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LOBLOLLY AND LONGLEAF PINE RESPONSES TO LITTER RAKING, PRESCRIBE BURNING AND NITROGEN FERTILIZATION

SHARON M. ROSS, WILLIAM H. McKEE AND MICHELE MIMS[1]

Abstract.--The objectives of this study were to evaluate the effects of prescribe burning and litter removal on soil nutrient levels and tree growth. An additional objective was to determine if nitrogen can be replaced with the application of fertilizer. There were no statistically significant changes in the soil nutrient levels or tree growth after six years, but there were significant changes in forest floor weights and nutrient levels.

INTRODUCTION

Harvesting pine straw has increased in recent years because of its value for landscaping. There is concern that mineral nutrients are being removed from the site and that disruption of biological processes associated with organic matter litter mineralization are disrupted as a result. Since these consequences may affect long term site productivity, the development of optimum forest floor management practices is important.

McLeod et al. (1979 a,b) reported that forest floor removal disrupts the hydrologic and macronutrient cycles of 20 to 30 year old longleaf pines. They also concluded that tree growth was reduced the year following litter removal. By comparison, prescribed burning that consumes an appreciable portion of the

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Biologist and Soil Scientist, respectively, USDA Forest Service, Southeastern Forest Experiment Station, The Center For Forested Wetlands Research, Charleston, SC and Biologist, USDA Forest Service, Savannah River Forest Station, Akien, SC.

forest floor does not result in a net loss of mineral soil nutrients. McKee (1982), reported nitrogen tends to accumulate in the surface mineral soil on some sites following prescribed burns.

Considerable information has been developed on the components of nutrient pools and rates of litter decay, however, application of these principles to forest floor management has not been developed. Therefore, the objectives of this study were to evaluate the effects of prescribed burning, a silvicultural management practice, and litter removal on: (1) the growth of loblolly and longleaf pine; (2)nutrient pools in the forest floor and surface soil, and (3) determine if nitrogen applications will alter tree growth and/or forest floor properties.

MATERIALS AND METHODS

This study was located on the Savannah River Site in Aiken County, South Carolina. The soil in the area is mapped as Fuquay fine sandy loam (Arenic Plinthic Paleudult, loamy siliceous, thermic). It is well drained with a 2 percent or less slope. The stands were originally in agriculture and were planted or seeded to either loblolly or longleaf pine in the early 1950's. In 1971 the loblolly pine stand was clear-cut, sheared and root raked, then replanted with 1-0 loblolly pine with an approximate 1.80 by 3.04 meter spacing. The treatment plots were 0.16 hectares with some variation in size depending on site properties. The longleaf stand was thinned in the mid 70's with approximately half the stems removed. The plots in the longleaf stand were 0.19 hectares with 1.80 by 3.04 meter spacing. The study consists of three replications for the loblolly stand and two replications for the longleaf stand in a randomized split plot design. There are three treatments imposed on the loblolly stand which are 1) no treatment (control), 2) prescribed burn treatment in winter at three year intervals and 3) red straw (litter layer) raking treatment in winter at three year intervals. The longleaf stand received all the above treatments plus a total raking treatment in the winter at three year intervals. The split plot factor consists of no fertilizer or 100 kilograms of nitrogen as urea and 12 kilograms of phosphorus as triple super phosphate per hectare.

For the raking treatment, pine straw was removed from the plots manually, making sure only red straw was removed. For the total raking treatment all the red straw plus the fermentation and humus layer was removed to the mineral soil. Prescribed burns were cool winter backing fires where flames did not exceed a half meter above the ground. About 75 to 80 percent of the forest floor was consumed with these burns.

Tree diameters were measured at 1.37 meters above the ground. Basal area was computed as the sum of the stem cross sectional area on each measurement plot expanded to square meters per hectare.

The forest floor was sampled prior to the treatments in 1987 and at 3 year intervals. Ten sample points (15.2 centimeters square) were collected and composited by plot. Forest floor material was separated into the litter layer and humus plus the fermentation layer. Two 15 centimeter mineral soil cores were extracted at each of ten forest floor sample points and the soil composited in 5 centimeter increments by plot. The soils were air dried and sieved to < 2 mm. Forest floor samples were oven dried at 65°C and ground to pass a 1.0 mm mesh screen.

Total Kjeldahl nitrogen was measured on both forest floor and mineral soil samples (Nelson et al., 1973). Exchangeable bases were extracted from the soil with 1 N ammonium acetate at pH 7 (Thomas, 1982). Organic matter content for the soil was determined by the Walkley and Black Method (Jackson, 1958). Soil pH was determined on a 1:1 soil to water paste.

Statistical analysis was performed separately for the loblolly and longleaf components of the study. Response to treatment were tested by analysis of variance with significance at the 0.05 level. The tree growth data was analyzed with covariance using the initial stand (1987) values as the covariant.

RESULTS AND DISCUSSION

There were no treatment effects on loblolly or longleaf pine basal area over the seven years of observation. There were significant treatment differences in mortality for the loblolly pine (Table 1). The red straw raked treatment had significantly lower mortality than the control and the prescribed burn treatments. To date, we do not have an explanation for this observation but the difference in tree mortality maybe related to differences in stand growth and competition.

The treatments have not significantly altered the chemical properties of the soil in the upper 15 centimeters (Table 2). Treatments had an affect on the physical properties of the forest floor after six years, although the response of the litter and humus layers were different within the treatments. Litter mass on the loblolly stand was about twice that of the longleaf stand as well as being two folds higher in nutrient levels (Table 3). The difference in the weight of the loblolly and the longleaf needle production and the amount of nutrients found in the foliage may reflect differences in the species and/or differences in the age of the stands. In contrast the mass and nutrients of the humus layer was higher on the longleaf than on the loblolly forest floor (Table 4). The heavier humus layer of the longleaf stand is attributed to stand age and a slower rate of decomposition. The lower nutrient level is also an indicator of a slow rate of decomposition.

Fertilization treatments (Table 3) did not alter the physical properties of the litter layer on the loblolly or the longleaf stand. Although the physical properties (weights and nutrients) were not significant, there was an observable response to the fertilization treatment by the longleaf stand. The fertilizer increased litter production from 1.98 to 3.47 metric tones and the weight of the nutrients increased by 85 percent for nitrogen, 236 percent for phosphorus, 43 percent for calcium and 57 percent for magnesium.

Forest floor treatments altered the response of the humus layer (fermentation plus humus) for both species (Table 4). The control plots for the loblolly stand contained more organic material than the prescribed burn humus layer. The rake plots were not significantly different than other forest floor treatments. Nitrogen content of the humus layer was higher on the control plots than prescribed burn plots with the raked plots not being different from the other treatments. Phosphorus levels were not affected by forest floor treatments and ranged from 25.9 to 48.3 kilograms per hectare. Potassium levels were 0.21 to 0.85 kilograms per hectare higher on the control and raked plots than the prescribed burn plots.

The mass of the longleaf humus was not significantly affected by fertilizer treatments, although it increased for the fertilized plots. The weight of the humus for the forest floor control and red straw raked treatments were significantly greater than the weight of the humus that received the prescribed burn and total raked treatments. Nitrogen levels in the humus layer responded similarly to the organic weights, with the prescribed burn and the total raked treatments having less nitrogen than other treatments.

SUMMARY AND CONCLUSIONS

So far, results of this study has not shown a reduction or an increase in tree growth. It has shown that prescribe burning may enhance nutrient cycling creating an improved environment for tree growth. This has been shown by other studies (Hough 1981 and McKee 1982). McKevlin and McKee (1986) showed that seedling growth was greatly improved on soil taken from a site annually burned as compared to the same soil unburned. Litter raking decreased the nutrients in the foliage for both tree species. Fertilizer application replaced the nutrients in the foliage for each species as well as increasing the litter yield for the longleaf. Morris et al. (1991) also expressed concern over possible loss of site fertility due to litter raking and indicated that the application of fertilizer did appear to maintain soil fertility and increase litter yield. This study should be continued for two additional 3 year intervals.

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Table 1--Loblolly and longleaf pine stand initial and seven year measurements for basal areas and mortality

Treatments	F	Basal area 1987	Basal area 1994	DA	Mortality
Loblolly					
	kg/ha	--------m/ha--------			pct
Control	0	20.4	29.8	9.4	13.5[a]
	112	23.3	33.5	10.2	19.7[a]
Prescribed burn	0	25.5	34.4	8.9	14.5[a]
	112	23.3	34.1	10.8	12.2[a]
Red straw raked	0	22.3	33.3	11.0	4.8[b]
	112	19.8	32.3	12.5	4.1[b]
Longleaf					
Control	0	39.0	33.3	-5.7	4.5
	112	29.2	34.9	5.7	5.5
Prescribed burn	0	25.6	29.0	3.4	10.5
	112	29.2	25.2	-4.0	24.0
Red straw raked	0	26.2	36.2	10.0	9.5
	112	23.7	33.2	9.5	7.0
Total raked	0	33.2	36.0	2.9	5.5
	112	29.3	33.8	4.5	6.0

Columns without letters are not significantly different at $p<0.05$ level.
F=fertilizer; DA=difference in basal area

Table 2--Soil properties after two 3-year interval treatments

Treatments	F	Loblolly OM	Loblolly N	Loblolly Bases	Longleaf OM	Longleaf N	Longleaf Bases
0-5 cm	kg/ha	pct	pct	meq/100g	pct	pct	meq/100g
Control	0	3.23	0.11	0.96	1.58	0.14	0.11
	112	2.85	0.17	1.27	1.92	0.12	0.09
Prescribed burn	0	3.40	0.16	1.30	2.03	0.14	0.23
	112	3.37	0.17	1.46	2.99	0.13	0.26
Red straw raked	0	3.45	0.15	0.73	2.03	0.13	0.15
	112	3.08	0.17	0.99	2.14	0.14	0.16
5-10 cm							
Control	0	1.98	0.13	0.37	1.37	0.11	0.06
	112	1.99	0.13	0.30	1.49	0.11	0.07
Prescribed burn	0	2.30	0.14	0.42	1.56	0.12	0.08
	112	2.71	0.15	0.27	1.58	0.12	0.09
Red straw raked	0	2.04	0.14	0.26	1.36	0.12	0.05
	112	2.19	0.14	0.33	1.51	0.12	0.08
Total raked	0	----	----	----	1.60	0.11	0.11
	112	----	----	----	1.85	0.12	0.06
10-15 cm							
Control	0	1.33	0.10	0.16	0.87	0.10	0.07
	112	1.37	0.11	0.15	0.92	0.11	0.06
Prescribed burn	0	1.27	0.11	0.23	1.24	0.11	0.06
	112	1.33	0.11	0.13	0.92	0.11	0.10
Red straw raked	0	1.47	0.10	0.16	1.28	0.10	0.20
	112	1.45	0.11	0.17	1.07	0.11	0.06
Total raked	0	----	----	----	1.00	0.10	0.80
	112	----	----	----	1.07	0.12	0.14

F=fertilizer; OM=organic matter; N=nitrogen

Table 3--Weights and nutrient levels in the forest floor for loblolly and longleaf pine litter after two treatment intervals

Treatment	F	LW	N	P	K	Ca	Mg
Loblolly							
	kg/ha	Mg/ha	---------------		kg/ha	-------------	
Control	0	6.52	36.4	12.7	0.84	19.9	4.8
	112	7.98	50.1	13.0	1.64	24.9	5.6
Prescribed burn	0	5.61	34.6	12.0	0.86	16.9	4.6
	112	5.43	30.6	13.6	0.69	16.7	4.5
Red straw raked	0	4.08	22.2	8.1	0.21	11.8	3.3
	112	5.27	31.7	22.6	0.44	14.7	4.0
Longleaf							
Control	0	2.39	9.1	1.12	0.21	7.77	0.15
	112	4.05	14.3	3.52	0.27	12.10	1.02
Prescribed burn	0	1.40	5.2	0.56	0.10	4.58	0.30
	112	3.69	15.3	5.64	0.26	11.47	0.82
Red straw raked	0	2.02	6.5	1.72	0.26	5.76	0.09
	112	3.29	13.7	3.65	0.22	9.73	0.08
Total Raked	0	2.09	8.8	0.82	0.17	6.20	1.20
	112	2.87	11.6	1.31	0.30	8.88	1.89

F=fertilizer; LW=litter weight

Table 4--Weight and nutrient levels in the forest floor for loblolly and longleaf pine humus after two treatment intervals

Treatment	F	HW	N	P	K	Ca	Mg
Loblolly							
	kg/ha	Mg/ha	----------	----------	kg/ha	----------	----------
Control	0	13.64[a]	108.8[a]	48.3	1.28[a]	37.0	5.6
	112	13.39[a]	111.0[a]	46.7	2.02[a]	41.0	5.7
Prescribed burn	0	10.23[b]	80.4[b]	34.4	1.95[b]	28.0	6.9
	112	7.06[b]	57.0[b]	25.9	0.92[b]	17.8	3.5
Red straw raked	0	13.26[ab]	97.2[a]	41.8	2.02[a]	41.1	8.4
	112	11.62[ab]	96.8[a]	37.7	2.56[a]	27.2	5.7
Longleaf							
Control	0	59.74[a]	394.2[a]	24.53[ab]	9.41	157.14	30.24
	112	61.27[a]	403.2[a]	50.62[ab]	8.21	155.46	29.12
Prescribed burn	0	5.48[b]	35.8[b]	5.15[b]	0.40	16.24	2.24
	112	11.75[b]	70.6[b]	15.12[b]	1.74	43.57	6.05
Red litter raked	0	32.94[a]	197.1[a]	47.60[a]	0.48	76.72	14.45
	112	73.53[a]	460.3[a]	86.58[a]	0.87	218.85	39.87
Total raked	0	7.88[b]	49.3[b]	6.50[b]	0.48	19.49	2.46
	112	10.48[b]	67.2[b]	13.55[b]	0.87	33.49	4.82

Columns without letters are not significantly different at $p<0.05$ level.
F=fertilizer; HW=humus weight