Double vs. Single-Row Pine Plantations for Wood and Forage Production

Clifford E. Lewis, George W. Tanner, and W. Stephen Terry

ABSTRACT. To find planting patterns for growing high volumes of wood while maintaining forage for cattle and wildlife habitat, slash pine (Pinus elliottii Engelm*) was planted in various configurations to increase the open space between rows while holding tree density constant. Thirteen years after planting, there were few significant differences in survival, height, and diameter; basal area and total wood volume were as good or greater in the 4 × 8 foot double-row configuration spaced 40 feet apart. Double-row configurations produced more forage than single-row. This configuration offers a high timber volume and forage mass alternative to the currently favored 8 × 12 foot spacing used for dual resource management.*

Managers of timber, wildlife, and cattle need guidelines for determining individual product yields from multiproduct management. Wood producers have growth and yield tables for predicting return from their woodlands, but tables presently available are based on stocking levels and spacings which optimize wood production. Therefore, timber managers seeking management systems to include wildlife and cattle want to know how much fiber production may be reduced when trying to maintain forage throughout the rotation. By the same token, cattle operators in Florida will plant pines on their open range or pasture lands only if assured that the added investment will produce greater returns than those they receive from cattle alone, and that the trees will not eliminate the grazing or wildlife resource.

Effects of pine canopies on herbage have been correlated with various densities or canopy cover in several forests in the South. In south Georgia, native grass yields on pine-wiregrass range decreased with each increasingly denser canopy of natural pine stands (Halls et al. 1956). In Louisiana and Texas a similar relationship was found on pine-bluestem range (Cassady 1951) and, in Texas, under mixed pine-hardwood forests (Halls and Schuster 1965). However, trends in forage yield under planted slash pine exhibited a somewhat different response; yields remained high during the first 10 to 13 years, then began to decline as crowns closed and basal area increased (Lewis et al. 1982, Pearson 1982).

Growth and yield studies for slash pine plantations traditionally have been conducted with spacing configurations that provide a uniform areal distribution of trees. Although square configurations have been modified to rectangular to accommodate mechanization in thinning and harvesting, effects of configurations have not received much attention; primary interest has been in tree density (Harms and Collins 1965).

The objective of our investigations was to compare growth responses of planted pines to various tree spacings within and between single planting rows, or between double rows at given stocking levels from three different locations. We report here on pine and forage growth at age 13.

METHODS

Alapaha Experimental Range

In January 1965, improved slash pine and improved loblolly pine (*Pinus taeda*) were planted on the Alapaha Experimental Range near Alapaha, Georgia. This south Georgia site was typical flatwoods of the Lower Coastal Plain formerly occupied by longleaf (*Pinus palustris*) and slash pines with saw-palmetto (*Serenoa repens*), gallberry (*Ilex glabra*), and pineland threeawn (*Aristida stricta*) being the primary understory species. Soils on the 3-acre area were Plummer and Ona fine sands which are very wet, acidic, and light textured. Water movement through the surface horizons is moderately free; natural fertility is low. All trees had been removed and a 7-year rough was burned in December 1964.

Pine seedlings were hand-planted in double rows at 6 × 6 ft. with 18 ft. between these strips of trees; designated a (6 × 6) 18-ft. spacing configuration. This gave a density of 605 trees/ac as in the adjacent plantation at 6 × 12 ft. One-half of

the area was planted to slash pine and one-half to loblolly. This was a pilot-test for observing the growth of these improved selections of pines; therefore, no study designed was involved.

Measurements were made on 36 trees in each of two subplots from 4 blocks in each species. Heights were measured to the nearest ft. and diameter at breast height (dbh) to the nearest tenth of an inch.

Withlacoochee State Forest

The study was installed on the eastern portion of the Richloam Unit of the Withlacoochee State Forest near Brooksville, Florida. The area consisted of a relatively good flatwoods site with an estimated slash pine site index (age 50) of about 70 ft. based on the previous stand. The vegetation on the study area was typical of wet flatwoods; slash pine and longleaf pine dominated the overstory and saw-palmetto and gallberry dominated the understory. The primary herb was pineland threeawn, commonly called "wiregrass."

The area had been clearcut and site prepared by burning and double-chopping in 1969. Following site preparation, 12 treatment plots of 330 × 369 ft. (3 ac) were laid out to accommodate two complete replications of six treatments assigned at random. Two additional replications were planned for the next year but a change in research priorities prevented their installation.

Treatments consisted of six single-row and six double-row spacing configurations at a uniform stocking level of 454 trees per acre. Configurations were: (1) single rows at 8 × 12 ft. (S-1), 4 × 24 ft. (S-2), and 2 × 48 ft. (S-3) and (2) double rows at (6 × 8) 24 ft. (D-1) (i.e., 6 ft. between trees within rows, 8 ft. between rows, and 24 ft. between pairs of rows), (4 × 8) 40 ft. (D-2), and (2 × 8) 88 ft. (D-3). The customary spacing of slash pine planted on the Withlacoochee State Forest for integrated resource management is 8 × 12 ft.; therefore, this spacing is used as the control treatment. Slash pine seedlings were carefully hand planted in January and February 1970 to assure accurate spacings within and between rows. Seedlings were from an improved selection for high gum yield. The area was neither mowed nor fertilized, and plantations were not thinned. Light grazing by cattle was allowed during the first 5 years. Prescribed fire was applied in February 1982.

A 0.5-ac area near the center of each 3-ac treatment plot was established for tree measurements. A 200-ft. line across the plot traversed a minimum of 4 rows of trees which were measured for 109 ft. along the rows. Heights and diameters were measured on all trees at age 13 within the 0.5-ac measurement plot. Heights were measured to the nearest ft, and dbh to the nearest tenth of an inch. Survival was determined at 3 months, 4 years, and 13 years. Total tree volumes were calculated using the formula.

$$\text{Volume} = 0.0399 + 0.002645\ (\text{dbh}^2 \times \text{ht})$$

(Moehring et al. 1973).

Because shading by overstory trees tends to decrease forage yields, percentage of land directly under the pine canopies was estimated for the six treatment spacings. Shape of the crowns did not appear to be affected by configuration. Assuming that crown cover by pines would have maximum influence in a zone 6 ft. along each side of a tree row (visually estimated radius of average canopy), the following percentages of an acre were calculated to be under the canopy or in the open:

Spacing configuration	Treatment	Under canopy	Open condition
Feet		*Percent*	
8 × 12	S-1	100	0
4 × 24	S-2	53	47
2 × 48	S-3	29	71
(6 × 8)24	D-1	60	40
(4 × 8)40	D-2	44	56
(2 × 8)88	D-3	20	80

Herbaceous vegetation was clipped on 50 randomly located, 0.5 m^2 quadrats in each measurement plot during October 1982, at age 13, one growing season following the February prescribed burning. Half the quadrats were located midway between rows of trees and half immediately adjacent to the tree rows, but none between the double rows. Individual species or groups of species sampled were pineland threeawn, creeping bluestem (*Schizachyrium stoloniferum*), chalky bluestem (*Andropogon capillipes*), other bluestems (*Andropogon* spp.), various panicum grasses (*Panicum* and *Dichanthelium* spp.), lopside indiangrass (*Sorghastrum secundum*), other grasses, grasslikes (rushes and sedges), legumes and other forbs. Oven-dry (dried 48 hours at 65°C) weights are reported.

Tree and vegetation data were analyzed by analysis of variance for a completely randomized block. Differences between the control (8 × 12 spacing) and other treatments were tested for significance at the 0.05 level using Dunnett's procedure (Steel and Torrie 1960).

Avon Park Bombing Range

This study was conducted on the U.S. Air Force's Avon Park Bombing Range near Avon Park, Florida. The area is typical of cutover and grazed pine flatwoods of south Florida. The soil type is Basinger fine sand that is typically found in wet prairies or "sloughs." The dominant vegetation was pineland threeawn with scattered saw-pal-

metto. Creeping bluestem, chalky bluestem, panicums, and little bluemaiden cane (*Amphicarpum muhlenbergianum*) were common throughout the area.

The site had been cleared of trees, periodically burned, and grazed prior to establishment of the study. Fifteen treatment plots of 2 ac each (264 × 330 ft.) were identified and randomly assigned to five treatments with three replications in a randomized block design. Site preparation consisted of single-chopping an entire plot or strip-chopping only the planting row in November 1970. Slash pine was planted the following December and January at 8 × 12 ft. (control) with single-chopping, and at (4 × 8) 40 ft. and (2 × 8) 88 ft. with both single-chopping and strip-chopping. These trees were machine planted by contract, therefore exact control of spacing within rows was not obtained. However, the resulting density was considered typical of what might be expected under ordinary planting conditions.

A 0.5-ac area near the center of each 2-ac treatment plot was established for tree measurements as in the previous study. Heights and diameters were measured on all trees at age 13 within the measurement plot. Heights, diameters, and volumes were determined as in the previous study. Data were analyzed by analysis of variance and differences between the control and other treatments were tested for significance at the 0.05 level using Dunnett's procedure.

RESULTS AND DISCUSSION

Alapaha Experimental Range

At age 13 the improved slash pine and improved loblolly pine planted in double rows were somewhat taller and larger in diameter than the nearby slash pine planted at 6 × 12 ft. (Table 1). Currently at age 19, there is little difference in tree responses. A higher rate of mortality has occurred in the double-row plantings because of a lightening strike and insect attacks.

At age 13, the canopy of both double-row plantings remained open in the 18 ft. between rows. However, by age 15 it was observed that the crowns had closed in these areas by the loblolly pine but were still relatively open in the slash pine. Self-pruning by both species has been normal.

To date there seems to be no disadvantage to planting in double rows as compared to a standard configuration of 6 × 12 ft. However, the average annual growth rate between ages 13 to 19 indicate the single-row spacing may be experiencing less tree-to-tree competition. Height growth was 2.50 vs. 2.35 and 2.08 ft./yr. and diameter growth was 0.23 vs. 0.20 and 0.22 in./yr. for single-row and double-row slash and loblolly pines, respectively.

Withlacoochee State Forest

Survival percentages were not statistically different among the six spacing treatments at age 13 (Table 2). Survival 3 months following planting ranged from 80 to 90%. Survival at age 4 indicated an overall survival rate similar to that at age 13. A portion of the mortality by age 4 was attributed to a road made by hunters driving across the study plots. Hot spots during burning and some pitch canker (*Fusarium moniliforme* var. *subglutinans*) contributed to mortality between ages 4 and 13. Missing trees due to all causes were fairly evenly distributed throughout the stands and did not preclude valid tests of planting configuration effects

Height growth through age 4 averaged 1.8 ft./yr. and between ages 4 and 13 averaged 3.1 ft./yr. Heights at age 13 were not significantly different among the treatments, ranging from 32.1 to 36.4 ft. (Table 2). Mean height of trees in the 8 × 12 control (S-1) was midway between the heights of the other treatments. These heights are typical of other site index 70 plantations in this vicinity.

Diameters, likewise, were not significantly different among the treatments, ranging from 4.3 to 5.7 in. at age 13 (Table 2). Average diameter was greatest in the S-1 configuration and smallest in D-3. It appears that the tree-to-tree competition

Table 1. Pine responses to planting in double-row as compared to single-row spacings at a density of 605 trees per acre in south Georgia.

Plantation age	Pine species	Survival	Height	Diameter	Basal area	Volume
Years		Percent	Ft.	In.	Sq. ft./ac	Cu. ft./ac
13	Loblolly[1]	81	34.7	4.7	62.9	1139
	Slash[1]	83	32.3	4.6	64.9	1152
	Slash[2]	87	30.9	4.4	60.4	983
19	Loblolly[1]	73	48.8	5.9	91.3	2302
	Slash[1]	69	44.8	5.9	88.4	1960
	Slash[2]	85	45.9	5.8	100.1	2386

[1] Improved loblolly and improved slash pine planted at (6 × 6) 18 ft.
[2] Normal slash pine planted at 6 × 12 ft.

Table 2. Average survival, tree height, diameter, basal area, and total-tree volume at age 13 of slash pine planted in single-row and double-row configurations at 454 trees/ac, Withlacoochee State Forest, Brooksville, Florida.[1]

Spacing configuration	Survival	Height	Diameter	Basal area	Volume
	Percent	*Ft.*	*In.*	*Sq. ft./ac*	*Cu. ft./ac*
S-1, 8 × 12	61	34.6	5.7	50.4	903
S-2, 4 × 24	68	34.7	5.2	48.6	866
S-3, 2 × 48	68	36.4	5.1	52.2	973
D-1, (6 × 8)24	67	32.1	5.0	39.8*	658*
D-2, (4 × 8)40	67	36.1	5.5	59.2	1086
D-3, (2 × 8)88	74	33.5	4.3	33.1*	580*
Average	68	34.5	5.2	47.2	844

[1] Means in a column marked with an asterisk are significantly different from the control (S-1) treatment at the 0.05 level according to Dunnett's procedure.

among trees within closely spaced rows apparently was beginning to reduce individual tree growth by age 13.

The overall poorer growth of the D-3 treatment is especially apparent in the basal area and volume data (Table 2). Basal area was considerably less than that of the other treatments. The poor growth rate of D-1 is probably related to site differences rather than spacing configuration. The D-2 configuration (Figure 1) yield of wood (1,086 cu. ft./ac) approached the level of yields from the double-row configurations on the Alapaha Experimental Range.

The diameter distribution in the 8 × 12 ft.

Figure 1. Slash pine planted with 454 trees/ac in double rows at (4 × 8) 40 ft. averaged 36.1 ft. in height with 5.5 in. diameter at age 13. Tree growth form and natural pruning were similar in all spacing configurations. Open spaces between the double rows allowed full growth of herbaceous plants.

control (Table 3) is similar to that reported by Bennett and Clutter (1968) for old-field plantations on a comparable site at age 15. However, the S-1 trees lagged behind about one size class because they were two years younger. Comparing the other configurations with the diameter distribution of S-1 shows that D-2 is the most similar while the D-3 has the greatest departure. The other configurations were fairly similar but contained more trees in the smaller size classes. The S-1 and D-2 configurations had 31 and 35%, respectively, in size classes below a merchantable size for pulpwood (5 in. used here). The S-2, S-3, and D-1 contained about 45% below merchantability while the D-3 contained 68%. Planting as close as 2 ft. within rows in the S-3 and D-3 configurations apparently was beginning to affect diameter growth by age 13, especially when double rows were planted.

Height distributions were not greatly different among most configurations except for D-1 in which about 30% of the trees below the 30- to 35-ft. height class encompassed the mean height of 34.5 ft. (Table 3). All other configurations had 80 to 90% of the trees in the mean or larger height classes. The S-3 and D-2 configurations contained the greatest proportion of tall trees.

These distributions of heights and diameters are directly reflected in total wood yields (Table 2). Since the diameter distribution patterns were similar to those reported by Bennett and Clutter (1968), our planting configurations could be expected to yield pulpwood, poles, and sawtimber volumes similar to that of old-field slash pine plantations in Florida.

Total forage yields were similar between the canopy (1290 lb/ac) vs. open condition (1300 lb/ac). Only legumes were significantly more productive under the pine canopy (202 lb/ac) than in the open area (68 lb/ac). However, a significant interaction showed that the higher legume production occurred primarily under the D-2 and D-3 configurations, where sensitive partridgepea (*Cassia nictitans*) was very abundant. This response possibly was the result of a concentration of needle fall under these spacings which would produce a hotter fire when burned. High temperatures have been suggested as an important condition for increasing the germination of partridgepea (Martin and Cushwa 1966, Harshbarger et al. 1975).

Total herbaceous yields were significantly higher in the D-3 configuration than in the control (S-1) (Table 4). Yields in the other double-row configurations were higher than the single rows but not significantly so. The low yield in the S-2 treatment appeared to be the result of dense gallberry, which is known to reduce yields of herbaceous plants (Lewis and Hart 1972). These levels of forage production are fairly typical of those reported for a developing pine plantation at age 13 (Lewis et al. 1982). The yields in D-3 are similar to open, cutover pinelands.

Individual forage species having significantly greater yields than in the control were pineland threeawn and other bluestems in the widest spacings. However, distinct trends in yields as related to spacing configuration or degree of openness were not apparent.

Table 3. Height and diameter distributions by size classes at age 13 of slash pine in single- and double-row configurations at 454 trees/ac, Withlacoochee State Forest, Brooksville, Florida.

Size class	Spacing configuration					
	S-1	S-2	S-3	D-1	D-2	D-3
	Percent					
Diameters (in.)						
1–2	0.0	0.0	0.0	0.0	0.0	0.3
2–3	1.1	3.5	2.6	1.5	1.7	9.2
3–4	7.8	11.7	12.7	10.9	8.4	24.7
4–5	22.3	29.3	31.2	31.6	25.1	33.9
5–6	29.0	29.3	29.2	35.6	31.4	27.3
6–7	19.3	19.6	17.1	13.3	20.7	4.6
7–8	13.3	5.7	5.8	1.0	9.8	0.0
8–9	5.6	0.9	1.2	0.0	2.3	0.0
9–10	1.5	0.0	0.3	0.0	0.6	0.0
Heights (ft.)						
5–10	0.0	0.0	0.0	0.0	0.0	0.3
10–15	0.0	0.0	0.0	0.0	0.3	0.7
15–20	1.1	0.3	0.6	0.7	0.6	2.3
20–25	5.2	4.4	2.9	6.9	2.6	8.2
25–30	11.9	13.6	7.3	22.9	6.4	8.2
30–35	32.0	34.1	18.7	38.5	27.5	34.5
35–40	36.4	33.4	48.7	28.4	43.4	37.8
40–45	11.2	12.9	21.3	2.2	18.8	7.9
45–50	2.2	1.3	0.6	0.4	0.6	0.0

Table 4. Forage yields at plantation age 13 of slash pine planted in single- and double-row configurations at 454 trees/ac.[1]

Species	Spacing configuration					
	S-1	S-2	S-3	D-1	D-2	D-3
	(Lb/ac)					
Pineland threeawn	660	227	512	939	804	1877*
Creeping bluestem	34	34	79	13	55	136
Chalky bluestem	0	4	4	0	37	6
Other bluestems	21	56	108*	24	32	70*
Panicums	126	97	83	123	54	96
Lopside indiangrass	29	1	4	12	16	70
Other grasses	46	14	31	3	11	7
Grasslikes	4	4	34	6	30	6
Legumes	161	48	37	146	106	131
Other forbs	58	55	177	81	120	173
Total herbaceous	1138	542	1069	1347	1264	2573*

[1] Means in a row marked with an asterisk are significantly different from the control treatment (S-1) at the 0.05 level according to Dunnett's procedure.

Table 5. Average survival, height, diameter, basal area, and total-tree volume at age 13 of slash pine planted in single- and double-row configurations at about 454 trees/ac, Avon Park, Florida.[1]

Spacing configuration[2]		Living trees	Survival[3]	Height	Diameter	Basal area	Volume
		No.	*Percent*	*Ft.*	*In.*	*Sq. ft./ac*	*Cu. ft./ac*
8 × 12	C	342	64 (75)	30.2	4.8	45.0	700
(4 × 8)40	C	282	75 (62)	31.8	4.7	35.4*	581
(4 × 8)40	SC	276	67 (60)	34.1*	4.9	38.0	665
(2 × 8)88	C	264	58 (58)	29.9	4.3*	28.8*	455*
(2 × 8)88	SC	276	52 (61)	29.4	4.5	32.0	497*
Average		288	63 (63)	31.1	4.6	35.8	580

[1] Means in a column marked with an asterisk are significantly different from the control (8 × 12) configuration at the 0.05 level according to Dunnett's procedure.
[2] Spacings followed by a C were chopped over the whole plot while those marked SC were strip-chopped only along the planting row.
[3] Percentages in parentheses indicate survival rate as if planted at 454 trees/ac while the other percentages reflect actual survival of all planted trees.

Avon Park Bombing Range

Survival was not significantly different between the double-row configurations as compared to the 8 × 12 ft. control (Table 5). However, slash pine density was not rigidly controlled at planting, and the control was planted much more closely than had been planned, which resulted in a density of 539 trees/ac. If survival is calculated on the basis of living trees as related to the planned density of 454 trees/ac, the 75% survival of the control is significantly ($P < 0.05$) better than the other spacings. At age 4, survival averaged 64%; therefore, little mortality occurred from age 4 to 13.

Heights at age 13 averaged 31.1 ft. with only the (4 × 8) 40 SC being significantly taller than the control (Table 5). These trees had averaged growing 2.4 ft./yr. as compared to the 2.7 ft./yr. by the plantings on the Withlacoochee State Forest and the 2.5 ft./yr. on the Alapaha Experimental Range. Trees planted on this wet-prairie site grew somewhat more rapidly than anticipated, although no site index figures were available.

Diameters averaged 4.6 in. (Table 5). Only the (2 × 8) 88 C treatment was significantly different from the control. These diameters were somewhat smaller (0.6 in.) than similar spacings on the Withlacoochee State Forest.

Basal areas and volumes reflect the original planting density and make comparisons between configurations difficult. The control was planted more densely and had about 70 more living trees

Table 6. Height and diameter distributions by size classes at age 13 of slash pine planted in single- and double-row configurations at 454 trees/ac, Avon Park, Florida.

Size class	Spacing configuration				
	8 × 12	(4 × 8)40C	(4 × 8)40SC	(2 × 8)88C	(2 × 8)88SC
Diameters (in.)	*Percent*				
0–1	0.2	0.0	0.0	0.0	0.0
1–2	0.2	0.5	0.5	1.3	1.9
2–3	2.4	5.2	3.6	9.6	8.9
3–4	16.5	16.7	12.1	25.9	21.9
4–5	32.2	34.9	34.1	33.2	30.8
5–6	36.1	31.6	32.6	23.9	26.0
6–7	10.4	9.7	15.2	4.8	9.6
7–8	1.8	1.4	1.9	1.3	0.7
8–9	0.2	0.0	0.0	0.0	0.0
Heights (ft.)					
5–10	0.2	0.0	0.0	0.0	0.0
10–15	0.2	0.0	0.2	1.3	1.2
15–20	0.6	2.1	1.0	5.8	3.4
20–25	6.7	6.1	2.7	7.6	9.2
25–30	27.9	14.6	9.7	19.1	19.0
30–35	54.0	49.1	31.9	52.9	61.0
35–40	10.0	25.5	44.7	11.6	6.0
40–45	0.4	2.6	9.4	1.8	0.2
45–50	0.0	0.0	0.5	0.0	0.0