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## RESPONSE OF LOBLOLLY PINE PLANTATIONS TO WOODY AND HERBACEOUS CONTROL—EIGHTH-YEAR RESULTS OF THE REGION-WIDE STUDY - THE COMPROJECT<sup>1</sup>

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**Abstract**—Eight-year response of planted loblolly pine to woody and herbaceous control following site preparation, studied at 13 locations, differed by pine response variable and hardwood level grouping. Treatments affected average pine height the same at both low hardwood (<6 ft<sup>2</sup>/ac basal area at age 8) and high hardwood (>13 ft<sup>2</sup>/ac) levels, and ranked: total control (woody + herb control) > herb control only > woody control only > no control. The same ranking held for pine dbh, basal area/ac, and volume index/ac at the low hardwood level. However, at the high hardwood level, dbh response from woody control only exceeded that for herb control only, while basal area/ac and volume index/ac response were equal for the two treatments. Volume index increases over no control on the low and high hardwood levels averaged 127% and 336% greater with total control; 32% and 57% greater with woody control only, and 92% and 73% with herb control only, respectively. Treatment effects on all pine response variables were additive at the low hardwood level, and more than additive at the high hardwood level.

### INTRODUCTION

Over the past 20 years a wealth of research has been published summarizing the impact of woody and herbaceous competition on the growth of southern pines, principally loblolly pine, *Pinus taeda* L. With the exception of work done by Clason (1976, 1984), Bacon and Zedaker (1987), and Haywood and Tiarks (1990), individual studies have generally focused on the effects of controlling herbaceous (e.g. Nelson et al. 1981, Creighton et al. 1987, Lauer et al. 1993) or woody (e.g. Langdon and Trousdell 1974, De Wit and Terry 1982, Glover et al. 1991) vegetation alone, or controlling both components (e.g. Swindell et al. 1988, Shiver et al. 1990). As a result, our understanding of how woody and herbaceous control may interact to influence response of loblolly pine is limited.

In the early 1980's the Competition Omission Monitoring Project (COMP or COMProject) was developed, in part, to compare the relative effects of herbaceous control, woody control and their interaction on the response of planted loblolly pine across a wide range of sites throughout the Southeast. One feature of this region-wide study is that a uniform study design and protocol have been used at each study location. This uniformity makes consolidation of data and comparison of results across study locations more reasonable compared to attempting a similar effort across studies established by independent research workers.

Results from the COMProject have been reported previously following the first and second (Miller et al. 1967), third (Zutter 1988), fourth (Zutter 1990) and fifth (Zutter 1990, Miller et al. 1991) growing seasons. A summary of vegetation dynamics, focusing on prevalence of herbaceous and woody species/genera across the study locations, through eight seasons has been reported by Miller et al. (1995b). In addition, a tabular summary of data by location through age eight will soon be published (Miller et al. 1995c). The present paper summarizes effects of herbaceous control, woody control, and their interaction on the response of loblolly pine eight growing seasons since study establishment. A companion paper in these proceedings projects yields and economic outcomes using the age eight data (Miller et al. 1995a).

### STUDY AREAS

Study locations were distributed across several physiographic provinces from Louisiana to Virginia. In general, most sites were previously occupied by loblolly pine or loblolly/shortleaf pine (*Pinus echinata* L.)-hardwood stands, harvested in late 1982 or early 1983, chopped and burned in the spring or summer of 1983, and planted in early 1984. Site-specific information may be found in Miller et al. (1991).

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## METHODS

### Study Design and Plot Layout

In general, a randomized complete block design was used to establish four blocks of four plots at each location. Treatment plots were typically 0.25 ac in size (104 ft x 104 ft) with interior pine measurement plots of approximately 0.09 ac (63 ft x 63 ft). At most study sites, planting locations were established on a 9 ft x 9 ft spacing, with two 1-0 loblolly pine seedlings hand-planted 1-ft apart at each planting location. Seedlings were thinned, with selection made at random, to one seedling at each planting location after one growing season. Double-planting was used to help ensure adequate initial planting survival and minimize effects of variability in stocking on long-term results. Additional details and slight departures from the above noted procedures for specific sites can be found in Miller et al. (1991).

### Application of Treatments

Four treatments were randomly assigned to plots within each block:

- 1) *No control.* No treatment of competing herbaceous or woody vegetation following site preparation except for treatment of infestations of vines and injection of large residual hardwoods missed in site preparation. Vines were treated with directed foliar sprays of glyphosate (Roundup) or triclopyr (Garlon) in water or wick applications of triclopyr. Triclopyr was used for injection at the few locations where large residuals needed to be removed.
- 2) *Woody control.* Hardwoods and shrubs were treated with herbicides during the first five growing seasons. Treatment usually involved directed foliar sprays of glyphosate in water and/or basal wipes or sprays of triclopyr in diesel fuel.
- 3) *Herbaceous control.* Herbicides were applied one or more times during each of the first four growing seasons to control herbaceous plants. Treatment typically involved application of sulfometuron (Oust) at 2-5 oz ai/ac in the spring of each year prior to emergence of herbaceous plants followed in the summer by directed foliar sprays of glyphosate to regrowth. All vines and semi-woody plants such as blackberry (*Rubus* spp.) were included in the herbaceous component.
- 4) *Total control.* Hardwoods, shrubs and herbaceous vegetation were treated using a combination of treatments above to control all competing vegetation.

### Assessment and Analysis

Following eight growing seasons (years), total height and diameter at breast height (dbh) were measured on all pines within each pine measurement plot (49 planting spots per plot). A volume index was computed for each measured tree as follows:  $dbh \cdot dbh \cdot (\text{total height})/3$ , where both dbh and total height are in feet. Mean total height and dbh, density in trees/ac, basal area/ac, and volume index/ac was computed for each treatment plot for use in statistical analyses.

Eighth-year pine data were analyzed by first placing each of the 13 study locations into one of two groups based on the level of arborescent hardwood basal area/ac at age eight on the herbaceous control only treatment. Basal area/ac for the "low hardwood" group averaged 3.5 ft<sup>2</sup>/ac (n=5, range= 2.1-5.4 ft<sup>2</sup>/ac) and the "high hardwood" group averaged 17.3 ft<sup>2</sup>/ac (n=8, range= 13.2-22.7 ft<sup>2</sup>/ac). Mean site index (base age 25) was approximately 65 ft for both groups (Miller et al 1995b).

A separate analysis was done for each of the two hardwood levels (groups). The analysis of variance for each hardwood level included tests of the main effects of woody treatment ((woody control + total control)/2) versus ((no control + herb control)/2), herbaceous treatment ((herb control + total control)/2 versus ((no control + woody control)/2), and the interaction of woody and herbaceous treatment. When the interaction was statistically significant, Tukey's HSD test was used to separate the individual treatment means. All statistical tests were made at p=0.05. For the sake of clarity, references to effects of woody treatment or herbaceous treatment will refer to tests of main effects, whereas references to no control, woody control only, herbaceous control only or total control will refer to the four treatments within the study design.

## RESULTS

### Density Response

After eight years, pine stocking averaged across locations was very good, exceeding 90 percent for all treatments. Neither woody nor herbaceous treatment had significant effects across low or high hardwood levels. Under low hardwood levels density averaged 517, 506, 513, and 517 trees/ac and under high hardwood levels density averaged 505, 486, 491, and 505 trees/ac for no control, woody control only, herbaceous control only, and total control, respectively.

### Height Response

Mean pine height through eight years was positively affected by woody and herbaceous treatment at both low and high hardwood levels (Table 1). Rankings in response among treatments followed the same pattern under both levels of hardwood: total control > herb control only > woody control only > no control (Table

Table 1—Mean pine height and dbh, basal area/acre, and volume index/acre after five and eight growing seasons, gain over no control after eight growing seasons, and growth from age five to eight by vegetation control treatment and hardwood (hdwd) level<sup>a</sup>.

| Vegetation control                  | Height   |           | Dbh      |           | Basal area              |           | Volume index            |           |
|-------------------------------------|----------|-----------|----------|-----------|-------------------------|-----------|-------------------------|-----------|
|                                     | Low hdwd | High hdwd | Low hdwd | High hdwd | Low hdwd                | High hdwd | Low hdwd                | High hdwd |
|                                     | (feet)   |           | (inches) |           | (ft <sup>2</sup> /acre) |           | (ft <sup>3</sup> /acre) |           |
| <u>Age 8</u>                        |          |           |          |           |                         |           |                         |           |
| None                                | 23.8     | 22.6 d    | 4.16     | 3.62 d    | 51.1                    | 38.0 c    | 548                     | 399 c     |
| Woody                               | 26.1     | 24.7 c    | 4.65     | 4.56 b    | 62.1                    | 56.5 b    | 723                     | 627 b     |
| Herb                                | 29.9     | 27.1 b    | 5.27     | 4.27 c    | 80.4                    | 53.5 b    | 1056                    | 689 b     |
| Total                               | 31.4     | 32.1 a    | 5.61     | 5.87 a    | 91.0                    | 95.7 a    | 1245                    | 1343 a    |
| <u>Gain over no control - Age 8</u> |          |           |          |           |                         |           |                         |           |
| Woody                               | 2.3      | 2.1       | 0.48     | 0.94      | 11.0                    | 18.5      | 175                     | 228       |
| Herb                                | 6.1      | 4.5       | 1.11     | 0.65      | 29.3                    | 15.5      | 508                     | 290       |
| Total                               | 7.6      | 9.5       | 1.45     | 2.25      | 39.9                    | 57.7      | 697                     | 944       |
| <u>Age 5</u>                        |          |           |          |           |                         |           |                         |           |
| None                                | 12.1     | 11.2      | 1.88     | 1.49      | 11.1                    | 7.7       | 66                      | 45        |
| Woody                               | 13.6     | 12.5      | 2.22     | 2.03      | 14.9                    | 12.7      | 96                      | 78        |
| Herb                                | 17.0     | 15.5      | 3.06     | 2.40      | 28.0                    | 18.6      | 221                     | 146       |
| Total                               | 17.8     | 18.5      | 3.32     | 3.61      | 33.3                    | 38.1      | 275                     | 323       |
| <u>Growth - Age 5 to 8</u>          |          |           |          |           |                         |           |                         |           |
| None                                | 11.6     | 11.5 c    | 2.28     | 2.13      | 40.0                    | 30.3 d    | 482                     | 353 c     |
| Woody                               | 12.6     | 12.2 b    | 2.43     | 2.52      | 47.2                    | 43.8 b    | 627                     | 549 b     |
| Herb                                | 12.9     | 11.6 c    | 2.21     | 1.87      | 52.3                    | 34.8 c    | 834                     | 543 b     |
| Total                               | 13.5     | 13.6 a    | 2.29     | 2.26      | 57.7                    | 57.6 a    | 970                     | 1020 a    |

<sup>a</sup> Statistical analyses performed on age eight response and growth from age five to eight only. Separate analyses were conducted at low and high hardwood levels (All tests of significance at  $p=0.05$ ). Main effects of woody treatment and herbaceous treatment were significant in each instance at both low and high hardwood. The woody x herbaceous treatment interaction (W x H) was not significant at low hardwood level in any instance, but was significant at high hardwood for all but dbh growth from age five to eight. Where W x H was significant, means are separated using Tukey's HSD test ( $p=0.05$ ).

1). However, under high hardwood the interaction between woody and herbaceous treatment was significant due to combined effects of herbaceous and woody treatments being more than additive. Controlling both woody and herbaceous components (total control) yielded a gain in height of 9.5 ft compared to 6.6 ft when gains from controlling woody vegetation only (2.1 ft) and herbaceous vegetation only (4.5 ft) are summed. In comparison, under low hardwood, gains from woody and herbaceous control were additive, 7.6 ft with total control versus 8.4 ft when

gains from woody control only and herb control only are summed.

Ranking among treatments for mean pine height did not differ between ages five and eight at either level of hardwood (Table 1). Woody and herbaceous treatment each had a significant effect on height growth from age five to eight at both low and high hardwood, with a significant interaction between woody and herbaceous treatment noted only at high hardwood. At low hardwood, growth followed the pattern noted at age eight for total height: total control > herb control

only > woody control only > no control, while at high hardwood: total control > woody control only > herb control only = no control (Table 1).

### Dbh Response

Levels of arborescent hardwood had a decidedly different influence on the effects of treatments on pine dbh compared to height. As noted for height, effects of woody treatment and herbaceous treatment were significant and positive for both low and high hardwood levels, with the interaction between woody and herbaceous treatment being significant only with high hardwood. However, while rankings among the treatments for dbh at low hardwood levels followed that noted for height: total control > herb control only > woody control only > no control; at high levels of hardwood the ranking of response to herb control only and woody control only was reversed (Table 1). The gain from control of both woody and herbaceous vegetation (total control) was more than additive where hardwood levels were high: 2.25 in. from total control versus a sum of 1.59 in. from woody control only (0.94 in.) and herb control only (0.65 in.); and additive where hardwood levels were low (1.45 in. versus 1.60 in. (0.49 + 1.11)).

Ranking in effects on pine dbh through age five was identical for both levels of hardwoods, following the pattern noted for dbh at age eight for low hardwood. Dbh growth from age five to age eight at both low and high hardwood levels was greatest for woody control only. Dbh growth at high hardwood was over 0.6 in. greater with woody control only compared to herb control only, resulting in the reversal in the ranking of response for those two treatments from age five to age eight.

### Basal Area and Volume Index Response

Trends in effects of treatments and hardwood level on basal area/ac and volume index/ac roughly paralleled those noted for dbh (Table 1). Effects of woody and herbaceous treatment each had a significant positive effect at both hardwood levels, with the interaction of woody and herbaceous treatment being significant only at high hardwood. Rankings among treatments at low hardwood were the same as those noted for mean height and dbh: total control > herb control only > woody control only > no control. At the high hardwood level, ranking of response was similar, except response from woody control only and herb control only did not differ (Table 1), hence the significant woody and herbaceous treatment interaction.

Average gains over no control in basal area/ac and volume index/ac from woody control only were greater at high compared to low hardwood levels (18.5 versus 11.0 ft<sup>2</sup>/ac, 228 versus 175 ft<sup>3</sup>/ac), while gains from herb control only were greater at low compared to high hardwood levels (29.3 versus 15.5 ft<sup>2</sup>/ac, 508 versus 290 ft<sup>3</sup>/ac). Gains over no control from controlling both

woody and herbaceous vegetation (total control) were additive for low hardwood (39.9 versus 40.3 ft<sup>2</sup>/ac, 697 versus 683 ft<sup>3</sup>/ac) and more than additive for high hardwood (57.7 versus 34.0 ft<sup>2</sup>/ac, 944 versus 518 ft<sup>3</sup>/ac). Expressed on a percent basis, volume gains over no control on the low and high hardwood levels averaged 127% and 336% greater with total control; 32% and 57% greater with woody control only; and 92% and 73% with herb control only, respectively.

### DISCUSSION

The more than additive effect when woody and herbaceous treatments are combined on sites where hardwood levels are high is not too surprising. Hardwoods may usurp from the pines some of the additional resources made available as a result of controlling only herbaceous plants, with a much larger uptake at high hardwood levels. In addition, this increased acquisition of resources by hardwoods allows them to attain a larger size and have a greater long-term effect on pines than if herbaceous plants had not been controlled. Average hardwood basal area/ac was 5 ft<sup>2</sup>/ac greater (17.3 ft<sup>2</sup>/ac versus 11.9 ft<sup>2</sup>/ac) and mean heights of those hardwoods 3.0 ft greater (14.8 ft versus 11.8 ft) on herbaceous control only compared to the no control treatment. The greater than additive effect noted at high hardwood by combining woody and herbaceous control is consistent with the idea that control of one competitive component will increase the response of other competitive component(s), and this response will limit the resources available to the crop.

The change noted in the ranking between woody control only and herbaceous control only treatments for dbh, basal area/ac, and volume index/ac from age five to eight under high hardwood levels illustrates the greater influence of herbaceous plants relative to arborescent hardwoods during the first few years of stand development, and an increase in the influence of hardwoods as the stand closes. Based on growth from age five to age eight, it appears likely that cumulative basal area/ac and volume index/ac response of pines under woody control only should exceed that from herb control only sometime in the next few years.

### SUMMARY AND CONCLUSIONS

Grouping of COMProject locations by level of arborescent hardwoods, and analyses of treatment means by these hardwood groups yielded the following observations:

- 1) For all response variables, except density, the control of both woody and herbaceous plants resulted in responses which, compared to the sum of responses of controlling each component separately, were additive under low hardwood levels (<6 ft<sup>2</sup>/ac basal area/ac at age eight) and more than additive under high hardwood levels (>13 ft<sup>2</sup>/ac).

- 1) Rankings among treatments for total pine height were identical at both low and high hardwood levels at ages five and eight. Rankings were: total control > herb control only > woody control only > no control
- ) At age five, rankings among treatments for dbh, basal area/ac, and volume index/ac at both low and high hardwood levels were identical to those for height.
- ) By age eight, rankings among woody control only and herb control only treatments had changed at high hardwood levels for dbh, basal area/ac, and volume index/ac. Ranking for dbh was: woody control only > herb control only, and the ranking for basal area/ac and volume index/ac: woody control only = herb control only.

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