Nitrogen and Cotton Gin Waste Enhance Effectiveness of Pine Bark Soil Amendment

R. Crofton Sloan,[1]
Richard L. Harkess,[2] and
William L. Kingery[2]

ADDITIONAL INDEX WORDS. soil amendment, pine bark, plant bed, bed preparation, urban soil

SUMMARY. Urban soils are often not ideal planting sites due to removal of native topsoil or the mixing of topsoil and subsoil at the site. Adding pine bark based soil amendments to a clay soil altered soil bulk density and soil compaction which resulted in improved plant growth. Addition of nitrogen (N) or cotton gin waste to pine bark resulted in improved plant growth compared to pine bark alone. Growth of pansies (*Viola ×wittrockiana*) during the 1999–2000 winter growing season was enhanced by the addition of pine bark plus nitrogen at 3- and 6-inch (7.6- and 15.2-cm) application rates (PBN3 and PBN6) and pine bark plus cotton gin waste at the 6 inch rate (CGW6). Plant size and flower production of vinca (*Catharanthus roseus*) were reduced by pine bark amendments applied at 3- or 6-inch rates (PB3 or PB6). Crapemyrtle (*Lagerstroemia indica*) grown in plots amended with 3 or 6 inches of pine bark plus cotton gin waste (CGW3 or CGW6) and pine bark plus nitrogen at 3- or 6-inch rates (PBN3 or PBN6) produced greater shoot growth than other amendment treatments. In some instances PB3 treatments suppressed growth. High levels of N and soluble salts derived from CGW and PBN soil amendments incorporated into the soil probably contributed to the improved plant growth observed in this experiment.

Urban soils are often not ideal planting sites. Properties of topsoil that make for a good plant growth environment, such as organic matter, macro- and micropores, soil insects and microorganisms, are not desirable for building foundations because they are not stable (Franklin et al., 1973). The topsoil is usually removed to construct the building's foundation, and the remainder of the site graded to optimize drainage away from the building and to allow driveway access. Even if topsoil is retained, it is often mixed with the subsoil, and properties beneficial for plant growth properties are altered or lost. Strategies to improve the soil environment for plant growth would benefit property owners and landscape professionals in their attempts to establish and maintain landscape plantings. Desirable characteristics of a soil for plant growth include resistance to compaction, adequate aeration and drainage, satisfactory water holding capacity and permeability, adequate rooting volume and formation, adequate fertility and chemical balance, and surface protection (Craul, 1985). Compaction alters the distribution of pore sizes, particularly macro pores and the pore space between aggregates (Soane, 1990). Addition of organic matter into soils can lessen the tendency of the soil to compact when pressure is applied (Soane, 1990). Furthermore, organic matter decomposition produces humic acid which improves the ability of the soil to retain nutrients and to release previously unavailable nutrients (Relf and McDaniel, 1996). Amending subsoils with composted biosolids contributed nutrients to the soil which resulted in better turfgrass growth compared to nonamended subsoils (Loschinkohl and Boehm, 2001).

Recommended amendments for clay soils are pine bark humus, composted leaf mold, and small pea gravel (Bailey et al., 1998). Addition of bark soil amendment may not increase pore space, and subsequently reduce soil bulk density, in a soil until a large enough percentage of the volume of the soil amendment mix consists of bark. Soil particles may fill in the macropore space between the bark particles or the bark may float in the soil until the threshold proportion of bark is reached (Spomer, 1975). The amount of amendment needed to exceed the threshold for increased porosity can be as much as 75% to 90% by volume and is influ-

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Contribution of the Mississippi Agricultural and Forestry Experiments Station journal article no. J10189.

[1] Assistant research professor, North Mississippi Research and Extension Center, P.O. Box 1690, Verona, MS 38879.

[2] Associate professor, Department of Plant and Soil Sciences, 117 Dorman Hall, Box 9555, Mississippi State University, Mississippi State, MS 39762.

enced by the bark particle shape and size (Spomer, 1975). Addition of soil amendment will not result in increased pore space until the threshold is reached. There has to be enough amendment to create enough pore space so that the soil particles do not fill the pores (Spomer, 1976). Applications of 3 and 4 inches of compost to landscape beds resulted in enhanced azalea (*Rhododendron indicum*) growth compared to a 2-inch application to a sandy soil (Beason and Keller, 2001). Soil compaction can inhibit plant root growth. Root growth of trees with a fine textured root system such as western black cherry (*Prunus serotina*) was diminished in a compacted silt loam soil while growth of coarse roots of yellow poplar (*Liriodendron tulipifera*) was not affected (Oddiraju et al., 1996). Cottonseed hulls and sphagnum peatmoss soil amendments in a clay soil reduced soil bulk density 7 months after application, although the cottonseed hull soil amendments did reduce pansy plant foliage quality, presumably due to N immobilization (Sloan et al., 2002).

Applications of N must be made to soil where wood chips have been incorporated to prevent a reduction in plant growth due to N immobilization as the wood chips decompose (Salomon, 1953). Bollen and Glennie (1963) and Schrock and Rothenberger (1997) reported that the addition of N to bark and wood byproducts resulted in increased plant growth due to the reduction of N immobilization. In an eroded sandy clay loam soil, evaluations of several soil amendments indicated that amendments with higher N contents resulted in greater crop growth compared to amendments with lower N contents (Larney and Janzen, 1996). Compost made from yard and landscape wastes were evaluated in a greenhouse trial. The carbon to nitrogen ratio (C:N) was very low, less than 12:1, but it was determined that N was immobilized in the soil (Hartz et al., 1996). The authors concluded that the N immobilization was due to low N content of the compost. Results from a short-term laboratory study suggest that the available N status due to microbial decomposition of crop residues in a clay loam soil is more dependent on the composition of the organic material added to the soil than on the C:N ratio. The rates of N immobilization of crop residues with similar C:N ratios were very different. Just because an amendment had a low C:N ratio does not mean that N immobilization would not occur (McKenney, et al., 1995). Greenhouse studies evaluating the effect of the addition of organic materials to a silt loam soil indicated that C:N ratios of the organic material may not be the best indicator of the value of an organic material for amending a soil. Lignin or other organic components might be more significant in determining the N availability or immobilization attributed to an organic source (Fauci and Dick, 1994).

The objective of this trial was to evaluate the effects of the addition of nitrogen or cotton gin waste to pine bark soil amendment compared to pine bark alone on landscape plant growth.

Materials and methods

This experiment was conducted on an eroded hillside at the North Mississippi Research and Extension Center, Verona, Miss. The soil series was a Savannah sandy clay loam. The thin A horizon was removed by a bulldozer to expose the subsurface layer of soil in order to simulate soil conditions frequently found at recently completed construction sites.

Fifty-six plots measuring 15 × 4 ft (4.6 × 1.2 m) each were created. Three soil amendments were used: 1) pine bark commercially treated with anhydrous ammonia (1.0 % N by dry weight) and iron (0.08 % by dry weight) (PBN), 2) pine bark mixed with composted cotton gin waste at a 2:1 ratio (CGW) and, 3) pine bark (PB). Pine bark used in each treatment came from the same source and was screened to a 3/8-inch (0.95-cm) maximum particle size. Nutrient analysis of the PBN amendment was 6.7, 1.19, 124.0, 9.8, 0.5, 27, and 9; of CGW 7.5, 2.78, 51.1, 15.4, 5.8, 511, and 66; of PB 6.9, 0.10, 13.1, 2.1, 0.03, 9, and 17 (pH, EC $\text{Mmhos}\cdot\text{cm}^{-1}$, ammoniacal N ppm ($\text{mg}\cdot\text{kg}^{-1}$), nitrate N ppm, phosphorus (P) ppm, potassium (K) ppm, and calcium (C) ppm, respectively). The C:N ratio for the PBN amendment, 12:1 was sufficiently low so that N was available for plant uptake while the C:N ratio for CGW, 112:1 was very high. The C:N ratio for PB was 49:1. The amendments were applied to the surface of each plot in layers 3 or 6 inches deep; therefore, there were six pine bark based soil amendments evaluated in this trial: pine bark 3- and 6-inch applications (PB3 and PB6), pine bark plus nitrogen 3- and 6-inch applications (PBN3 and PBN6), and pine bark plus cotton gin waste at 3- and 6-inch applications (CGW3 and CGW6). The soil amendments were incorporated into the plots at either 4 or 8 inches (10.2 or 20.3 cm) deep on 20 Oct. 1999. The control plots received no amendment, but 3 inches of unamended soil was added to each control plot to raise the surface to approximately the same height as the other treatments.

The experimental design was a split plot with tillage depth as the main plot and the subplots consisting of an augmented factorial arrangement of a control, soil amendment type, and amendment application rate. The main plots were arranged in a randomized complete block. There were four replications of each treatment plot.

Two summer crops and one winter crop were planted in the plots to evaluate plant growth due to soil amendment treatments. Six plants of pansy ‘Purple Rain’ were planted into each plot on 2 Nov. 1999. Pansy plant height and width were measured on 4 Jan. and 27 Mar. 2000. Pansy dry weight was measured at harvest on 3 May 2000. One-gallon (3.8-L) liners of crapemyrtle ‘Carolina Beauty’ were transplanted into the plots on 10 Apr. 2000. All new shoot growth was removed at planting to assess the growth response due to the soil amendment treatments after one summer. Shoot length, increase in stem diameter, number of panicles per plant, plant height and plant width were collected on all crapemyrtle plants on 18 Oct. 2000. Six plants of vinca ‘Raspberry Cooler’ were planted in the beds on 10 May 2000. The crapemyrtle were planted at one end of the plot while the vinca were planted at the other end. Vinca plant height and width were measured on 21 June and 28 Sept. 2000. Vinca plant dry weight was collected at harvest on 28 Sept. 2000. A growth index was calculated using $\pi\cdot r^2\cdot h$, where $r^2 = [[(\text{width 1} + \text{width 2})/2]/2]^2$. Width 1 was measured across the widest part of the plant and width 2 was measured at a right angle to the first width and h = plant height.

Soil samples were collected from amendment plots after soil amendment treatments were applied. Results indicated that no lime was needed as sample pH ranged from 6.2 to 7.0. The fertilizer recommendation was $0.5\ \text{lb}/1000\ \text{ft}^2$ ($24.41\ \text{kg}\cdot\text{ha}^{-1}$) of N and $1.2\ \text{lb}/1000\ \text{ft}^2$ ($58.59\ \text{kg}\cdot\text{ha}^{-1}$) of K which was applied before the first crop

Table 1. Bulk density measured on 7 Feb. 2000 (107 d after treatment) at two measurement depths in a clay subsoil amended with either 3 or 6 inches (7.6 or 15.2 cm) of pine bark (PB3 or PB6), pine bark with nitrogen (PBN3 or PBN6), or pine bark with composted cotton gin waste (CGW3 or CGW6) incorporated at 4- or 8-inch (10.2- or 20.3-cm) depths.

	3-inch Depth			
Soil amendment	4-inch Tillage (lb/ft^3)[y]	8-inch Tillage (lb/ft^3)	$LSD_{0.05}$[z] across tillage	6-inch Depth (lb/ft^3)
Control	91.8[x]	80.5	NS	99.9[w]
PB3	61.8	79.3	16.9	91.8
PB6	43.7	61.8	16.9	81.2
PBN3	64.3	72.4	NS	96.1
PBN6	52.4	65.5	NS	88.0
CGW3	56.8	72.4	NS	91.1
CGW6	40.0	61.8	16.9	82.4
$LSD_{0.05}$	15.6	15.6		11.2
Tillage				
4-inch				99.3[v]
8-inch				81.8
$LSD_{0.05}$[y]				13.7

[z] Least significant differences at $P = 0.05$ using Fisher's protected least significant difference test.

[y] 1.0 lb/ft^3 = 16.02 $kg{\cdot}m^{-3}$.

[x] Means of four observations.

[w] Means of eight observations.

[v] Means of 28 observations.

was planted. Thereafter, each plot received monthly 6.4 lb/1000 ft^2 (312.47 $kg{\cdot}ha^{-1}$) of a homogenized fertilizer 8-8-8 (8N–3.5P–6.6K) (IMC Rainbow Agribusiness, Florence, Ala).

Soil samples were collected in a 1.9 inch diameter and 1.3 inch deep (4.83 × 3.30 cm) cylinder at two depths (3 and 6 inches) at two locations in each plot to determine bulk density. The samples were oven dried at 219.2 °F (104 °C) for 48 h and then weighed. Bulk density measurements were made of the native soil in the site of the experiment before bed construction 13 Oct. 1999. Bulk density measurements were also made 7 Feb. 2000, 107 d after treatment (DAT), and 24 Aug. 2000, 309 DAT.

Soil compaction was measured on 16 Aug. 2000, 301 DAT, using a soil compaction meter (The Investigator; Spectrum Technologies, Plainfield, Ill.). Readings were made at 2- and 4-inch depths and were recorded in pounds per square inch ($lb/inch^2$). Two measurements were taken in each plot.

Data were analyzed with SAS PROC MIXED (SAS Institute, Cary, N.C.) If there was an interaction between the main plot units and the split plot units. If there was no interaction, PROC GLM was used. Mean separation was conducted with Fisher's protected least significant difference at the 0.05 significance level.

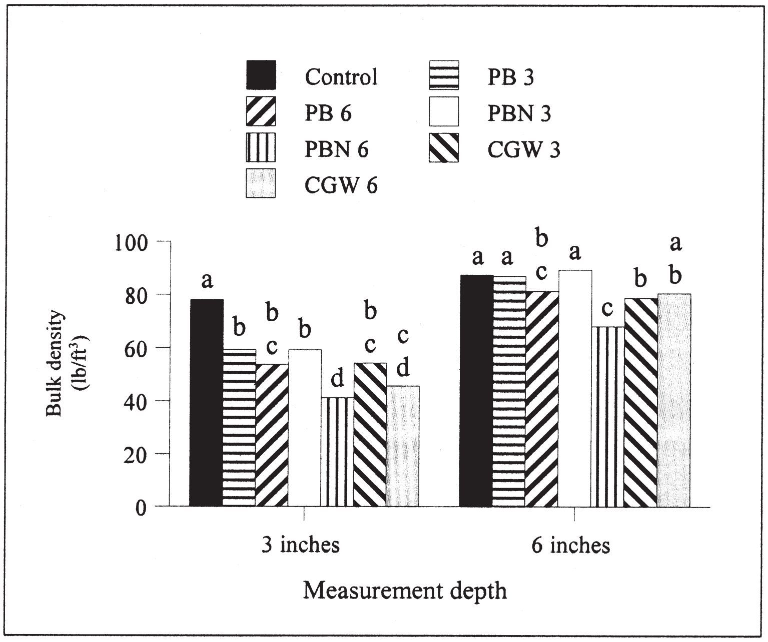

Fig. 1. Bulk density measured 308 d after treatment (DAT) at two measurement depths in clay subsoil amended with either 3 or 6 inches (7.6 or 15.2 cm) of pine bark (PB3 or PB6), pine bark with nitrogen (PBN3 or PBN6), or pine bark with composted cotton gin waste (CGW3 or CGW6). Columns within a measurement depth with the same letter are not statistically different by Fisher's protected least significant difference test ($P = 0.05$, n = 8) (1 lb/ft^3 = 16.0 $kg{\cdot}m^{-3}$).

Results and discussion

SOIL BULK DENSITY. Soil bulk density samples taken from trial site before plot construction reveal an average bulk density of 108 lb/ft^3 (1729.94 $kg{\cdot}m^{-3}$). Analysis of bulk density data from the 3-inch measurement depth 107 DAT revealed an interaction between tillage depth and soil amendment effects. Bulk density at the 3-inch measurement depth for 4-inch tillage was greatest for the control treatment (Table 1). This agrees with previous research that demonstrated that addition of organic matter to a clay soil reduced bulk density (Ekwue and Stone, 1995; Sloan et al., 2002). At the 3-inch depth for 8-inch tillage, soil bulk densities for the PB3, PBN3, PBN6, and CGW3 treatments were not significantly different than the control, while the PB6 and CGW6 treatments did reduce soil bulk densities compared to the control. The soil amendment was mixed with more soil and the threshold amount of soil amendment referred to by Spomer

Table 2. Penetrometer measures of soil compaction on 16 Aug. 2000 (301 d after treatment) recorded at 2- and 4-inch depths in a clay subsoil amended with either 3 or 6 inches (7.6 or 15.2 cm) of pine bark (PB3 or PB6), pine bark with nitrogen (PBN3 or PBN6), or pine bark with composted cotton gin waste (CGW3 or CGW6) incorporated at 4- or 8-inch (10.2 or 20.3 cm) depths.

	2-inch Depth			4-inch Depth		
	Soil compaction					
Soil amendment	4-inch Tillage (lb/inch^2)^y	8-inch Tillage (lb/inch^2)	LSD$_{0.05}$^{z} across tillage	4-inch Tillage (lb/inch^2)	8-inch Tillage (lb/inch^2)	LSD$_{0.05}$ across tillage
Control	186.0^x	163.9^x	NS	179.7^w	166.4^w	NS^x
PB3	164.9	141.4	NS	193.6	127.0	63.1
PB6	95.9	117.4	NS	104.4	128.2	NS
PBN3	228.6	133.2	60.4	188.4	112.0	63.1
PBN6	58.7	138.4	60.4	84.9	138.9	NS
CGW3	119.7	149.1	NS	193.5	139.5	NS
CGW6	91.7	113.5	NS	124.2	134.5	NS
LSD$_{0.05}$	60.4	NS		63.1	NS	

[z] Least significant differences at $P = 0.05$ using Fisher's protected least significant difference test.
[y] 1.0 lb/inch^2 = 70.31 g·cm^{-2}.
[x] Means of 16 observations.
[w] Means of eight observations.

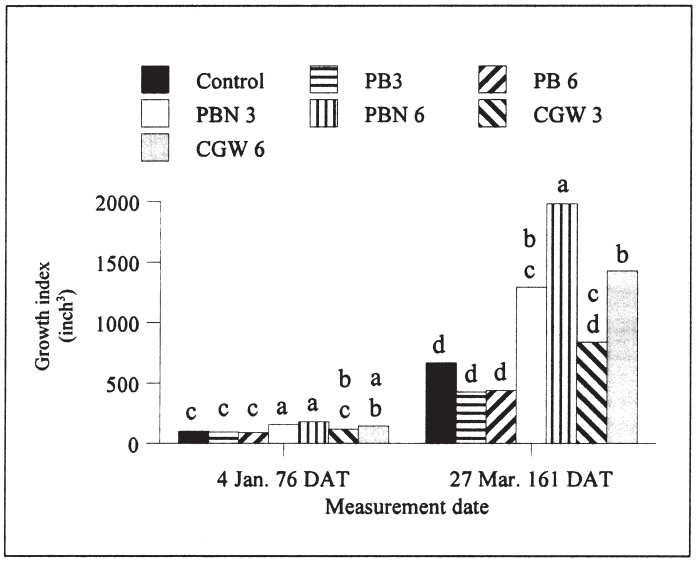

Fig. 2. Growth response at 76 and 161 d after treatment (DAT) of pansy 'Purple Rain' when grown in a clay subsoil amended with either 3 or 6 inches (7.6 or 15.2 cm) of pine bark (PB3 or PB6), pine bark with nitrogen (PBN3 or PBN6), or pine bark with composted cotton gin waste (CGW3 or CGW6) (growth index = $\pi \cdot r^2 \cdot h$). Columns within a measurement date with the same letter are not statistically different by Fisher's protected least significant difference test ($P = 0.05$, n = 32) (1 inch^3 = 16.4 cm^3).

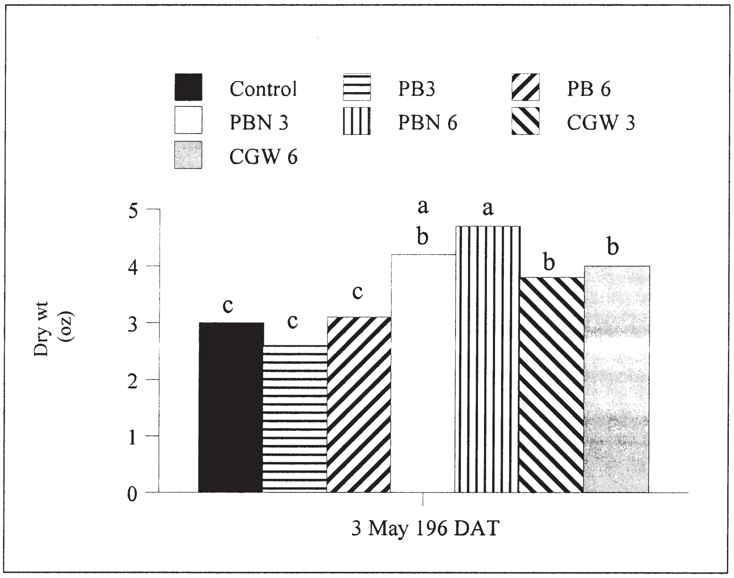

Fig. 3. Dry weight measured 196 d after application of treatment (DAT) of pansy 'Purple Rain' when grown in a clay subsoil amended with either 3 or 6 inches (7.6 or 15.2 cm) of pine bark (PB3 or PB6), pine bark with nitrogen (PBN3 or PBN6), or pine bark with composted cotton gin waste (CGW3 or CGW6). Columns with the same letter are not statistically different by Fisher's protected least significant difference test ($P = 0.05$, n = 32) (1 oz = 28.35 g).

(1976) required to produce macropores was not sufficient. At the 6-inch depth, there was no interaction. The 8-inch tillage produced a lower soil bulk density than 4-inch tillage. The PB6, PBN6, and CGW6 plots tilled 8 inches deep had less bulk density than the control. Higher rates of soil amendment were required to reduce soil bulk density. This agrees with the results of King (1979) who reported that addition of wood fiber at a rate of 4% and 6% dry weight to a clay loam subsoil reduced soil bulk density while amendment with 2% wood fiber did not reduce bulk density.

Soil bulk density was measured again at 308 DAT. At the 3-inch measurement depth, the control plots had a greater bulk density than the amended plots (Fig. 1). Soil bulk density of PBN6 plots was less than all other treatments, except CGW6 plots. At the 6-inch depth, only the PBN6 plots had less bulk density than the control. Results of bulk density measurements indicate that 6 inches of soil amendment were needed in this trial to affect a reduction in soil bulk density at the 6-inch depth.

SOIL COMPACTION. Soil compaction was measured at 301 DAT at two depths, 2 and 4 inches. There was an interaction between tillage depth and soil amendment at both depths. The CGW3, PB6, CGW6, and PBN6 plots tilled 4 inches deep had lower soil compaction at the 2-inch measurement depth compared to the control (Table 2). Soil compaction at the 4-inch depth in the plots tilled 4 inches deep was less in the plots amended with PB6 and PBN6 compared to the control. These results agree with those of Haiquan, et al. (1997), where increasing the amount of organic matter incorporated into a clay soil resulted in a decrease of penetration resistance.

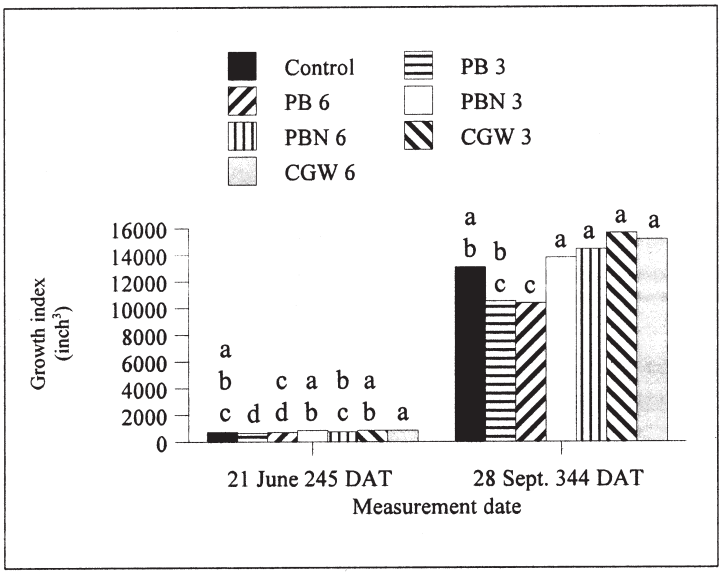

Fig. 4. Growth response measured at 245 and 344 d after treatment (DAT) of vinca 'Cooler Raspberry Red' when grown in a clay subsoil amended with either 3 or 6 inches (7.6 or 15.2 cm) of pine bark (PB3 or PB6), pine bark with nitrogen (PBN3 or PBN6), or pine bark with composted cotton gin waste (CGW3 or CGW6) (growth index = $\pi \cdot r^2 \cdot h$). Columns within a measurement date with the same letter are not statistically different by Fisher's protected least significant difference test ($P = 0.05$, n = 64) (1 inch^3 = 16.4 cm^3).

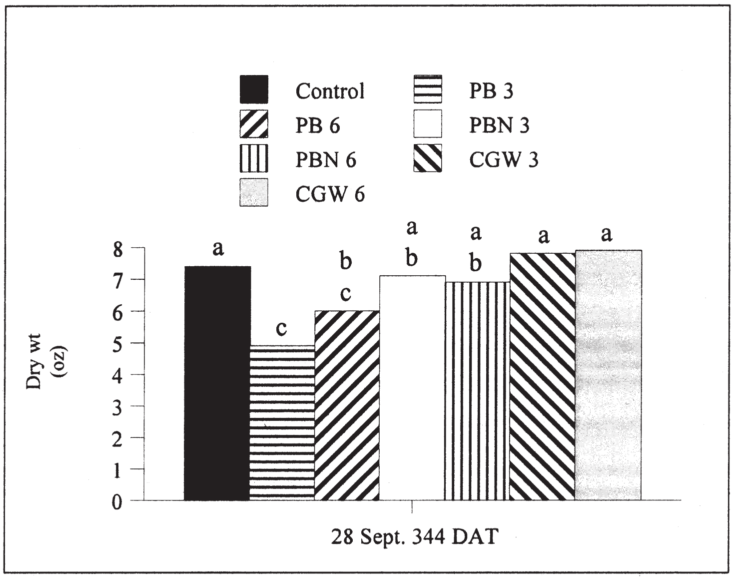

Fig. 5. Dry weight measured 344 d after treatment (DAT) of vinca 'Cooler Raspberry Red' when grown in a clay subsoil amended with either 3 or 6 inches (7.6 or 15.2 cm) of pine bark (PB3 or PB6), pine bark with nitrogen (PBN3 or PBN6), or pine bark with composted cotton gin waste (CGW3 or CGW6) (growth index = $\pi \cdot r^2 \cdot h$). Columns with the same letter are not statistically different by Fisher's protected least significant difference test ($P = 0.05$, n = 64) (1 oz = 28.35 g).

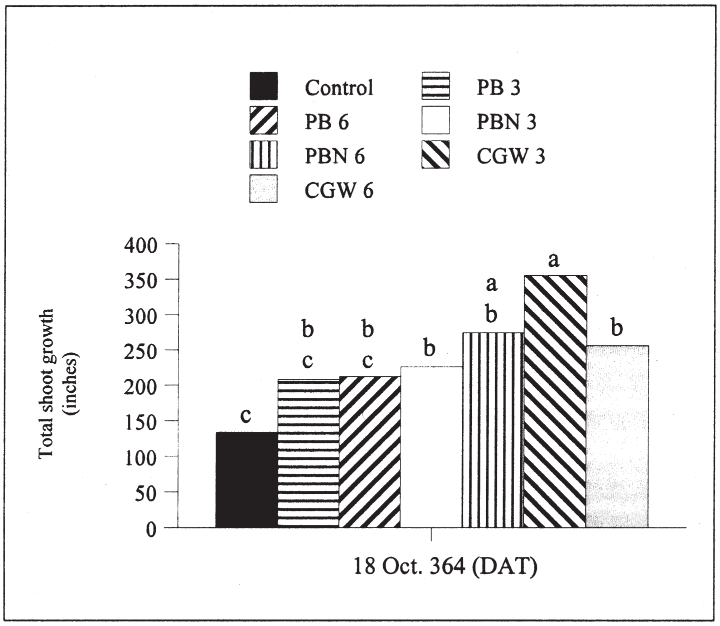

Fig. 6. Shoot growth of 'Carolina Beauty' 364 d after treatment (DAT) grown in a clay subsoil amended with either 3 or 6 inches (7.6 or 15.2 cm) of pine bark (PB3 or PB6), pine bark with nitrogen (PBN3 or PBN6), or pine bark with composted cotton gin waste (CGW3 or CGW6) (growth index = $\pi \cdot r^2 \cdot h$). Columns with the same letter are not statistically different by Fisher's protected least significant difference test ($P = 0.05$, n = 64) (1 inch = 2.54 cm).

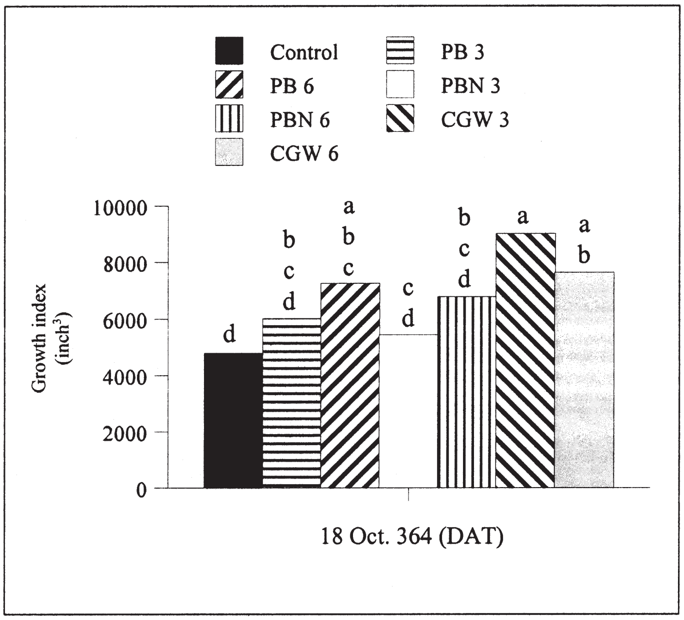

Fig. 7. Size of 'Carolina Beauty' 364 d after treatment (DAT) grown in a clay subsoil amended with either 3 or 6 inches (7.6 or 15.2 cm) of pine bark (PB3 or PB6), pine bark with nitrogen (PBN3 or PBN6), or pine bark with composted cotton gin waste (CGW3 or CGW6) (growth index = $\pi \cdot r^2 \cdot h$). Columns with the same letter are not statistically different by Fisher's protected least significant difference test ($P = 0.05$, n = 64) (1 inch^3 = 16.4 cm^3).

The addition of soil amendment to the plots did not reduce soil compaction at the 6-inch measurement depth (data not shown). The proportion of soil amendment added to the native soil needed to reduce soil compaction was not achieved. The same trend in soil compaction observed at the 6-inch depth was also observed at the 8-inch measurement depth (data not shown).

GROWTH RESPONSE OF PANSY. The first evaluation of the growth response of pansy 'Purple Rain' occurred on 4 Jan. 2000, 76 DAT. The pansy plant size was larger for plants grown in beds amended with PBN3, PBN6, and CGW6 compared to plants grown in control plots

(Fig.2). Width and height of the pansy plants were again measured on 27 Mar. 2000, 161 DAT. Plants grown in the PBN3, PBN6, and CGW6 plots were again larger than plants grown in the control, PB3, or PB6 plots. Measurements of dry weight at 196 DAT show that pansy plants grown in CGW3, CGW6, PBN3, and PBN6 plots were larger than plants grown in the control plots (Fig.3). Plants grown in the plots amended with PBN and CGW were larger than plants grown in the control and PB plots. The N contents of the PBN and CGW amendments were higher than PB. Larney and Janzen (1996) proposed that amendments with a high N content released more N into the soil compared to amendments with lower N content. The high C:N of the CGW amendment should have reduced plant growth due to N immobilization, but this was not observed. McKenney et al. (1995) and Fauci and Dick (1994) postulated that the availability of N in a clay loam soil is more dependent on the organic amendment composition rather than the C:N ratio. The high soluble salts in the CGW and PBN amendments could have provided sufficient nutrients, especially K, to enhance pansy growth.

GROWTH RESPONSE OF VINCA. Measurements on 21 June 2000, 245 DAT, of vinca 'Cooler Raspberry Red' showed that plants grown in the PB3 plots were smaller than the control while plants grown in the other treatments were the same size as the control (Fig. 4). On 28 Sept. 2000, 344 DAT, there were no differences in plant size between the control and the other treatments except for the PB6 plot which was smaller. At harvest on 28 Sept. 2000, there were no differences in dry weight of plants from the control plots and the PBN3, PBN6, CGW3, and CGW6 treatments while plants grown in the PB3 and PB6 plots were smaller than the control (Fig. 5). All treatment plots received the same monthly rate of fertilizer application. Amending the plots did not result in an increase of vinca growth as was observed with the pansies. The PB amendment could have immobilized the N from the fertilizer and resulted in decreased growth of the vinca.

GROWTH RESPONSE OF CRAPEMYRTLE. Growth response of crapemyrtle 'Carolina Beauty' was evaluated on 18 Oct. 2000, 365 DAT. Shoot growth was greater for plants grown in the PBN3, PBN6, CGW3, and CGW6 compared to plants grown in the control (Fig. 6). The shoot growth for PB3 and PB6 plots did not differ from the control. These results are similar to those observed in the growth response of pansy at 76 DAT. Growth indices of plants from PB6, CGW3, CGW6 plots were larger than the control (Fig. 7). Neither soil amendment nor tillage depth affected the increase in stem diameter or the number of panicles on the crapemyrtle plants (data not presented).

Conclusion

Each of the amendment treatments in this trial reduced clay soil bulk density. Reduction of bulk density in a clay soil often results in improved growth of landscape plants. In this trial, however, reduction of soil bulk density did not necessarily result in improved plant growth compared to the control treatment. Pansies and crape myrtles grown in the plots amended with CGW and PBN produce a greater growth response than those plants grown in the control and PB plots. The enhancement in growth may have been due to increased levels of N and other soluble salts in the treated plots leached from the CGW and PBN treatments. These results are similar to those observed by Larney and Janzen (1996) who concluded that soil amendments with higher N levels released larger amounts of N to the soil. The C:N ratio of the PBN treatments was low which is assumed to result in N being readily available for plant utilization. The C:N ratio of CGW treatments was high which should have made N unavailable for plant utilization. Several previous studies indicate that the C:N ratio by itself may not be the best indicator of the availability of N from a soil amendment (Hartz, et al., 1996, and McKenney, et al., 1995). Fauci and Dick (1994) proposed that organic components of an amendment could be responsible for determining N availability from soil amendments. The growth response of vinca did not duplicate the response on pansy in this trial

In this study, the plant growth responses of three crops of landscape plants measured for 365 d show that amending a Savannah sandy clay soil with pine bark plus nitrogen or pine bark plus cotton gin waste resulted in superior plant growth compared to pine bark soil amendment alone. In some instances pine bark amendment alone suppressed growth.

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