Advantages of an Effective Weed Control Program for Populus Hybrids

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Two weed control programs were used to establish two intensive-culture short-rotation plantations containing Populus maximowiczii x trichocarpa *hybrid (NE-388) in central Pennsylvania. As compared to mechanical weed control only, a combination mechanical and chemical weed control program reduced the establishment phase for this clone to less than 1 year. Net results of the mechanical-chemical weed control program, as compared to mechanical only, were greater average tree size variables and total tree ovendry weight at the end of a 4-year rotation. When considered as a marginal investment proposition, the discounted value of the added yield was greater than the added cost of the chemical weed control measures.* Tree Planters' Notes 43(3):81-86:1992.

Populus hybrids are very sensitive to weed competition during establishment. Earlier planting successes in herbaceous plant-dominated ecosystems were best achieved by mechanical or physical weed control (Bowersox and Ward 1969, Ford and Williamson 1952). Cunningham and Sower (1962) evaluated varying rates of simazine and reported that cultivation alone produced higher 2-year-old survival and more than double the 2-year-old height than the best herbicide treatment. In the late 1970's, attempts to culture *Populus* hybrids on large areas in short-rotation biomass systems were limited by the availability of biologically safe and financially attractive weed control measures. In the same time period, the menu of available herbicides was expanding rapidly. *Populus* hybrid plantings vary considerably in sensitivity to herbicide damage. Susceptibility to herbicide damage has been associated with application date (Danfield et al. 1983), tillage (Aird 1962, Akinyemiju and Dickmann 1982a), chemical sensitivity (Akinyemiju and Dickmann 1982b, Dickmann et al. 1977, Netzer and Noste 1978, White et al. 1982a, White et al. 1982b) and parentage (Akinyemiju and Dickmann 1982a, Von Althen 1979).

In 1980 and 1981, cuttings for a *Populus* hybrid were planted to conduct net financial and energy analyses for biomass production under four management strategies (Blankenhorn et al. 1985). Not willing to risk the project on untested herbicides, the researchers established the 1980 plantings with mechanical site preparation only. The 1981 plantings were established by a combination mechanical-chemical site preparation and weed control program (Grado et al. 1988). Since 1980, site preparation and weed control programs have been developed for establishing plantations in the Lake States (Hansen et al. 1983) and Ontario (Barkley 1983). Both these programs recommend pretreatments with non-selective herbicides, mechanical site preparation, and pre-emergence herbicides. In general, our 1981 weed control program was similar to the Lake States and Ontario procedures, and this paper describes the potential advantages of an effective weed control program for intensive culture *Populus* plantations.

Methods

Plantations. Two plantations of *P. maximowiczii x trichocarpa* (clone NE-388) were established on abandoned fields in central Pennsylvania. They were about 30 km southwest of State College and within 1 km of each other. The two plantations were designed to evaluate growth and yield from existing fertility and rainfall (control), fertilization, irrigation, and fertilization/ irrigation and to assess the economics of these cultural strategies in dense plantations. This report focuses on the control trees only.

Each plantation (0.6 ha) consisted of 6 blocks of all treatments, 3 planted in 1980 and 3 in 1981. Planting year was randomly assigned to each block, and control treatment was randomly assigned to 1 of the 4 treatment plots per block. The Basher plantation was on a nearly level flood plain derived from red shale and sandstone and the soil was a Basher site loam (Fluvaquentic Dystrochrept; coarse-loamy, mixed, mesic). The Morrison plantation was on a gently sloping upland area where sandstone and dolomite had weathered to a Morrison sandy loam (Ultic Hapludalf; fine-loamy, mixed, mesic).

Dormant, unrooted cuttings were planted in early May in rows 0.8 m apart and 0.6 m between trees in a row for 0.48 m^2 of growing space per tree. All cuttings came from the same stool bed and were collected in March of the specific planting year. All cuttings were 25 cm long and 0.6 to 1.9 cm in mid-point diameter and stored in wet sawdust at 3 °C. Planting methods were the same for each year, except that the 1980 planting required 2 weeks and the 1981 planting required 1 week. Each plot had 272 study trees that were bordered with 2.4 m of similarly spaced trees. There were 3 border rows on the sides and 4 border trees at the end of each row. A total of 550 trees was planted on each 0.026-ha plot.

Height in the first and second growing seasons was measured weekly to biweekly on independent, randomly selected (without replacement) 10 tree subsets per block. Studies designed to evaluate height growth patterns repetitively measured the same trees. In this study, we wanted to test the differences in average height at various measurement dates. Our procedures were used to eliminate previous measurement bias, but this also created the potential that a subsequent average height could be lower than an earlier average height. Height and stem diameter at 15 cm above ground were measured annually on all surviving trees. Total tree yield from all living trees per block (wood, bark, and branchwood) at age 4 was determined from actual harvest (field weight) and ovendry equations (Blankenhorn et al. 1985). Statistical analyses of the annual tree size variables were conducted on a random (with replacement) 100-living-tree subset of the 272 study trees per block (600 trees per planting year), and on the collective yield from all living trees per block (6 blocks per planting year). Analysis of variance was used for all statistical tests at the 0.05 level.

Weed control. The herbaceous communities in the abandoned fields were undisturbed until scheduled for planting. Plowing and disking prior to planting were the only weed control measures available to establish the 1980 plantations. Preplanting chemical weed control was not possible in these plantings because of limited knowledge on safe herbicides for *Populus* hybrids. In July, invading weeds were reducing height growth (figure 1). To remedy this situation, mowing, hand weeding, and shielded applications of glyphosate were instituted in August. These practices would not have been conducted in a production scale plantation. They were conducted to ensure acceptable survival rates to complete the overall research objective. Survival values at the end of the 1980 growing season average 86%.

In consultation with weed control experts, the researchers organized a weed control program for the 1981 plantings that was started in 1980. In August 1980, glyphosate at 2.24 kg/ha and dicamba 3.36 kg/ha, active ingredients (a.i.) were used at the Basher site and glyphosate at 2.24 kg/ ha a.i. at the Morrison site. A root-absorbed herbicide (dicamba) was used at the Basher site to control a carpet of broadleaf weed seedlings under the main abandon-field herbaceous community. These 1- to 2-cm-tall broadleaf weed seedlings were shielded from the foliar-absorbed glyphosate by the 1-m-tall main herbaceous canopy, and they were considered too young to be controlled by the glyphosate. These conditions were not present at the Morrison site. Most of the recommended pre-emergent herbicides were developed for agronomic crops and their toxicities to *Populus* trees being established from cuttings were unknown. Greenhouse trials were used to select the herbicides most likely to safely control the expected weeds (Blankenhorn et al. 1985). The following herbicides were applied to the plowed and disked soils in spring 1981:

Basher site--post-planting broadcast of a pre-emergent herbicide to control nutsedge (*Cyperus esculentus* L.) (metolachlor at 3.36 kg/ha a.i.) plus a pre-emergent to control grasses and broadleaves (oxyfluorfen at 1.12 kg/ha a.i.).

Morrison site--post-planting broadcast of a pre-emergent herbicide to control grasses and broadleaves (oxadiazon at 8.97 kg/ha a.i.).

The amount of weeds in the establishment year of the 1980 plantings was not measured. For the 1981 plantings, estimates of the amount and type of weeds were determined from four 1.0-m^2 sample plots per block at each site (total N = 24). Control plots were also established on adjacent unplanted areas that were tilled but not treated with herbicide (three blocks with four 1.0-m^2 sample plots per block at each site and planting year). In late August, weeds were cut at ground line and ovendry weights for broadleaves and grass were measured for each plot.

Financial evaluations. Procedures involved in the financial evaluation of the first rotation for a 5-rotation system have been reported by Strauss et al. (1987). An accounting-type cost analysis was used, including the proration of establishment costs over the five 4-year rotations, assessment of an economic rent for land use, and identification of all other operating and maintenance charges. The financial costs were developed for the base year 1981.

Results and Discussion

Tree response. Overall, there were significant differences in average tree diameter and height between planting years at the end of the fourth growing season (table 1). Differences between sites were not significant, except for a small (0.02 cm) but significant difference in stem diameter for the 1980 planting. Therefore, data were pooled over sites to examine differences between planting years. Averaged over sites, the 1980 plantings were 5.5 m in height and 3.4 cm in diameter and had 20.2 ± 5.2 ovendry (OD) tonne/ha of total tree yield at the end of 4 growing seasons. The 1981 plantings averaged 6.7 m in height and 4.2 cm in diameter and had 33.1 - 5.2 OD tonne/ha of total tree yield.

Table 1—*Average 4-year-old survival, total height, stem diameter at 15 cm above ground, and total tree ovendry yield for trees planted in 1980 and 1981*

Planting year & site	Survival (%)	Total height (m)	Stem diameter (cm)	Total tree yield (OD tonne/ha)
1980				
Basher	84	5.7 a	3.5 b	21.7 a
Morrison	88	5.3 a	3.3 a	18.7 a
1981				
Basher	91	6.8 c	4.2 c	34.2 b
Morrison	90	6.7 c	4.2 c	31.9 b

Variable values with the same letter were not significantly different at the 0.05 level. By planting year and site, N was 816 for survival, 300 for total height and stem diameter, and 3 for total tree yield.

Even with the high degree of site, stock, and operational standardization, year-to-year comparisons are difficult to evaluate because of variable weather conditions. Weather conditions in the 1980 to 1984 growing seasons were not extreme, but the extent to which weather influenced the differential growth rates of the 1980 and 1981 plantings is unknown. Rainfall values during the growing seasons did not vary greatly until 1983 (table 2). When the trees planted in 1980 were in their fourth growing season, rainfall was low (1983). When the trees planted in 1981 were in their fourth growing season, rainfall was high (1984).

Table 2—*Rainfall at the study sites during the 1980 to 1984 growing seasons*

Month	Rainfall by growing season (cm) 1980	1981	1982	1983	1984
June	7.6	13.3	10.9	7.1	12.7
July	10.2	7.8	10.5	3.1	7.7
August	8.2	4.7	4.4	1.9	15.2
Total	26.0	25.8	25.8	12.1	35.6

From U.S. weather station 30 km northeast of plantations in 1980. Recorded daily from two rain gauges at each plantation in 1981 through 1984 and averaged together.

Height growth rates during the first and second growing seasons were strikingly different for the 2 planting years (figure 1). At the end of the first growing season, all trees planted in 1980 averaged

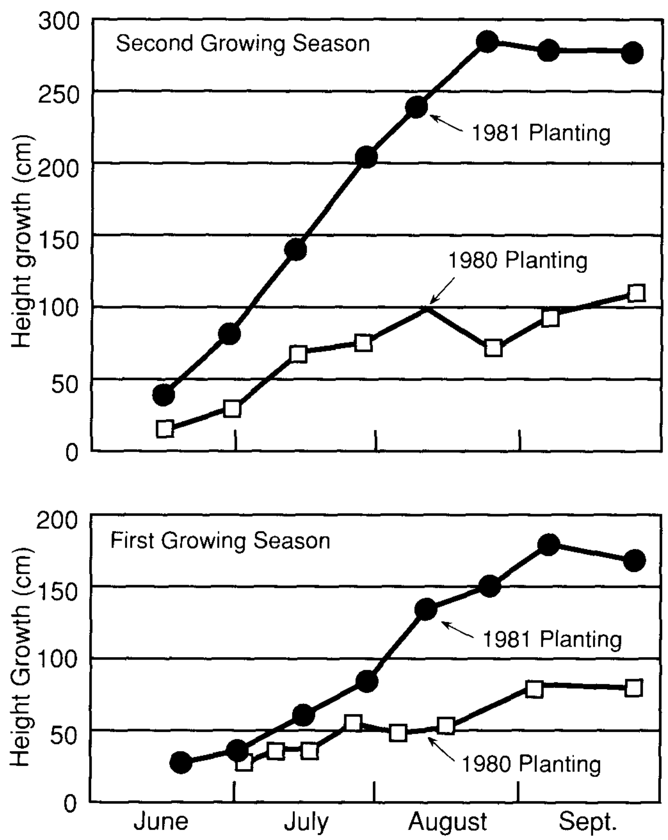

Figure 1—*First- and second-year height values of the 1980 and 1981 tree plantings. Lower sequential values were not significantly different from previous value and were due to sample error. Each value was based on 60 independent trees, averaged over the two plantation sites.*

0.8 m in height whereas all trees planted in 1981 averaged 1.7 m. Compared to the first-year height growth from other central Pennsylvania plantations (of the same hybrid) where weeds were controlled by hand hoeing or black polyethylene mulch (Bowersox and Ward 1969, Bowersox and Ward 1976, Bowersox et al. 1979), the height growth of the 1980 plantings was about 40% lower than what should be expected; that of the 1981 plantings was about 40% higher than what should be expected.

Low rainfall in June 1980 (7.6 cm) may be partly responsible for the reduced height growth in the first growing season for the 1980 planted trees (figure 1), but we believe that weed competition was a more controlling factor. The mechanical site preparation used for the 1980 plantings established a relatively weed free condition until late June. However, by mid-July, the weeds rapidly developed to the height of the trees. Remedial weed control measures were enacted after August 1. Height growth in late July and August 1980 appeared to be very sensitive to weed competition (figure 1). In contrast, the 1981 plantings were relatively weed free through July and once the trees started to grow rapidly in height (early July), their growth was unrestricted. Overall, site preparation and weed control program for the 1981 plantings reduced the weed growth in the Basher and Morrison plantations by 80 and 87%, respectively, when compared to the control plots (table 3). Total amount of weeds in the plantations and the control plots was lower at the Morrison site than at the Basher site. This was largely due to the amount of grasses (mainly nutsedge) at the Basher site.

Table 3—*Ovendry weight of herbaceous vegetation in late August 1981 for herbicide (tilled plus pre-emergent herbicides) and control (tilled only), by site and weed group*

	Basher (g/m²)		Morrison (g/m²)	
Weed group	Herbicide	Control	Herbicide	Control
Grasses	25	45	2	12
Broadleaves	30	235	22	178
Total	55	280	24	190

Quality of the establishment-year weed control program appears to have a carryover to the second growing season. Total height growth in the second growing season was markedly greater for the trees planted in 1981 than for those planted in 1980 (figure 1). The 1980 plantings grew an average of about 1.0 cm/day in June, July, and August for a second growing seasonal height growth of 1.0 m.

Trees planted in 1981 grew an average of 2.0 cm/ day during June, July, and August of their second year. After two growing seasons, total height of the 1980 plantings averaged 1.8 m and the 1981 planted trees averaged 4.4 m (figure 2).

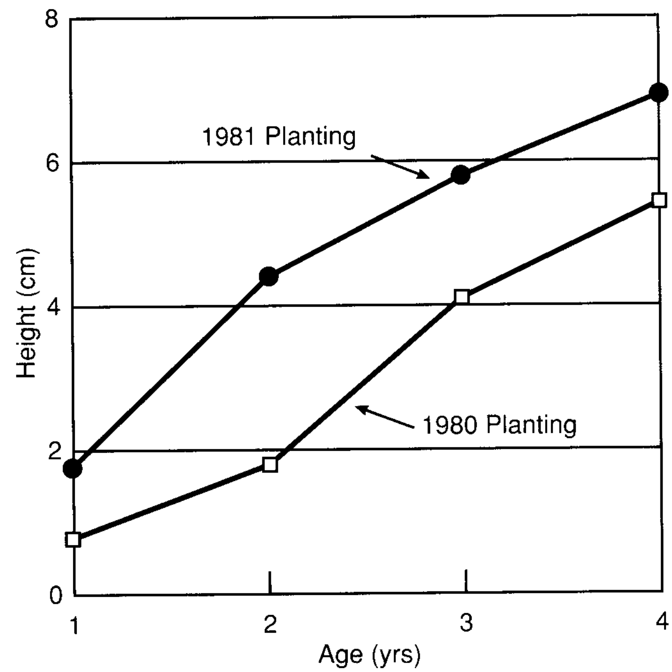

Figure 2—*Average total height for the 1980 and 1981 plantings by age. Values were based on 600 trees, averaged over the two plantation sites.*

Height growth of the 1980 plantings was restricted in the first and second growing seasons and the establishment period was prolonged. Once the trees were well established (1981 plantings by the end of their first growing season and 1980 plantings by the end of their second growing season) total height growth rates were similar (figure 2). Height increment for the second growing season of the 1981 plantings was similar to the third-year increment for the 1980 plantings; third- and fourth- year height increments for the 1981 plantings were similar to the fourth-year increment of the 1980 plantings. In essence, the weed control measures used in the 1981 plantings resulted in an establishment phase of 1 year, whereas the measures used in the 1980 plantings resulted in an establishment phase of 2 years.

Average height, diameter, and total tree ovendry yield for the trees planted in 1981 were greater than for the trees planted in 1980. These differences could have been due to unknown establishment and tending practices, weather conditions, or unique factors for this particular clone at these specific sites. However, we believe the main reason for the differences in average tree size and total tree yield for the 1980 and 1981 plantings was the effectiveness of the establishment-year weed control programs.

Financial response. The potential increase of 64% to the first-rotation yields associated with a weed control program would provide a substantial cost reduction for the short-rotation intensive culture system. Financial evaluations of the commercial-scale establishment and maintenance costs for the plantations, excluding any herbicide treatments, placed the total costs for the first rotation at $942/ha. This included the prorated cost of establishment for the first rotation, the annual maintenance and operating costs, and the economic rent for using the agricultural sites (Strauss et al. 1987). Estimated first-rotation yields of 20 OD tonne/ha placed the stumpage cost for the biomass at $47 per OD tonne. Costs for remedial mowing, hand weeding, and shielded applications of glyphosate used in the 1980 plantings were not included in the analyses, and there is also some possibility that expected yields for the 1980 plantings would have been lower without these treatments.

The chemical weed control program for the 1981 plantings increased the establishment charges by $210/ha; which, when prorated over 5 rotations, raised the end-of-rotation costs to $1,015/ha. However, the more effective weed control program increased yields to 33 OD tonne/ha. The cost of the 1981 weed control program was greater than the 1980 weed control program, but the 1981 program produced substantially more biomass. The net effect of the 1981 weed control program reduced the stumpage costs to $31 per OD tonne, or 34% lower than the less effective (1980) weed control program.

The weed control programs were evaluated as a marginal investment proposition, given two assumptions. These assumptions were (1) the yield increase of 13 OD tonne/ha would only have occurred in the first rotation, and (2) the value of the stumpage was equal to its cost (a financially break-even situation). Using a 5% real rate of return, the discounted value of the 13 OD tonne/ha gain, priced at $31 OD/tonne, was $332/ha. This return exceeded the initial cost of $210/ha for the weed control program and, again, justified its investment.

Conclusions

Populus hybrids are very sensitive to weed competition, particularly in the establishment phase. Establishing plantations from dormant unrooted cuttings requires a unique herbicide program that will both control weeds and cause minimal damage to root and stem tissues. The combined mechanical-chemical program we used for one *Populus* clone in central Pennsylvania was similar to the recommendations for establishing *Populus* plantations in the Lake States and Ontario. The chemicals we used should not be taken as a recommendation. Specific chemicals will vary, depending on soil, climate, weed species, cultural practices, and *Populus* parentages. New products or label changes will require herbicide program adjustments. In this case, for a 4-year biomass rotation, we believe the combined mechanical-chemical weed control measures were cost effective and allowed the trees to more fully exploit the potential of the site.

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