leaves can be more closely related to total growth than any other factor studied. Leaf sampling in late July and August was based on earlier work with *Taxus* (5) which showed that leaf N concn varied least during mid-summer.

All growth responses observed correlated best with leaf N, with the exception of average growth per lateral in *P. coccinea,* which had a correlation coefficient of -.34. Applied K did not influence growth, and the N x K interaction had no effect on leaf N. Cannon et al. (2) indicated that K level may affect leaf N of *Gleditsia triacanthos* 'Moraine' in a up and then down pattern; this, however, was not found for either *P. coccinea* or *I. crenata.*

N and K rate and winter survival. A correlation coefficient of -.88 was found between applied N and winter survival and between leaf N and survival. Applied K seemed to have no effect on hardiness with an r value of -.09 for these 2 factors (Table 4). The effect of N and K rate on winter survival of *P. coccinea* is shown in Table 5. As N rate increased winter survival decreased. This lack of hardiness may be due to plants receiving the higher rates of N not "harding up" sufficiently before cold weather. Because of winter conditions, none of the *I. crenata* survived, regardless of treatment.

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Utilization of Hardwood Bark in Media for Growing Woody Ornamental Plants in Containers[1]

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Abstract. Hardwood bark was used in combination with other materials as media for forsythia and juniper plants in containers with various growing procedures, bark sources, and fertility practices. Based on dry wt, the most rapid growth of forsythia was obtained in a bark and fine sand medium; whereas, the least growth was obtained in soil, peat, and perlite. However, pfitzer juniper plants under 2 different fertility regimes grew most rapidly in a bark, soil, and peat medium, slowest in a bark and torpedo #2 sand medium, and at an intermediate growth rate in soil, peat, and perlite. The standard mix (soil, peat, and perlite) was more acidic than the experimental mixes containing bark and sand. Chlorotic plants were more numerous in acidic mixes. Leaf tissue analyses from the plants grown in the peat amended bark and standard mix had higher Fe and Mn concn than plants grown in a bark-sand mix.

Agriculture offers promising means for the utilization of hardwood bark including its use as a mulch material and soil amendment. Lunt and Clark (9), Isomaki (8), and Bollen (2) reported greater water retention and air space in soil amended with bark than in soil alone. Also, certain chemical characteristics of bark-amended soil are different including the cation exchange capacity. Bollen (2) found ground bark to have 2 to 3 times the capacity for cation exchange compared to a silt loam soil.

Since bark contains only 0.1 to 0.2% N, a N deficiency problem develops in bark-amended soil (1, 2, 7). Lunt and Clark (9) emphasized that most growth suppression of plants growing in bark are due to lack of N and not to presence of any toxic materials. This problem can be overcome by adding N to bark when incorporating bark with soil. Plants can be grown successfully in hardwood bark mixes if adequate N is supplied (1, 4).

Rigby (10), Bosley (3), and Gartner et al. (5, 6) reported the use of hardwood bark as a growing medium for container-grown nursery plants. Our experiments were designed to further determine the feasibility of utilizing hardwood bark as a container-growing medium.

Materials and Methods

During 1969, 2 experiments were initiated utilizing hardwood bark mixed with other materials as media for container-grown forsythia and juniper. These woody plants were potted in various media and compared to growth of plants in the standard mix (soil, peat, and perlite).

The hardwood bark samples were obtained from 2 different Midwest paper mills and labeled A and B. The bark samples were from mixed species (Table 1) and were ground in different hammermills resulting in slightly different particle size distributions (Table 1). Bark B was composted for about 8 weeks, whereas bark A was composted for only 3 weeks.

In September 1969, 15 rooted cuttings of *Forsythia intermedia* Zabel 'Lynwood Gold' and *Juniperus chinensis Pfitzeriana* Spaeth, were potted in 9 different mixes (Table 2). At time of mixing, 2.0 lb. $CaSO_4$, 1.5 lb. superphosphate, and 0.5 lb. $MgSO_4$ were incorporated per yard^3 of mix. A slow-release plastic-coated soluble fertilizer[4] was added to all mixes except the standard mix at 15 lb. per yard^3.

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[4]Osmocote (18-6-12) manufactured by Sierra Chemical Company, Newark, California.

Table 1. Species composition and particle size distribution for barks A and B.

Species	% of total	Particle size (diam)	Bark A	Bark B
Eastern Cottonwood	21	Larger than 6.4 mm	0.7%	2.7%
Pin Oak	13	Between 3.2 and 6.4 mm	12.9%	12.9%
Black Oak	5	Between 1.6 and 3.2 mm	32.6%	23.8%
Other oaks	17	Between 0.7 and 1.6 mm	17.6%	18.0%
White Ash	5	Between 0.5 and 0.7 mm	9.7%	10.8%
Silver Maple	15	Smaller than 0.5 mm	26.5%	31.8%
Hickory	5			
Elm	3			
Sycamore	2			
Misc. other	14			

The plants were placed pot-to-pot under 100-watt incandescent lamps and grown through the winter in a temp-controlled greenhouse (19°C night and 22°C day). On May 26, 1970, the plants were shifted to a graveled area out of doors until termination of the experiment on August 31, 1970. Nutrients were applied with every other watering at the rate of 200 ppm N using a 20-20-20 analysis fertilizer.

In October 1969, *Forsythia intermedia* 'Arnold Dwarf' and *Juniperus chinensis Pfitzeriana* were planted in the same 9 media. Amendments as in Experiment 1 were used except the slow release fertilizer was added at 7.5 lb. per yard^3 (½ amount used earlier). The plants were randomly spaced in a cool greenhouse (4°C night and 9°C day) during winter 1969-70. No supplementary light was provided and the plants were watered only as needed thereby holding the plants in a dormant condition. However, day and night temp rose in the greenhouse during early spring, 1970, and growth started. During the last week of May, 1970, the plants were placed outside. Management practices were then the same as those of the first group.

Table 2. Mean dry wt of group 1 *Forsythia intermedia* 'Lynwood Gold' and *Juniperus chinensis Pfitzeriana* greenhouse grown at 22°C from September 1969 to May 1970 then grown outdoors until August 1970.

Media	Mean dry wt(g) Forsythia	Juniper
Soil, peat, perlite (1:1:1)	37.74 c[z]	38.59 c
Bark A and soil (2:1)	29.61 c	41.03 cb
Bark A, soil and peat (1:1:1)	32.70 c	43.39 cb
Bark A and fine sand (2:1)	49.03 b	38.85 c
Bark A and torpedo #2 sand[y] (2:1)	50.53 b	25.11 d
Bark B and soil (2:1)	37.67 c	44.19 cb
Bark B, soil and peat (1:1:1)	48.58 b	49.80 ab
Bark B and fine sand (2:1)	68.09 a	53.26 a
Bark B and torpedo #2 sand (2:1)	66.18 a	43.72 cb

[z]Like letter designation indicate means that are not significantly different at 5% level using Duncan's New Multiple Range Test.

[y]Torpedo #2 sand is a grade of cement sand.

The forsythia and juniper plants were arranged separately in completely randomized designs in both the greenhouse and outdoors.

Leaf tissue samples from both groups were taken from randomly selected plants. The leaf samples were taken from the fourth to eighth node down from the terminal bud from forsythia, and at random from juniper. The leaf samples were then dried and ground in a Wiley mill and later analyzed for elemental content. Total N was determined by Kjeldahl method and the other mineral element concn were obtained with a Jarrell Ash Mark IV Ebert Direct Reading Stigmatic Spectrograph. Eight different media samplings were taken in group I and 3 samplings from group 2 and analyzed by the Spurway soil test. Since a slow release plastic coated fertilizer was used in the experiment, the media samples were not ground prior to analysis. During August, 1970, the groups 1 and 2, plants were cut off at the soil line and fresh wt recorded. Dry wt were recorded 48 hr later after being dried in a forced draft oven at 55°C.

Results and Discussion

The results of the 2 concurrent and complementary experiments were measured primarily through: 1) dry wt of the plants and 2) chemical analyses of leaf tissues. A secondary aim was to discover, through periodic growing-media tests, the effects that changes in pH, major, and minor elements might have on plant growth.

Visual observations borne out by dry wt data from group 1 forsythia plants showed the best growth in the bark B and fine sand and bark B and torpedo #2 sand mixes (Table 2). Dry wt data from the group 2 forsythia plants also showed the best plant growth in the bark B and fine sand mix (Table 3). The chemical analyses (Table 4) of 'Lynwood Gold' and 'Arnold Dwarf' forsythia showed no great differences in N, P, and K values; however, the greatest N percentage was from leaf samples of plants grown in a bark, soil, and peat mix. No great differences in minor elements were observed except that greater

Table 3. Mean dry wt of group 2 *Forsythia intermedia* 'Arnold Dwarf' and *Juniperus chinensis Pfitzeriana* grown at 9°C from September 1969 to May 1970 then grown outdoors until August 1970.

Media	Mean dry wt (g) Forsythia	Juniper
Soil, peat, perlite (1:1:1)	13.11a[z]	22.28 c
Bark A and soil (2:1)	18.15 b	25.09 c
Bark A, soil and peat (1:1:1)	27.78 a	39.93 ab
Bark A and fine sand (2:1)	28.24 a	18.72 c
Bark A and torpedo #2 sand (2:1)	21.12 b	20.89 c
Bark B and soil (2:1)	25.78 a	34.93 b
Bark B, soil and peat (1:1:1)	28.66 a	45.45 a
Bark B and fine sand (2:1)	30.53 a	33.69 b
Bark B and torpedo #2 sand (2:1)	25.94 a	35.27 b

[z]Like letter designations indicate means that are not significantly different at 5% level using Duncan's New Multiple Range Test.

Table 4. Chemical analyses of leaf tissue samples taken in August 1970, from *Forsythia intermedia* 'Lynwood Gold' and 'Arnold Dwarf'.

	Group I *Forsythia intermedia* 'Lynwood Gold' Element							Group II *Forsythia intermedia* 'Arnold Dwarf' Element						
Media	N %	P %	K %	Ca %	Mg %	Fe ppm	Mn ppm	N %	P %	K %	Ca %	Mg %	Fe ppm	Mn ppm
Soil, peat, perlite	2.96	.24	1.92	.63	.25	422	281	2.17	.26	1.77	.36	.24	207	405
Bark A, soil	3.14	.38	1.76	.90	.25	274	1090	1.90	.20	1.25	.63	.22	87	159
Bark A, soil, peat	3.18	.36	2.29	.71	.25	318	1323	2.17	.36	1.17	1.05	.41	204	852
Bark A, fine sand	2.94	.32	1.26	.76	.24	130	688	1.90	.20	1.25	.63	.22	87	159
Bark A, tor. #2 sand	2.80	.22	1.45	.72	.19	134	314	1.93	.17	1.32	.58	.19	96	131
Bark B, soil	3.20	.28	2.32	.85	.19	308	539	2.10	.20	1.31	.86	.26	109	195
Bark B, soil, peat	3.50	.35	2.25	1.02	.35	273	714	2.14	.32	1.23	.99	.36	190	574
Bark B, fine sand	2.90	.28	2.11	.96	.22	144	298	2.04	.20	1.08	.62	.23	82	129
Bark B, tor. #2 sand	3.04	.29	1.89	1.18	.25	156	597	1.77	.86	.91	.86	.30	121	99

concn of Fe and Mn were recorded in the mixes containing peat. Iron and Mn are metallic cations that are more soluble in acidic media. The pH values of the mixes containing peat moss and soil were more acidic than the bark and sand mixes. Certainly, concn of Mn above 1000 ppm are higher than normal for most plants. The Ca percentages of the leaf samples from both cultivars of forsythia grown in standard mix were lower than the percentage recorded from plants grown in bark-amended mixes. This could result because the bark material is about 3 to 4 percent Ca by dry wt.

The mean dry wt from the group 1 pfitzer junipers plants (Table 2) showed the best growth in bark b and fine sand and in bark b, soil, and peat mixes and poorest growth in the bark A and torpedo #2 sand mix. The dry wt data from the group 2 pfitzer juniper plants (Table 3) showed the best growth again in the bark, soil, and peat mix. The poor growth from group 2 juniper plants grown in bark A-sand mixes (Table 3) resulted possibly because these plants were held dormant in a cool greenhouse during the winter without liquid feeding. Therefore, the plants could have been deficient in some nutrients, especially N, when placed outside. The liquid feeding program which started when the group 2 plants were placed outside possibly did not supply enough N to compensate for the initial N depletion problem in the bark A-sand mix. Also, more bark was utilized in the bark-sand mix; therefore, more N would be required as compared to a bark, soil, peat mix. Chemical analyses of groups 1 and 2 juniper plants showed little variation in the relative proportions of the N, P, and K, or of Ca and Mg percentages. However, Fe concn were much higher in leaf samples taken from plants which grew the poorest.

The pH, N, P, K, Ca, Mg, and soluble salt levels, which are not shown in this paper, were recorded from each of the mixes, but some difficulty was encountered in determining the values. The slow release fertilizer capsules in some cases were ruptured, thereby releasing potentially but not currently available nutrients in the samples. The pH values of the mixes containing peat and soil were more acidic than the bark-sand mixes. Gartner et al. (5) reported that bark and soil media always had higher pH values than peat and soil media with the same amount of added lime. A pH change toward neutrality was observed in all the mixes after initial potting. Bollen (2) stated that acidity of bark is due to the presence of polyphenols. Harkin (7) stated that this acidic nature of bark begins to subside 4 to 5 months after initial potting possibly due to an increase in cation-exchange capacity of the media due to decomposition.

An N deficiency problem in bark-amended mixes was reported by Allison (1) and Bollen (2). Previous experiments (5) demonstrated that a slow release fertilizer incorporated in the mix prevented N deficiencies. The N, P, and K levels increased after the initial mixing with the slow release fertilizer and it appeared N was not a limiting factor in our bark amended mixes. Calcium levels increased initially in the bark-amended mixes and declined when the plants were growing actively during spring and summer. The bark-amended mixes had higher levels of Ca and Mg than the standard mix throughout the experiment. The high levels could have resulted from the fairly high concn of Ca and Mg in the bark itself or in water used during the experiment.

The following comparisons can be drawn. Pfitzer juniper plants showed better plant growth in bark B, soil, and peat mix at both nutritional levels. Plant growth of junipers was poorest in bark A and torpedo #2 sand mix at both nutritional levels. Dry wt of forsythia plants showed the best growth of those potted in bark B and fine sand mix, thereby eliminating soil and peat from the potting mix. The poorest forsythia plant growth resulted in soil, peat, and perlite mix.

Forsythia plants grown in standard mix were chlorotic and this mix had pH values which were more acidic than the experimental mixes containing bark and sand. Tissue analyses and soil tests from plants in groups 1 and 2 showed that certain minor elements might be present in toxic amounts in mixes containing soil and peat. The major elements were generally available in adequate amounts in the mixes which had the slow release fertilizer incorporated at the time of potting.

Plants grown in mixes containing bark B exhibited more growth than plants grown in mixes containing Bark A. That difference could have been due to the longer composting period of the bark B mixes. Also, bark B had a greater percentage of large and small particles (1/2-inch or larger and 1/50-inch or smaller). The greater percentages of bark particles in these classifications could have effected favorably certain physical properties in the mixes containing bark B.

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