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WEED CONTROL FOR ESTABLISHING INTENSIVELY CULTURED HYBRID POPLAR PLANTATIONS

Edward Hansen, *Principal Hydrologist,*
Daniel Netzer, *Forester,*
and **W. J. Rietveld,** *Principal Plant Physiologist,*
Rhinelander, Wisconsin

ABSTRACT.—Compares effects of various weed-control methods, including herbicides, cultivation, and legume cover crop, on tree survival and height growth of 2-year-old hybrid poplars. Cultivation and herbicides singly or in combination gave consistently better results than the other treatments tested.

KEY WORDS: Intensive culture, plantation establishment, glyphosate, linuron, cultivation, cover crops, nitrogen fixers, *Populus* spp., short rotation, energy plantations.

Control of weeds is essential for successfully establishing hardwood plantations (Tillotson 1921, Lane and McComb 1953, Bey *et al.* 1975, von Althen 1979). A variety of weed control measures have been tried. Byrnes *et al.* (1978) found that for black walnut (*Juglans nigra* (L.)) and yellow poplar (*Liriodendron tulipifera* (L.)), chemical treatment was better than cultivation and that both were better than the control. In contrast, von Althen (1981) reported slightly better results for hybrid poplar with rototilling than with the herbicide Simazine at various rates.

Our study compared eight weed control methods that included cultivation, herbicides, and a legume cover crop singly and in various combinations. These methods were some of the best of more than 400 variations we tested in small-plot trials over a 3-year period. Our objective was to develop a group of alternative weed control methods that might be useful on a variety of soils and over a range of soil moisture conditions.

METHODS

The study area was located at the North Central Forest Experiment Station's Harshaw Forestry Research Farm near Rhinelander, Wisconsin. Before its development as a forestry research area, the Harshaw Farm had a 50-year history as a potato farm. Soils are padus series silt loam grading to a sandy loam with a plow layer at 25 cm and a pH ranging from 6 to 7. Quackgrass (*Agropyron repens* (L.) Beauv.) is the main weed competitor; other significant weeds include yellow rocket (*Brassica* spp.), wild mustard (*Brassica kaber* (DC.) Wheeler), lambsquarters (*Chenopodium album* (L.)), white cockle (*Lychnis alba* Mill.), marestail (*Conyza canadensis* (L.) Cronq.), and pigweed (*Amaranthus retroflexus* (L.)).

The experiment was a split-plot design with two replications. Irrigation was the main-plot treatment (not randomized), and weed-control treatments (subplots) were randomly located within the main-plots. Within each weed-control treatment, three *Populus* clones of four rows each were positioned systematically as sub-subplots. It was assumed that lack of randomization in the sub-subplots did not affect the analysis for clones. A fourth clone was used for a two-row border on either side of each weed-control treatment subplot and was not used in the analysis of the results. Each weed control subplot was 16 ×84 m and trees were spaced at 1 ×1 m. The three clones were NE-386 (NC-5263) *P. Candicans'* ×*(P.* ×*berolinensis)*, NE-1 (NC-5272) *P. nigra* ×*P. laurifolia* 'Strathglass', NC-9921 *P.* spp.; the border clone was NC-5260 *P. tristis* ×*P. balsamifera* 'Tristis #1'.

The 4.3 ha experimental area was seeded to white dutch clover (*Trifolium repens* (L.)) in the spring of 1979, 1 year prior to establishing the weed-control study. Site preparation, which began in August, consisted of moldboard plowing to a 25-cm depth followed by alternate disking and chisel-plowing at different depths every 8-10 days to eliminate weeds. Disking was repeated in May 1980 just before applying the treatments.

Unsoaked, unrooted, 20-cm-long cuttings were machine-planted 15 cm deep in all treatments except the furrow cultivation treatments on May 9, 1981. The two-furrow cultivation treatments (table 1) were planted with both 20- and 30-cm-long cuttings by dividing the four rows of each clone into two rows of each cutting length. The 20-cm cuttings were used to compare the furrow cultivation treatments with the other treatments. The 30-cm cuttings were used only for comparison with the 20-cm cuttings in the furrow cultivation treatments.

The furrow-cultivation method consisted of plowing 10-cm-deep furrows with scalper blades at the time of planting. The cuttings were then planted 10 cm deep in the bottom of the furrows. The longer cuttings were included to determine if it was desirable to avoid complete burial of cuttings as the furrows were gradually cultivated full. Since fairly tall weeds could be buried by filling in the furrow, the first cultivation of the furrow-cultivation treatment was started later than that of the standard cultivation treatment.

Cultivation to the 7-cm depth was done with a four-row rolling cultivator. The shallow cultivation minimized damage to *Populus* roots. It was necessary to repeat cultivation about every 10 days to effectively control weeds.

The pre-emergent herbicide linuron (Lorox)[1] was applied at 2.2 kg active ingredient (a.i.)/h (2 lb/A) with a tractor-mounted boom sprayer just prior to planting the cuttings. Glyphosate (Roundup), a broad-spectrum contact herbicide, was applied at 2.2 kg a.i./ha with a shielded boom sprayer. Benfluralin (Balan) was applied with a boom sprayer at 1.7 kg a.i./ha (1.5 lb/A) on 6 to the legume subplot and incorporated to a 8-cm depth by disking just prior to seeding and planting. Application of benfluralin prior to seeding legumes in the spring is a standard agricultural practice for establishing legumes. The legume white dutch clover was hand-seeded at a rate of 6.7 kg/ha in the spring with a cyclone seeder. The legume subplots seeded in late summer (August 28) were cultivated just prior to seeding to loosen the soil and create a better seedbed, and were seeded at double the spring rate.

[1] *Use of trade names does not constitute endorsement by the USDA Forest Service.*

Table 1.—*Description and dates of application of eight weed control treatments. The treatments are ranked in order of 1st-year height-growth (all treatments were planted with cuttings on May 9).*

	First year					Second year			
	Broadcast-spray					Broadcast-spray			
Weed control treatment	Benflur-alin	Linuron	Cultivate	Shield-Spray glyphosate	Seed legume[1]	Glyphosate	Linuron	Cultivate	Shield-spray glyphosate
Linuron-legume		5/6			8/28				
Linuron-cultivation		5/6	7/10-8/25(5x)[2]					5/14	
Linuron-glyphosate		5/6		7/22			5/4		5/15
Cultivation			5/20-8/25(11x)					5/14	
Legume	5/6				5/6				
Glyphosate				6/11,7/17					5/15
Furrow cultivation-legume			6/3-8/25(10x)		8/28			5/14	
Furrow cultivation			6/3-8/25(10x)			4/25		5/14	

[1]The legume was white dutch clover.
[2]Signifies 5 cultivations.

In the spring-seeded legume treatment there was an invasion of wild mustard that was not controlled by benfluralin. The mustard reduced, and in some areas prevented, establishment of clover. Therefore, the results of the "legume" treatment may have been affected as much by the mustard as by the legume.

Some of the treatments involving herbicides or cultivation had several applications the first year (table 1). In the spring of the second year, herbicide and cultivation plots were treated one last time. The plots with legume had no further treatment after the legume was seeded. Since it is well documented that omitting post-planting weed control for hardwoods results in poor survival and growth, and occasionally complete failure, we did not include an untreated control in our tests.

The two irrigated blocks were irrigated overhead with a cart-mounted traveling irrigation gun whenever soil moisture tension reached –0.5 bars at the 15-cm depth. A 28-percent nitrogen solution was applied to the entire study area through the irrigation system at the rate of 168 kg/ha/yr. Application was split, with half applied in June and half in July. Fertilizer was applied to the unirrigated blocks by the same method, with the irrigation-fertilization scheduled immediately after rainstorms to minimize the irrigation effect.

Tree survival and height were measured at the end of the first and second growing seasons. Sample trees were those in the interior portion of the two center rows of each clone. Survival was based on samples of 140 and 30 trees in each treatment subplot the first and second growing seasons, respectively. Height was based on samples of 40 and 30 living trees in each treatment subplot the first and second growing seasons, respectively. Because of heterogeneity of variance, the survival data were transformed by Tukey's version of the arcsin transformation. The data were analyzed by ANOVA with $p = 0.05$. Significant differences between treatment means were tested using the Newman-Keuls multiple comparison method.

RESULTS AND DISCUSSION

Even though the experimental design did not provide an error term for testing irrigation effect, there was no evidence of an irrigation effect on either survival or height growth.

Although cutting length had no significant effect on survival, it had a significant effect on first-year tree height. However, if the tree heights were adjusted by the 10-cm difference in cutting length, (the longer cuttings protruded about 10 cm farther from the ground), there was no significant difference in tree growth.

The weed control treatments had significant effects on tree survival:

Weed control treatment	Survival (Percent)
Glyphosate	81
Linuron-legume	76
Linuron-glyphosate	73
Linuron-cultivation	72
Cultivation	57
Legume	49
Furrow cultivation	35
Furrow cultivation-legume	18

(Treatments next to a common line are not significantly different.)

Treatments that included either linuron or glyphosate herbicide had significantly higher survival than the furrow cultivation treatments. Treatments with legumes or cultivation only generally ranked in the lower half.

There was no difference in survival among *Populus* clones for six of the eight weed-control treatments. However, the clones differed significantly in their response to the two furrow cultivation treatments. For those two treatments, clone NE-386 had the best survival (37 percent) and NC-9921 the poorest (26 percent). However, the overall survival for the furrow cultivation treatments was so poor that differential clonal response may have little meaning.

The weed control treatments significantly affected first-year height growth. The two best treatments were significantly different from the last three. The three best treatments all contained the herbicide linuron. Our standard cultivation practice ranked in the upper half also. Treatment with glyphosate alone did not appear to be as effective, although it did not differ significantly from the three above it. The furrow cultivation treatments ranked last.

The ranking of treatments by height changed somewhat by the end of the second year:

Rank 1st year	Rank 2nd year	Weed control treatment	Height (meters) 2nd year
2	1	Linuron-cultivation	3.2
3	2	Linuron-glyphosate	3.2
4	3	Cultivation	2.9
1	4	Linuron-legume	2.7
8	5	Furrow cultivation	2.7
6	6	Glyphosate	2.5
7	7	Furrow cultivation-legume	2.2
5	8	Legume	2.1

(Treatments next to a common line are not significantly different.)

The linuron and cultivation treatments still ranked high as a group. However, two of the three treatments that included a legume dropped in the rankings and the third retained its already low ranking. The two top-ranking treatments (linuron-cultivation and linuron-glyphosate) were significantly different from the two bottom ranking treatments (furrow cultivation-legume and legume). An analysis of tree *growth* during the second year showed that the three treatments with the least growth all included legumes.

Within any subgroup of similar treatments, the legume treatment always ranked last in terms of second-year tree height. Specifically, legumes were last in the combination treatments that included an herbicide (Nos. 1,2,4), in the single treatment types (Nos. 3,6,8), and in the furrow cultivation treatments (Nos. 5,7). Although differences in tree height within these subgroups were not significant, this pattern of consistently lower tree height suggests a treatment effect.

All three *Populus* clones differed significantly in second-year height, with NE-1 the tallest and NC-9921 the shortest. There were no significant interactions, indicating the three clones responded similarly to the weed control treatments.

From the standpoint of tree survival and growth, the pre-emergent herbicide linuron applied alone or combined with other treatments gave consistently superior performance. Linuron is applied just prior to planting and prevents weed seed germination for 4-6 weeks. We have experienced tree damage from linuron in only one year out of 10. That year 25 cm of rain in June leached the still active linuron into the rooting zone.

Glyphosate is extremely difficult to apply after planting without damaging tree seedlings. Actively growing young hybrid poplars are easily damaged by even small amounts of glyphosate spray drift, but are not affected through the soil, when dormant, or through bark older than 1 year (Akinyemiju *et al.* 1982). Although we applied it very carefully and shielded the trees from the spray, they were still damaged. Although tree survival in the glyphosate treatment ranked highest, it did not differ significantly from the three linuron treatments or from the cultivation-only treatment. However tree height with the glyphosate treatment was much reduced, ranking sixth of the eight treatments. Glyphosate damage was evident in the off-color leaves and stunted appearance. The best all-herbicide treatment tested was a pre-planting application of linuron followed by a mid-summer application of glyphosate. Linuron is a "safe" herbicide for hybrid poplars and allows the application of glyphosate to be delayed until the trees are bigger and hardier. The glyphosate treatment, which consisted of two applications (the first in early June), resulted in poorer (but not significantly different) height growth than the other herbicide treatments.

Cultivation resulted in generally good tree survival and height growth. Linuron combined with cultivation permitted the first cultivation to be delayed until the trees were large enough to tolerate soil movement without being buried. In contrast, the cultivation-only treatment that began May 20 had lower survival and slightly less growth due to damage to the young trees. However, the differences were not significant.

Furrow cultivation was tested to determine if weeds within the row could be buried by gradually filling the furrow while cultivating. The approach was successful in giving better control of within-row weeds, but the more exposed cuttings had much higher mortality due to dessication. Although we have since had success with the method during one wet spring, it appears that furrow cultivation will not be consistently successful.

Using herbaceous nitrogen-fixing legumes as a cover crop to suppress weeds and enrich the soil is a popular idea. However, in our tests it appears that the legume (white dutch clover) is a formidable competitor itself. We know from prior tests that planting trees in an established legume cover results in plantation failure. This agrees with the experiences of Van Sambeek and Rietveld (1982), who tested several annual and perennial herbaceous legumes in intensively cultured black walnut plantations. Our study showed that seeding the legume at the time of tree planting resulted in poor tree survival and growth even though the plots were fertilized and some were irrigated. It is likely that a legume cover crop without irrigation or fertilization would result in even poorer tree establishment. Moreover, in closely spaced plantations, only a few years are available for the legumes to fix nitrogen before they are shaded out.

In contrast to the poor performance of the legume and furrow cultivation-legume treatments, the herbicide-legume treatment consisting of a pre-planting application of linuron followed by late-summer seeding of a legume was one of the better treatments. It ranked first in height growth at the end of the first year, and second in survival and fourth in height at the end of the second year. The high ranking the first year is attributed to the pre-emergent herbicide and not the legume effect. The legume was established late, was present during only the last few weeks of tree growth, and grew very little. During the second year the legume became well established, and by the end of the growing season the treatment dropped to 4th in ranking. At the same time the "legume" treatment dropped from 5th to 8th. We attribute these drops to the competitive effects of the legume and invading weeds and/or to the lack of any weed control measures in the legume treatments during the spring of the second year—in contrast to the other treatments which all had one last cultivation or herbicide application (table 1). This study did not allow separation of the competitive effects of the legume (and the weeds) from the lack of second year weed control in legume treatments. The first-year results of this treatment suggest that the "best" treatment may be a pre-emergent herbicide with no additional treatment during the first summer.

In this study the legume white dutch clover resulted in poorer tree establishment than comparable treatments without legumes. But this loss may be offset by future gains in tree growth or savings in fertilizer cost. Also, maintenance of some ground cover during tree establishment will reduce nutrient losses that would otherwise occur from bare soil. Finally, we have observed that herbaceous ground cover reduces wind-throw of the young, rapidly growing trees. So the net gains or losses of using a legume cover crop have yet to be demonstrated.

Based on our recent research on pre-planting site preparation treatments (Hansen *et al.* (In prep.)) and the results of this study on weed control treatments during the planting year, it appears that the following combination of treatments results in the most successful plantation establishment: (1) fall application of a contact herbicide (glyphosate) followed by plowing and disking, (2) spring disking and application of a pre-emergent herbicide (linuron) at the time of planting, and (3) cultivation or application of a contact herbicide during the spring of the second growing season. We are using such a method for establishing our plantations with one exception: we now believe that the fall disking following the plowing is not necessary. The spring disking provides adequate leveling of the field surface while loosening the soil just prior to planting.

CONCLUSIONS

The results of this study illustrate that there are a number of weed control methods that give satisfactory results. Better herbicides and more effective treatment combinations will no doubt be developed in the future.

Herbicides, particularly pre-emergents, result in good plantation establishment. But cultivation with or without herbicides can also give satisfactory establishment. Legumes generally result in poorer tree establishment.

For now it appears that the best recommendation for weed control in establishing hardwood plantations is to keep the weeds (including legumes) at a low density. This appears to be best accomplished by using a pre-emergent herbicide at the time of planting, possibly followed in midsummer on some sites with cultivation or a contact herbicide.

Although some specific weed control methods ranked highest in this test, it is likely that some of the others will be better on other sites or under different first-year climatic conditions. The study demonstrates that an array of weed control strategies will work; those described here will provide a starting point for land managers to design systems adapted to their particular sites and growing conditions.

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LITERATURE CITED

Akinyemiju, O. A.; Isebrands, J. G.; Nelson, N. D.; Dickmann, D. I. Use of glyphosate in the establishment of *Populus* in short rotation intensive culture. In: Proceedings, 19th annual meeting North American Poplar Council; 1982 July 20-22; Rhinelander, WI; 1982: 161-169.

Bey, Calvin F.; Krajicek, John E.; Williams, Robert D.; Phares, Robert E. Weed control in hardwood plantations. In: Herbicides in forestry: Proceedings, John S. Wright Forestry conference; West Lafayette, IN; 1975: 69-74.

Byrnes, W. R.; Merritt, C.; Braun, J. M. Growth response of black walnut and yellow-poplar to site improvement and weed control. In: Phillip E. Pope, ed. Proceedings, Central hardwood forest conference; Purdue University; 1978: 412-424.

Hansen, Edward; Netzer, Daniel; Rietveld, W. J. Site preparation for intensively cultured hybrid poplar plantations. (In prep.).

Lane, R. D.; McComb, A. L. Effects of grass competition upon the establishment of hardwood plantations in Iowa. Res. Bull. 399. Iowa State College, Agricultural Experiment Station; 1953: 435-459.

Tillotson, C. R. Growing and planting hardwood seedlings on the farm. USDA Farmers Bull. 1123. 1921. 29 p.

Van Sambeek, J. W.; Rietveld, W. J. Leguminous cover crops can supress weeds and accelerate growth of black walnut seedlings in intensively cultured plantations. In: Proceedings, 4th central hardwood forest conference; 1982 November 8-10; Lexington, KY: University of Kentucky; 1982: 229-243.

von Althen, F. W. Preliminary guide to site preparation and weed control in hardwood plantations in southern Ontario. Rep. 0-X-288. Sault Ste. Marie, Ontario: Great Lakes Forest Research Centre; 1979. 22 p., appendices.

von Althen, F. W. Planting studies with hybrid poplars and cottonwood in southwestern Ontario. Rep. 0-X-332. Sault Ste. Marie, Ontario: Great Lakes Forest Research Centre; 1981. 17 p., appendix.