PINE BARK AS A SOIL AMENDMENT[1/]

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Abstract.--Milled pine bark added to nursery soils increases total porosity, water retention, air space, percolation rate, cation exchange capacity, lowers soil bulk density, and suppresses plant pathogens. Advantages of milled pine bark as a soil amendment are: 1) a slow rate of decomposition, 2) reduced nitrogen tie-up in comparison to other wood fragments, 3) ready availability, 4) processibility into a uniform standard product, and, 5) suppression of certain soil-borne plant pathogens.

Additional keywords: Hardwood bark, sawdust, peat moss, chemical properties, particle size, lignin

Pine bark and other organic materials such as hardwood bark and sawdust are increasingly being used as a peat moss substitute in container plant production, soil conditioning for growing crops and landscape maintenance. The scarcity and high cost of peat moss have forced growers to utilize other readily available organic materials, formerly waste products of the forest industry. These organic residues can provide long-term improvement in the physical and chemical characteristics of soil. Pine bark, in particular, serves as an excellent alternative as a soil medium amendment.

DESIRABLE PARTICLE SIZING OF SOFTWOOD BARK

Pine bark is removed from the log in large slabs or pieces and in this condition is generally unusable as a soil conditioner. Hammer-milling and screening are required to reduce large bark pieces to a suitable size for soil conditioning purposes. Lunt and Clark (1959) suggest that milled pine bark with a particle range of 1 mm to 8 mm in diameter is satisfactory for most soil amendment uses. Bollen and Glennie (1963) used Douglas fir bark soil conditioner with particles in the range of 0.42 mm to 2.00 mm while Harder and Baker (1971) worked with mixed softwood bark with particles less than 3.35 mm in diameter. Research at the University of Georgia has shown that milled pine bark with 70-80% of the particles in the range of 0.59 mm to 4.76 mm in diameter and with 20-30% of the particles smaller than 0.59 mm is satisfactory as a potting medium component and/or soil amendment (Pokorny 1979). This particle distribution is similar to that reported by Gartner et al. (1970, 1972, 1973) for hardwood bark.

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South (personal communication) currently is evaluating coarse grades of pine bark as a soil amendment in four forest tree nurseries. Three nurseries are located in Florida and one in Texas (table 1).

Table 1.--Particle size distribution of pine bark tested as a soil amendment in four forest tree seedling nurseries[z/]

Nursery location	Particle size classes			
	>25 mm (1 inch)	25 mm-12.5 mm (1-½ inch)	12.5-6.25 mm (½-¼ inch)	<6.25 mm (¼ inch)
	% by wt			
St. Regis - Florida	4	12	26	58
St. Regis - Texas	4	9	25	62
Container Corp. - Florida	6	16	28	50
Chiefland (State) - Florida	7	14	18	61

z/Unpublished data supplied by David South, Auburn University, 1982.

PHYSICAL PROPERTIES OF ORGANICALLY AMENDED SOILS

Generally, milled pine bark is mixed with existing soil at the rate of 10 to 33% by volume. Thus, ½ to 2 inches of bark mixed into the upper 4 to 6 inches of soil will provide the necessary volume mixture (table 2). The influence of various volume additions of bark, peat, and sawdust to soil on soil moisture equivalent and permeability are reported by Harder and Baker (1971) (table 3). Bark and peat amended soil exhibited similar soil moisture equivalents and permeability over the range of 8-33% volume additions to the soil. Fine sawdust had a greater influence than either bark or peat moss only on water permeability as moisture equivalent and plant yields were less in the sawdust amended soils (Harder and Baker 1971). In experiments at the University of Georgia, Thurman (1967) found that the addition of 25 to 50% by volume milled pine bark to a sandy soil decreased bulk density and increased total pore space, water retention, and air space of the soil-bark mixtures. Addition of milled pine bark or other organic residues in quantities greater than 33% by volume to existing soil for amendment purposes is probably not economically feasible.

THE DEGRADATION PROCESS OF SOFTWOOD BARK

An important characteristic of softwood barks, especially pine, is their resistance to decay (Allison and Murphy 1962, 1963). Complete decomposition may require from 5 to 7 years (Lunt and Clark 1959). Though the high C/N ratio of pine bark would indicate the need for a substantial nitrogen addition to accommodate the needs of microorganisms involved in organic matter decomposition, approximately ¼ lb N/cu yd will overcome the problem of nitrogen draft (Pokorny 1979). It would appear that reduced need for high supplemental N

Table 2.--Equivalent quantity of bark expressed as inches applied or tons applied and mixed with soil when compared to percentage by volume of bark applied

Percentage bark applied (vol)	Tons of bark applied	Inches of bark applied	Inches of soil applied
0	0	0	6.0
8	25.5	0.5	5.5
16	51	1.0	5.0
33	102	2.0	4.0
50	153	3.0	3.0

(Adapted from: Harder and Baker 1971.)

Table 3.--Influence of additions of different volume ratios of bark, peat and sawdust to a Palouse silt loam soil on moisture equivalent and permeability

	Bark added (%/v)				
Organic amendment	0	8	16	33	50
Bark					
Moisture equivalent	26.8	27.3	27.4	29.4	31.8
Permeability (ml/10 min)	29.5	30.5	78.8	90.3	132.0
Peat					
Moisture equivalent	26.8	26.7	28.4	32.6	35.6
Permeability (ml/10 min)	29.5	60.8	73.0	123.3	132.3
Fine sawdust					
Moisture equivalent	26.8	25.9	26.4	28.0	31.3
Permeability (ml/10 min)	29.5	71.5	113.0	276.0	459.0

(Adapted from: Harder and Baker 1971.)

rate with southern pine bark is related to its high lignin and low cellulose content (table 4) and its slow rate of decomposition (Allison and Murphy 1962, 1963). Lunt and Clark (1959) suggest that the degree of nitrogen deficiency is directly related to the rate of decomposition of added wood fragments. Another approach to overcoming the problem of nitrogen tie-up by the application of raw wood wastes to the soil for amendment purposes is to compost the material prior to soil application. Composting is the controlled process of biological degradation of waste organic matter removing mostly cellulose (wood and cambium) and toxic substances which may be present in wood and bark

Table 4.--Carbon nitrogen ratio, lignin and cellulose content of bark and sawdust of pine and hardwoods and of sphagnum peat moss

Organic soil amendment	C/N ratio	Lignin %	Cellulose %
Pine bark	112--144	50	5-30
Pine sawdust	327-1313	27-30	42-46
Hardwood bark	110--167	25-40	40
Hardwood sawdust	134--253	18-25	45-58
Sphagnum peat moss	53---96	18-64	0.6-24

(Sources: Baxter 1969; Bollen and Glennie 1961; Bollen and Glennie 1963; Forest Products Laboratory 1957; Fuchsman 1980; Giddens and Baxter 1965; Hoitink 1980; Koch 1972.)

fragments. Gartner et al. (1973) have shown that fresh barks of certain hardwood species inhibit plant growth (table 5). Certain softwood tree barks also are reported to suppress plant growth (Hoitink et al. 1978, Lunt and Clark 1959). These plant growth inhibitors are dissipated after at least 30 days of composting (Gartner et al. 1973, Hoitink et al. 1978). Factors affecting the composting of tree barks are detailed by Hoitink et al. (1978, 1980).

Table 5.--Reported phytotoxicity of bark used as a soil amendment of some hardwood and softwood species

Hardwood species	Softwood species
Ash	Douglas fir
Cottonwood	Incense fir
Hackberry	Norway Spruce
Red oak	Redwood
Silver maple	Sitka spruce
Sycamore	
White oak	

(Sources: Gartner et al. 1973; Hoitink 1980; Lunt and Clark 1959.)

CHEMICAL CHANGES IN A PINE BARK/SOIL MIX

Pine bark, as well as other wood wastes, has substantial cation exchange capacity (CEC) (table 6) which greatly exceeds that of a silt loam soil (Bollen and Glennie 1963). Addition of pine bark to sand or sandy soils will increase the CEC of the bark amended soil, depending upon the quantity of bark applied (Brown and Pokorny 1975). Further decomposition of pine bark will additionally increase CEC and prevent leaching of cations from the soil (Bollen and Glennie 1963).

Pine and hardwood barks and sawdust are slightly to strongly acidic (table 6) with the pH of pine bark closely approximating that of sphagnum peat moss. Although the addition of pine bark to a soil may initially slightly depress acidity, for crops requiring a soil pH of near 7.0, the addition of agricultural limestone is necessary (Lunt and Clark 1959). No agricultural limestone need be applied when acid requiring crops are grown (Baxter 1969).

Pine bark, other wood fragments, and peat moss contain small quantities of all the macro- and micronutrients needed for plant growth (table 6). Lunt and Clark (1959) suggest that, in some cases, phosphorous and potassium derived from bark may initially contribute to the soil fertility. The contribution of the soil microelement content of barks and sawdusts is unknown.

PATHOGEN SUPPRESSION BY TREE BARKS

Hardwood and pine barks have been shown to suppress soil-borne pathogens (Bollen and Glennie 1963, Gugino et al. 1973, Hoitink et al. 1978, Hoitink 1980). In addition to decomposition of easily degradable compounds and cellulose during the composting operation, sufficiently high temperatures in the range of 40-80°C (104-176°F) are generated to kill most pathogens. Hoitink (1980) reports that the incidence of a wide range of soil-borne diseases has been reduced in nursery, floricultural and in foliage plants when the potting medium contains 50% or more by volume of composted hardwood or pine bark (table 7). Red stele of strawberry, caused by the organism Phytophthora fragariae, has been suppressed for several years after the application of 90-225 tons/ha (36-91 tons/acre) of ammoniated Douglas fir bark (Bollen and Glennie 1963). Conversely, Douglas fir sawdust incorporated into the soil increased incidence of this disease.

The first suggestion of pathogen suppression utilizing pine bark in container media was reported by Gugino et al. (1973). 'Helleri' holly root weights were increased with increasing increments of pine bark in a container medium irrespective of high Pythium irregulare populations recovered from the medium.

Sekiguchi, as reported by Hoitink (1980), found that Fusarium wilt of Chinese yam was controlled by incorporation of 30 tons/ha (12 tons/acre) of pine bark into field soil. Fusarium control was similar to that obtained with methyl bromide fumigation or with the application of benomyl fungicide. Generally, the suppressive effects of tree barks on soil-borne pathogens is rapidly diminished when the bark is contaminated with high percentages of wood.

The mechanism of pathogen suppression by tree bark is currently unknown. However, it is thought that the incidence of soil-borne diseases is diminished because: 1) improvement in physical properties of the soil creating an environment more favorable for root development, 2) bark amended soils support high levels of organisms antagonistic to pathogens, and/or 3) bark contains natural chemicals which are fungicidal in nature. Evidence indicates that the mechanism of pathogen suppression is complex and that all of the postulated means for pathogen suppression are involved to some degree (Gugino et al. 1973, Hoitink 1980).

Table 6.--Cation exchange capacity, pH, and mineral element content of pine and hardwood barks, sawdusts, and sphagnum peat moss soil amendments

Chemical property	Soil amendment				
	Pine bark	Pine sawdust	Hardwood bark	Hardwood sawdust	Peat moss
CEC - me/100 g	30-57	28	--	77	30-120
pH	3.5-5.0	4.1-6.0	5.0-6.4	4.1-7.0	3.0-5.0
N - %	0.28-0.39	0.14	0.28-0.61	0.08-0.11	0.5-2.1
P - %	0.02	0.02	0.03-0.12	0.003-0.02	0.05
K - %	0.10	0.10	0.15-0.62	0.03-0.12	0.01
Ca - %	0.51	0.06	0.88-3.96	0.003-0.02	0.27
Mg - %	0.14	0.03	0.02-0.11	0.01-0.03	0.04
Mn - ppm	119	1115	169-1195	29-72	95
Cu - ppm	77	--	4-10	4- 7	Trace
Zn - ppm	112	--	9-53	17-28	13
B - ppm	9	--	4-24	1- 2	--
Fe - ppm	790	64	174-743	10-12	30

(Source: Allison and Murphy 1962; Baxter 1969; Brown and Pokorny 1975; Fuchsman 1980; Gartner *et al*. 1972; Goh 1979; Haramaki *et al*. 1971; Koch 1972; Lunt and Clark 1959; Maas and Adamson 1972; Martin and Gray 1971; Murphy and Rishel 1977; Pokorny 1979; Self *et al*. 1967; Young and Guinn 1966.)

Table 7.--Soil-borne pathogens suppressed by composted hardwood and softwood bark soil amendments

Pathogen	Suppressed by Hardwood bark	Suppressed by Softwood bark
Pythium irregulare	Yes	Yes
Phytophthora spp.	Yes	Yes
Phytophthora cinnamomi	Yes	Yes
Fusarium spp.	Yes	Yes
Pythium ultimum	Yes	?
Verticillium albo-atrum	Yes	?
Rhizoctonia solani	Yes	No
Thielaviopsis basicola	Yes	?
Some nematodes	Yes	?

(Sources: Gugino *et al.* 1973; Hoitink 1980; Hoitink and Poole 1980; Hoitink *et al.* 1978; Malek and Gartner 1975.)

CONCLUSIONS

Milled pine bark as a soil conditioner is advantageous in several respects. Pine bark is available, especially in the South, and can be processed by hammer-milling and screening into a uniform standard product. It is slow to decompose, thus providing a relatively long term conditioning effect when mixed with soil. Pine bark suppresses certain soil-borne plant pathogens and offers an alternative means of controlling diseases which attack root systems of plants.

Large scale use of milled pine bark in forest tree seedling nurseries should be determined by cost in relation to benefits derived. This will need to be analyzed by each nurseryman based on operational requirements.

LITERATURE CITED

Allison, F. E., and Murphy, R. M. 1962. Comparative rates of decomposition in the soil of wood and bark particles of several hardwood species. Soil Sci. Soc. Amer. Proc. 26:463-466.

Allison, F. E., and Murphy, R. M. 1963. Comparative rates of decomposition in soil of wood and bark particles of several species of pine. Soil Sci. Soc. Amer. Proc. 27:309-312.

Baxter, H. O. 1969. Summary of research on sawdust and bark for agricultural uses. Univ. Ga. Agr. Ext. Ser. Mimeo. 16 p.

Bollen, W. B., and Glennie, D. W. 1961. Sawdust, bark, and other wood wastes for soil conditioning and mulching. For. Prod. J. 11:38-46.

Bollen, W. B., and Glennie, D. W. 1963. Fortified bark for mulching and soil conditioning. For. Prod. J. 13:209-215.

Brown, E. F., and Pokorny, F. A. 1975. Physical and chemical properties of media composed of milled pine bark and sand. J. Amer. Soc. Hort. Sci. 100:119-121.

Forest Products Laboratory. 1957. Chemical composition and uses of bark. USDA Forest Serv. Rept. 1666-5. 6 p.

Fuchsman, C. H. 1980. Peat and industrial chemistry and technology. 279 p. N. Y.: Academic Press.

Gartner, J. B., Hughes, T. D., and Klett, J. E. 1972. Using hardwood bark in container growing mediums. Amer. Nurseryman 135:10-11, 77-79.

Gartner, J. B., Saupe, D. C., Klett, J. E., and Yocom, T. R. 1970. Hardwood bark as a medium for container growing. Amer. Nurseryman 131:11, 40, 42-44.

Gartner, J. B., Still, S. M., and Klett, J. E. 1973. The use of hardwood bark as a growth medium. Proc. Inter. Plant Prop. Soc. 23:222-229.

Giddens, J., and Baxter, H. O. 1965. Use of wood residues for soil improvement. Ga. Agr. Res. 6:8.

Goh, K. M. 1979. Chemical characteristics of some commonly used media and their components. In Development and use of soilless media for horticulture. Hort. Res. Centre, Levin, N. Z. Paper 6-1.

Gugino, J. L., Pokorny, F. A., and Hendrix, F. F., Jr. 1973. Population dynamics of Pythium irregulare Buis. in container plant production as influenced by physical structure of media. Plant and Soil 39:591-602.

Haramaki, C., Nuss, J. R., Oliver, C. S., and Williams, P. H. 1971. Water soluble extractives in bark. In Progress report on the study of the feasibility of using deciduous tree bark as a soil substitute and as a mulch material for ornamental plants, 1969-1970, p. 12-26. Penn. State Univ., Dept. of Hort.

Harder, R. W., and Baker, G. O. 1971. Utilization of waste bark as a soil conditioner. Compost Sci. 12:6-9.

Hoitink, H. A. J. 1980. Composted bark, a lightweight growth medium with fungicidal properties. Plant Disease 64:142-147.

Hoitink, H. A. J., and Poole, H. A. 1980. Factors affecting quality of composts for utilization in container media. HortScience 15:171-173.

Hoitink, H. A. J., Wilson, J. H., and Poole, H. A. 1978. Factors affecting composting of hardwood tree bark. In Proc. Second Woody Ornamental Disease Workshop, p. 11-18. Univ. of Mo., Columbia.

Koch, P. 1972. Utilization of southern pines. I. The raw material. 730 p. USDA Forest Serv. Ag. Handbook 420.

Lunt, O. R., and Clark, B. 1959. Horticultural applications for bark and wood fragments. For. Prod. J. 9:39A-42A.

Maas, E. F., and Adamson, R. M. 1972. Resistance of sawdust, peats, and bark to decomposition in the presence of soil and nutrient solution. Soil Sci. Soc. Amer. Proc. 36:769-772.

Malek, R. B., and Gartner, J. B. 1975. Hardwood bark as a soil amendment for suppression of plant parasitic nematodes on container-grown plants. HortScience 10:33-35.

Martin, R. E., and Gray, G. R. 1971. pH of southern pine barks. For. Prod. J. 21:49-52.

Murphy, W. K., and Rishel, L. E. 1977. Properties and potentials of bark as a raw material. Penn. State Univ. Prog. Rept. 363. 15 p.

Pokorny, F. A. 1979. Pine bark container media - an overview. Proc. Inter. Plant Prop. Soc. 29:484-495.

Self, R. L., Wear, J. I., Rouse, R. D., and Orr, H. P. 1967. Potting mixtures and fertilization practices for container grown ornamental plants. 10 p. Auburn Agr. Exp. Sta. Circ. 157.

Thurman, P. C. 1967. The relationship of several amended soils and compaction rates on vegetative growth, root development, and cold tolerance of Tifgreen burmuda grass [*Cynodon dactylon* (L.) Pers.]. M. S. Thesis, Univ. of Ga., Athens, Ga. 83 p.

Young, H. E., and Guinn, V. P. 1966. Chemical elements in complete mature trees of seven species in Maine. Tappi 49:190-197.