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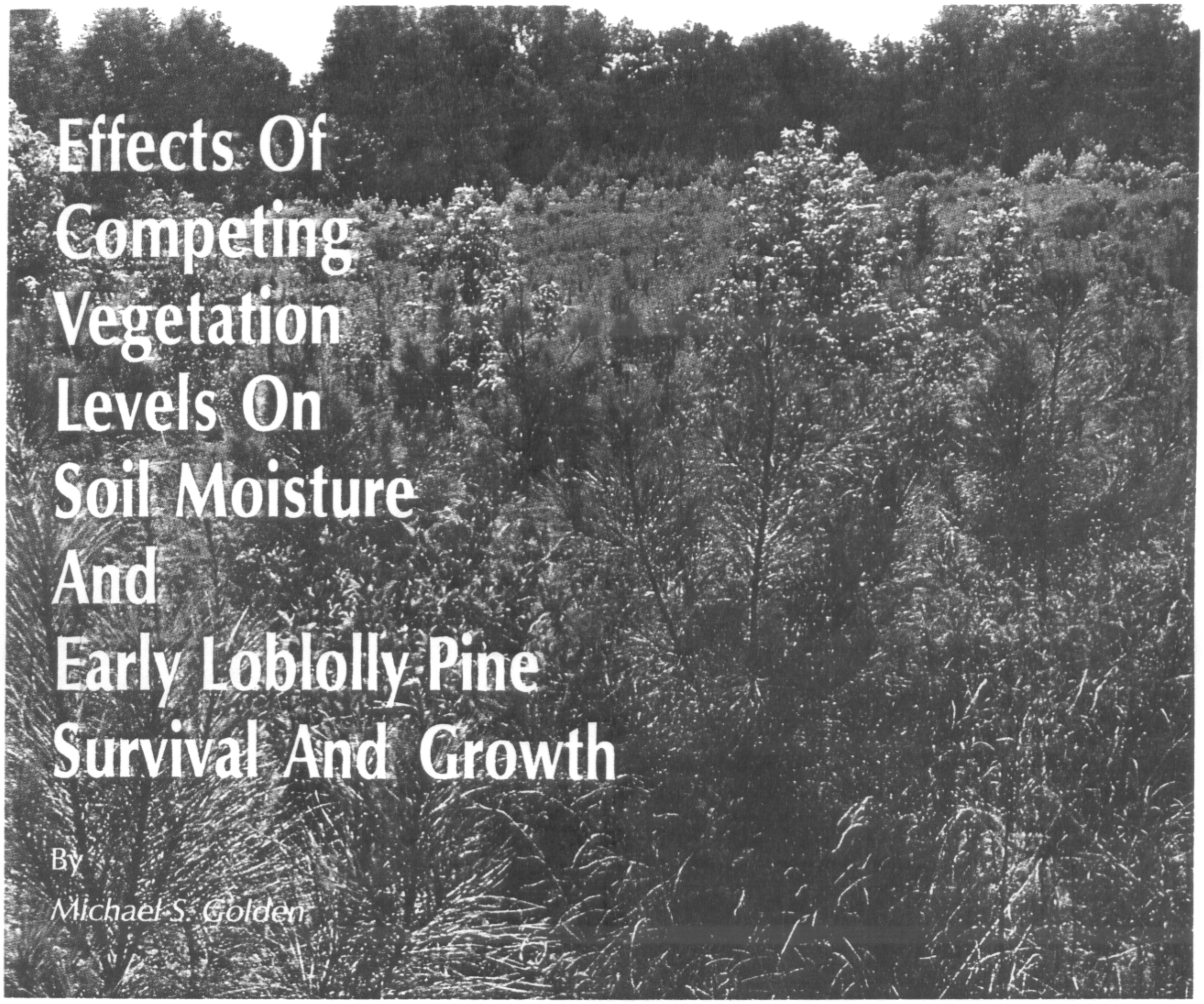

Effects Of Competing Vegetation Levels On Soil Moisture And Early Loblolly Pine Survival And Growth

By

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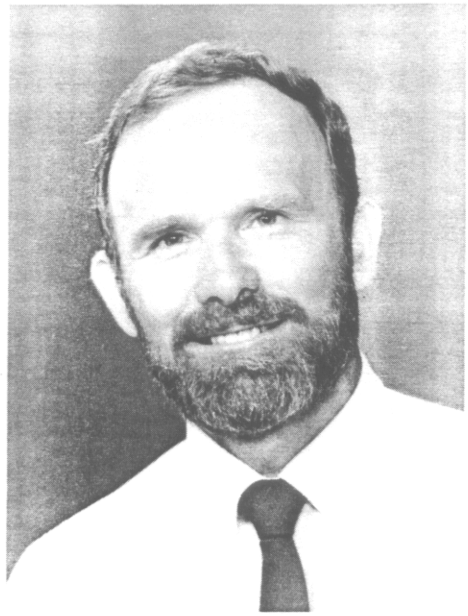

Michael S. Golden is an Associate Professor of Forestry at Auburn University and a staff member of the Alabama Agricultural Experiment Station. He received an M.S. in Forest Ecology from Auburn University and a Ph.D. in Plant Ecology from the University of Tennessee. He has been teaching and conducting research in silviculture and forest ecology at Auburn since 1975.

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INTRODUCTION

Recent studies have indicated that early pine seedling growth is markedly increased when competing grasses and herbaceous vegetation are killed (Knowe et al. 1985, Miller and Zutter 1987). Consequently, many forest landowners are applying herbicides for "herbaceous weed control" soon after planting pine seedlings. It is generally assumed that the mechanism which relates reduced herbaceous competition to increased pine seedling is increased soil moisture.

However, to this point little information is available which documents the relationships among herbicide application, non-pine vegetation, soil moisture, and pine seedling growth. The objective of this study was to examine these relationships for a specific site on the southern Piedmont during the first two growing seasons after planting.

METHODS

The study site is an old pasture located just north of Auburn, Alabama. At the time of study installation, the site had more than 90% cover of herbaceous and grass species. Colonies of *Rubus* spp. were at scattered locations. The soil is a Pacolet sandy loam, a moderatley deep, well-drained soil of the Piedmont, formed in residuum of granite, gneiss, and schist. It is classed as a clayey, kaolitic, thermic Typic Hapludult.

Forty-eight square 1/20 acre plots were established with buffer areas between them. Then 1-0 lobloilly pine seedlings were planted on an 8x8 ft. spacing in March, 1987. After buffer rows were maintained, each plot initially had 20 measurement trees. Initial seedling height and ground line diameter (gld) were taken immediately after planting.

PVC access tubes were installed in the center of each plot. Readings were taken at 1 ft. and 2 ft. depths with a soil moisture neutron probe biweekly (with a few exceptions) beginning the eighth week after the seedlings were planted (mid-May 1987) and continuing through mid-November 1988. Soil samples were taken during spring and summer and used to calibrate the probe readings to percent moisture.

In analyses, the soil moisture data were grouped by time periods in order to detect differences due to season. The soil moisture mean for an individual plot for a particular period was determined as the sum of the soil moisture percentages taken divided by the number of measurement times during the period. The periods examined were: May 1987, Summer 1987 (June-August), Fall 1987 (September-October), Winter 1987 (November-February), Spring 1988 (March-May), May 1988, Summer 1988, Fall 1988, Growing Season 1987 (May-October), Growing Season 1988 (March-November), Total 1987 (May-December), Total 1988 (January-November), and Study Period Total (May 1987-November 1988).

Treatments were assigned in a randomized block design for herbicide application. In order to obtain a range of live vegetative cover, Oust (75% sulfometuron methyl, as dispersible granules in water) was applied at rates of 0 (control), 1 oz., 2 oz., 4 oz., and 8 oz. of product per acre. The herbicide was applied in May, 1987 as a broadcast treatment evenly distributed over each plot at the specified rate.

In August, 1987, remaining live vegetative cover (as %) was estimated for each plot by means of the point-intercept method using 60 systematically-placed points in each plot. In this study, the term "cover" refers to the percentage of the total plot ground surface which would be covered by vertical projection of all living non-pine plant parts.

In order to provide a classification which could be used in testing for differences among varied levels of competing vegetation cover, the appropriate Braun-Blanquet cover-abundance scale value was assigned to each plot. This is a cover assessment scale that is widely used by plant ecologists, especially for non-tree vegetation (Mueller-Dombois and Ellenberg 1974). Numerically, the scale ranges from 1 to 5. For the range of vegetative cover encountered, the scale was applied as follows: Braun-Blanquet value 2=2 to 25% live cover, 3=26 to 50% cover, 4=51 to 75% cover, and 5=76 to 100% cover. Thus the Braun-Blanquet cover classification grouped the plots into four levels of competition for the pine seedlings.

Pine seedling heights and gld's were taken after the first (1987) and second (1988) growing seasons. Number of live seedlings was noted at the same times, and thus first-year and total two-year survival percentages were determined for each plot. Seedling growth for the total two-year period was calculated by subtracting the initial seedling measure (height and gld) from the measurement recorded at the end of the second year. Similarly, the first-year and second-year growth values were obtained by subtracting the appropriate beginning from ending measurements.

Soil samples were taken for each plot and characterized as to texture, exchangeable phosphorus, and total nitrogen. Soil total nitrogen and exchangeable phosphorus were determined for depths of 0, 3, 6, 24, and 33 inches after the end of each growing season. Additionally, foliar nitrogen was determined at the end of the 1988 growing season.

For purposes of examining the relationship between soil moisture and rainfall, precipitation data for the study period were obtained for the Auburn, Alabama weather station from the Southeast Agriculture Weather Service Center at Auburn University.

Analyses of variance (ANOVA) using general linear models (GLM) procedures were conducted using the Statistical Analysis System (SAS Institute Inc. 1988) in order to test for differences among seedling growth, nutrient, and soil moisture measures. Means were compared using the Waller-Duncan k-ratio t test (SAS Institute Inc. 1988, Petersen 1985) with the k ratio for significance set at 100, which approximates the probability level of .05 for other tests (Duncan 1975).

Simple Pearson product-moment correlations were calculated among the pine seedling survival and growth measures, live vegetation cover, and a number of soil moisture variables. These were followed by linear regression analysis for appropriate variable pairs. SAS procedures were used for these analyses also.

RESULTS AND DISCUSSION

Oust Treatment Levels

The application of varied levels of sulfometuron methyl resulted in a wide range of live vegatative cover three months after treatment, ranging from 13 to 100%. The means of treatment plot groups ranged from 29% to 93% (Table 1). The 0 to 4 oz. treatments each differed significantly in live cover, but the 8 oz. treatment did not reduce cover significantly below that of the 4 oz. treatment.

Pine seedling survival after two growing seasons was low on the untreated plots (55%). Although the trend in survival was upward with increasing Oust application (Fig. 1), it was significantly higher (74%) only where at least 4 oz. of Oust was applied (Table 1). There was no increase in survival where the rate was doubled from 4 to 8 oz.

The same trend, an increase with higher Oust application rates, was evident for two-year seedling height growth (Fig. 2) However, there was slightly better differentiation among application levels. The 2 oz. treatment did significantly increase height growth over the untreated controls (63.5 cm vs 50.1 cm) and the 4 oz. application increased height growth compared to the 1 oz. rate (Table 1). As was the case with live cover and survival, the doubling of Oust from 4 to 8 oz. did not significantly increase height growth.

The two-year seedling ground-line diameter growth showed the same pattern of relationships as did height growth (Fig. 3). However a statistically significant increase in gld growth (1.5 vs 1.2 cm) was achieved with the increase of Oust from 2 to 4 oz. per acre (Table 1). As with other measures, the increase from 4 to 8 oz. of Oust produced no increase in diameter growth.

Thus, for the conditions encountered in this study, the optimum broadcast application rate of Oust for pine seedling survival and growth was 4 oz. per acre. No advantage was gained by increasing the rate to 8 oz. The competition cover level produced by the 4 oz. Oust application rate was approximately 35% (Table 1).

Table 1: Mean loblolly pine seedling measures and mean live cover of non-pine vegetation, by Oust[1] treatment rates. Live cover was estimated in August 1987, three months after Oust treatment. Pine survival and growth measures are through two growing seasons (November 1988). Means with the same letter are not different (Waller-Duncan *k*-ratio *t* test, with *k*-ratio=100, p .05).

	Rate of Oust Product Applied				
	8 oz	4 oz	2 oz	1 oz	0oz
Live Cover (%)	29d	36d	54c	70b	93a
Survival (%)	74a	74a	64ab	61ab	55b
Tot. Ht. Growth (cm)	77.6a	73.4ab	63.5bc	56.9cd	50.1d
Tot. GLD Growth (cm)	1.5a	1.5a	1.2b	1.0bc	0.9c
No. Plots	9	10	10	10	9

[1] Trade name for DuPont's dispersible granules containing 75% sulfometuron methyl.

Vegetation Cover

Correlation analysis indicated that live cover was significantly correlated with pine seedling growth and survival (Table 2). The correlations were negative, reflecting reduced survival and growth with increasing vegetation cover. The negative correlation with survival was weak (-.39 for the two-year survival), reflecting high variability. The correlations with growth were fairly strong (Table 2), being strongest with gld growth (-.73 for the first growing season, -.69 for the two-year total).

The least-squares regression models for two-year height growth and gld growth on live cover were both highly significant (Table 3). The modest R-squares (.39 and .47 for height growth and gld growth, respectively) reflect considerable scatter, but the negative relationships were clear when presented graphically (Figs. 4 and 5). The model fit was better for first-year gld growth against cover, with an R-square of .53.

A reasonable distribution of plots among Braun-Blanquet (BB) cover classes was obtained, with at least 9 plots (class 2) in each class. The average live cover in each class was statistically different from all others, ranging from 22% in the class 2 plots to 92% in the class 5 plots (Table 4).

Although a clear trend emerged of decreasing survival with increasing BB class (Fig. 6) and the class 2 survival averaged 17% higher than that of class 5 (Table 4), the

Table 2: Simple linear correlation of live vegetation cover (%) with pine seedling survival and growth.

	Survival (%)		Height Growth (cm)			GLD Growth (cm)		
	1st yr	2-yr[1]	1st yr	2nd yr	2-yr	1st yr	2nd yr	2-yr
r with Cover	-.32	-.39	-.53	-.60	-.62	-.73	-.60	-.69
Prob. > r	.02	.006	.000	.000	.000	.000	.001	.000

[1]Total at the end of the second growing season.

analysis of variance F value was non-significant. This lack of significance is likely due to the high degree of variability for survival among the classes. Standard deviations for percent survival within BB classes ranged from 8.3 (class 2) to 21.8 (class 5).

A clear pattern of decreased two-year seedling height growth with increased BB value was evident (Fig. 7). Average height growth on the class 2 (lowest cover) plots was higher than for all others (Table 4), and class 3 plots had significantly greater height growth than did those of class 5 (68.4 vs 51.8 cm).

Increased cover had a stronger effect on height growth during the second year than in the first (Fig. 7). This contrasts with the pattern of cover/gld relationship, where the effect was as strong or stronger the first year (see below). This appears to be attributable to severe seedling tip damage having occurred during the first year. White tailed deer browsing was the major factor, although some insect damage was also observed. The deer population is quite high on the study site. They were observed frequently during data collection, and evidence of browsing was on the young seedlings during the first year was clear and abundant.

The pattern for two-year seedling gld growth was similar to that for height (Fig. 8), except that the class 3 plots had significantly greater growth than the class 4 plots (Table 4). Neither seedling growth measure differed significantly between the class 4 and class 5 groups. Also, the first-year relationship for cover/gld growth was strong, in contrast to that for height (Fig. 8), as noted earlier.

Soil Moisture

The only statistically significant direct correlation between soil moisture and percentage live cover was for the average moisture during the 1987 growing season (mid-May through October). This was rather weak, -.30.

Plots of mean biweekly soil moisture percentages (at 1 ft. depth) for the extremes in Braun-Blanquet cover classes (2 and 5) are presented in Fig. 9. In almost all cases, soil moisture was higher in plots with the lower cover value (class 2). The magnitudes of differences were not great, mostly less than 1% (Fig. 10), but the differences were consistent in direction, except for 3 times in 1988. All of the May through September 1987 differences were significant. The differences are generally lower during the winter and for much of 1988 (Fig. 10).

The May-September period soil moistures could be expected to reflect most directly any changes due to lower transpiration losses by non-pine vegetation, since this was the period where the herbicide effects were most pronounced. The narrowing in soil moisture differences shown in the 1988 growing season probably reflects the recovery and reestablishment of herbaceous vegetation, since herbicide was not reapplied.

The biweekly soil moisture measurements at 1 ft. depth generally followed the same pattern as rainfall totals for the previous 7 days (Fig. 9), and were significantly correlated (r= .48). This relationship was least apparent during November and December, when low rainfall caused little reduction in soil moisture. This is to be expected, since most vegetation was not transpiring and evaporation should have been low as well.

On the other hand, the soil moisture differences between the highest and lowest vegetation cover levels (BB 2 and 5) showed a negative relationship with rainfall. The differences in soil moisture generally increased at times when the recent rainfall decreased (Fig. 10). Again, this tendency is most pronounced during the growing season of 1987, when the competition cover was lowest on the herbicide-treated plots and the cover estimates most directly reflect the conditions during the period. Competing vegetation was having the greatest effect on soil moisture during dry periods due to its pulling moisture from well below the soil surface.

There were significant, although weak, correlations between two-year survival and the mean percent soil moisture of several specific time periods: May of each year, summer of each year, total of each year, and growing season of each year. These correlations were in the range, .31 to .40. The r's between average combined 1987-1988 growing season soil moisture and two-year survival and between total study period (mid-May 1987 through November 1988) average soil moisture and two-year survival were the same,.37.

There was only one significant correlation ($p<.05$) found directly between mean percent soil moisture and seedling height or diameter growth. This was between average 1987 growing season moisture (GSM-87) and

Table 3: Simple linear regression of two-year seedling height growth and ground-line diameter (GLD) growth on live cover (%): model characteristics and parameter estimates.

	Model Characteristics		Parameter Estimates	
Dependent Variable	Prob.>F	R^2	b_0	b_1
Ht Growth (cm)	.0001	.39	86.008	-0.38802
GLD Growth (cm)	.0001	.47	1.7224	-0.0091934

1987 gld growth. It was weak, .29.

Regression analysis of soil moisture averages and growth measures produced the same result: only GSM-87 as a predictor of 1987 gld growth provided a slope different from zero (.05 level). All other soil moisture-growth regression slopes were not.

Thus soil moisture level during the 1987 growing season (mid-May through November within the study period) does appear to have directly affected pine seedling diameter growth. This is the period which should have been most affected by reduced competing vegetation cover on the treated plots, since the herbicide was applied in mid-May and not reapplied. This is substantiated by the relatively high direct negative correlation (-.73) between live cover (measured in late 1987) and first year gld growth (Table 2).

The poor relationship determined directly between soil moisture and pine seedling growth may be due to a number of factors. Sampling error and within-plot variability probably contributed heavily. Soil moisture was monitored at only one discrete point in each 1/20 acre plot. The cover estimate was derived for the entire plot. This resulted in some of the soil moisture measurement points not being truly representative of uniform conditions. This was particularly true for plots with intermediate to low cover estimates but with localized patches of vegetation or bare areas surrounding the neutron probe access hole.

Another probable factor which may have affected these results was the unmeasured utilization of soil moisture by the pine seedlings. It is likely that the pine seedlings utilized significant amounts of soil moisture. This utilization should have been higher on plots with higher live pine densities and higher growth rates, which were normally those plots with lower competition cover levels. Thus this may have tended to reduce the soil moisture on the plots where pine growth was higher. To remove this confounding, it would be necessary to compare soil moisture levels on plots which varied in vegetation cover, but which had no pines present.

Any potential relationships of seedling height growth during the study were likely masked by deer and insect tip damage, which was most severe during the first year.

Soil And Foliar Nutrient Levels

The correlation analyses and ANOVA's revealed no significant and meaningful relationships between soil nitrogen, soil phosphorus, or foliar nitrogen and live cover or herbicide treatment levels. Significant but weak correlations appeared between surface soil phosphorus and both two-year seedling height growth and two-year seedling gld growth (r=. .36 and .34, respectively).

Table 4: Mean live cover of non-pine vegetation and mean loblolly pine seedling growth measures, by Braun-Blanquet cover class[1] levels. Liver cover was estimated in August 1987. Pine survival and growth measures are through two growing seasons (November 1988). Means with the same letter are not different (Waller-Duncan *k* test, with *k*-ratio *t* test, with *k*-ratio=100,p .05).

	Braun-Blanquet Cover Class			
	2	3	4	5
Live cover (%)	22d	43c	62b	92a
Survival (%)	75[2]	67	64	58
Tot. Ht. Growth (cm)	81.3a	68.4b	58.7bc	51.8c
Tot. GLD Growth (cm)	1.6a	1.4b	1.1c	0.9c
No. Plots	9	16	10	13

[1]Braun-Blanquet cover classes: 2=2-25% cover, 3=25-50%, 4=50-75%, 5=75-100%.

[2]ANOVA p>f=.13, so means comparisons were not made.

CONCLUSIONS

Lower levels of competing herbaceous vegetation achieved by herbicide application resulted in increased initial two-year pine seedling survival, height growth, and diameter growth. The relationship between non-pine live cover and pine growth was inverse and linear within the cover range achieved (13% to 100%). This relationship was clearest and strongest for gld.

Broadcast applications of sulfometuron methyl as Oust achieved optimum results for competition cover reduction and pine seedling survival and growth at a 4 oz. per acre rate. The remaining live cover on the 4 oz. treated plots averaged about 35%. This implies that a more effective herbicide application might have improved pine survival and growth.

Soil moisture levels clearly contrasted between high and low cover levels for the growing season immediately after cover was reduced. The reduction of soil moisture by a high level of vegetation compared to low appeared to increase during periods of low growing season rainfall. The direct quantitative relationship between live cover estimate and measured soil moisture was weak.

To clearly define the relationships between vegetation cover and soil moisture, more intensive studies which would closely limit variability are needed. A study is highly desirable which would focus specifically on the live vegetation/soil moisture relationship, where pine seedling moisture use does not confound the result.

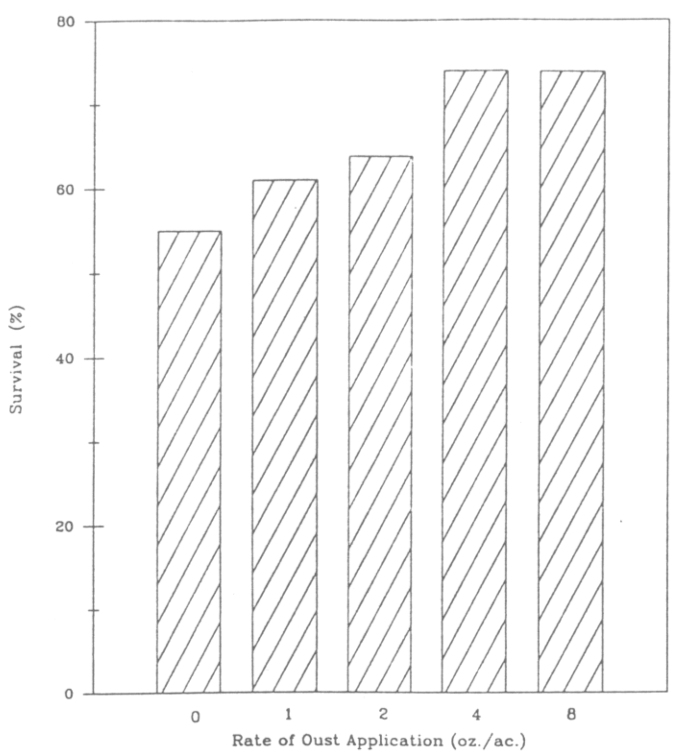

Figure 1. Loblolly pine seedling survival (%) after two growing seasons in relation to rate of Oust application (ounces/acre).

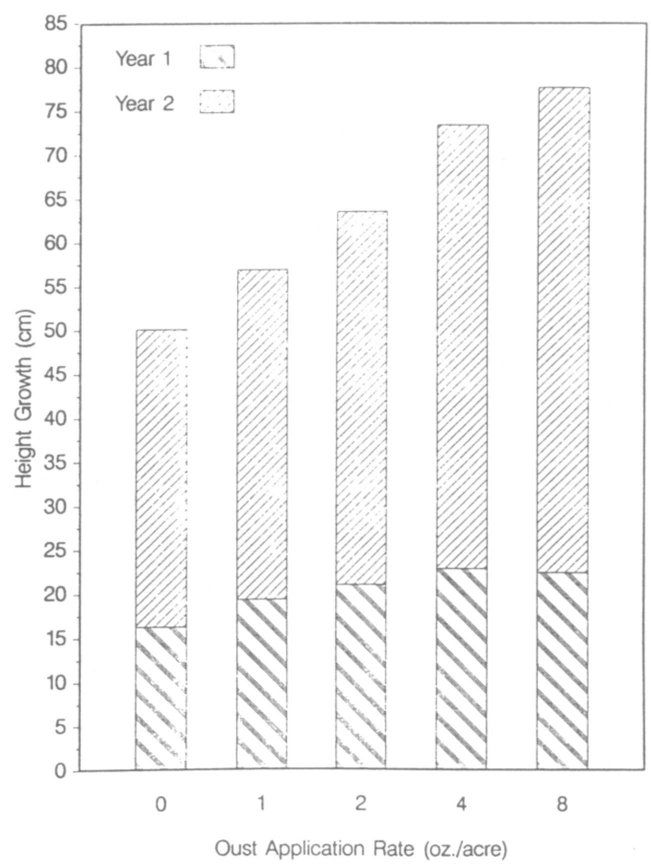

Figure 2. Two year height growth of loblolly pine at five levels of Oust application.

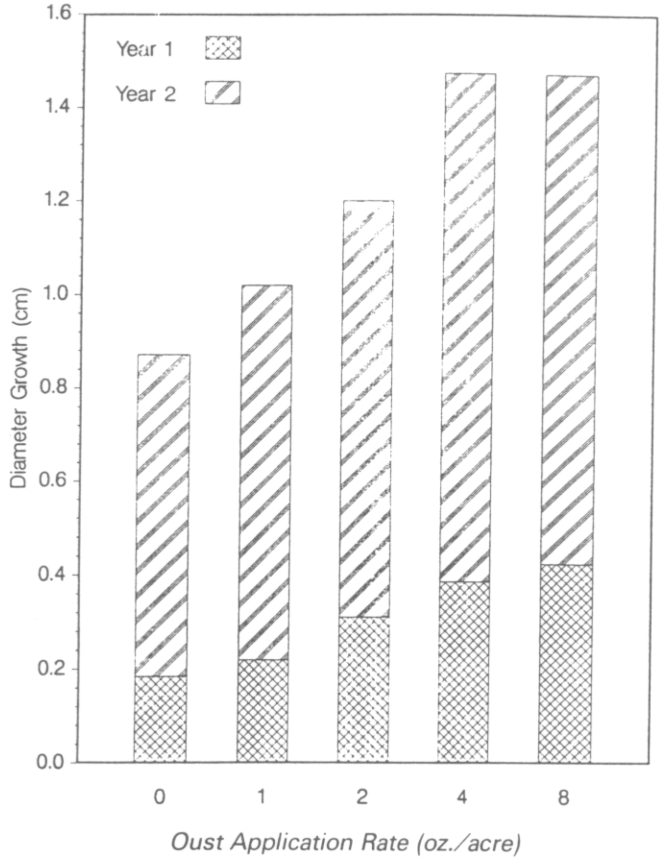

Figure 3. Two year ground line diameter growth of loblolly pine at five levels of Oust application.

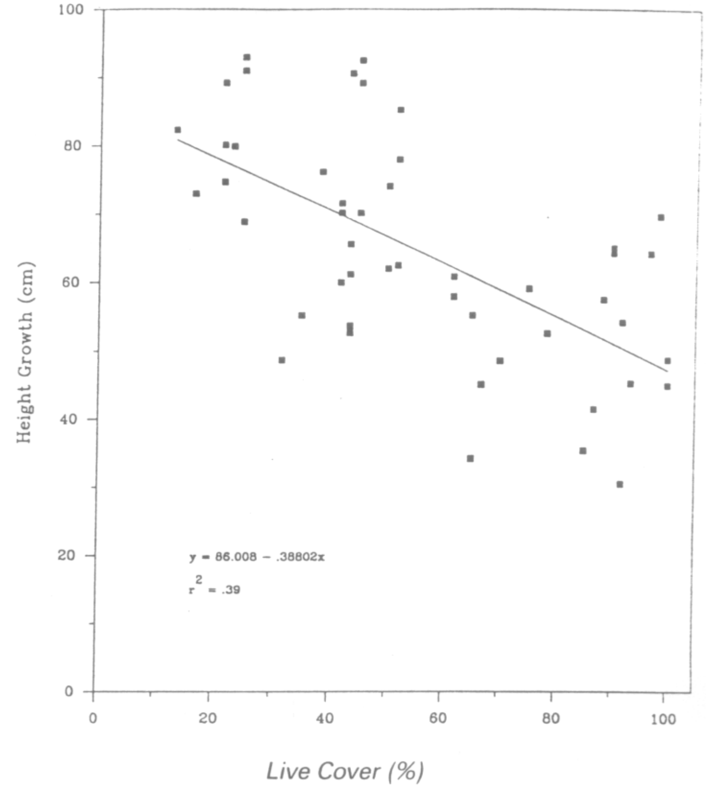

Figure 4. Two year height growth (cm) of loblolly pine seedlings in relation to surrounding live cover.

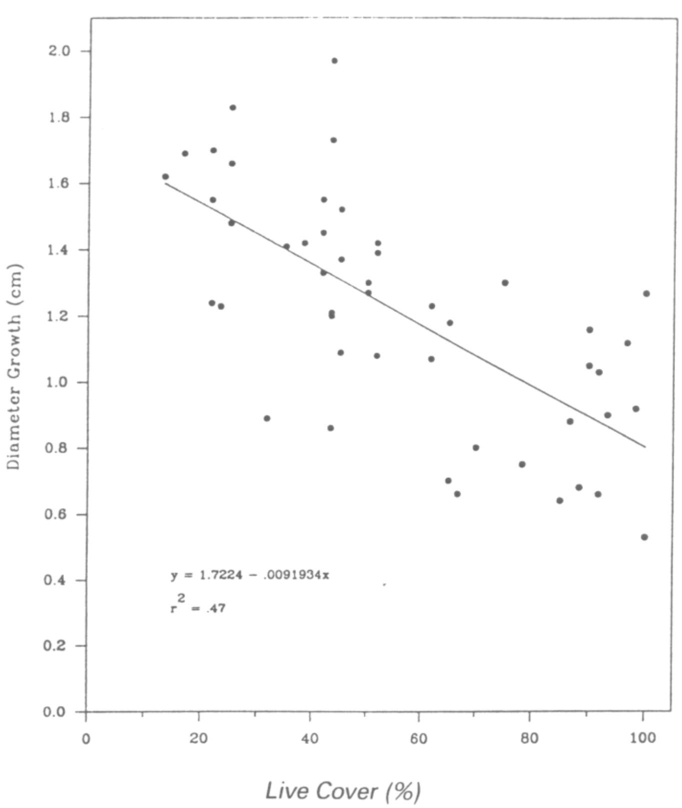

Figure 5. Two year ground line diameter growth (cm) of loblolly pine seedlings in relation to surrounding live cover.

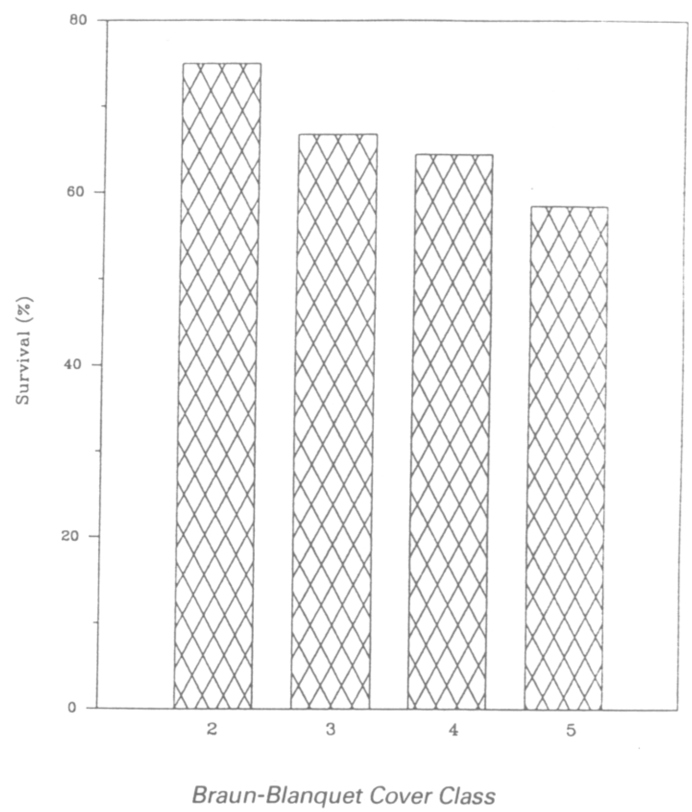

Figure 6. Loblolly pine seedling survival (%) after two growing seasons in relation to Braun-Blanquet cover class.

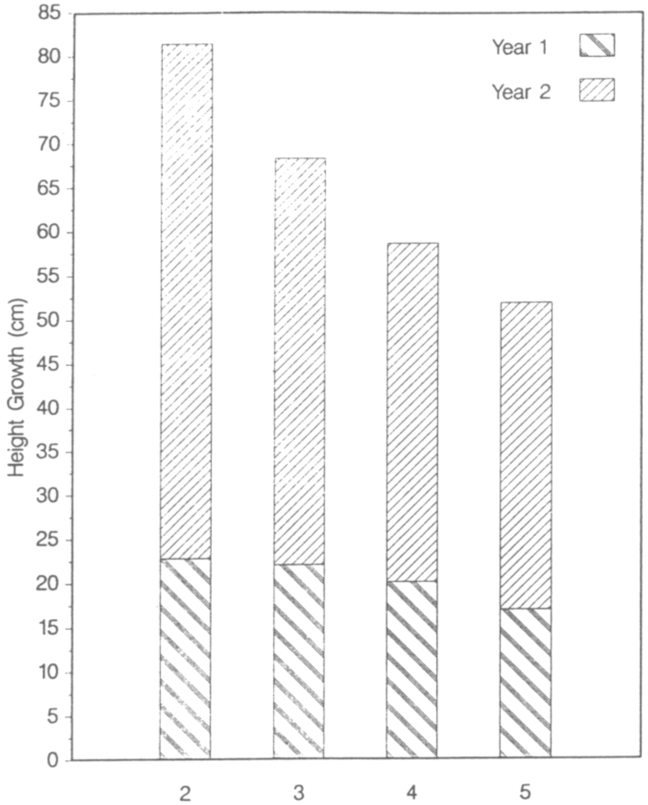

Figure 7. Two year height growth of loblolly pine at four levels of vegetative competition shown by Braun-Blanquet cover values (2=5-25% live cover, 3=25-50%, 4=50-75%, 5=75-100%).

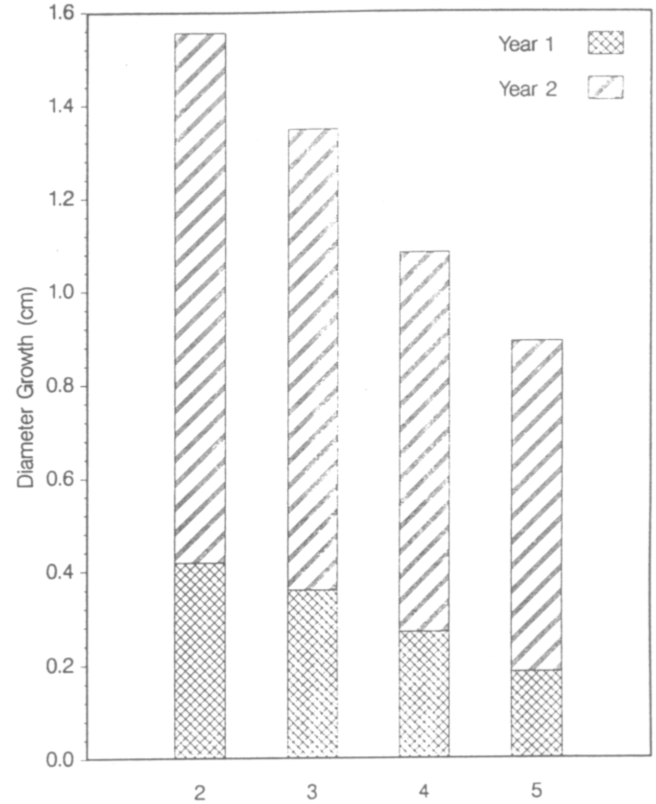

Figure 8. Two year ground line diameter growth of loblolly pine at four levels of vegetative competition shown by Braun-Blanquet cover values (2=5-25% live cover, 3=25-50%, 4=50-75%, 5=75-100%).

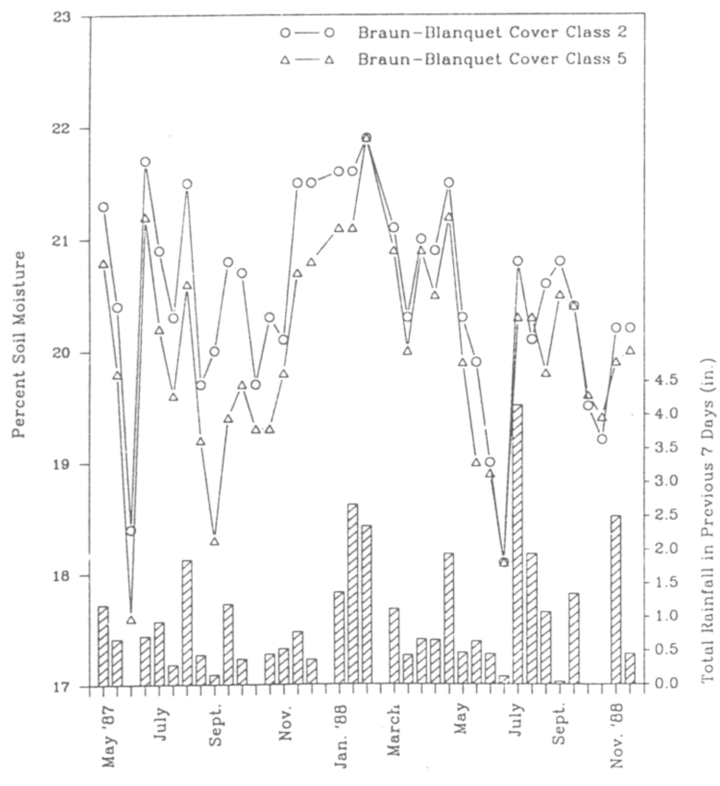

Figure 9. Soilmoisture (%) for two Braun-Blanquet cover classes plotted with 7 day rainfall totals (in.). Soil moisture readings were generally taken at intervals of two weeks throughout the study.

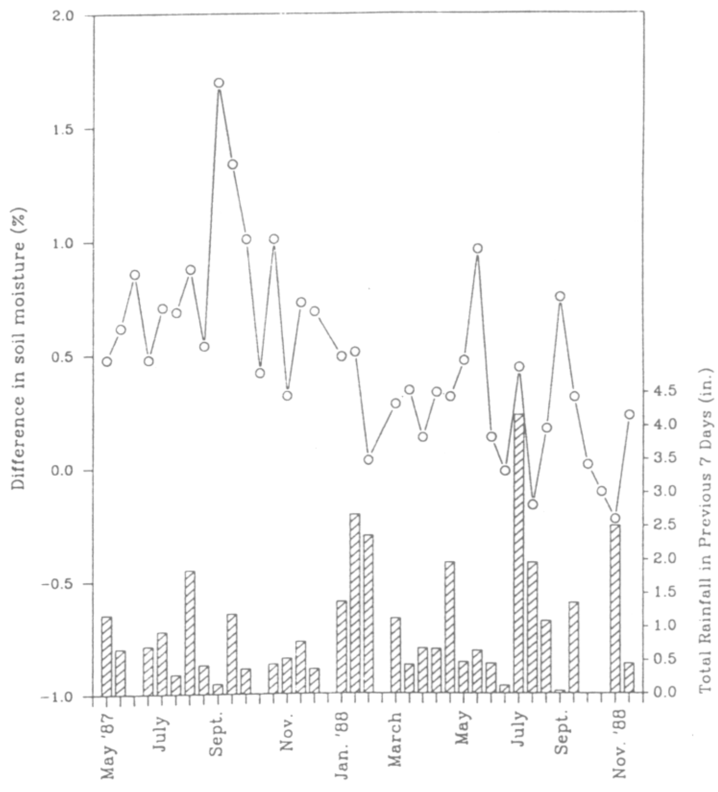

Figure 10. Difference in soil moisture (%) between Braun-Blanquet cover classes 2 & 5 plotted with 7 day rainfall totals (in.).

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