This article was listed in Forest Nursery Notes, Summer 2007

4. Rectangular spacing: an economic benefit? VanderSchaaf, C. L. and South, D. B. IN: Proceedings of the 12th biennial southern silvicultural research conference, p. 437-440 USDA Forest Service, Southern Research Station, General Technical Report SRS-71. Kristina F. Connor, ed. 2004.

RECTANGULAR SPACING: AN ECONOMIC BENEFIT?

Curtis L. VanderSchaaf and David B. South[1]

Abstract—Many loblolly pine (*Pinus taeda* L.) plantations are established at row spacings of 8 to 12 feet, but some companies are now using rows spaced 14 to 18 feet apart. Wide rows reduce establishment costs when sites are bedded, ripped, or machine planted. The cost of chemicals is also reduced when treatments are applied in bands along the row. A growth and yield program (Ptaeda2.1V) was used to predict volume losses from planting in 14- to 20-foot rows. Results suggest that when a thinning (to a constant basal area) is conducted at age 15, a rectangularity ratio of 2:1 reduces the amount of sawtimber predicted at age 23 by only 1 to 2 percent when compared to a square spacing. The cost savings associated with wider rows results in a slight increase in net present value (NPV). Field trials are needed to verify the biological effects of wide rows on volume growth and branch size of plantations established with less than 600 trees per acre.

INTRODUCTION

Seedling stocking and row spacing can affect the long-term growth and economics of loblolly pine (*Pinus taeda* L.) plantations. Although many papers have been published on the effects of planting density, only a few have been published on the effects of row configuration, *per se*, on loblolly pine (Adams and Clason 2002, Sharma and others 2002a, 2002b). Row width can affect the level of crown closure, and planting density can affect the age at which particular product-size trees are achieved (Sharma and others 2002a). Due to a lack of historical data on row-configuration, many foresters have relied on intuition and have opted to plant trees in square (1-to-1 ratio) or with low rectangularity ratios (i.e. less than 2-to-1). However, when trees are planted at stockings greater than 800 trees per acre, rectangularity of 3-to-1 has little effect on height, d.b.h., crown ratio, crown length, crown width, and survival of 16-year-old loblolly pine (Sharma and others 2002a).

Publications have shown that rectangularity has no effect on pine growth (Lewis and others 1985, Sharma and others 2002a, Zhang and others 1996). Lewis and others (1985) found that basal area and cubic-foot volume were not reduced in spacings of 24 feet by 4 feet (24 x 4) and 48 x 2 when compared to spacings of 12 x 8. Obviously, the 24 x 4 and 48 x 2 configurations are far from conventional for pine management, but they do show that extremely high ratio configurations (6:1 and 24:1) do not necessarily reduce growth.

Planting 300 to 400 trees per acre not only reduces planting costs but can also provide a quicker and greater return on investment (Balmer and others 1975, Caulfield and others 1992, Harms and Lloyd 1981, Marty 1988). This is especially true when the pulpwood market is depressed. To date, little research has been conducted on rectangularity at planting densities less than 500 per acre. For example, at a density of 453 trees per acre, a 12 x 8 spacing may produce a 9-year-old tree with a 0.82-inch branch while a 16 x 6 spacing might produce a tree with a 0.86-inch branch (Adams and Clason 2002).

Fifty years ago, Wakeley (1954) recognized that wide rows could reduce establishment costs. For example, the cost of machine planting is directly affected by row width (Incoll and others 1979). Although less time is required to hand-plant 1,000 seedlings in wide rows (due to less walking distance), the cost savings might not be passed on to the landowner when tree planters are paid a set price per tree. Rectangular spacings of 2-to-1 are used for pine in New Zealand (Maclaren 1993) and Europe (Savill and others 1997) because of the decreased costs and increased accessibility. Intensively cultured, short-rotation hybrid poplar (*Populus* spp.) plantations are commonly planted in rectangular configurations to accommodate mechanized equipment (DeBell and Harrington 2002). Several industrial foresters in the South have been planting on rectangular ratios since the early 1980s. When no thinning is expected, some plant with row spacings of up to 20 feet. When thinning, wide rows could eliminate the need to remove entire rows since most bunchers and skidders would fit between the rows. Wide spacing would also reduce scraping against residual trees. Skidders or tractors could easily pass through the stand if they were conducting herbicide or fertilization treatments, once again reducing the amount of damage to residual trees.

This study was conducted to simulate the effect of rectangularity ratios of 3 to 4 on volume growth and Net Present Value (NPV) of a plantation that was thinned at age 15 and harvested at age 23.

METHODS

An individual tree distance-dependent growth and yield model (PTAEDA 2.1V) was used to project the growth and yield of loblolly pine (Burkhart and others 2001). Simulations were conducted using the average output from 5 seed numbers (i.e. 400; 800; 1,100; 1,200; 1,500). Simulations involved two site productivity classes (site index 60 and 80 feet, base age 25) and three initial planting densities (i.e. 311, 436, 622 trees per acre). Site preparation costs were set at $100 per acre, and seedling cost was $40 per thousand. An annual tax of $2 per acre was

[1] Research Associate and Professor, School of Forestry and Wildlife Sciences, and Alabama Agricultural Experiment Station, Auburn University, Alabama 36849-5418, respectively.

Citation for proceedings: Connor, Kristina F., ed. 2004. Proceedings of the 12th biennial southern silvicultural research conference. Gen. Tech. Rep. SRS–71. Asheville, NC: U.S. Department of Agriculture, Forest Service, Southern Research Station. 594 p.

assumed for both sites. The cost of machine planting varied as a function of the number of passes required to plant an acre. It was assumed that at a row spacing of 8.37 feet, it would cost $40 an acre to plant and $40 an acre to conduct a banded herbicide application. The square root of 43,560 yields a side length of 208.71 feet. The number of passes it takes to machine plant an acre was determined by dividing 208.71 by 8.3666 (i.e. 24.95 passes per acre). Therefore, each pass costs $1.60. The planting costs and banded herbicide application costs associated with different between row distances were calculated by multiplying the required number of passes per acre times $1.60. For example, using a between row distance of 20 feet yields $16.73 per acre for machine planting [(208.71/20)*1.60].

Trees greater than 10 inches in diameter at breast height were considered sawtimber, and it was assumed 20 percent of all sawtimber sized trees had defects and were usable only as pulpwood. Thinnings (from below) were conducted at age 15, and stands were projected to age 23. Projected stands with site index (SI) of 60 and 80 were thinned back to basal areas of 60 and 80 square feet per acre, respectively.

In this analysis, pulpwood was valued at $15 per cord, and sawtimber was valued at $350 per thousand board feet. The economic analyses involved calculating NPV assuming a reforestation tax credit. This assumes that establishment of less than $10,000 can be amoritized over a 7-year period.

RESULTS

When compared to the square spacing, the rectangular spacing with ratios of 2 or less reduced production of sawtimber volume by only 1 to 2 percent (table 1). Row spacing of 14 feet tended to increase NPV (table 2). Generally, the NPV was greater when planting 311 trees per acre than when planting 436 or more trees per acre. The simulation indicated rectangularity had minimal effect on live crown ratio or height to the first live branch (table 1).

DISCUSSION

For both the low site and high site, the highest NPV was achieved by a low density (i.e. 311 trees per acre) and a rectangular spacing (14 x 10). However, the increase was only $3 to $6 more than the square spacing (11.8 x 11.8). The range of NPVs was much greater when planting at 622 trees per acre. At this initial spacing, values range from $46

Table 1—Predicted yields at age 23 for different initial spacings of loblolly pine on two sites

Initial	Row	Within	QMD	AH	Crown	Stem	Cord	Scribner	Cordthin
					Site index 60				
311	10	14	10.4	59.0	40.7	35.0	7.5	5327	4.3
311	11.83	11.83	10.4	59.0	40.7	35.0	7.4	5347	4.3
311	14	10	10.4	59.1	40.7	35.0	7.5	5315	4.3
311	20	7	10.3	58.6	40.5	34.9	8.8	4788	4.0
436	10	10	10.0	58.9	39.4	35.7	9.6	4517	5.9
436	14	7.14	9.9	58.8	39.4	35.7	10.0	4446	5.8
436	20	5	9.8	58.3	39.0	35.5	10.8	4013	5.1
622	7	10	9.6	58.9	38.3	36.4	11.0	3870	8.1
622	8.37	8.37	9.6	59.0	38.3	36.4	11.4	3836	8.0
622	10	7	9.6	59.0	38.2	36.4	10.9	3956	7.9
622	14	5	9.6	59.1	38.2	36.5	12.9	3396	9.0
622	17.5	4	9.3	58.3	37.7	36.3	13.2	3124	6.8
					Site index 80				
311	10	14	12.2	77.2	37.3	48.4	8.1	12486	9.1
311	11.83	11.83	12.2	77.3	37.3	48.5	8.1	12492	9.2
311	14	10	12.2	77.3	37.2	48.5	8.3	12428	9.0
311	20	7	12.1	76.9	37.1	48.4	8.2	12183	8.6
436	10	10	11.7	77.4	36.1	49.5	8.4	12110	12.7
436	14	7.14	11.7	77.5	36.0	49.6	8.5	12021	12.3
436	20	5	11.4	76.7	35.6	49.4	9.9	11320	10.9
622	7	10	11.1	76.8	34.8	50.1	9.2	11269	16.0
622	8.37	8.37	11.1	76.8	34.9	50.1	8.6	11325	16.4
622	10	7	11.1	76.7	34.8	50.0	8.6	11378	16.2
622	14	5	11.0	76.6	34.6	50.0	8.9	11301	15.2
622	17.5	4	10.8	75.9	34.4	49.8	10.5	10471	14.0

Initial = number of seedlings planted per acre; Row = feet between rows; Within = feet between trees within a row; SI = site index (base age 25) in feet; QMD = quadratic mean diameter; AH = average height of all trees in feet; Crown = crown ratio; Stem = height to first live branch; Cord = number of cords per acre to a 4 inch top at age 23; Scribner = board feet per acre; Cordthin = number of cords removed per acre to a 4 inch top at age 15.

Table 2—Costs and Net Present Values for various initial spacings of simulated loblolly pine stands thinned at age 15 and harvested at age 23

Initial	Row	Within	Seedling	Herb/planting	Disccost	Disccord	Discct	Discsaw	NPV
				Site index 60					
311	10	14	$12.44	$33.47	$204.10	$29.37	$26.91	$488.10	$340.29
311	11.83	11.83	12.44	28.28	193.73	28.98	26.91	489.96	352.12
311	14	10	12.44	23.90	184.97	29.45	26.91	487.01	358.40
311	20	7	12.44	16.73	170.63	34.71	25.04	438.68	327.80
436	10	10	17.42	33.47	209.08	37.54	36.93	413.93	279.32
436	14	7.14	17.42	23.90	189.95	39.11	36.30	407.41	292.87
436	20	5	17.42	16.73	175.61	42.49	31.80	367.71	266.38
622	7	10	24.89	47.81	245.23	43.04	50.57	354.61	202.99
622	8.37	8.37	24.89	40.00	229.61	44.77	49.95	351.49	216.59
622	10	7	24.89	33.47	216.54	42.73	49.57	362.50	238.25
622	14	5	24.89	23.90	197.42	50.81	56.33	311.16	220.89
622	17.5	4	24.89	19.12	187.86	51.99	42.44	286.28	192.85
				Site index 80					
311	10	14	12.44	33.47	204.10	31.65	57.21	1144.05	1028.81
311	11.83	11.83	12.44	28.28	193.73	31.97	57.58	1144.67	1040.49
311	14	10	12.44	23.90	184.97	32.75	56.58	1138.80	1043.16
311	20	7	12.44	16.73	170.63	32.20	53.58	1116.32	1031.47
436	10	10	17.42	33.47	209.08	33.06	79.49	1109.65	1013.13
436	14	7.14	17.42	23.90	189.95	33.46	76.99	1101.47	1021.96
436	20	5	17.42	16.73	175.61	38.88	68.47	1037.20	968.94
622	7	10	24.89	47.81	245.23	36.13	100.39	1032.60	923.89
622	8.37	8.37	24.89	40.00	229.61	33.93	102.65	1037.69	944.65
622	10	7	24.89	33.47	216.54	33.77	101.65	1042.54	961.41
622	14	5	24.89	23.90	197.42	34.95	95.26	1035.51	968.30
622	17.5	4	24.89	19.12	187.86	41.23	87.50	959.45	900.33

Initial = number of seedlings planted per acre; Row = feet between rows; Within = feet between trees within a row; SI = site index (base age 25) in feet; Seedling = cost of seedlings per acre; Herb/planting = is the cost per acre to do banded herbicide applications and for machine planting; Disccost = discounted costs of all operations; Disccord = discounted revenue of pulpwood harvested at age 23 to a 4 inch top; Discct = discounted revenue of pulpwood thinned at age 15 to a 4 inch top; Discsaw = discounted revenue of sawtimber harvested at age 23; NPV = net present value.
A 6 percent interest rate was used for all analyses.

on the low site (from $193 to $238) to $68 on the high site (from $900 to $968).

The minimal effect of rectangular spacing (i.e. 14 x 10 or 14 x 7.1) on volume production is similar to the results reported from unthinned stands. Zhang and others (1996) and Sharma and others (2002a, 2002b) found that when planting more than 800 trees per acre, growth of unthinned 16-year-old loblolly pine was not significantly affected by rectangularity. Although Adams and Clason (2002) reported the diameter of 9-year-old loblolly was 7.2 inches for a 12 x 8 spacing and 7.0 inches for a 16 x 6 spacing, this difference was not significantly different.

Some factors associated with rectangular spacing are difficult to quantify economically. For example, fifth-row-thinnings do not need to be performed. Wide distances between rows allows foresters more management flexibility when conducting selective thinnings. In addition, there may be a reduction in damage to stems during intermediate operations. Wide rows will aid habitat for certain wildlife species. In dense stands with closed canopies, understory vegetation production is small (Lewis 1989, Wolters 1973). Wide rectangular spacings will provide a longer duration of time where the overstory canopy does not completely shade out the understory. Of course, wide spacing between rows of pines was first adopted in the South by agroforesters (Lewis and others 1985).

CONCLUSIONS

Rectangular spacings are used as alternatives to square spacings to reduce regeneration and intermediate silvicultural operation costs, and to increase return on investment. It also provides many benefits that are difficult to quantify economically such as increases in wildlife habitat and easy access to the stand. It is not the point of this paper to provide an optimal planting configuration for all sites, stockings, thinning regimes, and species. Rather, the objective of this paper was to examine the possible economic advantage associated with planting trees in wide rows. Results from this preliminary investigation suggest that rectangular spacings can be used to increase return on investment.

LITERATURE CITED

Adams, J.C.; Clason, T.R. 2002. Loblolly pruning and growth characteristics at different planting spacings. In: Outcalt, K.W., ed. Proceeding of the eleventh biennial southern silvicultural research conference. Gen. Tech. Rep. SRS-48. Asheville, NC:

U.S. Department of Agriculture, Forest Service, Southern Research Station: 153-155.

Balmer, W.E.; Owens, E.G.; Jorgensen, J.R. 1975. Effects of various spacings on loblolly pine growth 15 years after planting. Res. Note SE-211. U.S. Department of Agriculture, Forest Service, Southeastern Forest Experiment Station. 7 p.

Burkhart, H.E.; Farrar, K.D.; Amateis, R.L.; Daniels, R.F. 2001. Simulation of individual tree growth and stand development in loblolly pine plantations on cutover, site-prepared areas. Publ. No. FWS-1-87. U.S. Department of the Interior, Fish and Wildlife Service. 33 p.

Caulfield, J.P.; South, D.B.; Somers, G.L. 1992. The price-size curve and planting density decisions. Southern Journal of Applied Forestry. 16: 24-29.

DeBell, D.S.; Harrington, C.A. 2002. Density and rectangularity of planting influence 20-year growth and development of red alder. Canadian Journal of Forest Research. 32: 1244-1253.

Harms, W.R.; Lloyd, F.T. 1981. Stand structure and yield relationships in a 20-year-old loblolly pine spacing study. Southern Journal of Applied Forestry. 5: 162-166.

Incoll, W.D.; Opie, J.E.; Aeberli, B.C. 1979. Effects of spacing on rate of machine planting of Radiata pine. Australian Forestry. 42: 176-180.

Lewis, C.E. 1989. Herbage yield response to the maturation of a slash pine plantation. Journal of Range Management. 42: 191-195.

Lewis, C.E.; Tanner, G.W.; Terry, W.S. 1985. Double vs. single-row pine plantations for wood and forage production. Southern Journal of Applied Forestry. 9(1): 55-61.

Maclaren, J.P. 1993. Radiata pine growers' manual. FRI Bulletin No. 184. Rotorua, New Zealand: New Zealand Ministry of Forestry. 140 p.

Marty, R. 1988. Red pine spacing and diameter growth. Northern Journal of Applied Forestry. 5(3): 224-225.

Savill, P.; Evans, J.; Auclair, D.; Falck, J. 1997. Plantation silviculture in Europe. New York: Oxford University Press. 297 p.

Sharma, M.; Burkhart, H.E.; Amateis, R.L. 2002a. Modeling the effect of density on the growth of loblolly pine trees. Southern Journal of Applied Forestry. 26: 124-133.

Sharma, M.; Burkhart, H.E.; Amateis, R.L. 2002b. Spacing rectangularity effect on the growth of loblolly pine plantations. Canadian Journal of Forest Research. 32: 1451-1459.

Wakeley, P.C. 1954. Planting the southern pines. Agric. Monogr. 18. Washington D.C.: U.S. Department of Agriculture, Forest Service. 233 p.

Wolters, G.L. 1973. Southern pine overstories influence herbage quality. Journal of Range Management. 26: 423-426.

Zhang, S.; Burkhart, H.E.; Amateis, R.L. 1996. Modeling individual tree growth for juvenile loblolly pine plantations. Forest Ecology and Management. 89: 157-172.

Proceedings of the 12th biennial southern silvicultural research conference

Author(s): Connor, Kristina F., ed.

Date: 2004

Source: Gen. Tech. Rep. SRS-71. Asheville, NC: U.S. Department of Agriculture, Forest Service, Southern Research Station. 600 p.

Station ID: GTR-SRS-071

Description: Ninety-two papers and thirty-six poster summaries address a range of issues affecting southern forests. Papers are grouped in 15 sessions that include wildlife ecology; fire ecology; natural pine management; forest health; growth and yield; upland hardwoods - natural regeneration; hardwood intermediate treatments; longleaf pine; pine plantation silviculture; site amelioration and productivity; pine nutrition; pine planting, stocking, spacing; ecophysiology; bottomland hardwoods - natural regeneration; and bottomland hardwoods—artificial regeneration.