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Forage Production in a Five-Year-Old Fertilized Slash Pine Plantation

LARRY D. WHITE

Highlight: Forest management companies in Florida currently fertilize approximately 10,000+ hectares of pine plantation annually. This paper reports excellent yields of bluestems with reduction in pineland threeawn 5 years after fertilization and establishment of slash pine on an Olustee-Mascottee-Leefield soil complex. Neither total understory live biomass nor total grass production was changed by fertilization. As much as a 250% increase in bluestem forage, preferred by cattle, was produced with several fertilizer combinations. In addition, understory plant responses in relation to the fertilized tree row indicate significant movement of fertilizers to adjacent unfertilized areas. Pineland threeawn, generally undesirable for cattle forage, was reduced with fertilization. The overall increase in bluestem forage resulting from plantation establishment and fertilization for increased tree yields is a complementary benefit valuable to forest landowners and cattle producers.

The southeastern United States is widely recognized as the area with the highest growth potential for meeting future wood and meat demands of the nation. Currently, well-managed forest-range grazing has economic superiority over improved pasture forage programs (Pearson 1974). Intensification of forest management practices offers opportunities for intensive range cattle operations to utilize available forage in an estimated 485,000 hectares of pine plantations in north Florida. In addition, forest fertilization for improved tree growth on approximately 10,000 hectares annually in 1974 is expected to increase to 28,000 hectares in 1985 (IFAS 1974). These practices may increase forage yields and quality from forest plantation management and increase forest landowner income while providing much needed low cost forage for beef cattle production.

The sudden release and disturbance of understory vegetation created by clearcutting, site preparation, and planting of pines appears to benefit many desirable plant species (Bennett 1965; White 1975) with little recovery of many undesirable forage plants. White (1973) noted substantial desirable forage production increases on many range areas following fertilization, brush control, proper grazing, and wider spacing of trees in forest plantations. A review of production capabilities of different southeastern ecosystems and their successional relationships was presented. Site preparation methods greatly affect species distribution in relation to tree rows, amount of soil disturbance, and fertilizer placement (White 1975). Increased intensity of site preparation on a wet savanna site decreased herbaceous and shrub biomass, primarily due to a decrease in undesirable forage species, but increased desirable bluestem production. Increased intensity of site preparation increased successional development towards a pine forest at the expense of many herbaceous species and certain wildlife (Harris et al. 1974; White et al. 1975). Nitrogen fertilization (90 kg/ha concentrated in 1.2-m bands along the tree row) increased grass biomass (primarily bluestems [*Andropogon* spp.]) from 960 kg/ha to 1,272 kg/ha 3 years after application (White 1975). Bennett (1965) reported tree response to fertilization was most consistent on grazed plots in a 25–28-year-old plantation. Hence, grazing may be needed to reduce competing vegetation and increase growth of fertilized pine plantations. Application of N-P-K on plantations in Louisiana increased protein content of mature herbage by one-third and yield by more than three-fold, but was considered uneconomical just for range improvement (Duvall and Grelen 1967). Fertilization of range in south Florida (with rock phosphate) can triple herbage yields (Lewis 1970).

This paper reports forage yields 5 years after fertilization of a newly planted slash pine plantation on an Olustee-Mascottee-Leefield soil complex in north Florida.

Author is associate professor, Range Ecosystem Management, School of Forest Resources and Conservation, University of Florida, Gainesville.

This study was a cooperative effort with Owens-Illinois, the Cooperative Research in Forest Fertilization (CRIFF) program (Study A-23) at the University of Florida, and the Florida Division of Forestry. Florida Division of Forestry personnel Paul Jastram, Mike Long, Bob Mikell, John Omera, and Donald Rogers collected all vegetation samples.
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Study Area and Methods

The study was installed by Owens-Illinois to determine slash pine growth and yield following fertilization soon after planting. The area selected, near Lake Butler, Fla., was a typical flatwoods site having less than 2% slope with soils of acid sands to loamy sands, poorly to somewhat poorly drained. The original vegetation was longleaf and slash pines with an understory of saw-palmetto (*Serenoa repens*) and pineland threeawn (*Aristida stricta*). The tree site index was estimated to be 17 m at age 25. Soil chemical analysis indicated pH of the A_1, A_2, and B horizons to be 3.65, 4.30, and 4.17, respectively. Total phosphorus, organic matter, and total nitrogen were 69 ppm, 3.04%, and 0.082%, respectively. The area was clearcut in 1967, burned, KG'd (residual trees, brush, and slash raked into windrows), disc harrowed once over, and bedded at 3-m intervals. Commercial slash pine seedlings were machine planted at approximately 2-m intervals along the tops of the beds in February, 1968. Fertilizers were applied in 1.2-m bands down the tree rows (2.5 times concentration of the per-hectare basis) in March, 1968. Tree survival in June, 1968, was 82%. The area was excluded from cattle grazing.

Fertilization treatments were applied in a 3 × 3 × 3 factorial experiment (replication × nitrogen × phosphorus) in a randomized block design on plots 24 by 32 m (Pritchett and Smith 1972). Nitrogen and phosphorus were applied in all combinations of 0, 22, and 90 kg/ha. An additional three plots per replicate with N-P-K (90-90-90 kg/ha), N-P-K (90-90-90 kg/ha) plus essential elements (56 kg/ha of micronutrient Frit-503), and N-P-K (22-22-90 kg/ha) were included to provide additional information.

Forage production measurements were made during October, 1973, from five randomly placed paired 0.20-m^2 quadrats per treatment. Each quadrat pair consisted of two niches: (1) on the bed midway between planting spaces and (2) midway between beds halfway between planting spaces. Paired niche quadrats were used to avoid questions of species availability for occurrence in each niche. Total standing biomass of understory vegetation (including current year's growth of woody plants, excluding pine trees) was clipped from the soil surface to a height of 1.5 m above each quadrat. Biomass was sorted into dead and live, but the latter sorted by species or species groups. Samples were dried (65°C) to constant weight. ANOVA procedures utilized a randomized block design to test treatment effects for each niche, followed by use of a Duncan's multiple range test to identify significant treatment differences. A standard *t*-test was used to identify significant niche differences within treatments.

Table 1. Average understory plant biomass (kg/ha) 5 years after establishment and fertilization of slash pine.

Plant name	Standing biomass
Live biomass	
Grasses	
Andropogon spp.	2198
Aristida spiciformis	1
A. stricta	559
Panicum spp.	2
Paspalum spp.	10
Sporobolus curtissii	5
S. junceus	2
Total grasses	2777
Forbs	
Aster squarrosus	Trace
Elephantopus tomentosus	Trace
Erigeron spp.	1
Erygnium yuccifolium	5
Eupatorium capillifolium	9
Heterotheca graminifolia	5
Hypercium stans	2
Lactuca canadensis	Trace
Trilisa odoratissima	16
Xyris spp.	1
Misc. forbs	1
Total forbs	40
Shrubs	
Befaria racemosa	Trace
Hypericum fasciculatum	3
Ilex glabra	464
Kalmia hirsuta	37
Lyonia lucida	3
Myrica cerifera	9
Quercus spp.	19
Rubus spp.	112
Serenoa repens	32
Smilax spp.	3
Vaccinium myrsinites	31
Total shrubs	713
Total live biomass	3530
Dead biomass	84
Total biomass	3614

Results

Understory vegetation 5 years after establishment of slash pine averaged 3,618 kg/ha live biomass over all plots measured and was composed of 29 species groups (Table 1). Grass biomass (2,777 kg/ha) was approximately four times shrub biomass (716 kg/ha) and 59 times forb biomass (47 kg/ha) in October. Although seven species of grasses were collected, only bluestems and pineland threeawn occurred in large quantities. Bluestems (2,198 kg/ha) were the most abundant grass species on the study area. Blackberry (*Rubus* spp.) (112 kg/ha) and gallberry (*Ilex glabra*) (464 kg/ha) were the most abundant shrubs, while deer tongue (*Trilisa odoratissima*) (16 kg/ha) and dogfennel (*Eupatorium capillipolium*) (9 kg/ha) were the more common forbs. Dead biomass (litter plus standing dead) was small (84 kg/ha) compared to standing live biomass. All firmly attached herbaceous material with live bases was considered live biomass.

Most understory plant species did not have significant responses due to the application of fertilizer. Only nine species or groups had significant responses (Table 2). On niche 1, three species showed significant response to application of fertilizer compared to control plots. Of these, blackberry and ground blueberry increased production with addition of 90-90-90 or 90-22-0 N-P-K, respectively. Other fertilizer treatments were not significantly different from the control. However, ground blueberry had significantly greater production on 0-90-0 and 22-22-90 N-P-K fertilizer combinations compared to other fertilizer treatments. Pineland threeawn had significantly lower production compared to the control with application of 22-0-0, 0-22-0, 22-22-0, 22-22-90, 90-22-0, 90-90-90 EE, and 90-90-90 EE N-P-K. However, 90-90-90 N-P-K was significantly higher than those same fertilizer combinations.

On niche 2, three species had significant fertilizer responses (Table 2). Bluestem had higher production with application of 90-0-0, 0-22-0, 22-90-0, and 90-90-90 N-P-K as compared to the controls. Since there were no significant fertilizer effects on niche 1 nor significant niche differences within treatments, this would indicate fertilizer movement. Although not significant, the higher production for niche 1 on control plots plus the lack of significance between niche 1 and niche 2 on fertilized plots indicate a positive response from bedding with a general additive effect from fertilization. Laurel (*Kalmia hirsuta*) had significantly lower production on some fertilized plots than on control plots. In addition, there were significant niche differences for control, 22-0-0, and 90-0-0 treated areas. Apparently, the bedding operation greatly reduced the abundance of laurel over the less disturbed area midway between tree rows. However, this trend was not consistent once fertilizer was applied to the

Table 2. **Significant understory plant responses (kg/ha) 5 years after establishment and fertilization of slash pine.**

Species	Niche	Fertilizer treatment (N-P-K applied in kg/ha)											
		Control	22-0-0	90-0-0	0-22-0	22-22-0	22-22-90	90-22-0	0-90-0	22-90-0	90-90-0	90-90-90	EE[1] 90-90-90
Andropogon spp.	1	1837a[2]	2900a	3097a	1953a	2947a	1902a	2153a	1965a	2338a	1591a	2707a	2308a
	2	1006c	1943abc	2562ab	2832a	2563ab	1255bc	2266abc	1041abc	2768a	1790abc	2560ab	2118abc
Aristida stricta	1	1114a	140b	673ab	154b	156b	177b	39b	284ab[3]	528ab	359ab	1161a	93b
	2	1171ab	634ab	408ab	618ab	680ab	784ab	230b	1196a[3]	503ab	343ab	1116ab	697ab
Total grass	1	3011abc	3084abc	3775ab	2135bc[3]	3161abc	2088c	2197bc	2258abc	2865abc	1950c	3879a	2400abc
	2	2102a	2577a	3021a	3555a[3]	3245a	2069a	2523a	2598a	3271a	2133a	3693a	2815a
Ilex glabra	1	482abc	543abc	639abc	758abc	307bc	200c	671abc	229c	1096a	500abc	223c	947ab[3]
	2	424a	255a	403a	578a	247a	319a	467a	257a	740a	259a	180a	412a[3]
Kalmia hirsuta	1	25a[3]	74a[3]	19a[3]	50a	36a	8a	88a	29a	44a	14a	0a	0a
	2	116ab[3]	0c[3]	129a[3]	16c	28bc	0c	96abc	48abc	41abc	30bc	0c	4c
Quercus spp.	1	0a	29a	17a	0a	41a	6a[3]	16a	30a	0a	41a	45a	0a
	2	5b	51ab	0b	0b	13b	82a[3]	0b	8b	16b	24ab	35ab	0b
Rubus spp.	1	41b	191b	48b	98b	171b	45b	121b	207b	118b	241b	251b	507a[3]
	2	23a	87a	6a	0a	38a	22a	29a	38a	8a	223a	127a	39a[3]
Vaccinium myrsinites	1	56bc	15c	6c	81abc[3]	5c	102ab[3]	0c	143a[3]	47bc	16c	29bc	0c
	2	32a	13a	0a	5a[3]	30a	0a[3]	36a	34a[3]	53a	29a	0a	10a
Total biomass	1	3823abc	4181abc	4574ab	3409abc	3956abc	2571c	3204abc	3045abc	4439ab	2875bc	4648a	3993abc
	2	2963a	3436a	3673a	4357a	3739a	3057a	3198a	3034a	4206a	2878a	4267a	3297a

[1]EE = essential elements applied from 112 kg/ha end of Ca So_4 and Mg So_4, and 56 kg/ha of Fritted Trace Element-503.
[2]Letters identify significant fertilization responses within niches ($P>0.05$).
[3]Identifies significant niche differences within fertilization treatments ($P>0.10$).

bedded area. Oak production was significantly higher than the control with application of 22-22-90 N-P-K to niche 1. Also, the niches were significantly different for this treatment.

Total grass, gallberry, and total biomass did not exhibit significant responses on either niche from fertilization compared to control plots (Table 2). However, each of these had some significant differences between fertilization treatments. Only total grass had a significant niche difference within a fertilization treatment (0-22-0 N-P-K).

Discussion and Conclusion

Total production of live understory and total grasses 5 years after fertilization were not affected, but species composition shifts resulted. The 5-year-old plantation became a bluestem range following site preparation, establishment of pines, and fertilization, which contrasts with the original pineland threeawn-saw-palmetto range described for the area. In addition, fertilization further reduced pineland threeawn and benefitted bluestem. These results and others (White 1975) suggest that systematic tree planting and site preparation techniques, including bedding, also restrict distribution of some species along man-made niches within plantations. Species such as bluestem that are prolific seeders occupy both niches following general soil disturbance by site preparation and bedding and take advantage of fertilization.

Fertilization to increase bluestem production would be most economical on treatments having the greatest tree response, although 90 kg/ha nitrogen alone greatly increased production. As indicated by White et al. (1975), increased growth rate of a forest overstory decreases the longevity of the "grassland" understory successional stage most desirable for cattle production. Comparison of niche 1 and niche 2, in light of the more rapid successional development, suggests that niche 1 may have been more productive when tree growth would be less competitive. Hence, niche 2 would be able to maintain production longer since it was the most distant point from trees. Also, fertilization effects on niche 2 may be indirect through litter deposition from niche 1 and the pine trees. Optimum tree and bluestem response would probably be best with phosphorus and nitrogen combinations (Pritchett and Smith 1974).

As reported by White (1975), blackberry was most productive with high rates of fertilization on the more disturbed areas. Blackberry provides limited wildlife value and often becomes impenetrable to livestock and man. Therefore, moderate fertilization rates and/or site preparation intensities would be recommended to produce good forage yields and reduce difficulty for animal movement while providing browse and berry production for wildlife.

Gallberry, oak, and ground blueberry responses were not consistent. These species are of minor value for cattle but could be important to wildlife.

Establishment and fertilization of slash pine produced a more desirable range resource readily utilizable by beef cattle while decreasing undesirable pineland threeawn. With an increase in acreage of fertilized slash pine plantations, a new productive and desirable forage is being developed in the Southeast. This valuable forage resource can be used by forest landowners to offset land ownership and plantation management costs while meeting the increasing needs of the southeastern cattle industry for low-cost, higher quality forage. Lewis et al. (1975) reported crude protein and digestibility of bluestems superior to pineland threeawn throughout the growing season. In addition, Hilmon and Hughes (1965) showed year-round cattle diet preference for bluestems although they had low forage production under pineland threeawn management objectives. Intensive forest management with fertilization of 90 kg/ha of nitrogen alone could increase cattle carrying capacity on slash pine plantations 250% 5 years after application, and probably greatly improve forage quality.

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Effects of Aqueous *Artemisia* Extracts and Volatile Substances on Germination of Selected Species

G. R. HOFFMAN AND D. L. HAZLETT

Highlight: The present study was done to determine the effects of *Artemisia* substances, both water-soluble and aromatic, on the germination of selected grassland species. Aqueous extracts of *Artemisia tridentata* litter inhibited germination of such species as *Agropyron smithii, Euphorbia podperae, Hedeoma hispida, Parietaria pennsylvanica,* and *Thlaspi arvense*. Aqueous extracts of *A. tridentata* and *A. cana* leaves inhibited germination of *Achillea millefolium, Artemisia cana, A. tridentata, Bromus inermis, Chrysothamnus nauseosus,* and *Thlaspi arvense*. Germination of these same six species was inhibited by volatile substances from leaves of *A. tridentata* and *A. cana*. Aqueous extracts of leaves of *Artemisia tridentata, A. cana, A. absinthium, A. frigida,* and *A. dracunculus* all inhibited germination of *Haplopappus spinulosus* and *Thlaspi arvense*. Germination of *Echinacea pallida* was inhibited by leaf extracts of all the *Artemisias* tested except *A. dracunculus*. Germination of *Plantago patagonica* was inhibited by leaf extracts of only *A. tridentata* and *A. dracunculus*. Germination of *Stipa viridula* and *S. comata* was stimulated by leaf extracts of *A. frigida* and *A. dracunculus*. Aqueous leaf extracts of *A. absinthium* strongly inhibited germination of *Stipa comata*, but stimulated germination of *Stipa viridula*. Germination of certain species, such as *Lepidium virginicum, Rumex crispus,* and *R. occidentalis,* were not at all inhibited by leaf extracts of any *Artemisias* tested. Results of this experiment suggest possible influences of *Artemisia* chemicals on species distributional patterns in *Artemisia*-dominated vegetation, though further studies are required to verify whether the influences are valid under field conditions.

There has long been considerable interest in the toxic effects of plant extracts on other plants and the possible role of plant-plant interactions in the make-up of the plant community. In the case of *Artemisia* spp. early studies of Bode (1939) and Funke (1943) showed that *A. absinthium* leaves contained a substance which inhibited members of the genera *Levistium, Melissia,* and *Salvia;* but the same substance had no effect on *Stellaria* spp. Later observations on *A. absinthium* and *A. vulgaris* indicated allelopathic influences by both these species, but Grümmer (1961) suggested that lack of nitrogen in the soil could also explain the paucity of other plants near these *Artemisias*. In a laboratory study Jameson (1961) observed that both water and alcoholic extracts of *A. tridentata* inhibited somewhat the radical growth of wheat seedlings. Muller (1966) reported that volatile terpenes from both *A. tridentata* and *A. californica* inhibited germination and seedling growth of several herbaceous species under laboratory conditions. Muller (1966) also indicated that allelopathy may be a predominant influence in *A. tridentata*-dominated vegetation of the Great Basin, though no experimental data were presented. In a greenhouse study Schlatterer and Tisdale (1969) found that water leachates of *A. tridentata* litter retarded the germination and early growth of *Stipa thurberiana, Sitanion hystrix,* and *Agropyron spicatum*. After 4 weeks these grasses outgrew the controls, a result attributed to higher nitrogen content of the litter treatments. Reid (1964) reported the presence of water soluble inhibitor(s) in leaves of *A. tridentata, A. cana, A. tripartata,* and *A. nova* which under laboratory conditions inhibited germination and growth of *Bromus inermis, Sitanion hystrix,* and *Agropyron trachycaulum* as well as several other plants including radish, wheat, barley, and beans.

In an earlier paper we described spatial distributions of plant species within 6 × 6 m plots of *Artemisia tridentata-* and *A. cana*-dominated vegetation in western North Dakota (Hazlett and Hoffman 1975). We found that some species including *Parietaria pennsylvanica, Hedeoma hispida, Descurainia pinnata,* and *Euphorbia podperae* were more abundant under or near the *Artemisia* shrubs and grasses *Agropyron smithii, Bouteloua gracilis,* and *Stipa viridula* were more abundant in the spaces between the *Artemisia* shrubs. Although certain

Authors are professor of biology and research assistant, Department of Biology, University of South Dakota, Vermillion, South Dakota 57069.

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