Growth Response of Black Walnut and Yellow-Poplar to Site Improvement and Weed Control

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ABSTRACT

Survival and growth of 2-0 black walnut and yellow-poplar in relation to pre-planting site improvement and post-planting weed control were studied over a 13-year period on bottomland, Genesee sandy loam, old field sites. Site improvement treatments included a no site preparation check and intensive site preparation involving fertilization and green manuring one year before planting. Post-planting weed control consisted of mechanical cultivation and chemical treatment with Amizine (8 kg/ha) during the first 3 years of tree establishment, 1965-67.

Site preparation in the form of fertilization and green manuring produced small increases in height and diameter growth of black walnut and yellow-poplar as compared to the check. Although these differences were not statistically significant, they were judged to be of practical importance. In contrast, major significant differences in total height, basal diameter and breast-height diameter of both species occurred in response to post-planting weed control treatments; the order being chemical > cultivation > no weed control.

An important response to both site preparation and weed control was the increased proportion of surviving trees in the larger size classes after 13 years of growth in comparison to the no site preparation and no weed control checks. This tree distribution provides more uniform plantation conditions and the opportunity for better selection of trees for the future stand.

INTRODUCTION

Artificial reforestation of abandoned agricultural land and open areas in existing forest stands began in the Central States in the early 1900's. Initial plantings were a trial-and-error process involving establishment of native and introduced species, both conifers and hardwoods. Little or no attention was given to site evaluation prior to planting and few plantations received cultural treatments to improve soil conditions or to reduce weed competition.

Conifer survival and growth in these early plantations were generally satisfactory. Successful establishment of hardwoods, especially on old field sites was rare, except for black locust. Nevertheless, after a few years the more valuable hardwood species began to invade most of the conifer plantations. In the absence of cultural treatment these hardwoods soon shaded out the conifers resulting in pure hardwood, or at best, mixed conifer-hardwood stands. This phenomenon was of such common occurrence that the saying was coined by foresters of the area, "If you want hardwoods, plant pine".

Though much study has been conducted in various parts of the world on the effect of pre-planting site treatments on hardwood establishment, few have been made in the Central States, particularly on old-field sites. Yellow-poplar has been found to respond to nitrogen fertilization on appropriate sites (Ike, 1972), and cottonwood and sweetgum have shown positive responses to fertilization. Merz and Finn (1955) found significant increases in height growth of yellow-poplar planted on the lay of double furrows as compared to planting in the trough of single furrows, in areas ripped to 28", in 2-foot square scalps and on control plots with no treatment.

Practically no research has been conducted on the effect of increasing soil organic matter or changing soil structural characteristics on hardwood establishment. However, the causal mechanism for the successional progression from pine to hardwoods has been shown to be related to changes in the soil (Auten, 1945; Clark, 1964; Carmean, et al., 1976). Amelioration of the microclimate plays a strong role also.

As with pre-planting treatments, few investigations have been made until recent years of the effects of post-planting cultural treatments, particularly weed control, on the establishment and growth of hardwoods. Early results from the study reported herein and other related work in weed control have been reported by Byrnes (1966; 1973).

In 1964 the senior authors initiated research to investigate methods of improving old field sites for artificial reforestation with selected hardwood species. Techniques studied included green manuring, fertilization and weed control treatments. Both bottomland and upland old-field sites were included in the study. Results of tree growth response from the bottomland plots are reported in this paper.

METHODS AND MATERIALS

This study was conducted on a bottomland "old field" site of the Purdue University Martell Forest in Tippecanoe County, Indiana. The soil is medium to dark colored, neutral to slightly acid, high bottom Genesee sandy loam. It developed in alluvium washed from upland areas of calcareous Wisconsin glacial drift. The soil is classified in the family fine-loamy, mixed, nonacid, mesic Typic Udifluvents. Predominant native plant species occupying the site before initiation of the study were giant ragweed (*Ambrosia artemisiifolia*), Jimson weed (*Datura stramonium*), smartweed (*Polygonum pensylvanicum*), lambsquarter (*Chenopodium album*), foxtails (*Setaria* spp.), and prickly lettuce (*Lactuca scariola*). Roots of native plants extended to a depth of 150 cm in the soil.

The study was designed to evaluate growth response of planted black walnut (*Juglans nigra*) and yellow-poplar (*Liriodendron tulipifera*) to intensive culture including pre-planting site improvement and post-planting weed control. For each species, the field layout was a randomized block, split-plot design with two replicates of each treatment.

Site improvement treatments assigned to main plots were:

1. Check - no site preparation except disking prior to planting in April 1965.

2. Site preparation - consisting of pre-planting fertilization and green manuring.

   Fertilizer - 448 kg/ha of 12-12-12 applied in June and September 1964 and April 1965.

   Green Manure - sudangrass seeded at 14 kg/ha June 1964 and plowed down September 1964; rye grain seeded at 14 kg/ha September 1964 and plowed down April 1965.

Two-year-old seedlings of black walnut, 1.0 m in height, and yellow-poplar, 1.2 m in height, obtained from Jasper-Pulaski State Nursery were planted in 23-cm-diameter augered holes at a spacing of 3 by 3 m in late April and early May, 1965. Individual subplots were 288 m^2 in area and consisted of 32 seedlings of a given species. Post-planting weed control treatments assigned to sub-plots were;

1. Check - no weed control

2. Cultivation - rototilled to a depth of 8 cm three times per season in 1965, 1966 and 1967.

3. Chemical - Amizine (45% simazine plus 15% amitrole) applied at 8 kg/ha over entire plot once per season in 1965, 1966 and 1967.

Measurements of tree survival, total height, and basal diameter at 7.5 cm above ground line were made in the fall 1965 through 1974 and in 1977. Breast-height diameter measurements were initiated in fall 1970 when trees in all treatments exceeded a height of 1.5 m. Data were subjected to analysis of variance and Duncan's mean separation. All tests were made at the 5% probability level.

RESULTS AND DISCUSSION

Variables included in the assessment of tree growth response to pre-planting site improvement and post-planting weed control are survival, total height, basal diameter, and breast-height diameter for black walnut and yellow-poplar in 1977 (Table 1). Mean annual total height and basal diameter increments were calculated for the periods 1965-68, 1969-72, and 1973-77 to illustrate differences in growth characteristics over time in relation to treatments (Table 2). Tabular data are summarized separately for site improvement and weed control treatments for easy comprehension. Growth trends among treatments, for total tree height, are graphically displayed from time-of-planting in 1965 through fall 1977 (Figures 1 and 3). Variation in tree size within and among treatments in 1977 is shown by the relative frequency of trees in six height classes (Figures 2 and 4).

Survival

Black Walnut: Black walnut survival in fall 1977, 13 years after planting, was very good with means among all treatments ranging from 79 to 91% (Table 1). The poorest survival occurred on plots with no site preparation and those subjected to mechanical cultivation for weed control. Most tree mortality occurred within the first 2 to 3 years after establishment. Some mortality in cultivated treatments may have resulted from machine damage to stems and roots in the surface soils even though special care was exercised in the cultivation process. On chemical treatments, no mortality could be associated with herbicide injury. On plots with no weed control survival was high, 89%, and equivalent to that achieved with chemical weed control and pre-planting site preparation. Although early growth rate is affected, as discussed later, it is evident that black walnut can survive and persist under stress conditions induced by weed competition.

Yellow-Poplar: Survival of yellow-poplar in fall 1977 was similar to black walnut and ranged from 79 to 99% among all treatments (Table 1). In a comparison of weed control treatments, the lowest survival, 79%, occurred on plots with no weed control. This was significantly less than the 92 and 99% survival where weeds were effectively controlled by cultivation and herbicides, respectively, during the establishment period. Weed competition for essential growth factors evidently affected yellow-poplar survival; however, some mortality also resulted from stem girdling by rodents harbored in the dense weed cover. Girdling did not occur on areas receiving cultivation or chemical weed control presumably due to the poor rodent habitat provided by bare soil or sparse weed cover. Yellow-poplar survival varied between site preparation and no site preparation treatments, but the difference was not statistically significant.

Table 1. Mean survival, height, and diameter of black walnut and yellow-poplar by treatment in fall 1977, 13 years after planting on Genesee sandy loam soil.

Treatment	Survival	Total height	Diameter Basal	Diameter Breast height
	%	m	cm	cm
		Black Walnut		
Site Improvement				
Site prep	91	5.9	10.0	8.1
No site prep	79	5.3	9.7	7.6
Weed Control				
No weed control	89	4.4	7.8	6.0
Cultivate	79	5.8	10.3	8.3
Chemical	88	6.6	11.5	9.3
		Yellow-Poplar		
Site Improvement				
Site prep	83	10.2	15.7	12.4
No site prep	97	9.1	14.2	11.0
Weed Control				
No weed control	79	8.3	13.1	10.1
Cultivate	92	9.8	15.0	11.8
Chemical	99	10.8	16.7	13.2

Total Height

Black Walnut: Mean total height of black walnut in 1977 ranged from 4.4 to 6.6 m among all treatments. Trees were shortest on plots with no weed control and tallest where weeds were chemically controlled with Amizine in the establishment period, 1965 to 1967 (Table 1). Trees in cultivated plots were intermediate, averaging 5.8 m total height in 1977. The height difference between pre-planting site improvement treatments was minimal; 5.9 m versus 5.3 m for site preparation and no site preparation, respectively.

The influence of treatments on black walnut height is best expressed by mean annual height growth at intervals representing the early establishment (1965-68), mid-(1969-72), and recent (1973-77) growth periods over the 13-year study (Table 2). There was little growth difference between site preparation and no site preparation treatment in all three periods, but mean height growth of 0.20 m from 1965-68 was less than one-half that in the latter two periods. In contrast, major growth differences were evident in relation to weed control treatments, especially during the

Table 2. Mean annual height and basal diameter growth of black walnut and yellow-poplar by treatment and growth period from 1965 to 1977 in Genesee sandy loam soil.

Treatment	Mean annual height growth			Mean annual basal diameter growth		
	1965-68	1969-72	1973-77	1965-68	1969-72	1973-77
	- - - m - - -			- - - cm - - -		
			Black Walnut			
Site Improvement						
Site prep	0.20	0.43	0.47	0.67	0.83	0.77
No site prep	0.16	0.42	0.42	0.58	0.83	0.76
Weed Control						
No weed control	0.00	0.36	0.40	0.22	0.72	0.71
Cultivate	0.20	0.45	0.45	0.65	0.87	0.80
Chemical	0.34	0.46	0.48	1.00	0.90	0.79
			Yellow-Poplar			
Site Improvement						
Site prep	0.25	0.82	0.95	0.82	1.47	1.31
No site prep	0.26	0.65	0.87	0.83	1.23	1.20
Weed Control						
No weed control	0.01	0.62	0.91	0.12	1.24	1.33
Cultivate	0.31	0.72	0.93	1.02	1.32	1.24
Chemical	0.44	0.85	0.90	1.32	1.50	1.19

early establishment period. Mean height growth was zero on plots with no weed control for the period 1965-68, 0.20 m with cultivation, and 0.34 m with chemical weed control. Growth differences among weed treatments decreased drastically by the mid period, 1969-72, and were practically non-existent during the 1973-77 period. This illustrates that black walnut is capable of surviving weed competition but has severe growth depression in the early establishment period. Survivors subsequently exhibit an accelerated growth rate equivalent to trees receiving cultivation or chemical weed control during the establishment period. Further, it appears that growth response to weed control peaks and levels off within 2 to 4 years after weed control is discontinued.

Although mean annual growth rates among all treatments were nearly equal from 1973-77, trees on areas with no weed control were still much shorter in fall 1977 (Table 1). With present growth trends (Figure 1), it is probable that they will not catch up in the foreseeable future. Trends in total height from 1965 to 1977 emphasize periodic growth patterns and separation among weed control treatments. The order of total tree heights

over the entire study period in relation to weed control treatments was chemical > cultivation > none (Figure 1). Total height was greater on plots receiving pre-planting site preparation, but was reversed after 1972 on cultivated plots. Although differences in total height between site improvement treatments were small in 1977 (Table 1), there has been increasing separation between them on chemical and no weed control treatments since 1971 (Figure 1).

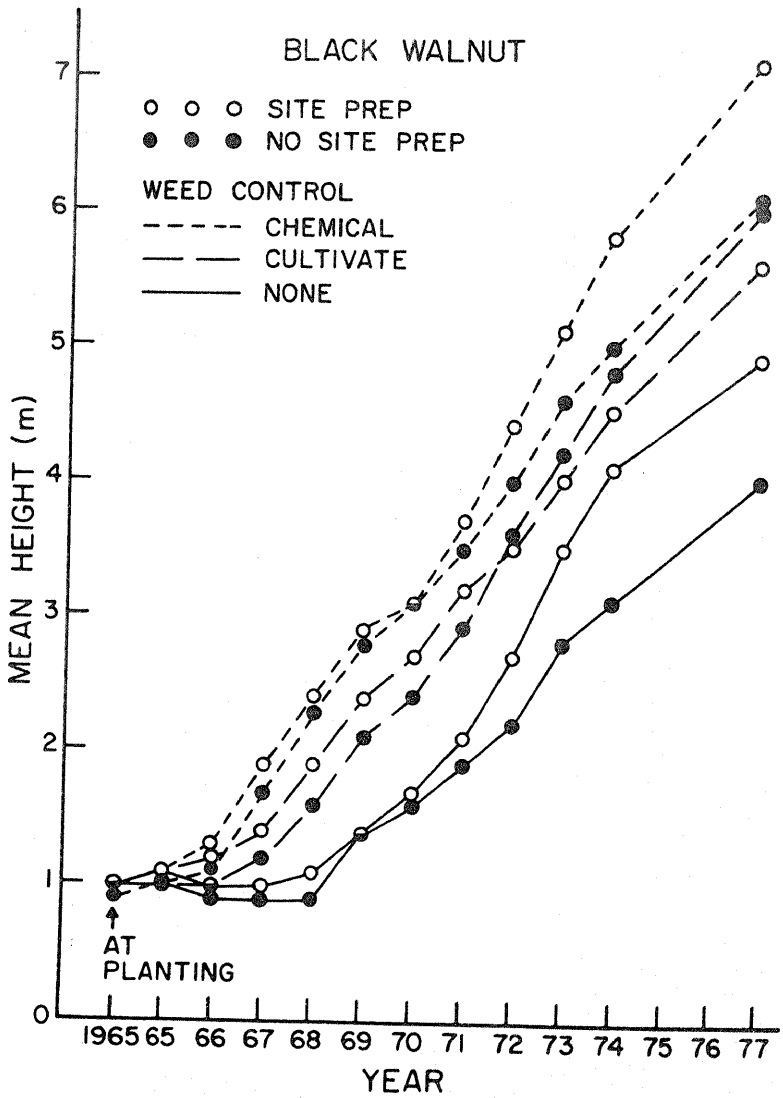

Figure 1. Mean total height of black walnut by site improvement and weed control treatments in spring 1965, at time-of-planting, and in fall 1965 to 1977 on Genesee sandy loam soil.

Although distinct differences in mean total height were evident among weed control treatments in fall 1977 (Table 1), these differences were not statistically significant. However, significant differences in total height did occur among weed control treatments from fall 1965 through fall 1971, while differences in walnut height between site improvement treatments were not significant over the entire 13-year study period. Lack of significant differences in height in recent years is likely due to increasing variation within treatments and minimal replication. This design was adequate under these site conditions to assess variability when seedlings were young and more uniform, but is not sufficiently sensitive at older ages when dominance is being expressed.

Variation in walnut total height, based on relative frequency within height classes in 1977, reveals that in most treatments there is sporadic distribution over six height classes from < 4 to > 8 m (Figure 2). A combined summary of tree height by site improvement treatments alone shows that 60% of trees on plots with pre-planting site preparation were taller than 6 m in contrast to 40% with no site preparation. A similar summary of weed control treatments alone reveals that 29%, 50%, and 72% of the trees in 1977 were taller than 6 m on no weed control, cultivation, and chemical plots, respectively. In plantation improvement activities, this distribution may serve as a basis for selection of trees for the future stand. The distribution on plots receiving chemical weed control in the establishment period offers the best opportunity for such selection due to the higher proportion of larger trees.

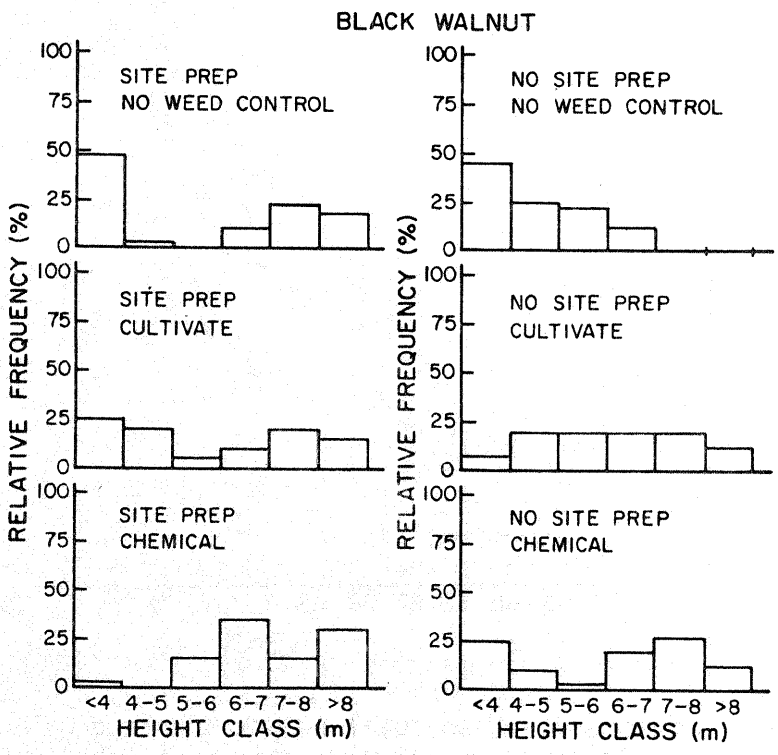

Figure 2. Relative frequency of black walnut by treatments within six height classes in fall 1977 on Genesee sandy loam soil.

Yellow-Poplar: Mean total height of yellow-poplar in 1977 of 10.2 m with pre-planting site preparation was not significantly greater than the 9.1 m height for no site preparation (Table 1). Trees receiving chemical weed control in 1965 to 1967, however, were significantly taller at 10.8 m than those with no weed control at 8.3 m height. Trees on cultivated plots attained a mean height of 9.8 m by fall 1977 which was intermediate but not significantly different from the no weed control check or chemical weed control treatments.

The rate of yellow-poplar height growth was equivalent, about 0.25 m per year, between site improvement treatments during the period 1965-68 (Table 2). During the period 1969-72, overall rate of height growth increased 2 to 3 times and was greater on plots with pre-planting site preparation. Additional increases in mean annual growth rate occurred from 1973-77, but with only minor differences between site improvement treatments, 0.95 m versus 0.87 m for site preparation and no site preparation, respectively. In contrast, prominent differences in mean annual height growth were evident among weed control treatments in 1965-68 ranging from practically zero growth with no weed control, to 0.31 m for cultivation, and 0.44 m for chemical weed control (Table 2). Differential growth responses among treatments were still evident but reduced from 1969-72 following termination of weed control measures in 1967. By 1973-77, however, mean annual height growth was equivalent, about 0.9 m per year, among all weed control treatments.

Mean total height of yellow-poplar from time-of-planting in 1965 through fall 1977 shows the trend of rapid initial growth response to weed control, both chemical and cultivation, and the 4 year delay in growth initiation related to weed competition effects (Figure 3). Also, growth response was consistently greater over the study period on areas receiving pre-planting site preparation and post-planting weed control treatments. Although, mean annual growth among treatments was essentially the same from 1973-77, it is evident that trees with the slow initial growth will not catch up at this current rate of growth.

Distribution of yellow-poplar in 1977 into six height classes from < 6 m to > 10 m reveals a concentration of larger trees on plots receiving chemical and cultivation treatments for weed control (Figure 4). A comparison of tree heights for weed control treatments alone shows that 97% of the trees on chemically treated plots were greater than 8 m in height, in contrast to 91% on cultivated plots and 56% on plots with no weed control. Thus, in addition to reduced growth, weed competition has resulted in greater variation in tree size after 13 years. A similar trend of height distribution, but with smaller differences, was observed in a comparison of site improvement treatments. In this comparison, 90% and 72% of the trees in fall 1977 were over 8 m in height on site preparation and no site preparation treatments, respectively.

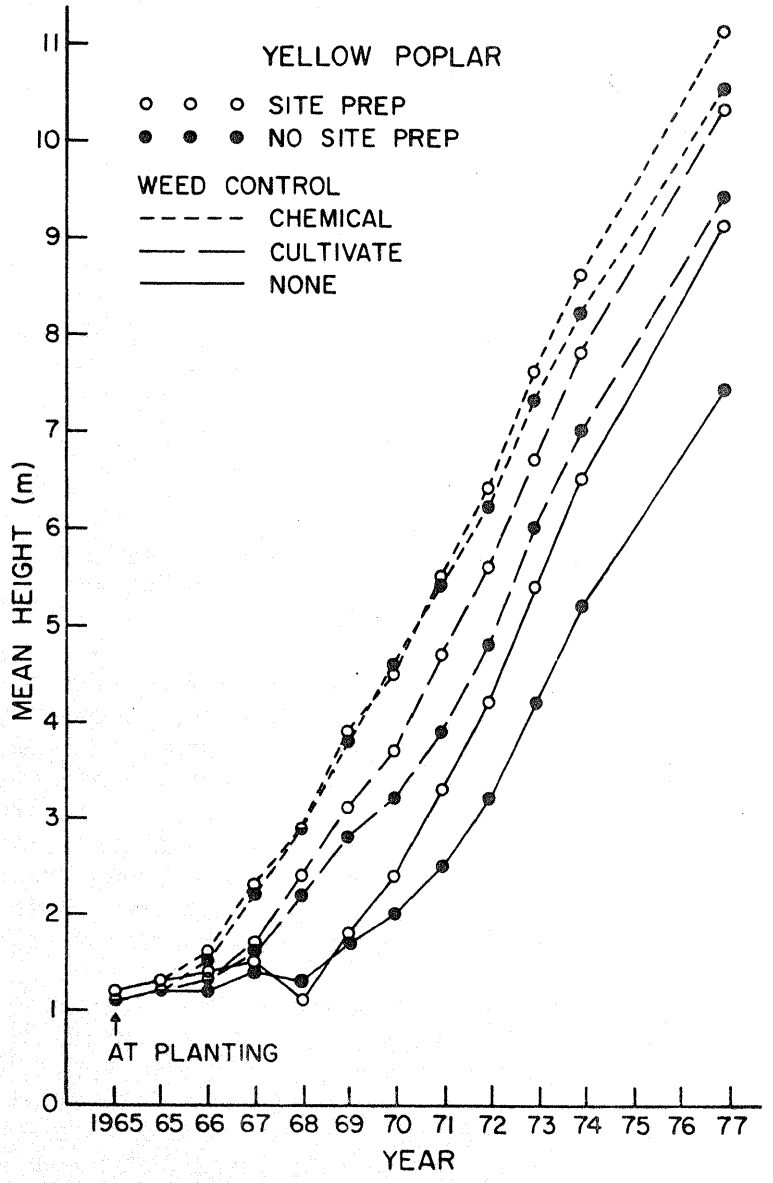

Figure 3. Mean total height of yellow-poplar by site improvement and weed control treatments in spring 1965, at time-of-planting, and in fall 1965 to 1977 on Genesee sandy loam soil.

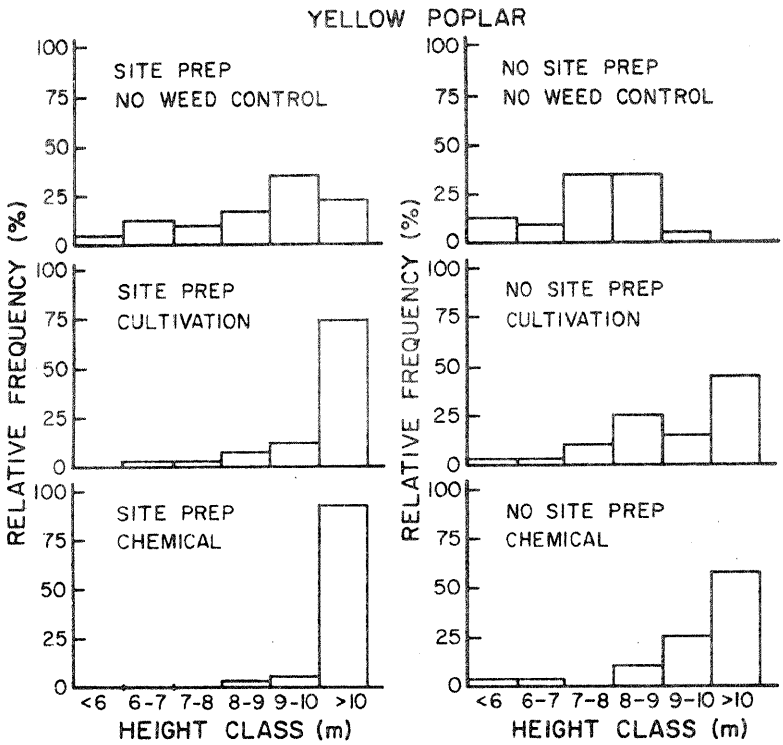

Figure 4. Relative frequency of yellow-poplar by treatments within six height classes in fall 1977 on Genesee sandy loam soil.

Diameter

Patterns of black walnut and yellow-poplar diameter growth and distribution by size classes in relation to site improvement and weed control treatments were similar to that of total tree height. The rate of diameter growth and ultimate size attained in fall 1977 varied as expected between the two species, with yellow-poplar being 1.5 times greater than black walnut (Tables 1 and 2).

Black Walnut: Differences in black walnut mean basal and breast-height diameter assignable to pre-planting site treatments were not significant at any time during the 13-year study (Table 1). Mean annual basal diameter growth was slightly higher during the 1965-68 establishment period for trees receiving site preparation in the form of fertilization and green manuring, but this advantage disappeared and was not evident from 1969 to 1977 (Table 2). Further, annual basal diameter growth rate increased for both treatments from 1965 to 1972, then declined from 1973 to 1977.

Notable differences in both basal and breast-height diameter were evident among weed control treatments in fall 1977, but again these differences were not statistically significant (Table 1). From a

practical standpoint, however, the difference of 3.7 cm in basal and 3.3 cm in breast-height diameters between no weed control and chemical treatments, respectively, is important. Interestingly, diameter differences between these same treatments were significant from 1965 to 1973, but not in recent years, presumably due to increased variation within treatments similar to that experienced with height growth characteristics. Likewise, significant differences in basal diameter were observed between cultivation and chemical weed control treatments until 1971.

The relationships discussed above are further elucidated in a comparison of mean annual basal diameter growth during early, mid-, and recent growth periods (Table 2). For the early period, 1965-68, black walnut annual basal diameter growth was 0.22 cm, 0.65 cm, and 1.00 cm for no weed control, cultivation, and chemical weed control, respectively. For the mid period, 1969-72, these growth differentials decreased to less than 0.2 cm between no weed control and chemical treatments and less than 0.1 cm between cultivation and chemical. From 1973-77 there was essentially no difference in growth rate among all weed control treatments.

Yellow-Poplar: In fall 1977, pre-planting site preparation in the form of fertilization and green-manuring resulted in a small but statistically significant increase of 1.5 cm in mean basal diameter for yellow-poplar as compared to the no site preparation treatment (Table 1). Basal diameter growth rate was higher from 1969 to 1977 for trees on plots receiving site preparation (Table 2). The difference in mean breast-height diameter between site improvement treatments in 1977 was not significant.

Post-planting chemical weed control, in comparison with the no weed control check, resulted in significantly larger mean basal and breast-height diameters of yellow-poplar in fall 1977 and throughout the 13-year study period (Table 1). In addition, mean basal diameter of trees was significantly greater on plots with chemical weed control than on cultivated plots from 1965-69, but this difference was not evident in recent years. In 1977, mean basal diameters were 13.1, 15.0, and 16.7 cm and breast-height diameters were 10.1, 11.8, and 13.2 cm for the check, cultivation, and chemical treatments, respectively. The most prominent differences in mean annual basal diameter growth among weed control treatments occurred during and one year after the application of weed control treatments, i.e., 1965-68 (Table 2). Annual diameter growth differences among weed control treatments were drastically reduced during the 1969-72 and 1973-77 periods. This reduction was due primarily to the increasing growth rate of yellow-poplar on check plots as well as declining growth rates on weed control plots where inter-tree competition is being expressed.

CONCLUSIONS

Pre-planting fertilization and green manuring did not have a statistically significant influence on survival or growth of black walnut and yellow-poplar on these site conditions. However, from a practical standpoint the small growth advantages throughout the 13-year study have

resulted in a clustering of trees in the larger height and diameter classes. Post-planting weed control during early establishment with herbicides and to a lesser extent with cultivation produced a significant growth advantage in both yellow-poplar and black walnut. Both species were able to tolerate weed competition on the check plots but had essentially no net growth during the first 4 years of establishment. However, after 4 years survivors began to grow at a rate comparable to trees previously receiving weed control treatments. At current growth rates trees on the check plots will not catch up to the average size of those on plots where weed competition was suppressed.

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