PHOSPHORUS FERTILIZATION AND NUTRIENT COMPOSITION OF FORAGE

FREDRICK WILLIAM KINARD, JR., Westvaco Corporation, Timberlands Division, Summerville, SC

Abstract: Twelve plant species occurring in the understory of young pine plantations in the South Carolina Coastal Plain were analyzed for phosphorus, calcium, magnesium, potassium and crude protein. Nutrient content of foliar samples from unfertilized and fertilized sites showed no significant difference for most elements. Forage production on fertilized sites was three times greater than unfertilized sites.

Proc. Annual Conf. S.E. Assoc. Fish & Wildlife Agencies 31:24-28

There are recognized phosphorus deficiencies in some soils of the southeastern Coastal Plain for the growth of southern yellow pines. Previous studies (Wells et al. 1973) have shown that the growth rate of loblolly pine (*Pinus taeda*) on some sites has been increased by fertilizing with phosphorus. While there is information on the effects of forest fertilization on pine plantation response (Wiley et al. 1970), there is a dearth of analytical data on nutritional quality of the associated understory vegetation. Adequate growth and development of deer can be limited by malnutrition. Nutrient levels by site, plant composition and soil fertility levels are useful in determining the availability of adequate forages for deer.

Application of fertilizers to sizable areas of commercial forests in the southeastern United States to improve growth of new plantations has gained acceptance and expanded rapidly in the past few years. Research has been aimed primarily at determination of optimum rates and methods of application of nitrogen (N) and phosphorus (P) fertilizers. There are two widely used approaches to forest fertilization. First is the application of P at planting time on phosphorus-deficient Coastal Plain sites and the second is the application of N to merchantable stands prior to harvest cuts. Georgia Kraft began pilot projects in 1966 with 20-10-5 fertilizer and gradually revised the fertilizer treatment to N only on their properties in the Georgia Piedmont. Union Camp has practiced forest fertilization since 1972 primarily using NP fertilizer. Weyerhauser is applying N and NP fertilizers on new plantings and merchantable pine stands in North Carolna, Mississippi and Arkansas.

Westvaco forest research centers have conducted field studies testing various fertilizer and application rates on loblolly pine stands both in the Piedmont and in the Coastal Plain of South Carolina. Since 1967, forest fertilization in South Carolina has been used by Westvaco Timberlands Division as a management practice. As a result, a method was developed for the evaluation of soil test data with the expected growth response to phosphorus fertilization (Crutchfield 1971). Between 1967 and 1976 Westvaco fertilized approximately 21,500 ha with triple-superphosphate.

The continuation of forest fertilization programs seems promising since fertilizer production and prices appear to be stabilizing. Forest fertilization in the pine regions of the southeastern United States should continue as an important silvicultural management practice for improved tree growth. Vegetation associated with pine plantations may be of low nutritional value but still important in the diet of wildlife species.

This study was an attempt to compare nutrient content of prevalent plant species associated with pine plantaions on unferilized and fertilized sites. The author wishes to thank Nicholas M. Berenyi, Ph.D., Senior Research Chemist, Westvaco Corporate Research Center, for the vegetation and soil analyses.

METHODS

The study area was in the lower Coastal Plain of Jasper County, South Carolina, on Westvaco's Oswald Unit; the main tract of the unit being approximately 4,800 ha in size. Topographic relief was slight having a gradient of approximately 5 cm per 1.6 km. The soil type is Echaw loamy fine sand. Although this soil series is classified as moderately well drained, the site was somewhat poorly drained. The soil was similar to Chipley, Leon, Ridegland, Scranton, Seewee and Witherbee.

Vegetation in the understory was typical of the lower Coastal Plain of southwestern South Carolina. The more prevalent plant species included sweet pepperbush (*Clethra alnifolia*) throughwort (*Eupatorium* spp.), gallberry (*Ilex glabra*), stagger-bush (*Lyonia mariana*), panic grass (*Panicum*, spp.), bracken fern (*Pteridium aquilinum*), running oak

(*Quercus pumilla*), blackberry and dewberry (*Rubus* spp.), greenbrier (*Similax* spp.), goldenrod (*Solidago* spp.) and blueberry (*Vaccinium* spp.). The principal trees were longleaf (*P. palustris*), slash (*P. elliottii*) and pond (*P. serotina*) pines. Botanical names follow those given by Radford et al. (1973).

The forest management plan was based on a rotation age of 30 years for pine and 40 years for hardwood. Forest compartments with timber of rotation age were harvested by the clearcut method. Site preparation included shearing-off all remaining stems (Burns and Hebb 1972) after timber harvest, raking of debris followed by burning. The final site preparation treatment consisted of bedding (Lennartz and McMinn 1973). The study area was planted using 1,600 loblolly pine seedlings per ha.

Soil was sampled to assess the need to add phosphorus to improve pine growth. Field sampling procedure was described by Crutchfield (1971). Soil samples were air dried in a forced air chamber at room temperature and ground in a hammer mill equipped with a 2mm screen at the Westvaco Corporate Research Center, Laurel, Maryland. The fraction exceeding 2mm was discarded. Samples were then extracted as described by Olsennladean (1965) and aliquots of the extract were used to determine available phosphorus, calcium, magnesium and potassium. Phosphorus was determined by the ascorbic acid modification of the ammonium molybdate method described by Coleman Instruments Corporation (1966), and cations (Ca, Mg, K) by atomic absorption spectroscopy.

Total-nitrogen was determined by the Dumas method, based on sample combustion followed by quantitative recovery and measurement of liberated nitrogen gas (N_2) as described by Fitts and Berenyi (1966). Electrometric measurement of ph was made in a 2:1 aqueous soil slurry.

Planting sites with available P below minimum threshold levels of 10 to 11 kg per ha were fertilized by helicopter with 91 to 113 kg of granular triple-superphosphate having a minimum analysis of 46 percent P_2O_5, with 1 percent sulphur and calcium in the carrier materials.

In 1975, four sample plots were established, each plot was a belt transect having a width of 1.5 m and length of 30 m with the longest axis being perpendicular to the site prepared beds. Plots were laid off parallel to each other and at a distance 30 m to their nearest side. Two of these plots were located on a site that had not been fertilized and two plots were fertilized. The four plots were planted in 1975.

In 1976, two additional plots were established in the study area with each having a width of 7.6 m and length of 30 m. These plots were subdivided into five subplots of 1.5 m by 30 m. The two plots were site prepared and bedded in September 1975, as previously described, but the sites were not burned. One plot was not fertilized and the other fertilized in November 1975. Both plots were planted in March 1976.

Foliar samples were collected annually in the late spring and early fall. Plots established in 1975 were sampled on 29 May and 11 September 1975 and 27 May and 13 September 1976. The 1976 plots were sampled on 27 May and 13 September 1976. Foliar samples of leaves and blades of grass were collected randomly throughout each plot by clippings from the top one-third of all prevalent plant species. In the laboratory all foliar samples were cleaned of debris, leaves were stripped from twigs, and each sample was placed in an oven at 70C for 24 hours. Oven-dry samples were placed in sealed bags and shipped to the Westvaco Corporate Research Center.

At the research center, the plant samples were re-dried at 70C for two days and ground in a Wiley-mill equipped with a 20-mesh screen. The ground material was ashed in a muffle furnace at 500C. The ashes were digested in concentrated HCl, and diluted to standard volume. Aliquots of the solution were used to test for phosphorus, calcium, magnesium and potassium. Total-nitrogen, phosphorus and cations (Ca, Mg, K) were determined by methods previously described.

On 27 May and 17 September 1976, one square m sample of the plots established in 1976 was clipped of all vegetation except for the planted pine seedlings. The 27 May sample was taken in the center of both the unfertilized and fertilized plots, and the 17 September sample taken from the northwest corner. All samples were oven dried at 70C for twenty-four hours and weighed.

RESULTS

Tables 1 and 2 give the results of spring and fall foliar analysis for P, Ca, Mg and K, reported as percent of dry matter by weight. Crude protein is the percent nitrogen multiplied by a factor of 6.25.

Table 1. Nutrient composition of forage species following timber harvest and reforestation in 1975. Foliar samples collected in May and September of 1975 and 1976.

	P				Ca				Mg				K				Crude Protein			
	(Percent Dry Weight)																			
	Unfertilized		Fertilized		Unfertilized		Fertilized		Unfertilized		Fertilized		Unfertilized		Fertilized		Unfertilized		Fertilized	
Plant Species	Spring	Fall	Spring	Fall	Spring	Fall	Spring	Fall	Spring	Fall	Spring	Fall	Spring	Fall	Spring	Fall	Spring	Fall	Spring	Fall
Clehtra alnifolia	0.12	0.10	0.10	0.12	0.48	1.06	0.84	1.06	0.68	0.49	1.04	0.56	0.30	0.30	0.34	0.40	9.91	6.66	6.44	8.22
Eupatorium spp.	0.31	0.25	0.36	0.24	0.68	0.79	1.28	1.12	0.69	0.38	1.42	0.50	0.66	0.60	0.64	0.74	16.50	13.19	12.81	12.28
Ilex glabra	—	0.03	0.07	0.04	—	0.56	0.51	0.50	—	0.27	0.34	0.20	—	0.12	0.10	0.21	—	4.03	3.12	4.59
Lyonia mariana	0.10	0.03	0.02	0.03	0.31	0.54	0.26	0.88	0.34	0.58	0.14	0.16	0.16	0.14	0.14	0.16	3.12	3.56	2.62	4.19
Panicum spp.	0.08	0.08	0.07	0.09	0.08	0.13	1.36	0.12	0.25	0.38	0.33	0.20	0.92	0.55	0.66	0.48	3.56	3.97	5.72	4.16
Pinus taeda	0.10	0.12	0.09	0.14	0.20	0.32	0.16	0.26	0.23	0.12	0.32	0.14	0.47	0.18	0.26	0.30	3.12	6.66	3.12	6.16
Pteridium aquilinum	0.16	0.16	0.16	0.12	0.16	0.28	0.74	0.28	0.42	0.32	0.61	0.35	0.74	0.52	0.92	0.69	3.12	10.25	11.22	8.19
Quercus pumila	0.08	0.05	0.09	0.07	0.45	0.70	0.66	0.92	0.53	1.12	0.78	0.18	0.44	0.14	0.52	0.20	3.12	3.12	7.50	6.75
Rubus spp.	0.17	0.10	0.20	0.09	0.44	0.66	0.99	0.54	0.74	0.40	1.31	0.35	0.58	0.26	2.33	0.45	8.75	6.50	12.00	7.75
Smilax spp.	0.10	—	—	—	0.24	—	—	—	0.24	—	—	—	0.80	—	—	—	7.97	—	—	—
Solidago spp.	—	0.13	—	0.08	—	0.71	—	0.57	—	0.46	—	0.20	—	0.10	—	0.28	—	8.38	—	8.38
Vaccinium spp.	0.08	0.04	0.08	0.04	0.62	1.22	0.36	1.03	0.28	0.82	0.45	0.27	0.24	0.20	0.54	0.14	5.62	3.47	6.16	4.94
Mean	0.13	0.10	0.12	0.10	0.37[a]	0.63	0.72[a]	0.66	0.44[a]	0.48	0.67	0.28	0.53	0.28[a]	0.64	0.37[a]	6.48	6.98	7.07	6.87

[a]Significant t test of paired samples for unfertilized and fertilized elements at 90% level.

Table 2. Nutrient composition of forage species following timber harvest and reforestation in 1976. Foliar samples collected in May and September 1976.

	P				Ca				Mg				K				Crude Protein			
	(Percent Dry Weight)																			
	Unfertilized		Fertilized		Unfertilized		Fertilized		Unfertilized		Fertilized		Unfertilized		Fertilized		Unfertilized		Fertilized	
Plant Species	Spring	Fall	Spring	Fall	Spring	Fall	Spring	Fall	Spring	Fall	Spring	Fall	Spring	Fall	Spring	Fall	Spring	Fall	Spring	Fall
Clethra alnifolia	0.13	0.06	0.12	0.09	0.69	1.20	0.50	0.73	1.26	0.45	0.51	0.29	0.88	0.59	0.03	0.70	11.69	7.94	9.06	9.44
Eupatorium spp.	0.19	0.24	0.06	0.16	3.04	0.81	0.13	0.45	1.68	0.40	0.34	0.20	0.76	0.90	0.20	0.62	15.75	13.44	13.94	6.76
Ilex glabra	0.11	0.04	—	0.04	0.30	0.38	—	0.54	0.54	0.17	—	0.18	0.18	0.08	—	0.12	7.56	5.56	—	4.69
Lyonia mariana	—	0.03	—	0.01	—	0.31	—	0.60	—	0.13	—	0.13	—	0.13	—	0.12	—	5.75	—	4.12
Panicum spp.	0.12	0.06	0.15	—	1.42	0.09	0.16	—	0.90	0.12	1.96	—	0.88	0.69	0.96	—	7.88	5.06	10.06	—
Pinus taeda	0.09	0.10	0.10	0.13	1.37	0.17	0.08	0.15	0.48	0.11	0.23	0.10	0.15	0.38	0.48	0.30	7.25	6.50	6.62	6.25
Pteridium aquilinum	0.09	—	0.19	0.22	0.47	—	0.20	0.25	0.34	—	0.56	0.25	0.37	—	0.02	0.65	11.50	—	9.69	6.12
Quercus pumila	0.10	0.06	0.12	0.10	0.66	1.00	0.52	0.86	0.50	0.13	0.59	0.22	0.06	0.35	0.37	0.17	8.81	6.12	10.81	4.94
Rubus spp.	0.14	0.09	0.20	0.11	0.45	1.10	7.85	0.93	1.14	0.33	1.43	0.31	0.94	0.89	0.02	0.35	15.06	10.12	14.06	11.62
Smilax spp.	0.12	—	—	—	1.08	—	—	—	0.64	—	—	—	0.44	—	—	—	10.88	—	—	—
Solidago spp.	—	0.10	—	0.12	—	0.57	—	1.00	—	0.24	—	0.25	—	0.25	—	0.34	—	3.94	—	6.81
Vaccinium spp.	0.09	0.06	0.11	—	0.67	0.59	0.53	—	1.84	0.15	1.56	—	0.47	0.27	0.47	—	7.06	7.06	9.06	—
Mean	0.12	0.08	0.13	0.11	1.02	0.62	1.25	0.61	0.93	0.22	0.90	0.21	0.51	0.45	0.32	0.37	10.34	7.15	10.41	6.75

[a]t test of paired samples for unfertilized and fertilized elements and crude protein in spring and fall was not significant.

In both unfertilized and fertilized plots of 1975, there was a general decrease from spring to fall for the elements P, Mg and K (Table 1). In unfertilized plots of 1975, Ca in 9 species increased from spring to fall while in fertilized plots it increased in only 5 species. Crude protein varied considerably between the spring and fall samples for both unfertilized and fertilized plant species. The t test of elements and crude protein for paired plots unfertilized and fertilized in both spring and fall was not significant, except significant at the 90 percent level or higher was Ca and Mg in fertilized spring, Mg in unfertilized fall and K in fertilized fall samples. *Eupatorium* spp. had the greatest P concentration both for unfertilized and fertilized samples. *Vaccinium* spp. had the greatest Ca concentration in unfertilized samples and *Eupatorium* spp. the greatest for fertilized samples. *Q. pumila* had the greatest Mg concentration in unfertilized samples and *Eupatorium* spp. the greatest in fertilized samples. *Panicum* spp. had the greatest K concentration in unfertilized samples and *Rubus* spp. the greatest in fertilized samples. *Eupatorium* spp. also had the greatest crude protein in both unfertilized and fertilized samples. *I. glabra* consistently ranked low in both mineral content and crude protein. Collectively, the twelve plant species analyzed showed slightly higher mineral and crude protein levels in fertilized samples.

In both unfertilized and fertilized plots of 1976, there was a general decrease from spring to fall in P, Ca, Mg, K and crude protein (Table 2). The t test of elements and crude protein for paired plots unfertilized and fertilized in both spring and fall was not significant. *Eupatorium* spp. had the greatest P concentration in unfertilized and *P. aquilinum* in fertilized samples. *Eupatorium* spp. had the greatest Ca concentration in unfertilized and *Rubus* spp. in fertilized samples. *Eupatorium* spp. also had the greatest Mg concentration in unfertilized samples. *Panicum* spp. had the greatest Mg concentration in fertilized samples, although only spring samples were available. *Rubus* spp. had the greatest K concentration in unfertilized samples while *Panicum* spp. had the greatest K concentration in fertilized samples only. In unfertilized plots, *Eupatorium* spp. had the greatest crude protein level with *Rubus* spp. second.

In fertilized samples, *Rubus* spp. had the greatest crude protein level with *Eupatorium* spp. second. *L. mariana* and *I. glabra* consistently rank low in mineral and crude protein levels. Collectively, the twelve plant species analyzed show a higher protein level in the unfertilized samples.

Soil samples were taken as plots established in 1975 and 1976. Soil analysis for 1975 plots fertilized exceeded those of unfertilized, except for K (Table 3). Soil analysis for 1976 plots fertilized were equal or exceeded the unfertilized, except for Ca, Mg and K.

Table 3. Soil analysis of unfertilized and feritlized plots.

	Unfertilized						*Fertilized*					
	P	Ca	Mg	K	N	pH	P	Ca	Mg	K	N	pH
Plots		(kg/ha)			(%)			(kg/ha)			(%)	
1975	4.48	145.70	39.23	63.88	0.02	4.4	8.97	257.78	47.07	38.11	0.06	4.2
1976	17.93	227.52	41.47	31.38	0.05	5.0	30.26	174.84	32.50	26.90	0.05	5.0

The clipped one square m samples of plots planted in 1976, were taken on 27 May and 17 September 1976. The dry weight of the sample taken from the unfertilized plot in May was 16.8 g and the sample in September was 152.3 g. The dry weight of the sample taken from the fertilized plot in May was 54.9 g and the sample in September was 470.1 g.

DISCUSSION

Considerable variation occurred in mineral levels by plant species, with a general decline from spring to fall for both unfertilized and fertilized plots reforested in 1975 (Table 1). Urness et al. (1971) considered protein intake of 11 to 12 percent as optimum for deer. According to this criterion only *Eupatorium* spp. had optimal crude protein levels in both unfertilized and fertilized samples in spring and fall. Collectively, the sampled plant species had greater mineral and crude protein levels in the fertilized samples.

Unfertilized and fertilized plots reforested in 1976 show a decrease in mineral levels from spring to fall (Table 2). None of the plant species had optimal crude protein levels for both unfertilized and fertilized in spring and fall. *Eupatorium* spp. unfertilized and *Rubus* spp. fertilized had optimal crude protein in spring and fall.

Of the 17 mineral elements that are essential, Ca, P, K and Mg are essential macronutrients in human nutrition (Krause and Hunscher 1972). The Ca-P ratio in the diet is important in the absorption of both elements and a desirable Ca to P ratio for deer appears to be between 1:2 to 2:1 (Dietz 1970).

In unfertilized plots of 1976, the Ca-P ratio exceeded 2:1 in all plant species except for fall samples of *Panicum* spp. and *P. taeda*. In fertilized plots of 1976, the only plants having a Ca-P ratio of less than 2:1 were *Panicum* spp., *Pteridium aquilinum* and *P. taeda* in spring samples and *Pteridium aquilinum* and *P. taeda* in the fall samples.

While the 12 species sampled differ in mineral levels, differences between unfertilized and fertilized samples were generally not significant. There was, however, significant difference in the dry weight of forage produced. Forage in fertilized samples was 3.3 times that of unfertilized in the spring and 3.1 times greater in the fall. Phosphorus fertilization appeared to increase the biomass but not the concentration of most nutrients in the foliage of plants studied.

LITERATURE CITED

Burns, R. M., and E. A. Hebb. 1972. Site preparation and reforestation of droughty, acid sands. USDA For. Ser. Agric. Handb. No. 426. pp. 15-19.

Coleman Instruments Corp. 1966. Operating directions for Coleman Model-29B Nitrogen Analyzer. Bull. B-291A. 34 pp.

Dietz, D. R. 1970. Animal production and forage quality. Pages 1-9 *in* Range and wildlife habitat evaluation. A research symposium. USDA For. Ser. Misc. Pub. No. 1147.

Crutchfield, D. M. 1971. Fertilization—effect on productivity. Proc. Ann. Mtg. Appal. Sec. Soc. Am. For. 50:27-34.

Fitts, J. W., and N. M. Berenyi. 1966. Operating soil-plant analysis laboratory. Soil Science Dept., N.C. State Univ., Raleigh. 22 pp.

Krause, M. V., and M. A. Hunscher. 1972. Food nutrition and diet therapy. W. B. Sanders Co., Philadelphia. pp. 99-120.

Lennartz, M. R., and J. W. McMinn. 1973. Growth of two varieties of slash pine on prepared sites in south Florida: 10-year results. USDA For. Ser. Southeast. For. Exp. Stn. Pap. SE-103. 10 pp..

Olsennladean. 1965. Phosphorus. Pages 1035-1048 *in* C. A. Black, ed., Methods of soil analysis. Am. Soc. Agron. Inc. Agron. Monogr. No. 9.

Radford, A. E., H. E. Ahles and C. R. Bell. 1973. Flora of the Carolinas. Univ. N.C. Press, Chapel Hill. 1183 pp.

Urness, P. J., W. Green and R. K. Watkins. 1971. Nutrient intake of deer in Arizona chaparral and desert habitats. J. Wildl. Manage. 35(3):469-475.

Wells, C. G., D. M. Crutchfield, N. M. Berenyi and C. B. Davey. 1973. Soil and foliar guidelines for phosphorus fertilization of loblolly pine. USDA For. Ser. Southeast. For. Exp. Stn. Res. Pap. SE-110. 15 pp.

Wiley, Jr., J. J., D. M. Crutchiefld, J. Marton and N. M. Berenyi. 1970. Forest fertilization in the South Carolina coastal plain TAPPI 53 (11):2136-2138.