Impacts of Harvest and Post Harvest Treatments on Early Height Growth Trends of Loblolly Pine (*Pinus taeda* L.)

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ABSTRACT

This study was conducted at two locations in Fred, TX and Bryceland, LA. The objectives of this study were to investigate the impacts of harvest and post harvest treatments of *Pinus taeda* L. on height growth trends between two successive rotations and to determine what age will be most applicable to individual stands between two rotations. Prior to establishment of new stands at both locations, stem analysis was undertaken in order to calculate ages for various stem heights. A randomized complete block design was used in both locations. The factorial treatments consisted of two levels of harvest techniques and three levels of post-harvest treatments. Linear regression analysis was used to predict plant height at different growth ages at both locations. In Fred, TX location, all treatments showed high significant effects on height growth. In the fertilized treatment, height growth was 24% greater than in the unfertilized treatment. In Bryceland, LA, harvesting and site preparation had high significant effects on height growth, the highest growth was detected in chemical site preparation plus broadcast burning. The unpaired t-test was used to assess whether the pre- and post-harvest treatments are significantly different at each age at both locations. In Fred/Texas, height growth was significantly increased in pre-and post-harvest treatments at the ages 3, 4 and 9 years. The same trend was observed in Bryceland, LA. In Bryceland, LA, all treatments exhibited a significant increase on plant growth except chemical site preparation plus a broadcast burn treatment, which showed a significant reduction in height growth at all ages.

Keywords: *Pinus taeda*, Stand establishment, Height growth, Pre-rotation, Post-rotation, Site preparation, Height growth trend.

INTRODUCTION

Loblolly pine (*Pinus taeda* L.) is a highly flexible species with respect to growth response to forest management. It is the most widely planted species across the southern United States; a region with the most expansive and intensively managed forest plantation in the world (Samulsen et al., 2004). Intensive silviculture may potentially affect site productivity through periodic addition and removal of nutrients and changing of soil physical and chemical properties during harvesting and preparation (Powers et al., 1990 and 1996; Xu et al., 1997; Carter et al., 2002; Borders et al., 2004). Forest site preparation manipulates surface soil and is intended to improve soil conditions for seedling survival and tree growth. Successful forest management depends on minimizing the negative effects of silvicultural practices, generating new stands to the same prior condition to harvesting and maximizing the positive effects of such operation on the ecosystem.

Sustainability of commercial important plantation species for wood production, such as loblolly pine in the

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southeastern United States, has intensified the need for information on the efficiency of silvicultural practices (site preparation, harvesting methods and fertilization) in order to sustain long-term site productivity.

Bedding improves seedling survival and growth of moderately and poorly drained silty loam or sandy soils. This can be attributed to an increase in aeration for roots. Bedding incorporates organic matter, exposes mineral soil, ameliorates disturbed soil and raises the seedbed above the water table to improve soil aeration. Results from lower coastal plains indicated that bedding effectively ameliorates disturbed soil properties and improves survival and growth in moderately to poorly drained silt loam or sandy soils (McKee and Schoulders, 1970 and 1974). Hence, many studies have shown that bedding has positive effects on survival, growth and early tree development, but the long-term effect of bedding may not be positive. Enhanced seedling growth usually occurs on bedded and other mechanical prepared sites until the age of 8-13 years, but growth rate converges to unbedded growth rates after the age of 14 years.

Height growth rate is an important indicator of productivity for understanding the whole process of stand development and helping predict appropriate silvicultural treatments for young stands in forest management. Research should have the ability to investigate the effect of current and previous silvicultural treatments that have been shown to enhance growth to evaluate their effects on long-term stability.

Degradation of forest ecosystems which leads to declining of stand growth may be attributed to various natural and anthropogenic factors such as climatic extremes, biotic stresses, selection of tree species, harvesting regimes, litter raking, off-site amelioration measures, former land use, air pollutant deposition and soil acidification (Wright and Bailey, 1982). Important factors for a loss of tree vitality are nutritional disturbances, eventually leading to declining stand stability and productivity. Marino et al. (2002) reported that in a mid-rotation loblolly pine plantation experiment in northeastern Texas, fire had a negligible effect on growth with or without fertilizers. They also suggested that thinning practices can significantly alter the impact of herbicides and fire on tree growth. Intensive cultural treatment (complete vegetation control plus annual fertilization) increased growth as compared to the best loblolly pine growth anywhere up to 270% (Border and Bailey, 2001). This is in agreement with James et al. (2004) who reported that site preparation, vegetation control and fertilization treatment combinations produced additional volume gains when compared to single treatments in loblolly pine in the southeastern U.S. Annual high rate of nitrogen fertilization and complete vegetation control plus fertilization increased stem diameter.

Borders and Bailey (2001) found that when fertilization and vegetation control were applied together, stand basal area and volume of 10-12 year-old-pine trees increased at only six sites in Georgia. Growth efficiency response to silvicultural treatments is also unpredictable in loblolly pine. Albaugh et al. (1998) reported that the growth efficiency of 8-year–old loblolly pine trees was positively affected by fertilization on nutrient deficient and drought sites, but Samuelson et al. (2004) reported no effect of fertilization on growth efficiency of 4-year-old loblolly pine trees on an old field site of moderate quality.

Fertilizers may be used to improve pine tree height growth in early plantation establishment. Fertilization may also result in a shift towards competing vegetation, causing a potential increase in pine mortality. Height growth response to fertilization may vary from site to site, depending on pre-treatment soil conditions such as nutrient, soil type and water availability (Borders and

Bailey, 2001; Nilson and allen, 2003). Chemical herbicides control of competing vegetation combined with fertilization may increase pine height growth when chemical competition control or prescribed burning is added to fertilization or site preparation practices.

Fertilization is a way to improve growth or overcome deficiencies on paleudult soils; it can increase slash pine yields in the first rotation as well as total height in the second rotation (Haywood and Tiarks, 1996; Jokela et al., 2000). Thus, to compare the height growth of two rotations of southern pine, we utilized two study areas in Fred, Texas and Bryceland, Louisiana that had been established to measure the effect of harvesting intensity, fertilization, harvesting, bedding and broadcast burning on stand development to compare height growth of loblolly pine by clear cutting and replanting loblolly pine in the same plots in order to understand how sustainable productivity can be influenced by silvicultural practices. Therefore, the objectives of this study were: (1) to compare height growth between successive rotations to identify the effect of treatments on differences in height growth of planted loblolly pine, (2) to determine what single function of age will be most applicable to individual stands.

MATERIALS AND METHODS

Study Sites

This study was conducted at two locations: near Fred, TX and near Bryceland, LA. The Fred site (30.6°N, 94.4° W) was a 26-year-old loblolly pine plantation on the property of Temple-Inland Forest Products Corporation. The site has a warm, humid climate with an average annual temperature of 19.4° C ranging in monthly means from 10°C in January (coldest month) to 27°C in July (warmest month). The average frost-free period is 241 days long. Average annual precipitation is 136 cm per year and precipitation is generally evenly distributed throughout the year. The elevation of the site ranges from 17 to 19 m above sea level with gentle slopes between 0 and 3%. The dominant soil was Kirbyville, a very deep, moderately drained, moderately permeable soil formed in loamy coastal plain sediments of mid Pleistocene age. Prior to harvest in August 1994, the site was a loblolly pine stand generated directly from seeds in 1968 and thinned in corridors at the age of 15 years. There had been at least three rotations of pine culture on the site.

The second location was in a 30-year-old plantation of loblolly pine beginning August 1995. This site is owned by Weyerhaeuser Co. The site (31°11` N, 92° 41` W) is characterized by a climate with an average annual temperature of 24˚C ranging in monthly means from 10°C in January (coldest month) to 27.5˚C in July (warmest month). The average frost-free season is 250 days long. Annual precipitation averaged 137 cm, generally evenly distributed throughout the year. The elevation of the site ranges from 80 to 90 m above sea level.

Experimental Design at Study Locations

Fred, Texas

The experimental design at this location was a randomized complete block design with twenty four (28 m x 52 m) plots assigned to three blocks. Eight factorial treatments were randomly assigned to plots within each block. The factorial treatments consisted of two levels of harvesting disturbance, presence or absence of bedding and presence or absence of fertilization. Harvesting levels were either a high intensity disturbance with whole-tree removal from the plot or low intensity disturbance with only the commercial portion of the bole removed. The high disturbance method removed large amounts of organic matter from the site and in many cases compacted the soil as a result of machine traffic on the site. Minimum disturbance harvesting removed the least possible amount of organic matter avoiding soil compaction associated with machine traffic. Fertilized plots received 250 kg/ha of diammonium phosphate. Prior to planting mixture of imazapyr and glyphosate (Arsenal and Garlon 0.56= 1.12kg/ha) were applied at site preparation rate. Harvesting occurred in August 1994, and trees were planted in 1995, seedlings were planted at a spacing of 2 m x 3 m .The average number of surviving trees/plot was about 85% (Carter et al., 1998).

Bryceland, Louisiana

The experimental design at this location was also a randomized complete block design, but with four blocks instead of three and six treatments instead of eight. Plots were also 28 m x 52 m. The factorial treatments consisted of two levels of harvest disturbance and three levels of postharvest treatments. The harvesting levels were the same as those used at Fred, TX. The postharvest treatments consisted of chemical site preparation, chemical site preparation plus herbaceous release with herbicides and chemical site preparation plus a broadcast burn treatment.

The area was harvested during the fall and winter of 1995/1996. Chemical site preparation was applied in June 1996, broadcast burning occurred in September and October and seedlings were planted during the winter of 1997. Herbaceous release was applied the following April at a spacing of 2 m x 3 m. The average number of surviving trees/plot was about 90 % (Carter et al., 1998).

Measurements

Prior to harvest, stem analysis was undertaken to estimate the height at various ages of the dominant and codominant trees in the stand. At the Fred site 72 trees were cut, and at the Bryceland site 56 were cut. Discs were cut every 0.5 m interval from the base of the tree to 10 m and were cut every 1 m from 10 m upward. The number of rings from the pith were counted to produce height and age curves for the prior stands. These values were compared to the annual height measurements of the newly planted stands to determine if regeneration practices positively or negatively affected site productivity.

Statistical Analysis

The normal distribution of heights in each age was evaluated by the Shapiro-wilk statistic (SAS, 1991). Data were analyzed using General Linear Models as implemented by SAS. Analysis of variance (ANOVA) procedures were conducted. All references to significance are based on α=0.05 unless otherwise stated.

Height growth rate was determined by generating a height distribution at each age from which height measurements were assigned and tested by fixing the intercept to -1.

RESULTS

Selection of a Height-Growth Model

All heights were included in the analysis over age data in Fred, TX (17339 pre-stand observations, 876 observations in post-stand) and in Bryceland, LA (16972 pre-stand observations and 1697 in post-stand observations).The linear regression analysis of the form height = b_o+b_1 (age) is best fit for the ages from 3 to 9 years in Fred, TX (Table 1) and from 3 to 8 years in Bryceland, Louisiana (Table 2). Data for each plot was fit to the linear model. To simplify the analysis, the intercept was fixed at -1, while fitting a linear model to the height and age data ignored curvilinearity in the data, fixing the slope and assuming linear growth allowed treatment comparisons of a standardized estimate of growth rate. Analysis indicated that slope coefficients obtained from treatments in all ages were over (r^2 = 0.92) in Fred, TX and over (r^2 = 0.84) in Bryceland, LA. The highest height growth can be obtained in Fred, TX where the slope =1.41 in block C where the treatments of mechanical whole bole harvesting with fertilization and bedding were implemented. The lowest height growth can be obtained where the slope = 0.91 in block C where the treatments of hand bole harvesting with no fertilization and no bedding were applied.

Table 1. Equations for height-age in Fred, TX, treatments, number of observations, slopes, R^2, Pr>F and R^2 tested at 0.05 level in post-harvest treatments.

Treatments				N	Slope	R^2	Pr>F
A	H0	F0	S0	738	1.215	0.9703	0.0001
A	H0	F0	S1	717	1.044	09667	0.0001
A	H0	F1	S0	656	1.172	0.9493	0.0001
A	H0	F1	S1	713	1.261	0.9724	0.0001
A	H1	F0	S0	566	1.114	0.9655	0.0001
A	H1	F0	S1	668	1.208	0.9717	0.0001
A	H1	F1	S0	792	1.147	0.9584	0.0001
A	H1	F1	S1	806	1.291	0.9846	0.0001
B	H0	F0	S0	968	1.033	0.9326	0.0001
B	H0	F0	S1	779	0.991	0.9700	0.0001
B	H0	F1	S0	747	1.243	0.9658	0.0001
B	H0	F1	S1	847	1. 227	0.9712	0.0001
B	H1	F0	S0	649	1.010	0.9432	0.0001
B	H1	F0	S1	721	1.051	0.9665	0.0001
B	H1	F1	S0	686	1.270	0.9659	0.0001
B	H1	F1	S1	784	1.294	0.9802	0.0001
C	H0	F0	S0	696	0.905	0.9209	0.0001
C	H0	F0	S1	663	1.068	0.9678	0.0001
C	H0	F1	S0	764	1.334	0.9778	0.0001
C	H0	F1	S1	717	1.351	0.9774	0.0001
C	H1	F0	S0	748	1.088	0.9797	0.0001
C	H1	F0	S1	774	1.127	0.9490	0.0001
C	H1	F1	S0	683	1.382	0.9614	0.0001
C	H1	F1	S1	619	1.407	0.9830	0.0001

Symbols: A B C= blocks, F0=no fertilization, F1=fertilization with diamonium phosphate, Ho=hand felling, H1=mechanical felling, S0=no bedding, S1=bedding.

At Bryceland, LA, the highest growth can be obtained where the slope = 1.90 in block A where hand felling harvesting with chemical site preparation treatments were applied. The lowest growth can be found where the slope = 0.96 in block A where treatments of mechanical whole bole harvesting with chemical site preparation were applied (Table 2).

Table 2. Equations for height –age, in Bryceland, LA, treatments, number of observations, slopes, R^2, Pr>F and R^2 tested at 0.05 level in post-harvest treatments .

Treatment			N	Slope	R^2	Pr>F
A	H0	S0	623	1.895	0.9674	0.0001
A	H0	S1	767	1.068	0.9823	0.0001
A	H0	S2	682	1.571	0.9802	0.0001
A	H1	S0	643	0.964	0.9787	0.0001
A	H1	S1	754	1.099	0.9806	0.0001
A	H1	S2	681	1.099	0.9816	0.0001
B	H0	S0	665	1.172	0.9821	0.0001
B	H0	S1	747	1.210	0.9891	0.0001
B	H0	S2	682	1.299	0.9832	0.0001
B	H1	S0	717	1.088	0.9870	0.0001
B	H1	S1	687	1.054	0.9682	0.0001
B	H1	S2	688	1.217	0.9863	0.0001
C	H0	S0	729	1.174	0.9865	0.0001
C	H0	S1	769	0.976	0.9770	0.0001
C	H0	S2	620	1.141	0.9810	0.0001
C	H1	S0	624	1.040	0.9771	0.0001
C	H1	S1	763	1.033	0. 9868	0.0001
C	H1	S2	776	1.271	0.9909	0.0001
D	H0	S1	736	1.235	0.9834	0.0001
D	H0	S2	760	1.226	0.9804	0.0001
D	H0	S2	708	1.281	0.9875	0.0001
D	H1	S0	754	1.198	0.9869	0.0001
D	H1	S1	767	1.140	0.9809	0.0001
D	H1	S2	629	1.085	0.844	0.0001

Symbols: Ho=hand felling, H1=mechanical felling, S0= chemical site preparation, S1= chemical site preparation plus herbaceous release with herbicides, S2= chemical site preparation plus broadcast burning.

Effects of Treatments on Height Growth in Fred, Texas

At Fred, Texas, analysis of variance indicated that all treatments of harvesting techniques, site preparations and fertilization treatments had high significant effect on height growth, the interaction between harvestings and site preparations also had high significant effect on height growth, where other second and third interactions between treatments had no significant effect (Table 3).

The greatest average height for all measured trees (6.57 m) occurred under fertilized treatment, where the lowest value (5.32 m) was under the no fertilization treatment. The fertilized treatments were 24 % greater than the unfertilized treatment. Mechanical harvesting was 4 % greater than hand bole felling. The same trend was shown in treatments by bedding. Treatment with bedding was 2.5 % greater than treatment without bedding (Table 4).

The greatest average height was obtained in the fertilized, bedded and mechanical harvesting treatment. This is expected from the main effect results and there were few interactions. This would suspect it to be significantly different from other interactions.

Table 3. Effect of harvesting, fertilization, site preparations (bedding) and interactions between treatments on height growth of *Pinus taeda* L. stands (ANOVA results) in Fred, TX.

Source	DF	Type III SS	Mean Square	F-Value	Pr > F
HARV	1	202.246818	202.246818	23.82	<.0001
FER	1	5304.938401	5304.938401	624.92	<.0001
SIT	1	80.152902	80.152902	9.44	0.0021
HARV*FER	1	15.039415	15.039415	1.77	0.1832
HARV*SIT	1	122.114076	122.114076	14.39	<.0001
FER*SIT	1	29.592998	29.592998	3.49	0.0619
HARV*FER*SIT	1	10.544298	10.544298	1.24	0.2651

Symbols: HARV= harvesting, FER=fertilization, SIT= site preparation.

Table 4. Effect of harvesting, fertilization, bedding, site preparations and interactions between treatments on mean height growth of *Pinus taeda* L. in Fred, TX .Means followed by the same letters are not significantly different at the 0.05 level according to DMRT.

Treatments	Mean Heights	Interactions between treatments	Mean Heights
H0	6.08b	H0*F0*S0	5.25a
H1	5.83a	H0*F0*S1	5.06a
F0	5.32b	H0*F1*S0	6.43a
F1	6.57a	H0*F1*S1	6.54a
S0	5.88b	H1*F0*S0	5.32a
		H1*F0*S1	5.63a
S1	6.03a	H1*F1*S0	6.47a
		H1*F1*S1	6.85a

Symbols: Ho=hand felling, H1=mechanical felling, F0=No fertilization, F1=fertilization with diamonium phosphate, S0=No bedding, S1=bedding.

Comparison of Growth Development between Two Rotations

In block A(according to unpaired t-test), the height growth of 3, 4 and 9 years old loblolly pine trees was significantly higher in the second rotation compared with the previous rotation (Fig.1). The percent increase in height growth of these ages was about 67, 23 and 13%, respectively. On the other hand, height growth was not significantly affected by post rotations in the ages of 5, 6, 7 and 8 years. The same results were obtained in block B(Fig.2), where height growth showed significant increase in the age of 3 years, the height growth increase was about two folds compared with the initial height. In the other ages, there was an increase in height growth in the post rotation but these heights were not significant. In block C (Fig. 3), the same height growth increase trends were observed in the age of 3 and 4 years, the percent increase was 63 and 31%, respectively. There was no significant height difference in the other ages even though a greater height was recorded in the post-rotation.

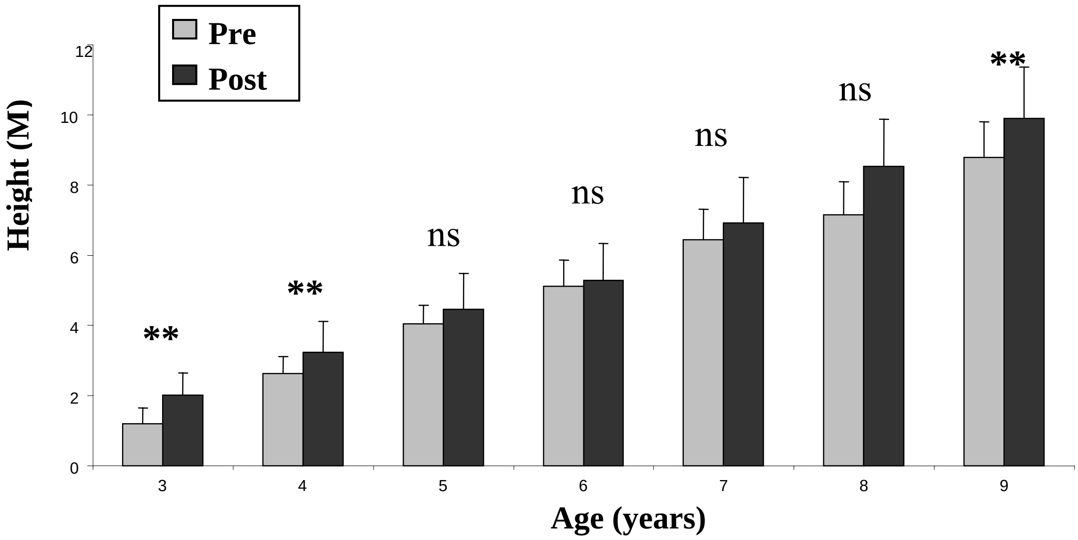

Figure 1. Pre-and post-rotation of *Pinus taeda* L. height growth. Mean height in block A (: significant differences; ns: not significant).**

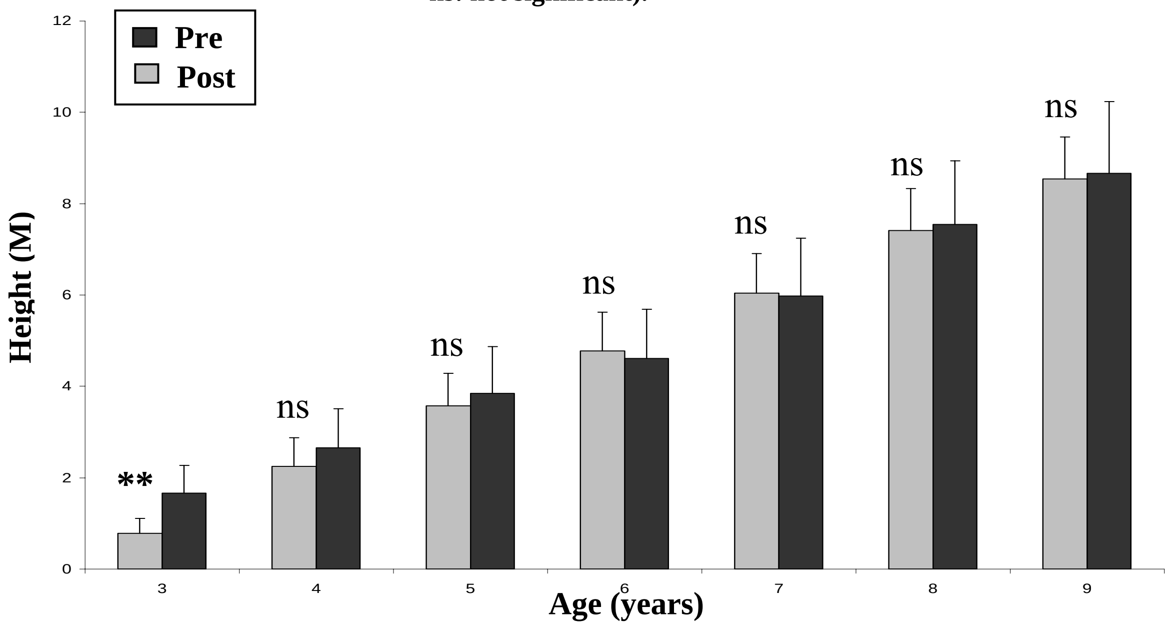

Figure 2. Pre-and post-rotation of *Pinus taeda* L. height growth. Mean height in block B (: significant differences; ns: not significant).**

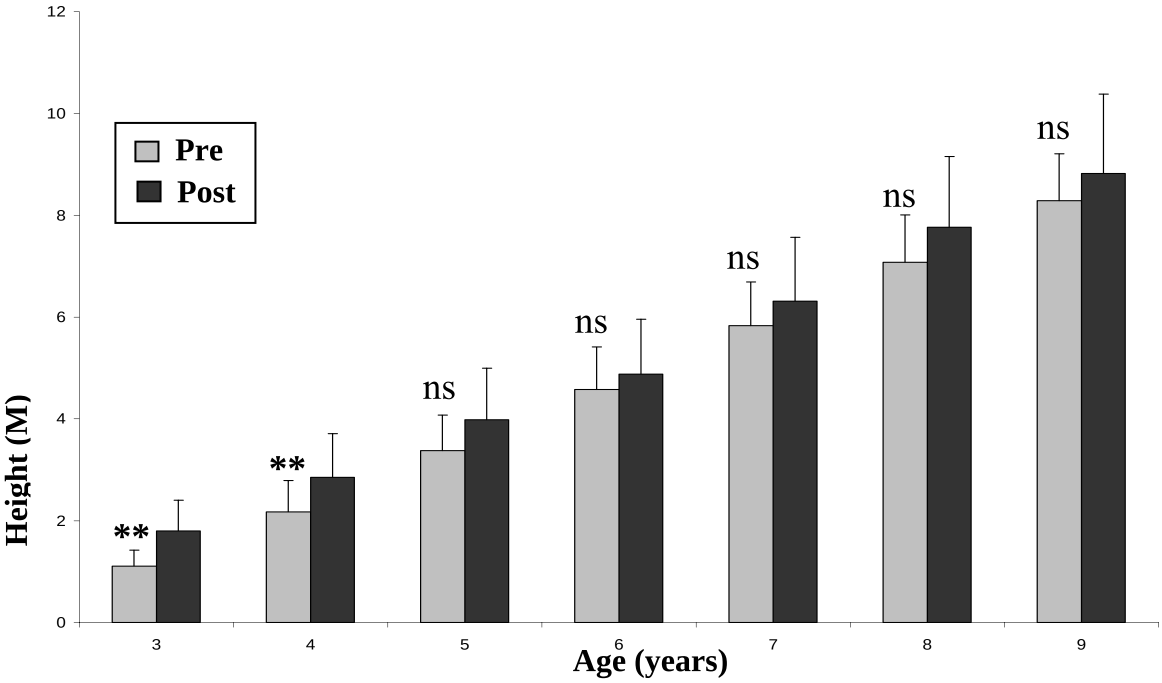

Figure 3. Pre-and post-rotation of *Pinus taeda* L. height growth. Mean height in block C (: significant differences; ns: not significant).**

Effects of Treatments on Height Growth (Brycland/LA)

Table 5 shows the ANOVA test results for treatment effects on the standardized estimate of the annual rate of height growth. Both treatments of harvesting technique and site preparation had high significant effect on height growth (p <0.0001), the interaction between these two treatments had also high significant effect on height growth of planted loblolly pine (p<0.0001) Table (5**).**

Table 5. Effect of harvesting, site preparation and interactions between treatments on height growth of *Pinus taeda* L. stands (ANOVA results).

Source	DF	Type III SS	Mean Square	F-Value	Pr > F
HARV	1	206.6277031	206.6277031	27.75	<.0001
PREP	2	599.9018042	299.9509021	40.28	<.0001
HARV*PREP	2	197.1622889	98.5811444	13.24	<.0001

Harvesting by hand felling showed 20% more height growth than mechanical felling. Height growth was significantly high in site preparation treatments. The maximum height growth was detected in the chemical site preparation plus broadcast burning (5.44 m), followed by site preparation by chemicals (5.10 m), and the lowest height growth was recorded in chemical site preparation plus herbaceous release (4.90 m). The highest growth was 5.51 m in the interaction treatment as compared with hand felling and chemical site preparation, but this difference was not significant compared to other interactions (Table 6**).**

Table 6. Harvesting and site preparation and their interaction effects on height growth of *Pinus taeda* L. stands. Means followed by the same letters are not significantly different at the 0.05 level according to DMRT.

Treatments	Mean height (m)	Interactions between treatments	Mean height (m)
H0	5.03a	H0* S0	5.51a
H1	5.04b	H0* S1	4.94a
S0	5.10b	H0* S2	5.47a
S1	4.90c	H1* S0	4.87a
S2	5.44a	H1* S1	4.85a
		H1* S2	5.41a

Symbols: Ho=hand felling, H1=mechanical felling, S0= chemical site preparation, S1= chemical site preparation plus herbaceous release with herbicides, S2= chemical site preparation plus broadcast burning.

Height Growth Trend in Post-rotation

In the treatment of chemical site preparation (according to t-test), height growth by ages of 4, 5, 7 and 8 years of loblolly pine trees was significantly higher in the second rotation compared with the previous rotation (Fig. 4). The percent increase in height growth of these ages was about 15, 13, 11 and 13 %, respectively, where in the ages of 3 and 6 years there was no significant difference even if there was a slight increase.

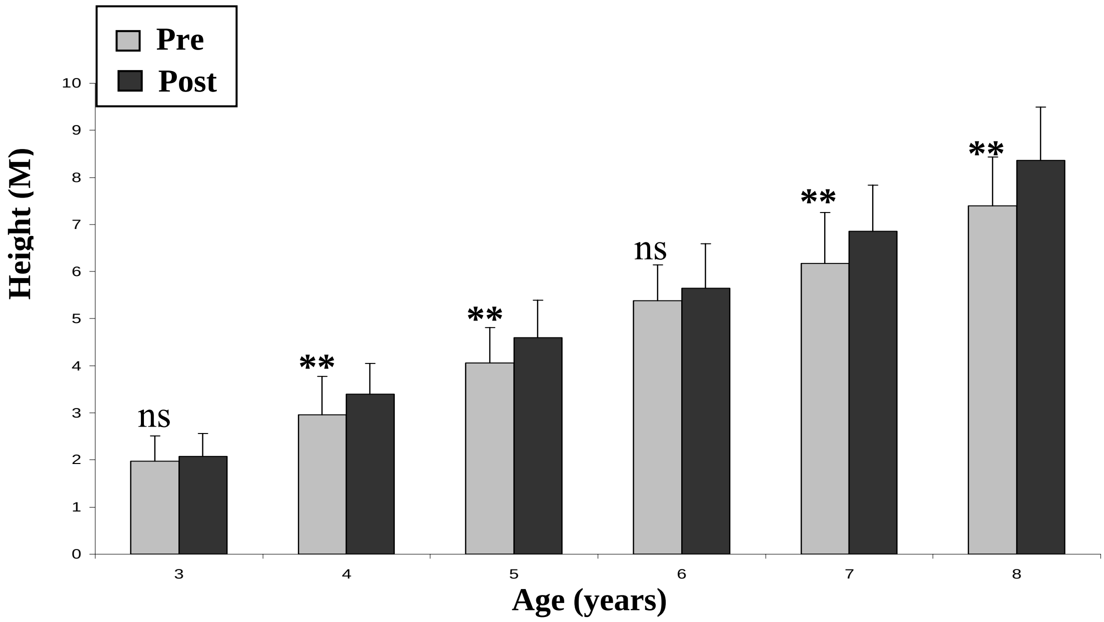

Figure 4. Height of *Pinus taeda* L. stands in the Pre-and post-rotations in the chemical site preparation treatment. Mean heights (: significant differences; ns: not significant).**

In the conducted broadcast burn treatment, the obtained results have taken a reverse trend. There were significant decreases in height growth in the ages of 3, 4, 5 and 6 years in the successive rotation. The percentages of reduction were about 12, 10, 10 and 7 %, respectively (Fig. 5), where in the age of 7 years there was the same height growth.

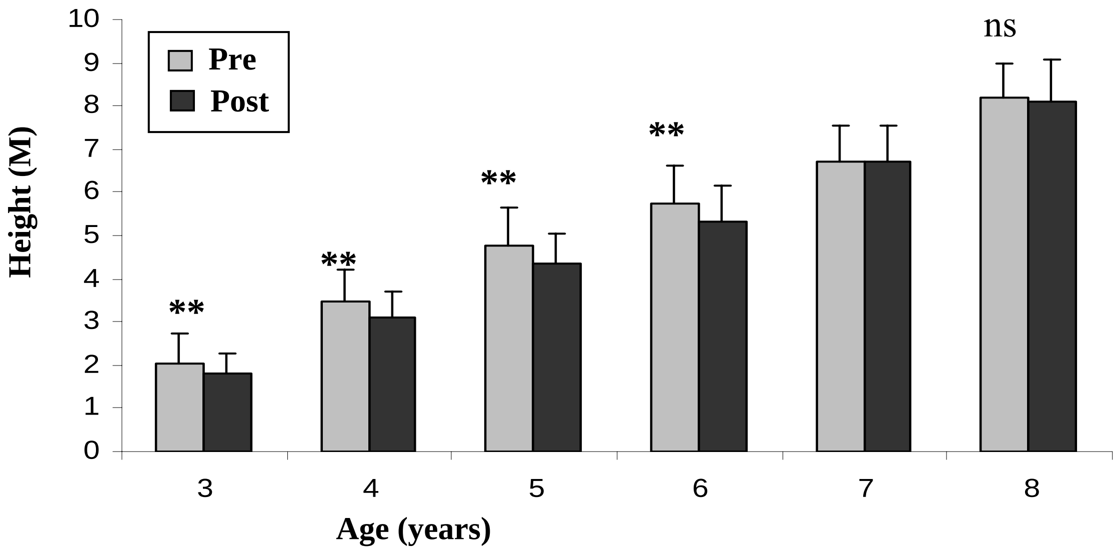

Figure 5. Height of *Pinus taeda* L. stands in the Pre-and post-rotations in the broadcast burn treatment (: significant differences; ns: not significant).**

In the herbaceous release treatment, there was the same trend as in the chemical site preparation treatment (Fig. 6) in the ages of 3, 4, 5, 6, 7 and 8 years. In successive post-rotation, there was a significant increase in height growth. The percent increases were 18, 16, 14, 18, 17 and 15 %, respectively.

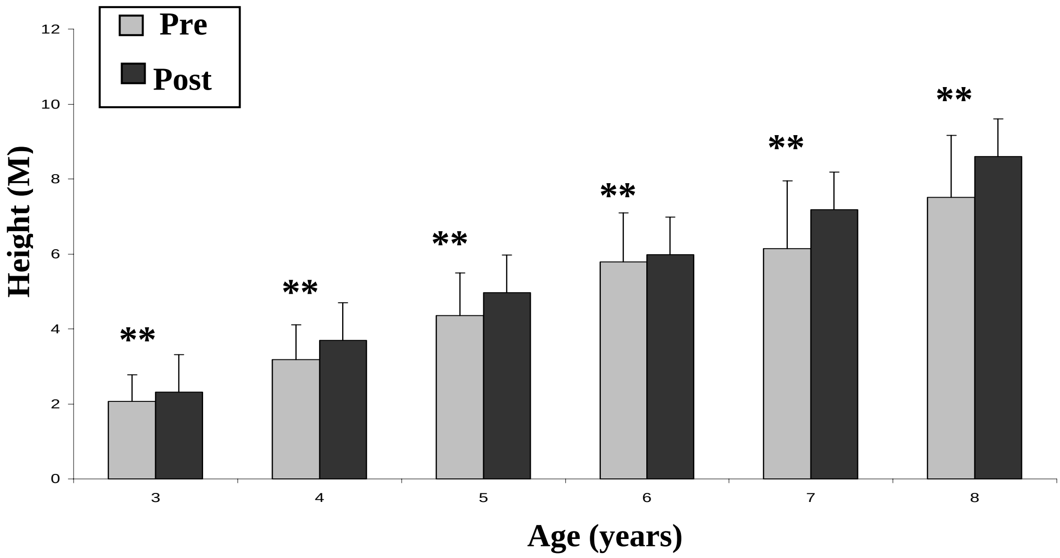

Figure 6. Pre-and post *Pinus taeda* L. stands treated with chemical site preparation (herbaceous release) (: significant differences; ns: not significant).**

DISCUSSION

Height growth as an indicator of productivity was studied in both locations. Harvesting techniques are of highly significant effect on height growth ($p < .0001$). Also, positive effect of fertilization on the rate of height growth was detected ($p < .0001$). Bedding as site preparation treatment has also a significant effect on height growth ($p < .0021$) as indicated by the ANOVA test. This result agreed with results obtained from equations which showed that highest height growth was the result of applying mechanical harvesting plus fertilization and bedding (Table 1). Height increase can be a result of fertilization and can be linked with increases in net photosynthesis and foliage production.

The effects of bedding and harvesting on height growth were additive or synergic to each other. These results agreed with previous research which has been reported that fertilization had the positive effects on loblolly pine above ground productivity (Albaugh et al., 1998; Albaugh et al., 2004; Border and Baily, 2001; Sword et al., 2004; Rahman et al., 2006). Fertilization can compensate the loss of nutrients as a result of whole bole removal, and bedding can improve soil aeration and compaction of soil as a result of mechanical harvest. In Bryceland, LA the highest growth was the result of hand felling and chemical site preparation, this can be explained by the fact that hand felling leaves un-commercial biomass which releases essential nutrients to the plants during decomposition and humus formation, and chemical site preparation suppresses competing vegetations as a result of more growth in height.

In post –harvest rotation, we also find that in the fertilized treatment height growth increase was about 67 % at the ages of 3 and 4 years in the second rotation. At ages of 5 to 9 years, only about 10 % increase in the current stand over the previous rotation (Fig.1, 2 and 3) was detected. Height growth increase can be attributed, in the ages of 3 and 4 years, to the acceleration of nitrogen mineralization and its availability to seedling roots reaching nutrients in the root zone. These results agreed with Nilson and Allen (2003) who reported that fertilization at planting, in combination with high intensive site preparation, improved volume growth during the first 10 years after planting, while fertilization at planting with combination with low intensive site preparation had little effect on volume growth. These findings also agreed with Haywood et al. (2003) who found that from the 6^{th} through 12^{th} growing season, the fertilization and herbicide main effect significantly increased loblolly pine total heights.

In Bryceland, LA, the differences in height before and after harvesting were significantly greater for the chemical site preparation treatment and the chemical plus herbaceous release treatment. In contrast, however, broadcast burning decreased height compared with preharvest heights at the ages of 3 to 8 years. These results can be explained by the fact that burning results in the loss of nutrients especially nitrogen which is more critical in the early stages of a pine plantation. These results agreed with the findings of Tiarks et al. (2002) who reported that broadcast burning causes survival increase during the first year but had no significant effect on height.

CONCLUSIONS

The significant treatment responses due to fertilization were detected in the current generation of trees in the Fred, Texas site, most likely due to improved nutrition. In general, the heights of current plantation are taller than the heights of the trees in the previous plantation at comparable ages.

At the Bryceland, LA site, chemical site preparation combined with broadcast burning had a negative effect on height compared with the height at comparable ages in the previous plantation. Chemical site preparation combined with herbaceous release improves height compared with the height of the previous stands.

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تأثير طرق الاستثمار (الحصاد) ومعاملات ما بعد الاستثمار في اتجاهات النمو الطولي المبكر في الصنوبر (*Pinus taeda* L.) Loblolly pine

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ملخـص

نفذت تجربة في موقعين هما منطقه فريد/ تكساس و برايسلاند/ لويزيانا لدراسة تأثير معاملات ما بعد الاستثمار في اتجاهات النمو الطولي في صنوبر (*Pinus taeda* L.) ومعرفة أية أعمار يكون النمو فيها أكثر لتطبيقها في كل مشجر على حدة وبين دورتين استثماريتين متعاقبتين.

قبل تأسيس المشجر وفي الموقعين وبعد عملية الاستثمار، تم تحليل سيقان الأشجار المقطوعة بهدف تحديد العمر لمختلف الأطوال. صممت التجربة على أساس نظام القطاعات العشوائية المتكاملة في الموقعين، واشتملت المعاملات العاملية على مستويين من الحصاد وثلاثة مستويات من تحضير الموقع.

وتم استخدام المعادلة الخطية لمعرفة النمو الطولي لمختلف الأعمار في الموقعين.

خلصت النتائج في فريد/ تكساس إلى أن جميع المعاملات كان لها تأثير معنوي في النمو الطولي؛ فقد زاد النمو الطولي 24 % في معاملة التسميد مقارنة مع معاملة عدم التسميد. وفي برايسلاند/ لويزيانا كانت معاملات طريقة الاستثمار وتحضير الموقع مضافا لها نشر الحريق ذات تأثير معنوي في النمو الطولي. استخدم t- test غير المزدوج لتقييم ما إذا كانت هناك فروق معنوية في النمو الطولي لفترة ما قبل الحصاد وما بعده للعمر المحسوب نفسه في الموقعين كليهما. وقد وجد انه في موقع فريد / تكساس كانت هناك زيادة في النمو الطولي قبل الحصاد وبعده للأعمار 3 ، 4، 9 سنوات، ووجد أن هناك الاتجاهات نفسها في برايسلاند/ لويزيانا؛ إذ أظهرت النتائج زيادة في النمو الطولي باستثناء معاملة تحضير الموقع بواسطة المواد الكيميائية مضافا إليها نشر الحريق؛ فقد كان هناك نقص معنوي في الطول لكل الأعمار لهذه المعاملة.

الكلمات الدالة: صنوبر *Pinus taeda* L. ، تأسيس المشجر، النمو الطولي ، الدورة الاستثمارية، ما قبل الحصاد، ما بعد الحصاد ، تحضير الموقع ، اتجاهات النمو الطولي.

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