in the production of long term perennial crops.

Introduction

Since the 1960s soilless substrates have been developed in for nursery crop production. The main components of most nursery and greenhouse soilless substrates include pine bark, peatmoss, and perlite (1, 2). Recent developments have raised concerns about the availability of pine bark and peatmoss because of other industrial uses and environmental concerns. Perlite is an igneous glassy rock that is mined and heated to

871C (1600F) to remove all water and expand the rock (7). Amending perlite into soilless substrates is beneficial because of its ability to add airspace to the substrate without affecting plant growth.

The production of perlite produces a very fine particle dust that is considered to cause lung and eye irritation (3). This problem that is associated with perlite has led nurseries and universities to look for alternatives that will be able to provide the same amount of airspace to the soil, but with less impact on environmental and health concerns. Some alternatives that have been shown to be successful replacements to perlite include: rice hulls (5), pumice (8), calcined clay (9) and expanded polystyrene (4). A possible new alternative that has the ability to provide the same amount of air space as perlite but with less environmental and health impact is the use of processed corncob.

Processed corncob is a waste by-product of the feed and seed industry that requires less energy to produce than perlite. Corncob is widely available which could result in lower transportation cost where regionally available. The purpose of this study was to evaluate effects on growth of container grown perennials in corncob amended substrates compared to an industry standard perlite mix.

Materials and Methods

An experiment was installed (May 13, 2011) at the Paterson Research and Teaching Facility at Auburn University. The substrate used was a 80:20 pine bark:peat (v:v) (PBP) mix with either processed corncob (C) (The Andersons Inc. Maumee, OH) or perlite (PL). Treatments were 90:10 PBP:C (v:v) 80:20 PBP:C (v:v) 70:30 PBP:C (v:v) 90:10 PBP:PL (v:v) 80:20 PBP:PL (v:v) 70:30 PBP:PL (v:v). Substrates were amended with 6.8 $\mathrm{kg \cdot mg^{-3}}$ (15 $\mathrm{lbs \cdot yd^{-3}}$) of 15N-2.6P-9.96K slow release fertilizer (15-6-12, Harrells, Lakeland, Fl), and 1.36 $kg \cdot mg^{-3}$ (3 $lbs \cdot yd^{-3}$) of dolomitic lime. After mixing, 1.56 L (1.64 qt) containers (EU105T5, ITML Horticultural Products, Middlefield, OH) were filled and one 5 cm^3 (2 in^3) pot liner of *Lantana camara* ‘Pink Caprice’, *Salvia guaranitica* ‘Black and Blue’, or *Miscanthus sinensis* ‘Rigoletto’ (Emerald Coast Growers, Pensacola, FL) were planted in each container. Containers were placed on a nursery pad under overhead irrigation.

Initial substrate physical properties including total porosity (TP), container capacity (CC), air space (AS), and bulk density (BD) were determined using the North Carolina State University porometer method (6). Leachates were collected using the Virginia Tech Pour Through Method and analyzed for pH and electrical conductivity at 0, 14, 21, 28, and 35 days after planting (DAP) (10). Final growth measurements collected at 35 DAP included: growth index (GI) [(height + width + perpendicular width ÷ 3 (cm)], and shoot-dry weights (SDW) (oven dried at 70C (158F) for 72 hours).

Containers were arranged in a randomized complete block design with 12 single pot replicates and each plant species was treated as a separate experiment. Data was subjected to analysis of variance using the general linear models and Duncans Multiple Range Test (Version 9.2: SAS Institute, Cary, NC).

Results and Discussion

Physical properties analysis (Table 1) showed that CC and AS of corncob-amended substrates were equal to their perlite amended counterparts. Results for substrates containing corncob had higher BD than all substrates containing perlite, with

30% corncob being highest. One explanation for the higher BD of the corncob substrates is because of the weight of the corncob compared to the weight of perlite.

Results of leachate pH showed that at 0 DAP (Table 2) corncob substrates had lower readings when compared to perlite mixes; 20% and 30% perlite had the highest pH readings. Results at 30 and 60 DAP for lantana and miscanthus showed substrates with corncob to be higher in pH than perlite substrates. However, at 90 DAP there were no differences in pH across all treatments. Electrical conductivity results at 0 DAP showed that corncob substrates were equal to their perlite counterparts. Results from 30 DAP indicated that substrates amended with corncob showed a decrease in EC and were less than all substrates containing perlite. At termination there were no differences across all treatments for both miscanthus and lantana in EC (Table 3).

Growth index for Salvia at 35 DAP (Table 4) showed a reduction in growth with an increase in percentage of corncob, with all substrates being less than those containing perlite. Results at 90 DAP differed from 35 DAP with all corncob-amended substrates being equal to its perlite counterpart. Lantana GI differed from salvia, with no difference in growth of corncob substrates and its perlite counterpart at 35 and 90 DAP. Shoot dry weights of salvia were similar to results in GI with a reduction in growth with an increase of corncob at 35 DAP. Shoot dry weight results at 90 DAP showed no differences in corncob and its perlite counterparts, results from lantana SDW were similar. Miscanthus results at 35 DAP differed slightly, with corncob substrates at 10% and 30% having lower shoot dry weights when being compared to its counterpart. However, at 90 DAP all weights were equal except for 30% corncob, which was lower than 30% perlite.

In conclusion, growth of lantana, salvia, and miscanthus in corncob-amended substrates were of equal growth when compared to its perlite counterpart at 90 DAP. Results from previous work reported mixed results in growth of greenhouse annuals in corncob amended substrates. Results from this study continue to show that corncob might be a viable alternative to perlite. Environmental and health concerns associated with perlite may be alleviated with the use of processed corncob. Advantages of corncob are its potential to be more regionally available and more carbon neutral when compared to perlite. Based on these results and previous research additional studies need to be conducted to further investigate corncob as a perlite replacement in greenhouse and nursery production.

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Table 1. Physical properties of corncob amended substrates.[z]

	Air[y] space	Container[x] capacity	Total[w] porosity	Bulk[v] density
	(% vol)			(g/cm^3)
10% corncob[u]	24.7b[t]	58.2a	82.8a	0.80b
20% corncob	29.9ab	51.7c	81.7a	0.80b
30% corncob	31.7a	52.3c	83.9a	0.82a
10% perlite	24.3b	56.5ab	80.8a	0.78c
20% perlite	28.3ab	55.2abc	83.4a	0.78c
30% perlite	26.6ab	53.4bc	80.0a	0.78c

[z] Analysis performed using the NCSU porometer.

[y] Air space is volume of water drained fromt the sample ÷ volume of sample × 100.

[x] Container capacity (wet weight - oven dry weight) ÷ volume of the sample × 100.

[w] Total porsity is container capacity + air space.

[v] Bulk density after forced air drying at 105C (221F) for 48 h.

[u] Base substrate = 80:20 pinebark:peat.

[t] Duncans Multiple Range Test ($P \leq 0.05$, n = 3).

Table 2. Effects of substrate on pH and electrical conductivity of *Lantana camara*.

	0 DAP[z]		30 DAP		60 DAP		90 DAP	
Substrates	pH	EC[y]	pH	EC	pH	EC	pH	EC
10% corncob[x]	4.93c[w]	1.36ab	6.19a	0.78b	6.11b	0.52b	6.34b	0.35a
20% corncob	4.82c	1.49ab	6.18a	0.58b	6.09b	0.70b	6.20b	0.42a
30% corncob	4.79c	1.96a	6.39a	0.63b	6.38a	081b	6.81a	0.38a
10% perlite	5.43b	1.24ab	5.54c	1.24a	5.78c	0.78b	6.0b	0.41a
20% perlite	5.93b	0.29b	5.59c	1.31a	5.76c	1.99a	6.27b	0.38a
30% perlite	5.98a	0.32b	5.87b	1.44a	5.70c	1.88a	6.29b	0.43a

[z] Days after planting.

[y] Electrical conductivity (dS/cm) of substrate solution using the pourthrough method.

[x] Base substrate = 80:20 pinebark:peat.

[w] Duncans Multiple Range Test ($P \leq 0.05$, $n = 4$).

Table 3. Effects of substrate on pH and electrical conductivity of *Miscanthus sinensis*.

	0 DAP[z]		30 DAP		56 DAP		90 DAP	
Substrates	pH	EC[y]	pH	EC	pH	EC	pH	EC
10% corncob[x]	4.93c[w]	1.36ab	6.08b	0.74b	5.66b	2.22a	6.0a	0.27a
20% corncob	4.82c	1.49ab	6.50a	0.65b	6.04a	1.80a	5.92a	0.26a
30% corncob	4.79c	1.96a	6.61a	0.67b	6.27a	0.42a	5.94a	0.26a
10% perlite	5.43b	1.24ab	5.48c	1.18a	4.94c	0.39a	5.72ab	0.24a
20% perlite	5.93b	0.29b	5.49c	1.17a	4.66c	0.65a	5.39b	0.27a
30% perlite	5.98a	0.32b	5.63c	1.29a	4.79c	0.88a	5.69ab	0.27a

[z] Days after planting.

[y] Electrical conductivity (dS/cm) of substrate solution using the pourthrough method.

[x] Base substrate = 80:20 pinebark:peat.

[w] Duncans Multiple Range Test ($P \leq 0.05$, $n = 4$).

Table 4. Effects of corncob in nursery perennial production.

	Salvia		**Lantana**		**Miscanthus**
	GI[z]	SDW[y]	GI	SDW	SDW
			35 DAP		
10% corncob[x]	37.3bc[w]	16.7b	35.2ab[w]	16.1abc	28.0b
20% corncob	35.1bc	11.8c	36.1ab	12.6bc	32.3ab
30% corncob	30.7c	9.8c	33.9b	11.6c	26.9b
10% perlite	44.7a	22.3a	41.8a	20.7a	50.7a
20% perlite	44.3a	20.4ab	39.0ab	18.0ab	42.2ab
30% perlite	40.0ab	16.9b	37.8ab	17.2abc	51.3a
			90 DAP		
10% corncob	42.9a	37.4a	67.6a	59.7ab	116.1ab
20% corncob	53.8a	39.6a	59.7ab	54.3b	88.8bc
30% corncob	59.7a	39.7a	52.2b	59.0b	63.7c
10% perlite	51.9a	49.2a	57.2ab	86.4a	149.7a
20% perlite	48.6a	51.4a	55.2ab	54.3b	133.5ab
30% perlite	54.9a	57.2a	52.8b	54.9b	111.0a

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

[y] Shoot dry weight measured in grams.

[x] Base substrate = 80:20 pinebark:peat.

[w] Duncans Multiple Range Test ($P \leq 0.05$, $n = 4$).

V. Milled *Paulownia tomentosa* as a Substrate Component in Annual Plant Production

Abstract

A possible new substrate alternative to peatmoss (P) for growing greenhouse crops is processed *Paulownia tomentosa* (Empress Tree) (PT). Two experiments were conducted to evaluate the use of PT as a substrate amendment in the production of *Petunia ×hybrida* and *Dianthus ×hybrida*. Substrates treatments were 20:80 PT:P (v:v), 40:60 PT:P (v:v), 60:40 PT:P (v:v), 80:20 PT:P (v:v), 100% PT, 80:20 P:perlite (PL) (v:v). Substrates containing higher amounts of PT had a greater air space. Substrate container capacity was highest in the low percentages of PT. All substrates containing PT had greater total porosity than the perlite standard. Bulk densities of the PT substrates were of equal value to the PL standard. At 0 days after planting pH of substrate leachates from petunias was similar to PL at treatments containing at least 40% PT. Substrate pH at 14, 21, and 28 DAP was highest for treatments containing 60% to 100% PT. Initial leachate substrate EC was greatest for PL and 20:80 PT:P, however by 35 DAP substrate EC was similar among all treatments. Petunia growth index (GI) was 63% to 400% greater for plants grown in PL compared to other treatments. Dianthus tended to respond better to PT as a substrate component than petunia. However, dianthus GI followed a similar trend with GI 26% to 135% greater in the PL treatment than all others. With one exception all other growth parameters followed similar trends in both species with plants

grown in PL having the highest bloom counts, root ratings, and shoot-dry weights of all treatments.

Index words: alternative substrate, greenhouse production, wood fiber, peatmoss, perlite, *Paulownia tomentosa*.

Species used in the study: *Petunia ×hybrida* 'Celebrity Rose' or *Dianthus ×hybrida* 'Telstar Crimson'.

Significance to the Industry

Due to the recent concerns of peatmoss availability and the environmental impact that the harvesting has on natural peat bogs, researchers have been looking for alternatives to peatmoss that will function the same at a lower or equal cost. The use of *Paulownia tomentosa* has the possibility of providing a new lightweight alternative that could serve as a peatmoss replacement and because of its larger particle size it could also eliminate the need for perlite as well.

Introduction

Increased demand for peatmoss and environmental concerns associated with harvesting of peat bogs provides justification for seeking new alternatives to the current standard industry substrates. Two alternatives currently marketed for greenhouse crop substrate use are rice hulls (5) and coconut coir (1). Recent research has indicated the potential use of wood fiber products for horticultural substrates. *WholeTree,* a substrate component made from loblolly pine (*Pinus taeda* L.) was evaluated along with a starter fertilizer rate in the production of greenhouse-grown petunia (*Petunia ×hybrida* 'Dreams Purple') and marigold (*Tagetes patula* 'Hero') (3). Results of this study revealed that with the addition of an adequate starter nutrient charge, *WholeTree* is an acceptable substrate component replacing the majority of peatmoss in production of petunia and marigold. Murphy et al. (6) processed various hardwood trees as peat alternatives in annual production, and reported that annuals grown in up to 50% red cedar showed similar results compared to a greenhouse standard peat:perlite mix. However, annuals grown in sweetgum and hickory amended substrates had significantly less growth than the greenhouse standard (6). A study by Wright et al. (8) evaluated mums and marigolds grown in white pine amended substrates. Results indicated both mums and marigolds had increased growth with the addition of peatmoss to the pine tree substrate at 25% or 50%. Plants had comparable growth to the control substrate with the addition of at least 50% peatmoss (8).

Another possible wood fiber alternative to peatmoss is processed *Paulownia tomentosa*. Paulownia, a known light weight tree could have a similar bulk density to peatmoss, unlike other recently investigated wood derived substrates which typically have higher bulk densities than peatmoss. Paulownia is currently used in several industries including lumber for furniture and other household items. The Paulownia tree has very fast, vigorous growth that could prove to be beneficial to growers. This study was conducted to determine the effects of *Paulowinia tomentosa* amended substrates on the production of greenhouse grown annuals.

Materials and Methods

Two experiments were installed at the Paterson Greenhouse Complex, Auburn University, Auburn, AL (August, 2010 and January, 2011). *Paulownia tomentosa* (PT) 30 cm (12 in) caliper trees were cut, de-limbed and chipped through a Vermeer BC1400XL chipper and then milled to pass through a 0.95cm (0.375 in) screen in a swinging hammer-mill (No. 30; C.S. Bell, Tifton, OH). Paulownia was then combined with varying rates of Canadian sphagnum peatmoss (P) to achieve six different treatments. Treatments were 100% PT, 20:80 PT:P (v:v), 40:60 PT:P (v:v), 60:40 PT:P (v:v), 80:20 PT:P (v:v), all compared to a standard peat-lite (PL) mix 80:20 P: perlite (v:v). Treatments were amended with 2.97 kg·mg^{-3} (5 lbs·yd^{-3}) of dolomitic lime, 0.68 kg·mg^{-3} (1.5 lbs·yd^{-3}) of Micromax (The Scotts Company, Marysville, OH), 7N-0.86P-8.3K nutrient charge (7-2-10, GreenCare Fertlizers, Kanakakee, IL) and 154.7 mL·m^{-3} (4 oz·yd^{-3}) of Aqua-gro L wetting agent (Aquatrols, Paulsboro, OH). 1.56 L (1.65 qt) containers (EU105T5, ITML Horticultural Products Middlefield, OH) were filled to capacity, tamped and re-filled August 14, 2010 and January 5, 2011. Two plugs 2 cm^3 (0.7 in^3) (200 cell flats) of either *Petunia ×hybrida* ‘Celebrity Rose’ or *Dianthus ×hybrida* ‘Telstar Crimson’ were planted in each container. Containers were placed in a twin wall polycarbonate greenhouse on elevated benches under full sun and hand watered as needed. Plants were liquid fed beginning 10 days after planting (DAP) utilizing a 200 ppm of N (20N-4.3P-16.6K liquid fertilizer, 20-10-20, SDT Industries, Inc. Winnsboro, LA). Data loggers were installed to measure greenhouse temperatures throughout the study. Greenhouse temperature daily average highs and lows were at 25/18C (77/65F). Containers were arranged in a random complete block design with 12 single pot replicates and each plant species treated as a separate experiment.

Initial substrate physical properties including total porosity (TP), container capacity (CC), air space (AS), and bulk density (BD) were determined using the North Carolina State University porometer method (4). Particle size distribution (PSD) was determined for all substrates by passing a 100 g air-dried sample through 12.5, 9.5, 6.35, 3.35, 2.36, 2.0, 1.4, 1.0, 0.5, 0.25, and 0.11 mm sieves with a Ro-Tap sieve shaker [278 oscillations/min, 159 taps/min (Ro-Tap RX-29; W.S. Tyler, Mentor, Ohio)].

Leachates were collected using the Virginia Tech Pour Through Method (9) and pH and electrical conductivity (EC) were analyzed at 0, 14, 21, 28, and 35 DAP in experiment 1 and 0, 14, 21, 28, 35, 42, 49 and 56 in experiment 2. Final growth measurements collected at termination included: growth index (GI) [(height + width + perpendicular width ÷ 3 (cm)], bloom count (BC) (number of blooms showing color), and visual root ratings (RR) on a 0 to 5 scale with 0 indicating no visual roots and 5 indicating complete coverage. At termination shoots were removed at the substrate surface and oven dried at 70C (158F) for 72 hrs and weighed to determine shoot dry weight (SDW). Data was subjected to analysis of variance using the general linear models procedure and a multiple comparison of means was conducted using Tukey's Studentized Range Test (Version 9.2; SAS).

Results and Discussion

Experiment 1. Substrates containing higher amounts of PT had greater AS than substrates containing 40% or less of PT (Table 1). Substrate CC was highest in the low percentages of PT with no difference between 40% and 20% PT when compared to the PL standard. All substrates containing PT had greater TP than the PL standard. Bulk densities of the PT substrates were of equal value to the PL standard. Substrate BD is usually higher in wood fiber substrates when compared to peat-lite mixes (2, 3, 7). Substrate PSD indicated substrates with 80% or greater PT had higher amount of coarse and medium particles than all other substrates (Table 2). The larger particle size of those substrates explains in part the greater AS and TP.

At 0 DAP substrate pH was similar to PL for all treatments containing at least 40% PT. Substrate pH at 14, 21, and 28 DAP was highest for treatments containing from

60 to 100% PT. By 35 DAP PL, and treatments containing at least 40% P were similar and lower than those containing less than 40%. Initial substrate EC was greatest for PL and 20:80 PT:P with the PL treatment having the highest EC at 14, 21, and 28 DAP. However by 35 DAP substrate EC was similar among all treatments (Table 3). Petunia GI was 63% to 400% greater for plants grown in PL compared to other treatments (Table 4). Dianthus GI tended to respond better to PT as a substrate component than petunia. However, GI of dianthus followed a similar trend to petunias with GI being 26% to 135% greater in the PL treatment than all others. With one exception, all other growth parameters followed similar trends in both species with plants grown in PL having the greatest BC, RR, and SDW of all treatments. The exception was with dianthus in substrates containing up to 60% PT which had similar RR to PL.

Experiment 2. Substrates containing 100% PT had the highest AS, similar to results found in Experiment 1. Substrates containing less than 60% PT were not different in AS, but were lower than substrates containing 100 and 80% PT (Table 5). Substrate CC showed similar results to Experiment 1. All substrates containing PT had greater TP than the PL standard, except for 60% PT, which was similar to PL. Bulk densities of the PT substrates, up to 80% PT, were of equal value to the PL standard. Substrate PSD indicated 60% or greater PT had higher amounts of coarse and medium particles than all other substrates (Table 6).

At 0 DAP substrate pH was similar to Experiment 1 with PL substrates being equal to treatments containing at least 40% PT. Substrate pH at 14, 21, 28, 35, 42 and 49 DAP was highest for treatments containing 80 to 100% PT (Table 7). Results from 56 DAP for petunias showed no difference in pH for all substrates. Electrical conductivity was similar for all substrates at 0 DAP. However, at 14 and 21 DAP EC for PL substrate was higher in petunias than PT amended substrates. Results from 28 DAP on showed no difference in EC for all substrates; dianthus followed similar trends.

Growth index from Experiment 2 followed similar trends to Experiment 1 with crops grown in PL being larger than plants grown in PT compared to other treatments (Table 8). Results from all other growth parameters followed similar trends in both species with plants grown in PT having the greatest BC, RR, and SDW of all treatments. The exception was with dianthus in substrates containing 60% PT which had similar RR to PL.

In conclusion, the data presented here indicates that PT amended substrates showed significant differences in growth when compared to the PL standard, casting doubt on whether PT could be a viable alternative substrate component. However, a possible explanation for reduced growth of plants in the PT amended substrates is N-immobilization from fresh PT fibers. Similar results were seen by Fain et al. (2), where smaller growth of petunia and marigold was seen with increasing rates of *WholeTree* as a substrate component. Fain et al. (2) suggests one explanation was nutrient immobilization, especially nitrogen, caused by the *WholeTree* component. This was confirmed in a follow up study (3) where results indicated that with the addition of an adequate starter nutrient charge, *WholeTree* was an acceptable substrate component replacing the majority of peatmoss in production of petunia and marigold. Future research with *Paulonia tomentosa* as a substrate component should address the potential problem of nutrient immobilization.

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Table 1. Physical properties of *Paulownia tomentosa* amended substrate (Experiment 1).

Substrates	Air[y] space	Container[x] capacity	Total[w] porosity	Bulk[v] density
	-----------------	(% vol)	----------------	(g/cm^3)
80:20 Peat:perlite[u]	12.6c[t]	72.2ab	84.7b	1.33b
20:80 Paulownia:peat[s]	14.1c	75.3a	89.4a	1.33b
40:60 Paulownia:peat	17.5bc	72.5ab	90.6a	1.39a
60:40 Paulownia:peat	23.6b	68.6b	92.1a	1.33b
80:20 Paulowina:peat	43.0a	48.2c	91.2a	1.38a
100% Paulownia	45.7a	43.8d	89.5a	1.33b

[z] Analysis performed using the NCSU porometer.

[y] Air space is volume of water drained from the sample ÷ volume of the sample × 100.

[x] Container capacity is (wet weight - oven dry weight) ÷ volume of the sample × 100.

[w] Total porsity is (wet weight - dry weight + drainage) ÷ volume of the sample × 100.

[v] Bulk density after forced air drying at 105C (221F) for 48 h.

[u] 80:20 = 80% peatmoss : 20% perlite (v:v).

[t] Tukeys Studentized Range Test ($P \leq 0.05$, n = 3).

[s] *Paulownia tomentosa* logs chipped and milled to pass a 0.95 cm screen and mixed with peatmoss.

Table 2. Particle size distribution of *Paulownia tomentosa* amended substrates (Experiment 1).

	Sieve opening (mm)												Texture group[z]		
Substrates	**9.50**	**6.35**	**3.35**	**2.00**	**1.40**	**1**	**18"**	**0.5**	**0.25**	**0.11**	**0.05**	**pan**	**Course**	**Medium**	**Fine**
80:20 Peat:perlite[y]	0.0[x]a	0.0a	7.4bc	10.7c	5.7abc	7.8d	7.0d	16.4b	17.6ab	18.1a	6.7a	3.2a	7.4bc	30.5cd	62.1a
20:80 Paulownia:peat[w]	0.0a[v]	0.0a	6.2c	8.1c	3.3c	9.2d	8.3cd	17.8a	18.8a	19.7a	6.9a	2.6b	6.2c	28.9d	65.0a
40:60 Paulownia:peat	0.0a	0.0a	9.0bc	11.2bc	4.8bc	11.8c	10.1bc	16.6ab	15.6bc	14.8b	4.6b	1.5c	9.0bc	37.9bc	53.1b
60:40 Paulownia:peat	0.0a	0.0a	9.9b	13.9b	5.9abc	13.1bc	11.1b	15.5bc	14.0c	12.3b	3.4b	0.9d	9.9b	44.0b	46.1b
80:20 Paulowina:peat	0.0a	0.0a	14.4a	18.6a	8.3ab	15.5ab	13.1a	13.7d	8.5d	5.8c	1.6c	0.5de	14.4a	55.5a	30.1c
100% Paulownia	0.0a	0.0a	14.7a	18.6a	8.6a	16.8a	14.5a	14.3cd	7.9d	4.0c	0.7c	0.0e	14.7a	58.4a	26.9c

[z] Coarse ≥ 2.0mm; medium <2.0 mm to ≥1.0mm; fine <1.0mm.

[y] 80:20 = 80% peatmoss : 20% perlite (v:v).

[x] Percent weight of 100-g sample collected on each screen.

[w] *Paulownia tomentosa* logs chipped and milled to pass a 0.95 cm screen and mixed with peatmoss.

[v] Tukey's Studentized Range Test ($P \leq 0.05$, $n = 3$).

Table 3. Effects of *Paulownia tomentosa* amended substrates on pH and electrical conductivity of greenhouse annuals (Experiment 1).

	0 DAP[z]		14 DAP		21 DAP		28 DAP		35 DAP	
	pH	EC[y]	pH	EC	pH	EC	pH	EC	pH	EC
	Petunia ×hybrida									
80:20 Peat:perlite[x]	3.75c[w]	4.11a	4.59d	5.07a	4.52c	4.56a	4.33d	4.03a	5.21b	1.56ab
20:80 Paulownia:peat[v]	4.07bc	3.82a	4.59d	3.82b	5.03b	3.22b	5.91c	2.45b	5.45b	1.72ab
40:60 Paulownia:peat	3.88c	3.05b	5.19c	2.48c	5.18b	3.14b	6.66b	1.54b	5.43b	1.79a
60:40 Paulownia:peat	4.68bc	2.33c	5.97b	2.50c	6.12a	2.30bc	7.09a	1.86b	6.24b	1.74a
80:20 Paulowina:peat	5.16ab	1.92cd	6.35ab	1.92cd	6.40a	1.84cd	7.14a	1.46b	6.70a	1.22ab
100% Paulownia	6.04a	1.44d	6.69a	1.28d	6.50a	1.30d	6.93ab	1.50b	6.82a	0.62b
	Dianthus ×hybrida									
80:20 Peat:perlite	3.75c	4.11a	4.47d	5.30a	4.66b	5.96a	4.38e	3.30a	4.95d	2.71a
20:80 Paulownia:peat	4.07bc	3.82a	4.47d	3.22b	5.11b	2.49bc	5.59d	2.30ab	5.29cd	1.72a
40:60 Paulownia:peat	3.88c	3.05b	5..03c	2.49bc	5.21b	3.12b	6.45c	2.22bc	5.40c	1.79a
60:40 Paulownia:peat	4.68bc	2.33c	6.01b	2.57bc	6.19a	2.72bc	6.94b	2.11bc	6.22b	1.74a
80:20 Paulowina:peat	5.16ab	1.92cd	6.48a	1.97cd	6.49a	2.02bc	7.20a	1.58c	6.54ab	1.03a
100% Paulownia	6.04a	1.44d	6.64a	1.37d	5.59a	1.54c	7.15a	1.65c	6.89a	2.02a

[z] Days after planting.

[y] Electrical conductivity (dS/cm) of substrate solution using the pourthrough method.

[x] 80:20 = 80% peatmoss : 20% perlite (v:v).

[w] Tukey's Studentized Range Test (P ≤ 0.05, n = 4).

[v] *Paulownia tomentosa* logs chipped and milled to pass a 0.95 cm screen and mixed with peatmoss.

Table 4. Effects of substrate on growth of greenhouse-grown *Petunia ×hybrida* and *Dianthus ×hybrida* (Experiment 1).

Substrates	GI[z]	BC[y]	RR[x]	SDW[w]
		Petunia ×hybrida		
80:20 Peat:perlite[v]	32.1a[u]	25.6a	5.0a	11.1a
20:80 Paulownia:peat[t]	19.4b	5.8b	3.3b	2.6b
40:60 Paulownia:peat	10.5c	1.1c	2.5c	1.0c
60:40 Paulownia:peat	7.0d	0.0c	2.0cd	0.4d
80:20 Paulowina:peat	7.0d	0.1c	2.3c	0.4d
100% Paulownia	6.5d	0.0c	1.5d	0.2d
		Dianthus ×hybrida		
80:20 Peat:perlite	20.7a	17.6a	5.0a	7.9a
20:80 Paulownia:peat	16.4b	4.8b	4.5ab	4.3b
40:60 Paulownia:peat	13.5c	0.9b	3.9ab	1.5c
60:40 Paulownia:peat	11.7cd	0.6b	4.3ab	2.3c
80:20 Paulowina:peat	10.3dc	0.9b	3.9b	0.8c
100% Paulownia	9.3e	0.0b	2.6c	0.8c

[z] Growth index [(height + width1 + width2)/3] (n = 12).

[y] Bloom count = number of blooms or buds showing color at 35 days after potting (n = 12).

[x] Root ratings 0-5 scale (0 = no visible roots and 5 = roots visable on the entire container substrate interface) (n = 8).

[w] Shoot dry weight measured in grams (n = 8).

[v] 80:20 = 80% peatmoss : 20% perlite (v:v).

[u] Tukey's Studentized Range Test ($P \leq 0.05$).

[t] *Paulownia tomentosa* logs chipped and milled to pass a 0.95 cm screen and mixed with peatmoss.

Table 5. Physical properties of *Paulownia tomentosa* amended substrates (Experiment 2).

Substrates	Air space	Container capacity	Total porosity	Bulk density
	----------------	(% vol)	----------------	(g/cm^3)
80:20 Peat:perlite[u]	10.74d[t]	59.29a	70.3c	0.89ab
20:80 Paulownia:peat[s]	21.01c	54.97ab	75.98b	0.88bc
40:60 Paulownia:peat	22.35c	53.57ab	75.92b	0.86bc
60:40 Paulownia:peat	21.97c	47.99bc	69.96c	0.93a
80:20 Paulowina:peat	35.78b	42.46c	78.04ab	0.85c
100% Paulownia	47.10a	33.14d	80.24a	0.85c

[z] Analysis performed using the NCSU porometer.

[y] Air space is volume of water drained from the sample ÷ volume of the sample × 100.

[x] Container capacity is (wet weight - oven dry weight) ÷ volume of the sample × 100.

[w] Total porsity is (wet weight - dry weight + drainage) ÷ volume of the sample × 100.

[v] Bulk density after forced air drying at 105C (221F) for 48 h.

[u] 80:20 = 80% peatmoss : 20% perlite (v:v).

[t] Tukeys Studentized Range Test ($P \leq 0.05$, n = 3).

[s] *Paulownia tomentosa* logs chipped and milled to pass a 0.95 cm screen and mixed with peatmoss.

Table 6. Particle size distribution of *Paulownia tomentosa* amended substrates (Experiment 2).

	Sieve opening (mm)												Texture group[z]		
Substrates	**9.50**	**6.35**	**3.35**	**2.00**	**1.40**	**1**	**18"**	**0.5**	**0.25**	**0.11**	**0.05**	**pan**	**Course**	**Medium**	**Fine**
80:20 Peat:perlite[y]	0.0[x]a	0.0a	7.1b	10.7c	8.1d	3.4d	8.4c	24.0ab	17.9a	8.6a	1.3a	0.2a	7.2b	29.2c	52.1a
20:80 Paulownia:peat[w]	0.0a[v]	0.0a	8.2b	8.1c	10.7cd	4.6cd	13.4b	24.6a	16.3a	7.3a	1.7a	0.3a	9.5b	41.5b	50.3a
40:60 Paulownia:peat	0.0a	0.0a	9.5b	11.2bc	12.8c	5.6c	13.6b	19.9abc	16.0a	8.2a	1.8a	0.4a	8.2b	44.2b	46.3a
60:40 Paulownia:peat	0.0a	0.0a	19.4a	13.9b	17.8b	7.6b	18.0a	15.4bc	7.1b	1.8b	0.0b	0.0a	19.4a	56.4a	24.1b
80:20 Paulowina:peat	0.0a	0.0a	19.3a	18.6a	19.4ab	8.6ab	18.9a	12.6c	5.0b	1.6b	0.7b	0.0a	19.6a	61.1a	19.3b
100% Paulownia	0.0a[w]	0.0a	17.6a	18.6a	22.0a	9.3a	17.8a	12.7c	5.5b	1.0b	0.7b	0.0a	17.6a	63.1a	19.3b

[z] Coarse ≥ 2.0mm; medium <2.0 mm to ≥1.0mm; fine <1.0mm.

[y] 80:20 = 80% peatmoss : 20% perlite (v:v).

[x] Percent weight of 100-g sample collected on each screen.

[w] *Paulownia tomentosa* logs chipped and milled to pass a 0.95 cm screen and mixed with peatmoss.

[v] Tukey's Studentized Range Test (P ≤ 0.05, n = 3).

Table 7. Effects of *Paulownia tomentosa* amended substrates on pH and electrical conductivity of greenhouse annuals (Experiment 2).

	0 DAP[z]		14 DAP		21 DAP		28 DAP		35 DAP		42 DAP		49 DAP		56 DAP		63 DAP	
	pH	EC[y]	pH	EC	pH	EC	pH	EC	pH	EC	pH	EC	pH	EC	pH	EC	pH	EC
	Petunia ×hybrida																	
80:20 Peat:perlite[x]	4.14 d[w]	2.01 a	4.38 d	5.14 a	4.32 d	5.37 a	4.61 e	2.47 a	4.74 d	2.26 a	4.51 e	1.33 ab	4.83 cd	1.83 a	1.83 a	0.83 a	n/a	n/a
20:80 Paulownia:peat[v]	3.75 e	1.78 a	4.26 d	4.01 b	4.36 d	4.21 b	4.54 e	2.23 ab	4.54 d	2.02 a	4.65 e	1.11 abc	4.65 d	1.25 ab	1.25 ab	0.61 ab	n/a	n/a
40:60 Paulownia:peat	4.05 d	1.75 a	5.38 c	2.94 c	5.30 c	3.48 b	5.20 d	2.30 ab	5.38 c	2.01 a	5.12 d	1.66 a	4.42 c	1.38 ab	1.38 ab	0.67 ab	n/a	n/a
60:40 Paulownia:peat	4.82 c	1.92 a	6.08 b	2.51 c	6.06 b	2.28 c	6.10 c	1.21 ab	6.05 b	1.14 ab	6.23 c	0.76 bcd	6.36 b	0.78 b	0.78 b	0.53 ab	n/a	n/a
80:20 Paulowina:peat	5.64 b	1.51 ab	6.52 a	1.40 d	6.47 ab	1.88 c	6.83 b	0.59 b	6.60 a	0.82 b	6.93 b	0.42 cd	6.90 ab	0.86 ab	0.86 ab	0.34 b	n/a	n/a
100% Paulownia	6.68 a	1.00 b	6.70 a	1.11 d	6.69 a	0.91 d	7.05 a	1.28 ab	6.84 a	0.43 b	7.20 a	0.30 d	7.18 a	0.38 b	0.38 b	0.26 b	n/a	n/a
	Dianthus ×hybrida																	
80:20 Peat:perlite	4.14 d	2.00 a	4.35 d	5.64 a	4.47 d	5.72 a	4.68 d	2.81 a	4.56 d	3.62 a	4.67 d	1.35 a	4.50 e	2.44 a	5.21 d	0.75 b	5.53 bc	0.58 ab
20:80 Paulownia:peat	3.75 e	1.78 a	4.30 d	4.17 b	4.32 d	4.23 b	4.56 d	2.62 ab	4.28 d	3.24 a	4.71 d	1.67 a	4.50 e	2.30 ab	5.13 d	1.23 a	5.10 c	0.78 a
40:60 Paulownia:peat	4.05 d	1.75 a	5.26 c	3.12 c	5.49 c	3.09 c	5.28 c	1.99 ab	5.37 c	2.24 ab	5.32 c	1.12 ab	5.23 d	1.80 ab	5.74 c	0.77 b	5.46 c	0.54 abc
60:40 Paulownia:peat	4.82 c	1.92 a	6.09 b	2.73 c	6.09 b	2.23 d	5.98 b	1.73 b	6.05 b	1.56 bc	6.19 b	1.27 a	6.13 c	1.85 ab	6.37 b	0.85 ab	6.22 ab	0.62 ab
80:20 Paulowina:peat	5.64 b	1.51 ab	6.67 a	1.59 d	6.55 a	1.23 e	6.78 a	0.66 c	6.78 a	0.64 bc	6.96 a	0.50 bc	7.01 b	0.44 ab	6.97 a	0.45 bc	6.92 a	0.30 bc
100% Paulownia	6.68 a	1.00 b	6.65 a	0.90 d	6.74 a	0.71 e	6.95 a	0.49 c	6.90 a	0.39 c	7.04 a	0.34 c	7.35 a	0.29 b	7.04 a	0.27 c	6.83 a	0.21 c

[z] Days after planting.

[y] Electrical conductivity (dS/cm) of substrate solution using the pourthrough method.

[x] 80:20 = 80% peatmoss : 20% perlite (v:v).

[w] Tukey's Studentized Range Test ($P \leq 0.05$, n = 4).

[v] *Paulownia tomentosa* logs chipped and milled to pass a 0.95 cm screen and mixed with peatmoss.

Table 8. Effects of substrate on growth of greenhouse-grown *Petunia ×hybrida* and *Dianthus ×hybrida* (Experiment 2).

	GI[z]	BC[y]	RR[x]	SDW[w]
Substrates		*Petunia ×hybrida*		
80:20 Peat:perlite[v]	28.7a[u]	17.1a	5.0a	8.8a
20:80 Paulownia:peat[t]	18.3b	7.9d	3.3b	3.6b
40:60 Paulownia:peat	12.5c	4.5c	3.3b	2.0c
60:40 Paulownia:peat	11.7c	4.8c	3.3b	1.7c
80:20 Paulowina:peat	12.0c	5.1c	2.5bc	1.6cd
100% Paulownia	9.9c	2.1d	2.0c	0.9d
		Dianthus ×hybrida		
80:20 Peat:perlite	22.6a	7.8a	4.6a	7.2a
20:80 Paulownia:peat	12.9b	1.6b	1.6cd	2.9b
40:60 Paulownia:peat	11.8b	0.5b	0.5d	1.4c
60:40 Paulownia:peat	10.7bc	0.3b	3.9ab	1.4c
80:20 Paulowina:peat	10.6bc	0.1b	2.9bc	1.5c
100% Paulownia	9.4c	0.3b	1.5cd	1.3c

[z] Growth index [(height + width1 + width2)/3] (n = 12).

[y] Bloom count = number of blooms or buds showing color at 35 days after potting (n = 12).

[x] Root ratings 0-5 scale (0 = no visible roots and 5 = roots visable on the entire container substrate interface) (n = 8).

[w] Shoot dry weight measured in grams (n = 8).

[v] 80:20 = 80% peatmoss : 20% perlite (v:v).

[u] Tukey's Studentized Range Test ($P \leq 0.05$).

[t] *Paulownia tomentosa* logs chipped and milled to pass a 0.95 cm screen and mixed with peatmoss.

VI. Final Discussion

The purpose of these studies was to evaluate alternative greenhouse substrate components for the production of greenhouse annuals. Currently peatmoss and perlite are the main ingredients used in soilless substrates for greenhouse and nursery production. Recent developments have questioned the availability of peatmoss, because of other industrial uses and environmental concerns (1). These concerns have led to the development of alternatives that will provide the same function as peatmoss and pine bark (3). The production of perlite produces a very fine particle dust that is considered to be a lung and eye irritant (2). This problem that is associated with perlite has led to the development of alternatives that will be able to provide the same amount of airspace to the soil but with less impact on environmental and health concerns (6). Possible new alternatives that have the ability to provide the same amount of air space and water holding capacity as perlite and peatmoss, but with less environmental and health impact are the use of processed corncob and *Paulownia tomentosa*.

In *Chapter 2* results showed that the physical properties analysis of corncob amended substrates resulted in equal or greater air space and bulk density than perlite substrates. Results from the growth parameters showed a reduction in growth with an increase in corncob percentage. Growth indices for all species were highest in perlite amended substrates with growth being up to 70% greater in Experiment 1 and 50% greater in Experiment 2. Impatiens from both experiments had the highest bloom counts in 10% corncob, when compared to all other substrates. Shoot-dry weights and root ratings were the highest in substrates containing perlite and were greater than all substrates containing corncob. From these results we can see that nutrient availability might be a problem in the corncob-amended substrates. Future studies on nutrient management and availability are warranted.

Results of the study in chapter 3 indicated that an increase in fertilizer had a positive effect on petunias growth in the corncob-amended substrates. Petunias grown in a peat-lite mix had greater growth than petunias grown in non-soaked and soaked corncob at their equal counterparts. Petunias grown in substrates with soaked corncob at 8 lbs/yd^3 fertilizer rate in both experiments had similar results to the peat-lite mix at 6 lbs/yd^3 with respect to GI, BC, and RR in Experiment 2. This suggests that pre-soaking the corncob before mixing could also have an effect on the growth of petunias.

In *Chapter 4* growth of lantana, salvia and miscanthus in corncob amended substrates had smaller growth compared to their perlite counterparts at 35 DAP while at 90 DAP there were no differences. There were mixed results in a previous study for the growth of short-term greenhouse annuals in corncob-amended substrates. Looking at these results, as well as what we saw from this study, we concluded that some type of nutrient competition is present in the first 35 days after planting. This competition could be the reason we saw reduction of growth in short term crops. A reason for the positive results at 90 days could be because the competition present at 35 days disappeared and the crops were able to obtain the nutrients available to them. Results from this study continue to show that corncob might be a viable alternative to perlite. Advantages of corncob are its potential to be more regionally available and more carbon neutral when compared to perlite. Based on these results and previous research additional studies need to be conducted to further investigate the relationship of corncob as a perlite replacement in greenhouse and nursery production.

In *Chapter 5*, *Paulownia tomentosa* (PT) amended substrates showed significant difference in growth when compared to the perlite standard, casting doubt on whether PT could be a viable alternative substrate component. However, a possible explanation for reduced growth of plants in the PT amended substrates is N-immobilization from fresh PT fibers. Similar results were seen by Fain et al. (4), where lower growth of petunia and marigold was seen with increasing rates of *WholeTree* as a substrate component. Fain et al. (4) suggests one explanation was nutrient immobilization, especially nitrogen, caused by the *WholeTree* component. This was confirmed in a follow up study (5) where results indicated that with the addition of an adequate starter nutrient charge, *WholeTree* is an acceptable substrate component replacing the majority of peat moss in production of petunia and marigold. Future research with *Paulownia tomentosa* as a substrate component should address the potential problem of nutrient immobilization.

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Appendix A

Analysis of Corncob	
pH	4.9
Nutrients	**ppm**
Salt	2618
NO^3	0.50
NH^4	20.90
P	61.85
Ca	4.36
Mg	46.89
K	1290.00
Na	5.31
So_4	30.75
B	0.20
Fe	0.76
Mn	0.63
Cu	0.18
Zn	1.52
Al	0.40
Mo	0.05