Loblolly Pine - Pushing the Limits of Growth

Bruce E. Borders and Robert L. Bailey

ABSTRACT

The age of intensive plantation forestry in the Southeastern US rapidly approaches. Based on data through age 9 from loblolly pine plantations subjected to complete weed control and multiple fertilizations, growth rates to be expected equal or exceed those for southern pines grown in other countries under intensive cultural practices. Predictions of continuing growth through age 15 and economical analyses indicate that these cultural practices will be excellent financial investments for the owners of forest land.

Loblolly Pine - Pushing the Limits of Growth

Bruce E. Borders and Robert L. Bailey

What is the potential growth rate of loblolly pine in the southeastern United States? Many theories have been proposed as to why pines native to the southeastern U.S. exhibit radically greater growth rates when moved to other parts of the world. It may be that the climate of these areas is responsible for dramatic growth differences and stand density carrying capacity (DeBell and others 1989). Furthermore, when southern yellow pines are grown in exotic locations they are in environments that contain no natural enemies and thus do not suffer attack from native fungi and insects. Clearly, factors such as these can explain part of the differences that have been observed over the years. However, the differences in growth rates of southern yellow pines grown in their native habitat and in exotic locations also have a great deal to do with how stands are managed starting from the time of planting. In fact, cultural practices are routinely very intensive for the management of plantation grown loblolly *(Pinus taeda* L.) and slash pine *(Pinus elliottii* in Brazil, South Africa and other areas where very fast growth rates have been reported for these species. It is routine management practice in many areas of the world to carry out very intensive site preparation (similar to agricultural fields), followed by treatments such as fertilization, mechanical and chemical weed control as well as cultivation treatments during the rotation (Evans 1992).

During the past 20 years study after study has reported large gains in growth due to control of competing vegetation in pine plantations in the southeastern U.S. (Miller and others, 1991; Pienaar and Shiver, 1993; Shiver and Pienaar, 1991; Swindel and others, 1988). Many studies have also shown dramatic increases in growth due to fertilization at time of planting or mid-rotation (Allen and others, 1990; Bengston, 1979; Gent and others, 1986; Stearns-Smith and others, 1992). Other studies have shown increases in growth due to genetic improvement (Cornelius 1994; Hodge and others, 1989; Talbert and others, 1985). Yet other studies have shown increases in growth related to seedling quality and planting method (Wakeley 1969, South 1993). Regardless of all of this evidence the general perception is that southern yellow pines will never realize growth rates in their native habitat that approaches their growth rates in other parts of the world. Below we present empirical evidence that growth rates of loblolly pine under intensive management in the southeastern U.S. may not be all that different from growth rates under intensive management in other parts of the world.

Data

We initiated a long-term growth study of intensively managed loblolly pine plantations in 1987[1]. The main objective of this study is to provide real growth series data for loblolly pine plantations managed under various scenarios that can be studied and possibly correlated to changing atmospheric conditions such as rainfall, temperature and possibly pollution levels. Study installations were established at six locations throughout Georgia. The original study plan called for two complete blocks, each containing four of the 3/8 acre treatment plots, to be established on site prepared land on two distinct sites in close proximity to a weather monitoring station. One of the following treatments was applied to each plot using a randomized complete block design:

H - Herbicide (non-soil active) used to control all herbaceous and woody competing vegetation throughout the life of the study.

F - Fertilize as follows: First two growing seasons - 250 lbs/ac DAP plus 100 lbs/ac KCL in the spring and 50 lbs/ac of DAP in mid-summer. During each subsequent growing season - 150 lbs/ac ammonium nitrate early to mid-summer.

HF - Both H and F treatments.

C - Control treatment - no treatment following standard site preparation.

A fifth treatment is replication of all treatment plots at each location every two years for the first ten years of the study. Due to space limitations it was impossible to apply all treatments described above at all locations. Furthermore, the interval between time replications has been increased to four years. The oldest trees in this study were established in Waycross, Georgia in 1987. For this location we have 9-year measurements. Two installations located in Eatonton,

‘Funding for this study was provided by Georgia Power Company and the Georgia Forestry Commission.

Georgia and one in Tifton, GA are currently 8 years old, and the installation in Athens, Georgia is currently 7 years old. Two other installations, Thompson and Dawsonville, Georgia, are not discussed in this report since there was no fertilizer treatment possible at Thompson (due to space limitations) and the plots in Dawsonville experienced various catastrophes ranging from floods to extensive beaver damage.

Borders et al. (1996) reported on the initial modeling results with data from this study and presented models that relate tree growth rates to environmental conditions and cultural treatments. In our current work we wish to report on the actual rates of growth per unit area for the various treatment combinations and relate these to the economics of timber production with southern pine plantations.

Results

Treatment responses for dominant height (ft) (HD), average diameter (in) (D), basal area per acre (ft^2) (BA), volume per acre (ft^3) (VOL), and surviving stems per acre (SPA) at each location (Tables l-6) shows that more intensive treatment plots grew at faster rates than less intensive treatments. In the following discussion, when specific treatment differences are discussed significance indicates that the differences were statistically significant at the .05 level unless otherwise indicated.

At all locations except the Waycross sites the effect of removing competing vegetation (H treatment) was significantly greater than the effect of the fertilization regime (F treatment). Note, however that at the Tifton site average diameter for the fertilization treatment was greater than for the herbicide treatment. This difference is a result of excessive mortality on the fertilization plots resulting in an average density of 336 spa compared to 624 spa for the herbicide only treatment plots. Magnitude of response at the Waycross sites was greater for the fertilization treatment than for the herbicide treatment, in fact the herbicide only treatment was not significantly larger than the control treatment. It seems that response due to fertilization is site specific, however, response due to vegetation control is more consistent from location to location (i.e. all sites exhibit a positive response due to control of competing vegetation). At the

Tifton location fertilization alone resulted in tremendously increased levels of competing vegetation which ultimately resulted in increased pine mortality. However, at the Waycross locations fertilization not only increased the amount of competing vegetation but increased pine growth over and above that observed on vegetation control plots. Another important observation is that the combination of fertilization and vegetation control resulted in the largest individual trees as well as the largest per acre basal area and volume at all locations.

The objective of this study was to create a series of plots established at the same point in time which grow at different rates. The treatments were not chosen with operational usefulness in mind. Yearly fertilization may or may not be necessary to achieve growth rates similar to those shown above. Regardless, the very intensive HF treatment used in this study may have resulted in achieving the maximum biological growth potential of loblolly pine grown in the southeastern U.S. Mean annual increment of cubic foot volume (MAI) for the most intensive treatment (HF) at the six locations described above ranges from 2.9 cords/acre at the Athens site to 4.7 cords/acre at the Waycross wet site (Table 7). A comparison of these growth rates with growth rates of pines in other states and parts of the world supports a view that our plots are exhibiting loblolly pine growth that approaches the biological maximum for this species. For example, growth through age 9 for the wet-site HF treatment at our Waycross location exceeds any other yet reported for loblolly pine in the US and is just 22 cu ft/ac/yr less than reported growth for the species in Brazil (Table 8).

Growth rates observed in this study are two to three times the levels of standard loblollv pine plantations grown on average sites in me southeastern U.S. which produce on the order of one to one and one half cords/acre/year. In fact, the data presented above show that loblolly pine grown in the southeastern U.S. can approach the highest yields produced anywhere in the world. This production is the result of intensive management including control of all competing vegetation and a yearly fertilization regime. Growth of tree species can be considered to be limited by the necessary factor in shortest supply. If tree nutrition is adequate then water availability may be the limiting growth factor. If water availability is adwquate then nutrition may the limiting factor. Of course there are many possible limiting factors. Allen and others

(1987) have defined a 1.1% level of Nitrogen content in the needles of southern pines as a critical level needed to insure good growth rates. However, in a study reported by Harms and others (1994) they reported on very fast growing loblolly pine in Hawaii that exhibited leaf nitrogen levels of 1.73% which is much higher than any nitrogen levels observed in loblolly pine grown in the southeastern U.S. Although we can not be sure why loblolly pine grown in Hawaii;; grows dramatically faster than most loblolly grown in the southeast, our study would suggest that increased nutritional levels (i.e. yearly fertilization) may be a factor.

Our trees are relatively young, so a reasonable question to ask is how will they grow for the next 5 to 10 years. It is difficult to make growth projections for these tree since there have been no models developed in the southeastern U.S. for loblolly plantations grown under such an intensive regime. However, some development patterns of pine plantations are quite predictable. For example, in general we know that for southern pines the average annual basal area growth culminates three to eight years prior to the age of maximum MAI. With such general patterns in mind, we attempted to identify recorded growth data and yield models for loblolly and other pine species grown in other areas where early growth patterns are similar to those observed on our study plots. By matching such a model or growth-series data to ours, we can then make reasonable projections of growth and preliminary financial analysis of intensive management alternatives.

Several growth and yield models were evaluated on their ability to predict per acre basal area and volume for the Waycross, Georgia wet site at ages 4, 6 and 9 years. Two models were found that gave acceptable predictions. One was developed for loblolly pine grown in South African[2] and the other for Pinus caribaea grown in Sri Lanka[3]. Based on predictions from these models, as well as known patterns of growth for BA and VOL, we extrapolated growth to ages 12 and 15 for the HF treatment at our Waycross wet site (Table 9).

Current production rates are not even close to their potential. Is it possible to realize this type of production operationally and economically? Our study was not intended to simulate

---

[2]Harrison, W.M. , Unpublished manuscript.

[3]Brister, G.H. The growth and yield of Caribbean pine plantations. Unpublished manuscript.

operational procedures. However, complete competition control is now being approached by several organizations on an operational scale. Maybe in the near future not only will complete vegetation control be routine but also multiple fertilization regimes will become operational. With the growth rates observed on these intensively managed areas it may be that in some parts of the Southeast such as south Georgia and other areas where pulpwood is very valuable and in high demand this type of management will not only be possible but will be economically desirable. Based on the data shown above and the extrapolation through age 15, it is clear that intensively managed stands should produce significant amounts of fiber as early as 12 to 14 years of age. It is not unreasonable to believe that current fiber rotation lengths of 20 to 25 years can realistically be reduced to 12 to 15 years while doubling or tripling production on a given acre of ground. Such an approach could have both economic and environmental benefits. From an economic perspective, fewer acres could reduce both harvesting costs and regeneration costs. Of course, from an environmental perspective, production of equal or greater amounts of fiber on fewer acres reduces pressure to convert more and more natural acres to plantations thus possibly facilitating protection of sensitive natural areas.

To look at the economics of intensive management treatments as discussed above we evaluated management scenarios that result in one of three possible yields (pessimistic, average, optimistic). The pessimistic yield assumption will be 4000 ft^3/ac at age 14 (approximately 44 cords/ac or MA1 of 3.1 cords/ac/year). The average yield assumption is 4500 ft^3/ac at age 14 (approximately 50 cords/ac or MA1 of 3.5 cords/ac/year). The optimistic yield assumption is 5000 ft^3/ac at age 14 (approximately 55 cords/ac/year or MA1 of 3.9 cords/ac/year). These yields may seem high when compared to stands that have been managed without intensive treatments. However, as shown above, these types of yields are quite realistic when stands are managed very intensively. We assumed a management scenario begins with a very intensive site preparation treatment which may be mechanical, chemical or a combination mechanical and chemical along with pre-planting fertilization (Table 10). Following a one year delay, the site will be planted at a cost of $80/ac with approximately 680 trees per acre, the planting density used in the our study. During the first and second growing seasons chemical control of herbaceous weed will be performed at a cost of $50/ac (Table 10). In years 2, 6 and 10 additional fertilizer will be applied at a cost of $75/ac (Table 10). We are not proposing any specific fertilization treatments since they will undoubtedly differ by site and soils. In our scenario, the stand will be harvested in year 14 assuming one of the three yield scenarios described above. Note that we are not suggesting that this management scenario is the optimal one or even that it is a reasonable one. We simply put it forward as one alternative that could be used to obtain growth rates of 3 cords/ac/yr, which appears realistic based on results of our study and rates of growth as reported by others (Table 8).

Bare land values (BLV) calculated for each yield scenario with a constant dollar analysis at a 5% discount rate assuming that all volume will be pulpwood at harvest clearly demonstrate the financial feasibility of such intensive management (Table 11). Three stumpage rates were applied ($40, $45 and $50 per cord) and annual taxes and administration costs were assumed to be $7/acre. The results clearly indicate that loblolly pine managed very intensively in the southeastern U.S. to achieve a MA1 of 3 or more cords per acre can be a financial success (Table 11). Even with our most pessimistic assumptions about stumpage rates and growth, the BLV is over $400/acre. The internal rates of return represented by the 9 combinations in Table 11 ranged from 7.8% to 11.6%.

Discussion

Current growth rates of loblolly pine in the Southeast are not even close to their potential. Our data indicate that loblolly pine grown in the Southeast can produce at rates comparable to those reported from its growth throughout other parts of the world. Furthermore, the investment required to obtain these growth rates will be economically feasible. As the forest production land base continues to erode from pressures such as environmental concerns and urban expansion it is sometime prudent to consider this type of intensive management in order to maintain productive capacity.

Literature Cited

Borders, B. E., Y. Zhang and R. L. Bailey. 1996. Modeling the effects of atmospheric inputs and cultural treatments on height growth of loblolly pine. For. Ecology & Mgt. (IN PRESS)

Burns, P. Y. and S. C. Hu . 1983. Ecological and silvicultural factors associated with rapid growth of loblolly pine stands. Proc. Second Biennial S. Silv. Res. Conf., USFS Gen Tec Rpt SE-24, pp. 261-268.

Cornelius, J. 1994. The effectiveness of plus-tree selection for yield. For Ecol and Mgmt 67:23 - 34.

DeBell, D.S., W.R. Harms, and C.D. Whitesell. 1989. Stockability: a major factor in productivity differences between Pinus taeda plantations in Hawaii and the southeastern United States. Forest Science 35(3):708-719.

Evans, J. 1992. *Plantation forestry in the tropics*, 2nd ed. Oxford Science Press. New York, NY. 403pp.

Gent, J.A.Jr., H.L.Allen, and R.G. Campbell. 1986. Phosphorous and nitrogen plus phosphorous fertilization in loblolly pine stands at establishment. Southern Journal of Applied Forestry 1 O(2): 114- 117.

Harms, W.R., D.S. DeBell, and C.D. Whitesell. 1994. Stand and tree characteristics and stockability in *Pinus taeda* plantations in Hawaii and South Carolina. Canadian Journal of Forest Research 24:511-521.

Hodge, G.R., T.L. White, G.L. Powell, and S.M. DeSouza. 1989. Predicted genetic **gains** from one generation of slash pine tree improvement. Southern Journal of Applied Forestry 13(1):51-56.

Miller, J.H., B.R. Zutter, S.M. Zedaker, M.B. Edwards, J.D. Haywood, and R.A. Newbold. 1991. A regional study on the influence of woody and herbaceous competition on early loblolly pine growth. Southern Journal of Applied Forestry 15(4): 169-l 79.

Pienaar, L.V. and B.D. Shiver. 1993. Early results from an old-field loblolly pine spacing study in the Georgia piedmont with competition control. Southern Journal of Applied Forestry 17(4):193-196.

South, D.B. 1993. Rationale for growing southern pine seedlings at low seedbed densities. New Forests 7(1):63-92.

Stearns-Smith, S.C., E.J. Jokela, and R.C. Abt. 1992. Thinning and fertilizing southern pine stands of the lower coastal plain: biological and economic effects. Southern Journal of Applied Forestry 16(4): 186-193.

Swindel, B.F., D.G. Near-y, N.B. Comerford, D.L. Rockwood, and G.M. Blakeslee. 1988. Fertilization and competition control accelerate early southern pine growth on flatwoods.

Southern Journal of Applied Forestry 12(2): 116- 12 1.

Talbert, J.T., R.J. Weir, and R.D. Arnold. 1985. Costs and benefits of a mature first-generation loblolly pine tree improvement program. Journal of Forestry 83: 162- 165.

Wakeley, P.C. 1969. Results of southern pine planting experiments established in the middle twenties. Journal of Forestry 67:237-241.

Table 1. Mean treatment values for the Athens location at age 7.

Treatment	HD(ft)	D(in)	BA(ft^2/ac)	VOL(ft^3/ac)	SPA
C	23.5	3.5	44.9	547	620
F	24.3	4.2	47.5	576	480
H	31.7	5.3	89.2	1369	580
HF	33.4	5.8	116.7	1843	616

Table 2. Mean treatment values for the B.F. Grant powerline site at age 8.

Treatment	HD(ft)	D(in)	BA(ft^2/ac)	VOL(ft^3/ac)	SPA
C	28.7	3.9	54.7	0	636
F	33.9	4.9	74.5	1226	564
H	39.3	5.4	101.9	1908	628
HF	42.3	6.3	125.3	2454	588

Table 3. Mean treatment values for the B.F. Grant monitor site at age 8.

Treatment	HD(ft)	D(in)	BA(ft^2/ac)	VOL(ft^3/ac)	SPA
C	27.0	3.8	51.4	708	640
F	31.4	4.7	73.6	1133	592
H	38.5	5.7	108.6	1951	612
HF	39.4	6.0	119.9	2225	584

Table 4. Mean treatment values for the Tifton site at age 8.

Treatment	HD(ft)	D(in)	BA(ft^2/ac)	VOL(ft^3/ac)	SPA
C	30.8	4.8	72.2	1110	568
F	34.1	6.6	82.6	1389	336
H	37.6	5.6	**109.7**	2037	624
HF	41.2	6.4	128.0	2533	564

Table 5. Mean treatment values for the Waycross dry site at age 9.

Treatment	HD(ft)	D(in)	BA(ft^2/ac)	VOL(ft^3/ac)	SPA
C	35.4	4.5	72.3	1217	592
F	46.9	6.4	137.2	2810	640
H	41.2	5.5	107.0	1928	624
HF	47.2	6.4	150.0	3133	648

Table 6. Mean treatment values for the Waycross wet site at age 9.

Treatment	HD(ft)	D(in)	BA(ft^2/ac)	VOL(ft^3/ac)	SPA
C	33.8	4.1	65.0	956	672
F	48.3	6.3	153.3	3276	684
H	40.3	5.2	101.0	1826	672
HF	53.5	6.6	158.9	3780	648

Table 7. Mean annual increment (ft^3/ac/yr and cords[1]/ac/yr) for the HF treatment at six locations.

Installation	Age	MAI(ft^3/ac)	MAI(cords/ac)
Athens	7	263.3	2.9
BF Grant - powerline	8	306.6	3.4
BF Grant - monitor	8	278.1	3.1
Tifton	8	316.6	3.5
Waycross - dry site	9	348.1	3.9
Waycross - wet site	9	420.0	4.7

1 Assume 90 ft^3 of wood and bark per cord

Table 8. Mean annual increment (MAI) of total volume (ft^3/ac) for plantations of various pine species at different locations around the world (bold type indicates sites from the University of Georgia study discussed above).

Location	Species	MAI	Rotation
Costa Rica[1]	P. caribaea	**572**	8
Brazil[1]	P. caribaea	**386**	16
Fiji[1]	P. caribaea	**300**	12-15
Swaziland[1]	P. patula	**272**	15
Malawi[1]	P. patula	**257**	**16**
South Africa[2]	P. taeda	**523**	**22**
Brazil[2]	P. taeda	**442**	**8**
Waycross, GA	**P. taeda**	**420**	**9**
Australia[2]	P. taeda	**382**	**16**
Hawaii[2]	P. taeda	**371**	11
S. Carolina[2]	P. taeda	**352**	11
Waycross, GA	**P. taeda**	**348**	9
Tifton, GA	**P. taeda**	**317**	8
Eatonton, GA	**P. taeda**	**307**	8
Eatonton, GA	**P. taeda**	**278**	8
Athens, GA	**P. taeda**	**263**	7
Louisiana[2]	P. taeda	**252**	19

1 From Evans (1992)

2 From Burns and Hu (1982)

Table 9. Actual growth for ages 4, 6 and 9 along with predicted growth for ages 12 and 15 for loblolly pine in the Southeast US under intensive cultural practices. Values shown for trees/acre, average height of dominant trees (HD), basal area (BA) and cubic volume per acre (VOL).

Age	Trees/ac	HD(ft)	BA(ft^2/ac)	VOL(ft^3/ac)
4	652	18.4	46.9	_
6	652	36.8	104.8	_
9	648	53.5	158.9	3780
12	632	65	197	4800
15	608	76	222	5500

Table 10. Costs of various management activities for an intensively managed stand which is harvested at age 14.

Year	Activity	Cost($)
0	Intensive site preparation	200
1	Planting	80
1	Herbaceous weed control	50
2	Fertilization	75
2	Herbaceous weed control	50
6	Fertilization	75
10	Fertilization	75
14	Harvest	

Table 11. Bare land value ($/acre) for three yield scenarios and 3 stumpage values for an intensively managed stand harvested for pulpwood at age 14.

	Yield Scenario		
Stumpage	Pessimistic	Average	Optimistic
$/ac	------ Bare Land Value		
40	452	675	860
45	656	906	1115
50	860	1138	1370