Tables 5 and 6 give nutrient content of bogs at two different depths.

Table 6. Inorganic nutrient content of peat from Georgia bogs.[1]

Samples taken at surface					
P	K	Ca	Mg	Fe	Mn
1708	222	9147	1064	1625	149
B	Cu	Zn	Mo	Na	Al
7	.4	20	.4	77	6838
Si	Co	Cr	Ni	Pb	Cd
566	7	5	1	26	4

[1] *Means, in parts per million, calculated from 50 random samples*

USE AS A HORTICULTURAL MEDIUM

Conover and Pool (1) summed-up an analysis of peats by saying that selection of a peat for use as a horticultural medium depends on personal preference, cultural practices, cost and availability. All peats are capable of growing plants, but cultural practices are less stringent for peats with the better physical characteristics.

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PINE BARK CONTAINER MEDIA — AN OVERVIEW

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Considerable research has been conducted to develop a standardized potting medium for growing flower, bedding and woody plants in containers. However, potting media in use by flower growers and nurserymen are varied. Imported peat moss has been an important source of organic matter used in potting media because it has been readily available at moderate cost. As costs continue to rise, growers will continue to seek less costly substitutes for peat moss which will impart the same desirable physical and chemical properties to their potting mixtures.

Tree bark, a by-product of the forestry industry, is an organic material that has undergone evaluation in recent years as a peat moss substitute for greenhouse and nursery crops (1,8,9,14,17,20,22,24,26,29). The advantages of using bark, either hardwood or softwood are: 1) it is a renewable resource; 2) it is currently available at lower cost to the grower than imported peat moss, and 3) bark can be processed by hammer-mill and screening to provide a material that is reproducible, thus providing a standardized product. In the South, pine bark is used in ever-increasing quantities by nurserymen in the formulation of potting media for container grown plants. An outstanding characteristic of pine bark is its resistance to decay. This is important to the container-plant producer since rapid decomposition of the organic fraction can result in rapid alteration of the air-moisture relationship existing within the medium. Overwatering and poor drainage can result if rapid structure loss occurs in the root media.

PHYSICAL AND CHEMICAL CHARACTERIZATION OF PINE BARK

Large slabs and pieces of pine bark are removed from a log in the debarking process; this material is seldom usable as a potting medium component. Processing by hammer-milling and screening is needed to reduce the particle size range to one which is suitable for plant growth. Even with hammer-milling and screening, the physical characteristics of processed pine bark vary considerably. Milled pine bark from six commercial nurseries was subject to particle size analysis in the laboratory (Table 1). None of the six pine barks tested were similar in particle size distribution nor in their physical properties (21). Mixing these pine barks with other components, which also vary in their texture and physical properties, results in potting mixtures that are quite different in physical properties (33). Thus, very different cultural programs are needed to grow a uniform crop in each different medium. Additionally, changes in the physical characteristics of the potting components from one potting period to the next necessitate additional changes in the in the

Table 1. Particle analysis (% wt) of pine bark amendment obtained from 6 commercial nursery sources.

NBS sieve #	Screen opening mm	Pine bark source					
		A	B	C	D	E	F
4	4.76	13.6	9.8	8.5	4.4	23.3	26.4
8	2.38	20.4	17.2	41.2	18.2	11.8	25.6
10	2.00	7.6	7.1	10.1	9.2	3.8	7.4
18	1.00	18.7	19.3	19.9	23.7	11.1	15.6
20	0.84	4.8	5.7	3.7	6.5	3.2	3.2
30	0.59	8.7	10.2	5.0	10.7	5.8	5.3
40	0.42	7.7	9.3	3.5	9.3	5.6	3.7
Pan		18.6	21.4	7.9	17.8	35.0	12.4

cultural program employed.

Research at the University of Georgia has shown that milled pine bark with 70 to 80% of the particles in the range of 1/40 to 3/8 inches in diameter and 20 to 30% of the particles smaller than 1/40 inch is very satisfactory as a potting medium and/or potting medium amendment (Table 2). This particle distribution is similar to that reported for hardwood bark by Gartner et al. (8,9). If the pine bark used is too coarse, insufficient water retention may result in poor plant establishment, poor growth, and/or plant death. Conversely, if an excess of fine bark particles are present, surplus water is retained, air is excluded from the medium, and poor growth results.

Table 2. Desirable particle size distribution for milled pine bark used as a potting medium and soil amendment.

NBS sieve no.	Screen opening mm	percent by wt
4	4.76	0.4
8	2.38	18.6
10	2.00	9.0
18	1.00	28.3
20	0.84	5.4
30	0.59	11.3
40	0.42	8.5
Pan	<0.42	18.6

Pine bark is acidic with an initial pH ranging from 4.1 to 5.0 (4,14). The pH of pine bark does not rise substantially with age. Preplant addition of dolomitic lime at the rate of 13 lbs./cu. yd. is necessary to raise the pH into the range of 6.0 to 7.0 (Table 3). If calcitic and dolomitic limestone are used, about 90 days are required for the necessary pH change to occur (25). For rapid pH adjustment, hydrated lime (8.3 lbs./cu. yd.) (Table 3) may be added at the time of mixing, but 7 days should be allowed before potting so that plant injury does not occur (19).

The chemical composition of milled pine bark is given in Table 4. Milled pine bark is low in both macro- and micronutrients needed for plant growth. Therefore, a fertilization program providing adequate nutrients is needed if optimum plant growth is to be achieved.

Table 3. Lime requirement for a pine bark potting medium.

meq Ca per 10 g bark	Equilibration pH	lbs $Ca(OH)_2$ yd^3	lbs $CaCO_3$ yd^3	lbs $Ca(Mg) CO_3$ yd^3
0	3.90	0	0	0
2	4.90	2.8	3.8	4.1
4	5.84	5.5	7.5	8.2
6	6.32	8.3	11.2	12.3

Table 4. Spectrographic analysis of milled southern pine bark used as a potting medium amendment.

Element	Water extract	Total
N	—	0.28%
NH_4-N	0.33 ppm	—
NO_3-N	0.67	—
P	9.0	0.02
K	27.6	0.10
Ca	7.6	0.51
Mg	1.6	0.14
B	0.15	9.33 ppm
Cu	0.17	76.94
Fe	ND*	790.40
Mn	0.01	118.85
Zn	0.06	111.60

* ND = not detectable.

FRESH, AGED, OR COMPOSTED BARK

One question a grower contemplating the use of pine bark frequently asks is: Shall I use fresh, aged or composted bark in my potting medium? In the South, large quantities of aged pine bark are used. Aging refers to the stockpiling and weathering of bark after hammer-milling and prior to its use. The aging process usually takes place on open-air stockpiles established by the bark producer or commercial grower. No fertilizer additions or pH adjustments are made during the aging period (3 to 18 months or more), nor is an attempt made to control the moisture content within the bark stockpile. During this aging period, the stockpile may undergo slight decomposition as evidenced by a buildup of heat, but temperatures attained within the pile are insufficient to kill pathogenic organisms (14). If the stockpiles are very large, partial decomposition will occur due to inadequate aeration within the depths of the pile. Under these conditions, compounds may be formed which are toxic to plants. Aging or weathering of pine bark enhances its wettability.

In contrast to aging, composting is the biological degradation of pine bark under carefully controlled conditions. Fertilizer additions (particularly N), the regulation of pH, moisture and aeration in the compost pile are important factors in the composting process. Composting procedures for both hardwood and softwood barks are summarized in detail by Hoitink and Poole (14). The advantages of compositing lie in the reduction of the carbon to nitrogen ratio, which minimizes the competition between plant and microorganisms for nitrogen, and in the destruction of pathogenic organisms due to the heat buildup within the compost pile (13,15). In contrast to hardwood bark, mandatory composting of pine bark is unnecessary.

Table 5. Growth index and fresh wt of *Ilex crenata* 'Rotundifolia' grown in fresh and aged milled pine bark-sand potting media.[1]

Medium (v/v mixtures)	Date of harvest 3/17 Growth[2] index	3/17 Fresh wt (g)	4/17 Growth index	4/17 Fresh wt (g)	5/17 Growth index	5/17 Fresh wt (g)	6/17 Growth index	6/17 Fresh wt (g)
1:1 fresh bark-sand	19.0[a]	24.5[a]	—	—	—	—	—	—
1:1 fresh bark-sand+1.0% N	18.7[a]	25.0[a]	—	—	—	—	—	—
1:1 bark (aged 1 mo.)-sand	—	—	20.0[a]	27.5[a]	—	—	—	—
1:1 bark (aged 1 mo.)-sand+1% N	—	—	18.7[a]	24.8[a]	—	—	—	—
1:1 bark (aged 2 mo.)-sand	—	—	—	—	22.5[a]	26.1[a]	—	—
1:1 bark (aged 2 mo.)-sand+1% N	—	—	—	—	22.3[a]	29.6[a]	—	—
1:1 bark (aged 3 mo.)-sand	—	—	—	—	—	—	28.3[a]	39.1[a]
1:1 bark (aged 3 mo.)-sand+1% N	—	—	—	—	—	—	28.7[a]	41.7[a]
1:1 bark (aged 6 mo.-1 yr.)-sand (control)	18.1[a]	23.4[a]	18.6[a]	22.4[a]	21.2[a]	24.3[a]	24.4[b]	25.8[a]

[1] 10 plants per treatment except 6/17 harvest (5 plants per treatment).

[2] Growth index $= \frac{\text{Ht} + \text{spread}}{2}$

[a] Means within a column followed by a common letter are not significantly different (5% level).

Self (29) and Self and Pounders (30,31) have shown that many plants can be grown successfully in fresh pine bark without the necessity of composting. Plantings delayed for 30 days following composting were also satisfactory, but in plantings made after composting 60 days poor results were obtained due to excessive leaching and salt accumulation, which depended upon the fertilizer additives incorporated (29,32).

In studies at the University of Georgia *Ilex crenata* 'Rotundifolia,' holly, were grown under a standard fertilization program in media containing fresh pine bark or pine bark aged from 1 to 6 months. Plants of similar size, fresh weight and quality were obtained whether or not N was added preplant to compensate for potential N competition (Table 5). Laboratory tests indicate that only ¼ lb. N/cu. yd. will provide adequate N for microorganisms acting on the pine bark (unpublished data).

THE WETTING PROBLEM

Milled pine bark, sometimes hot-air dried to facilitate processing and storage, and fresh pine bark are very difficult to wet (5). The wetting characteristics of the bark potting medium at the time of planting is a critical factor in the growth cycle of a plant since an initial growth delay, due to moisture stress, has been reported (11). Hydrophobicity, the initial resistance to wetting encountered with a dry pine bark medium, is probably due to chemical and/or physical factors. Most or all bark particle surfaces are covered with organic chemicals that resist water adsorption; rough particle surfaces cause an interfacial tension that resists adsorption and movement of water (4). Also, the quantity and size of pores within the particles are too small to allow entry of water (4,7).

Initial moisture content of bark particles influences infiltration, absorption and retention of applied water (Figure 1). With an initial moisture content of 34% or less (wet wt basis), milled pine bark resists water infiltration and holds insufficient moisture to adequately support plant growth (3). Therefore, the potential exists for total crop failure. Thus, a pine bark medium should be thoroughly wet prior to planting to ensure rapid plant establishment and development.

One way to overcome the difficulty in wetting is through the use of surfactants, which are chemical wetting agents. Approximately 24 surfactants have been evaluated for their effectiveness in overcoming resistance to wetting of dry pine bark. Nine have been found to be effective in achieving threshold wetting (35% wet wt basis) at concentrations ranging from 0.1% to 1.0% (Table 6). No phytotoxicity was observed at minimum concentrations required for threshold wetting.

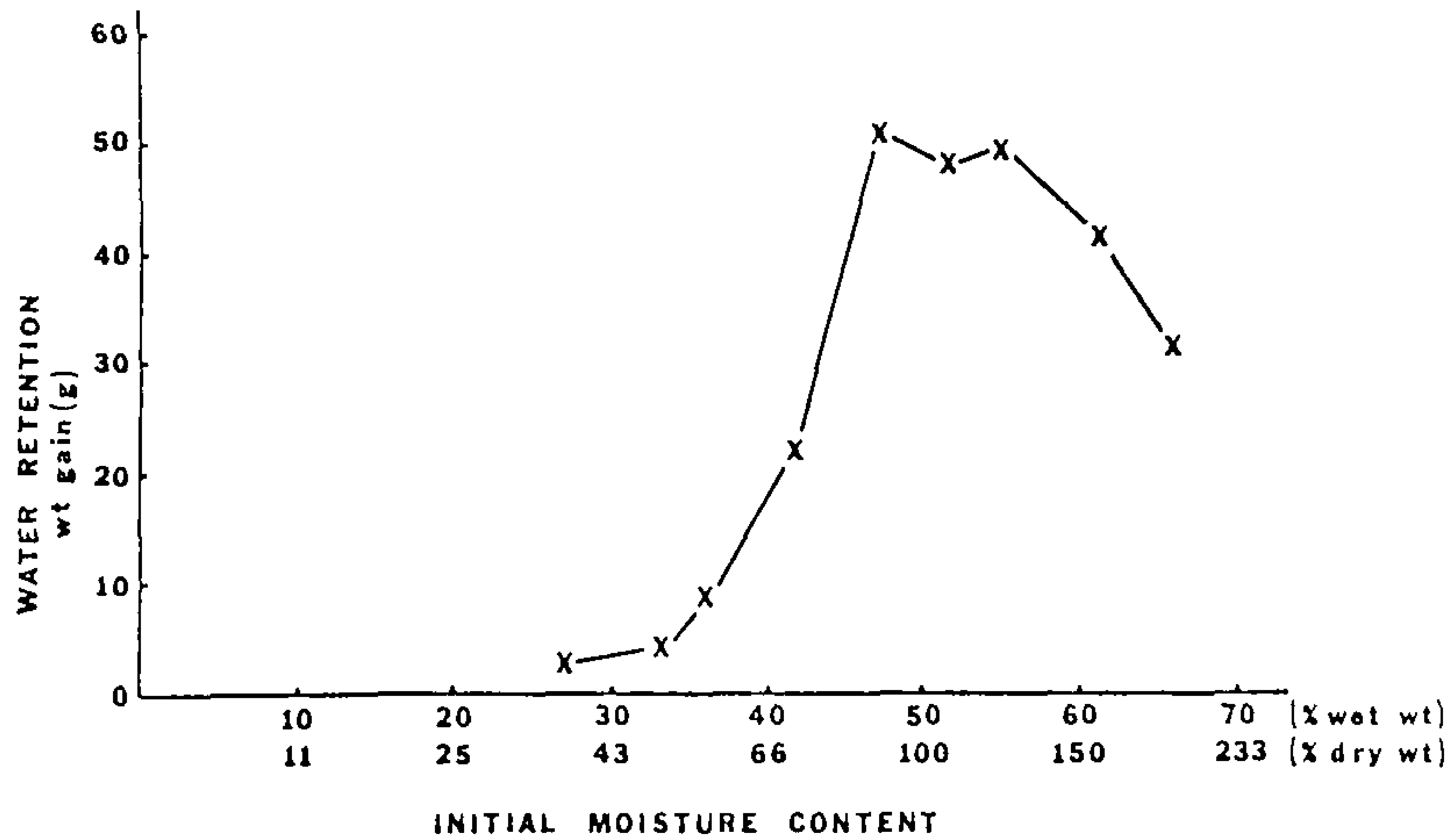

Figure 1. Influence of initial moisture content on water retention of milled pine bark.

Table 6. Surfactants and minimum concentration required to achieve threshold wetting (35% wet wt basis) of dry milled pine bark.

		Minimum concentration required					
Surfactant	Type	0.1%	0.2%	0.3%	0.4%	0.5%	1%
Neutronyx 600	non-ionic	—	x	—	—	—	—
Aqua Gro	non-ionic	—	—	—	x	—	—
Gafac PE510	anionic	—	—	—	—	x	—
Hydro-wet	non-ionic	—	—	—	—	—	x
Firechem	non-ionic	x	—	—	—	—	—
Triton CF-54	non-ionic	x	—	—	—	—	—
Triton DF-16	non-ionic	—	x	—	—	—	—
Triton X-100	non-ionic	—	x	—	—	—	—
Triton X-114SB	non-ionic	—	x	—	—	—	—

POTTING MIXTURES

Successful plant growth has been achieved with a wide range of potting media containing pine bark (Table 7). At the University of Georgia excellent results have been obtained with 1:1:1 v/v/v soil, sand, pine bark, 1:1:1 v/v/v soil, perlite, pine bark, 1:1 v/v pine bark, sand, 1:1 v/v pine bark, perlite, and in 100% pine bark (20,22). It has not proved necessary to incorporate peat moss since a fine grade of milled bark (Table 3) has been utilized as the organic amendment.

EARLY PLANT GROWTH DELAY AND WATER RELATIONS

Initial delay in plant growth has been reported when plants are grown in media containing milled pine bark (11). This prob-

Table 7. Partial range of potting mixtures utilizing pine bark as an organic component.

Potting medium (mixtures, v/v basis)	Crop grown	Literature citation
100% pine bark	*Pilea*, *Rhododendron obtusum*, *Saintpaulia*, *Coleus*, *Begonia semperflorens*	2, 22, 25, 26
3:1 pine bark-sand	*Centaurea cineraria*	16
1:1 pine bark-sand	*Saintpaulia*, *Coleus*, *Gardenia jasminoides 'Radicans'*, *I. crenata* 'Rotundifolia', *Rhododendron obtusum*	17, 20, 22
1:1 pine bark-perlite	*Saintpaulia*, *Gardenia jasminoides* 'Radicans', *Ilex cornuta* 'Burfordii'	20, 22
1:1 pine bark-vermiculite	*Chrysanthemum*	6
7:3 pine bark-vermiculite	Nursery crops	6
2:1:1 pine bark-peat-sand	*Ilex crenata* 'Hetzii', *Pinus thunbergii* *Quercus shumardii*, *Betula nigra*, *Carya illinoensis*	10, 12, 34
2:1:1 pine bark-peat-shale	*Rhododendron obtusum*	26
1:1:1 pine bark-peat-shale	*Rhododendron obtusum*	26
1:1:1 pine bark-peat-sand	*Rhodendron obtusum*	17
1:1:1 pine bark-soil-peat	*Rhododendron obtusum*	17
1:1:1 pine bark-soil-sand	*Pyracantha*, *I. cornuta* 'Burfordii', *Gardenia jasminoides* 'Radicans', *Saintpaulia*	10, 22
1:1:1 pine bark-soil-perlite	*Saintpaulia*, *Coleus*	22

lem has been simulated in the laboratory at the University of Georgia and results indicate it is not nutritional in nature. Rather, early growth delay, particularly with herbaceous plants, appears to be moisture related. Moisture retention in the surface 1 to 2 inches of a 1:1 pine bark-sand medium is less than in a 1:1 peat-sand mixture. Thus, newly transplanted seedlings, rooted cuttings, and/or liners tend to undergo moisture stress during the first several weeks after transplanting. However, once roots become established, plants rapidly develop. By changing the particular distribution of the pine bark to a finer grade or by frequent syringing for the first several weeks after transplanting, the problem can be eliminated.

Frequent irrigation to provide adequate moisture levels with pine bark media is necessary during the first 30 days after planting. Once plants become established, less watering is required (Figure 2). Pine bark retains less water than peat moss, but apparently more of the water held by pine bark is available for plant use.

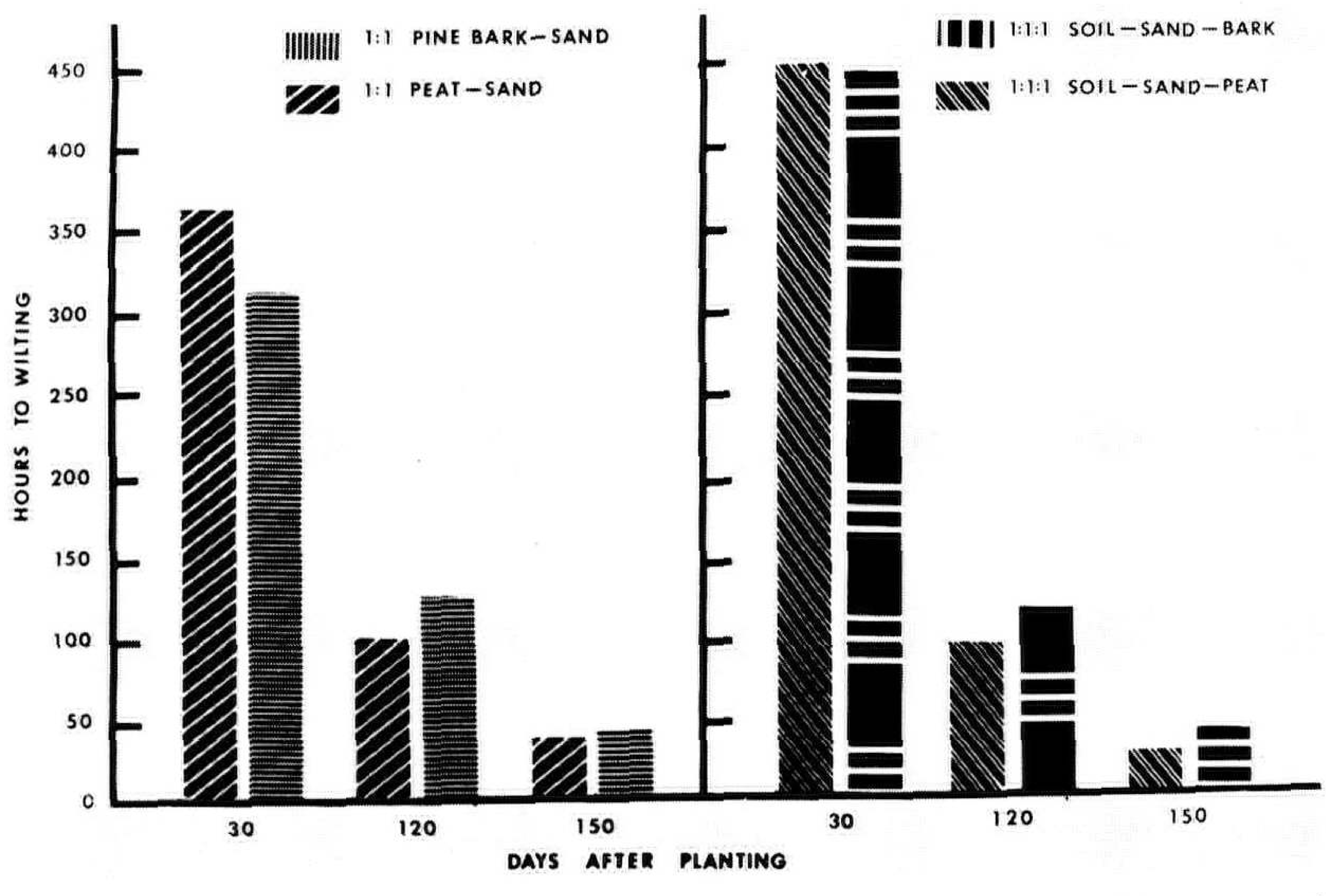

Figure 2. Influence of peat moss and pine bark as potting medium amendments on available soil moisture as exhibited by wilting of the indicator plant, *Hypericum* 'Hidcote'.

FERTILIZATION

In recently completed research in Georgia, it was found that nitrate base fertilizers (calcium nitrate, potassium nitrate) are preferred N sources for fertilization in comparison to ammonium sources of N. When ammonium supplied over 50% of the N, plant growth was suppressed (Table 8). Research indicates that this growth suppression is due to the tie-up of the ammonium by the pine bark particle rather than due to ammonium toxicity (1,18,23). Self (28) has shown that Osmocote 18-5-11 at 5 or 10 pounds./cubic yard and Special 7 are adequate for azalea growth. If Birmingham slate is included as a potting mix amendment, iron could be deleted from the preplant fertilizer addition (27).

Table 8. Effect of nitrogen source on dry weights of *Lycopersicon esculentum*, Mill., 'Beefsteak' plants grown in various sand/pine bark potting media in containers.

N source ratio		Sand/bark ratio				
NO_3	NH_4	75/25	50/50	25/75	0/100	Mean
		Dry wt (g)				
100	0	7.0	6.9	6.0	5.3	6.3
75	25	6.7	6.6	5.8	5.5	6.2
50	50	6.2	6.4	5.5	5.5	5.9
25	75	5.2	5.3	5.3	4.7	5.1
0	100	3.4	4.2	4.4	4.2	4.1

CONCLUSION

In the final analysis, each grower must decide upon a potting mixture that is most adaptable to his needs and develop a management program that will produce the best plant at the lowest cost. Milled pine bark can be utilized successfully in potting media for container plants and plant growth comparable with other organic soil amendments can be achieved.

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Questions for F.A. Pokorny:

GARY HUTT: What was the pH in the bark used for your nitrogen fertility study?

FRANK POKORNY: Initially the bark had a pH of 4.1. It was brought up to 6.2.

GARY HUTT: How does pH affect the choice of a nitrogen source?

FRANK POKORNY: If pH is high, the nitrogen material should be acid forming; if low, the fertilizer should give a basic reaction. The pH level, of course, does affect the availability of other nutrients.

RAY SELF: How do you obtain bark with the correct assortment of particle size?

FRANK POKORNY: If the bark is run through a ¾-inch screen, it has a good distribution of fine and coarse particles that is suitable for both propagation and growing.

FACTORS AFFECTING QUALITY OF COMPOSTS FOR UTILIZATION IN CONTAINER MEDIA[1]

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