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Original article

Is site preparation necessary for bur oak receiving post-planting weed control?

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Summary – Plowing and harrowing have been recommended before establishing hardwood plantations on abandoned farmland with herbaceous weed competitors. However, mechanical soil preparation is not always practical. The possibility of reducing site preparation efforts by using post-planting weed control treatments was tested. This study compares three different types of site preparation (plowing and harrowing; plowing, harrowing and simazine herbicide; a control), each plot of which were separated in two halves receiving either one of two post-planting weed control treatments (glyphosate herbicide or black plastic mulching) in 120 cm strips over the seedling rows of bur oak (*Quercus macrocarpa* Michx). After 5 years of weed control treatment, site preparation by plowing and harrowing did not produce superior growth results relative to the control. However, growth was superior when this mechanical site preparation was combined with simazine herbicide application. Oak seedling diameter and height were larger in the plastic mulch treatment than in the glyphosate treatment. Results support the feasibility of hardwood reforestation on sites where mechanical soil preparation is impractical, if post-planting weed control treatments are applied.

hardwood plantation / site preparation / herbicide / black plastic mulch / *Quercus macrocarpa*

Résumé – La préparation du site est-elle nécessaire lorsqu'un traitement de répression des herbacées est appliqué après la plantation de chênes à gros fruits ? Le labourage et le hersage sont recommandés avant l'établissement de plantations d'espèces feuillues de haute valeur sur des terres agricoles abandonnées et envahies par des espèces herbacées compétitrices. Toutefois, il n'est pas toujours possible d'effectuer la préparation mécanique du sol. L'utilisation de traitements de répression post-plantation des herbacées pourrait permettre de réduire l'effort de préparation du site. L'étude compare trois méthodes de préparation du site (labour et hersage ; labour, hersage et herbicide simazine ; un témoin), dont les parcelles ont été séparées en deux pour recevoir l'un ou l'autre de deux traitements post-plantation (herbicide glyphosate, paillis de plastique noir) appliqués par bandes de 120 cm sur la rangée de plants de chênes à gros fruits (*Quercus macrocarpa* Michx). Après 5 ans de traitements de répression des herbacées, la préparation du site par le labourage et hersage n'a pas produit des résultats de croissance supérieurs relativement au témoin. Toutefois, la croissance était supérieure lorsque la préparation mécanique était combinée à l'application de l'herbicide simazine. La hauteur et le diamètre des plants de chênes étaient supérieurs avec l'utilisation de paillis de plastique en comparaison à l'application de

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glyphosate. Ces résultats permettent d'envisager le reboisement en espèces feuillues sur des sites où la préparation mécanique du sol est impraticable, si des traitements de répression des herbacées sont appliqués après la plantation.

plantation d'espèces feuillues / préparation du site / herbicide / paillis de plastique noir / *Quercus macrocarpa*

INTRODUCTION

A high percentage of the terrain in parts of southern Quebec is recently abandoned agricultural land. Reforestation of these lands with valuable hardwoods is an attractive option. However, in order to establish successful plantations in varied edaphic conditions and vegetation types, the producer must be able to depend on diverse and efficient methods of plantation establishment. These methods must also allow for the individual capabilities and desires of the producer, such as the refusal to use herbicides.

Weed control can produce significant beneficial effects during the growth of crop trees (Nambiar and Sands, 1993). On abandoned farmland, many studies have linked the establishment success and productivity of hardwood plantations with the degree of weed control (von Althen, 1987; Cogliastro et al, 1990, 1993; Truax and Gagnon, 1993). Both mechanical site preparation of abandoned fields, and subsequent post-planting mechanical, chemical or manual weed control treatments are required for landowners to qualify for governmental hardwood reforestation aid programs in Quebec (ministère des Forêts du Québec, 1992). The question we are exploring, which has not been sufficiently studied, is the possibility that post-planting weed control could reduce the need for site preparation, or eliminate it altogether. This would be particularly useful on plantation sites where mechanical site preparation may be undesirable or impractical because the soil is too stony, topography that limits machinery accessibility or the presence of other valuable trees on the site.

Glyphosate herbicide and black plastic mulches are post-planting weed control treatments that have produced excellent growth results in hardwood plantations (Frochot and Levy, 1980; Davies, 1988; Marineau, 1992; Cogliastro et al, 1993; Truax and Gagnon, 1993). Some of these studies also demonstrate that mechanical site preparation alone is insufficient, and that it is necessary to apply a post-planting weed control treatment. Mechanical or chemical site preparation methods or a combination of both, without subsequent weed control treatments, cannot prevent recolonization by weeds for more than 1 year (von Althen, 1987).

Although weed control in plantations remains an important forestry problem, the environmental concerns caused by herbicides also need to be addressed. An effort must be made to improve the efficiency of their use in order to reduce the quantities needed. This can be achieved by using post-emergence herbicides, which are rapidly biodegraded, and applying them only on narrow strips near the planted trees, instead of on the entire plantation area (MacRae et al, 1990). Glyphosate (Vision®, Monsanto, Mississaugo, ON, Canada Inc) is a nonselective post-emergence herbicide. This herbicide has a demonstrated short persistence in the environment; its average half-life in soils being about 2 months (Ghassemi et al, 1982).

The purpose of this study is to determine if any of two recommended site preparation methods are necessary for the survival and growth of bur oak (*Quercus macrocarpa* Michx) seedlings when post-planting weed control is carried out on narrow strips, either by a black plastic mulch treatment or a glyphosate herbicide treatment. Weed biomass and soil moisture conditions in the various treatments are also presented.

METHODS

Site description

The plantation site is located in the Great Lakes Saint Lawrence forest region, Saint Lawrence section (Rowe, 1972). The site is within the regional county municipality (municipalité régionale de comté) of Haut-Saint-Laurent

(45° 05'N, 74° 17'W), southwest of Montreal, Quebec. A multidisciplinary study of the area (Bouchard et al, 1985), including geomorphology and land-use patterns, guided the selection of an experimental site which is typical of the zones with underused forestry potential. At an elevation of 90 m, the site is located on a morainal ridge overlying Beekmantown dolomite bedrock. This sedimentary rock type is the major element in the morainal surficial material of the region (Globensky, 1981).

The soil is a melanic brunisol (cultivated), developed on a sandy loam, of which the particles larger than 2 mm represent 25 to 30% of soil volume (Canadian Soil Classification Committee, 1978). Soil drainage is good to moderately good. Soil characteristics, measured in 1990 from 30 samples (composite sample of two per experimental unit) taken in the center of each plot between 10 to 20 cm depth, are presented in table I. The standard soil analysis methods used are described in Cogliastro et al (1990). Soil pH and Ca and Mg levels are particulary high, reflecting the influence of the dolomitic bedrock in the till. The principal herbaceous weed species are, in decreasing order of abundance: Gramineae, *Vicia cracca* L, *Ambrosia artemisiifolia* L, *Cirsium arvense* (L) Scop, *Achillea millefolium* L, *Trifolium hybridum* L and other minor species.

The region is characterized by an average frost-free period of 182 days. Mean annual temperature is 6.4 °C, and mean monthly temperatures of July and January are 21 °C and –10 °C, respectively. From May to October 1990, the year of plantation establishment, precipitation was generally more abundant than average, with 137% of normal received. The mean monthly precipitation is generally 83 mm from May to October (ministère de l'Environnement du Québec, 1991).

Experimental design and treatments

The split-plot experimental design of the plantation had five replicates (blocks). Within each replicate, three types of site preparation were randomly allocated (plowing and harrowing; plowing, harrowing and simazine herbicide; a control). These plots were then separated in two, each half receiving either one of two post-planting weed control treatments (glyphosate or black plastic mulching). No control treatment was included for the subplot factor, since the purpose of the study was to evaluate the importance of site preparation, when post-planting weed control treatments are applied. The two site preparation methods used are recommended in the two Canadian hardwood reforestation manuals (von Althen, 1990; ministère des Forêts du Québec, 1992). Plowing and harrowing were done (two passes) on 24 April 1990 in two blocks, and 3 days later in the three remaining blocks in the plots of the two types of site preparation (not in the control). One series of plowing and harrowing plots also received a chemical site preparation by an application of preemergent simazine herbicide on 30 April 1990. The application was done with a manual backpack sprayer at an application rate of 3.2 kg $\cdot$ ha^{-1}.

Post-planting weed control treatments by the use of glyphosate or black plastic mulch were applied in 120 cm strips over the seedlings rows. Glyphosate was applied once a year (mid-

Table I. Soil characteristics of the experimental sites, measured in 1990.

	Sand (%)	*Silt (%)*	*Clay (%)*	*NH_4*	*NO_3*	*P*[a]	*Ca*	*K*	*Mg*	*pH*
				(mg $\cdot$ kg^{-1})			*Extractable cations (meq $\cdot$ 100 g^{-1})*			
Mean (n = 30)	66	19.0	15	1.4	13	39	6.9	0.21	4.0	7.8
Coefficient of variation (%)	3	9	8	52	39	33	34	17	15	2

[a]Available phosphorus.

June for 5 years) in plots that had received a site preparation (plowing and harrowing and plowing, harrowing and simazine). In plots without site preparation (control), glyphosate was applied twice in the first year (May and July) and once a year in each of the subsequent 4 years (mid-June). The black plastic mulching was installed in continuous strips covering the seedling rows during the 2 weeks following planting. The strips were pre-cut to allow the stems of the planted seedlings to pass through the plastic.

The application of the glyphosate herbicide (Vision®) was done using a wheeled applicator bearing a wick (60 cm long, 2 cm diameter), inserted at eight places in a 4.7 L tubular container. This container was filled with a 50% Vision/50% water solution. The saturated wick was horizontally positioned on the wheeled applicator at 5–10 cm from the soil surface to moisten weeds with the herbicide solution by passing back and forth once on each side of the seedling rows. This herbicide application method eliminates the drift associated with spraying, which can be deleterious to planted trees, and restricts herbicide application to targeted weeds. A smaller wick, at the end of a hollow plastic stick, was used during the first and second growing seasons to treat weeds in close proximity to the seedlings in order to avoid touching them with the herbicide.

An experimental unit consisted of 48 seedlings of bur oak distributed in six rows of eight seedlings. Spacing was 3 m between rows and 1.5 m between seedlings within a row. The bare root seedlings were produced at the Berthier nursery of the Quebec Ministry of Natural Resources (2 + 0 age; provenance 87-K-73, zone 06). In total, 1 440 seedlings (46 cm mean height, 8.5 mm mean basal diameter) were planted by hand on 1–4 May 1990, on the 0.67 ha plantation.

Measurements and statistical analysis

In 1992, an index of soil water content was measured at three dates (July, August, September) and at two depths (20 cm, 40 cm) by measuring in situ the relative dielectric constant of the soil (frequency-domain reflectometry; Sentry® 200-AP, Troxler Elec Lab Inc, NC, USA), which is directly influenced by its water content (Rundel and Jarrel, 1989). These measurements were taken within seedling rows in two randomly selected experimental blocks, and in two site preparation types (control and mechanical site preparation). Water content was expressed as a percentage of soil volume.

For each of the site preparation types, in three randomly selected experimental blocks, weed biomass was measured from harvests done at two sampling positions in the experimental design: between tree rows (no post-planting weed control at that position) of i) glyphosate herbicide experimental units and ii) plastic mulch experimental units, as well as within tree rows (post-planting weed control) of herbicide experimental units. Because the plastic mulching prevents all growth of weeds within the tree rows, weed biomass sampling was omitted at that position. All samples were collected at the end of August 1991 and 1993. The aerial parts of the weeds were clipped in 0.25 m^2 plots located in the middle of the experimental units. Samples were dried at 70 °C for 72 h and then weighed.

The basal diameter and the height of all oak seedlings were measured between 25 August and 10 September after each growing season (except the fourth). A repeated measures ANOVA was used to perform the analysis of the repeated diameter and height data means per row (1990, 1991, 1992, 1994). ANOVAs were also run for soil water content and weed biomass. For the soil water content data, sampling date factor and all interactions with the other factors were added to the model and a MANOVA was performed on the two sampling depths. Tukey's multiple comparison test was used. The normal distribution criterium was not met in the 1990 weed biomass data, and non-parametric rank transformation was used. All statistical analyses were performed on SAS (SAS Institute Inc, 1989).

RESULTS

No statistically significant differences in soil water content were detected in relation to the type of site preparation used ($F = 1.00$; $P = 0.50$). Mean soil water content was higher under black plastic mulching ($F = 39$;

$P = 0.10$). Although this result is not statistically significant, but only by a narrow margin, it indicates an effect of the plastic mulch (fig 1).

No significant effect of site preparation on weed biomass was detected in 1990 ($F = 0.25$; $P = 0.79$) and 1992 ($F = 0.63$; $P = 0.58$). Weed biomass within the glyphosate-treated rows was reduced, by 63% in 1990 and by 50% in 1992, when compared to the biomass measured between rows (fig 2). Weed biomass between plastic mulch treated rows was 1.9 times that of weed biomass between glyphosate-treated rows in 1992 (fig 2).

Growth and survival of bur oak

Survival of bur oak seedlings after five growing seasons was high, varying from 93 to 96% (all site preparation types or post-planting weed control treatments pooled). The repeated measures ANOVA of bur oak size shows a highly significant difference in the trends of the diameter and height curves obtained with the different site preparation methods (year x site preparation interaction), as well as with the two post-planting weed control treatments (year x treatment interaction) (table II; fig 3). The bur oak seedlings attained the greatest sizes, in diameter and height, when simazine herbicide was used in conjunction with the mechanical soil preparation (fig 3). This advantage generally appeared after two growing seasons (fig 3). Without simazine application, the growth of the seedlings was similar whether or not soil mechanical preparation was done (fig 3). Post-planting weed control achieved by black plastic mulching produced the greatest seedling growth in comparison to glyphosate application (fig 3).

DISCUSSION

After 5 years of post-planting weed control treatments, tree growth was not improved by mechanical site preparation alone, but only when combined with chemical (simazine) site preparation. The strong effect of simazine use on bur oak size confirms the well known positive relationship between the productivity of planted hardwoods and the degree of weed control efforts. The advantage of mechanical site preparation has often been described in studies of hardwood plantations (von Althen, 1977, 1984, 1987; Cogliastro et al, 1990). Such reports come from studies of abandoned farmland, where soils are usually derived from lacustrine or marine surficial materials, and have a high percentage of clay and silt particles. Plowing and disking (or harrowing) may have

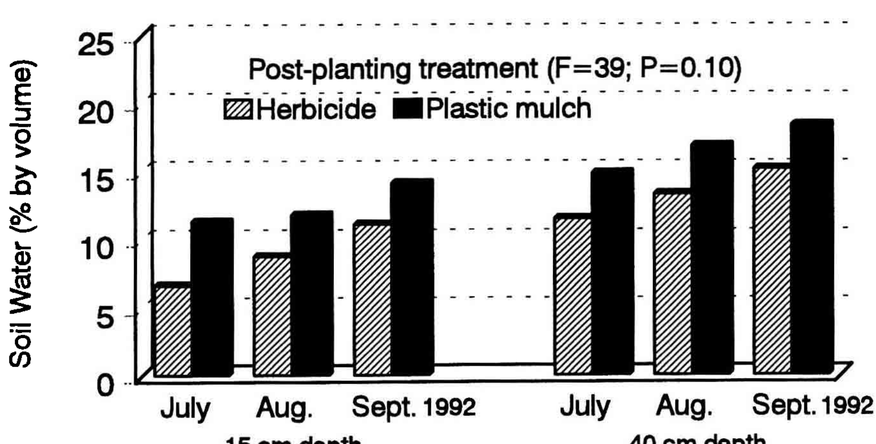

Fig 1. Soil water content in 1992 at two depths in the glyphosate herbicide and black plastic mulching post-planting treatments. Measurements were obtained by in situ frequency-domain reflectometry.

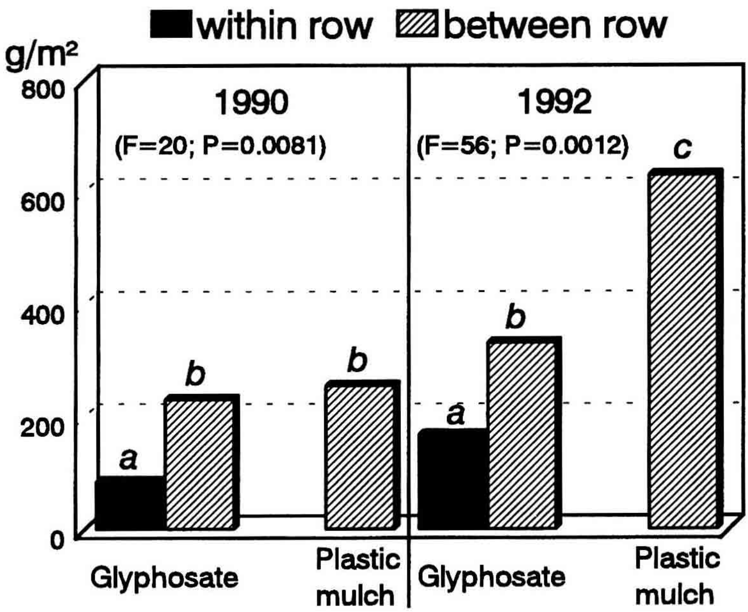

Fig 2. Weed biomass in experimental units with glyphosate herbicide and black plastic mulching post-planting treatments (1990 and 1992). Means within each year followed by different letters are significantly different at $P \leq 0.05$.

a greater beneficial effect when they are performed on a heavy textured soil, resulting in improved soil aeration before plantation establishment. Brais et al (1989) detected an increase in the macroporosity of a clay soil following mechanical site preparation. The beneficial effects of soil mechanical preparation on soil structure may be of lesser value on sandy loam soils of stony morainal surficial materials (as is the case of the plantation discussed here), which

Table II. Repeated measures ANOVA of the diameter and the height of seedlings (1990, 1991, 1992, 1994).

Source		*Diameter*			*Height*		
	df	*MS*	F	P	*MS*	F	P
Year (Y)	3	43.47	2 213.8	0.0001	124 462	1 394	0.0001
Y x block (B)	12	0.16	8.2	0.0001	1 274	14.3	0.0001
Y x site preparation (P)	6	1.18	21.7	0.0001	3 751	24.3	0.0001
Y x B x P	24	0.05	2.8	0.0001	154	1.7	0.0184
Y x post-planting weed control treatment (T)	3	1.40	20.1	0.0001	6 676	25.3	0.0001
Y x B x T	12	0.07	3.5	0.0001	264	2.9	0.0006
Y x P x T	6	0.05	2.4	0.0630	129	2.2	0.0772
Y x B x P x T	24	0.02	1.2	0.2730	59	0.6	0.8929
Error	450	0.02			89		

df: degrees of freedom; MS: mean square.

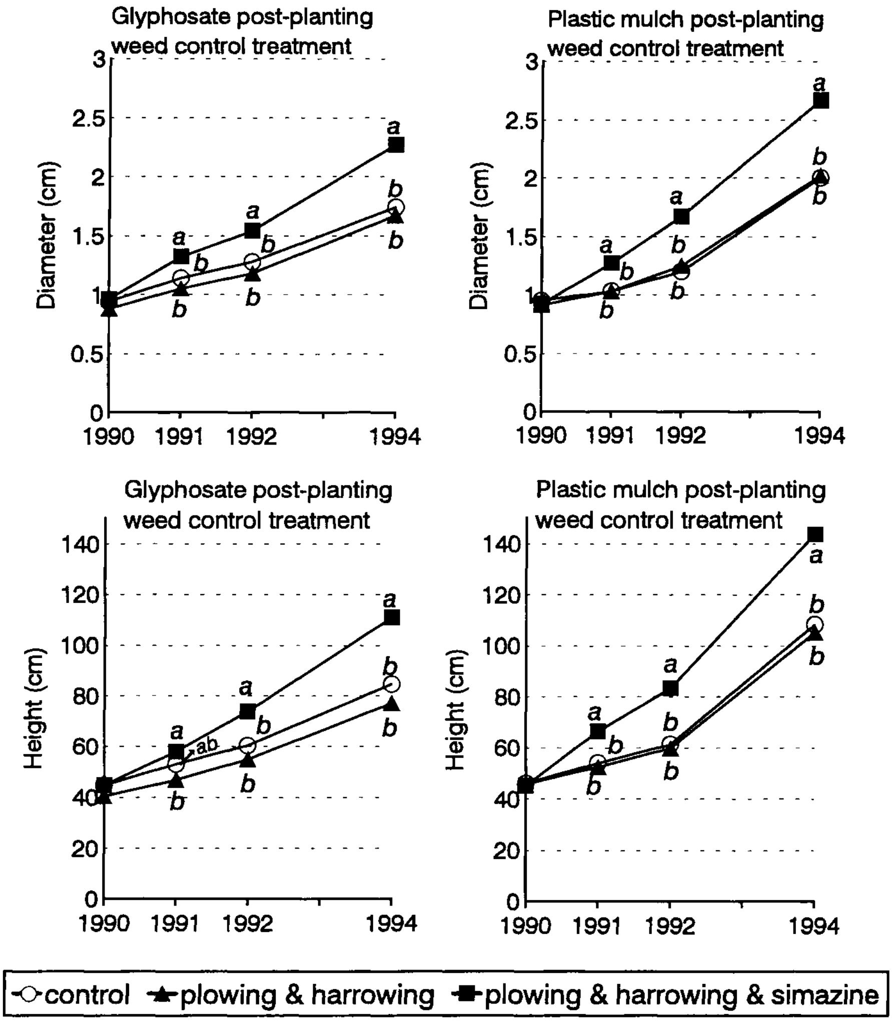

Fig 3. Diameter and height growth curves of bur oak seedlings in site preparation types for each post-planting weed control treatments. Means within each year followed by different letters are significantly different at $P \leq 0.05$.

are relatively resistant to compaction by agricultural machinery. Clay soils, which are also usually poorly drained, are the most sensitive to compaction (Doucet, 1992).

No reduction of weed biomass by site preparation types was detected as a possible causal factor for the strong positive effect on tree growth demonstrated by the addition of simazine to mechanical site preparation. The degree of competitive pressure by weeds on planted trees is a function of several characteristics such as weed species composition, height, density, distribution patterns and weed longevity. These factors were not included in the variables we sampled and may have been affected by simazine use.

Weed biomass between plastic mulch treated rows was higher than in between rows glyphosate-treated plots in 1992. Increases in weed biomass at the margin of black plastic mulch was also noted by others (Davies, 1988; Truax and Gagnon, 1993). This appears to be linked to the fact that weeds benefit from increased water and nutrient resources, which they tap from under the mulch with their root systems, although their aerial structures are restricted to the edges of the mulch. In spite of this probable underground competition, the 120 cm wide strips of black plastic mulching produced significantly larger tree sizes than the wick application of glyphosate after 5 years of growth. Mulching has also been shown by Lambert et al (1994) to have a positive effect on bur oak seedlings growth. Black plastic mulching is well known for producing a soil temperature increase (Brand and Janas, 1988; Marineau, 1992; Truax and Gagnon, 1993). Several studies have shown the effects of this increased soil temperature in improving the growth of tree seedlings, possibly by reducing the viscosity of soil water, thus increasing its availability along with nutrients in the soil solution (Brand and Janas, 1988; Cogliastro et al, 1993). In addition, as shown in this study, the mean soil water content was higher under plastic mulch.

The use in this study of a wick applicator for glyphosate herbicide has allowed a reduction of weed biomass, in the first growing season, comparable to the 70% reduction obtained in a nursery by Chandler and Filer (1980) using similar equipment. However, the efficiency of this method was reduced in the third growing season (1992). This may be attributed in part to an increase in weed species that are more resistant to glyphosate. We have observed an increase in the abundance of *Cirsium arvense* (L) Scop, known to be very resistant to glyphosate (Carlson and Donald, 1988), and of *Cirsium vulgare* (Savi) Tenore on herbicide-treated strips (A Cogliastro, personal observation).

Davies (1988) has shown a better efficiency of polyethylene mats over herbicide spot spraying, when the area treated was larger than 1 m^2. A 3 year comparative analysis of the costs of using 1 m^2 of black plastic mulching or glyphosate herbicide (by spraying at the periphery of planted hardwoods), both methods having produced the same growth results after 3 years, showed that the use of the herbicide was 20% cheaper (Marineau, 1992). However, this cost analysis did not include the future disposal of the plastic, which should not be left to degrade in the environment. Moreover, 5 years of treatment, as in the present study, include extra herbicide costs for each additionnal year of application, whereas the plastic costs are covered once at the onset and the effect lasts many years (> 5 years).

CONCLUSION

Site preparation by plowing and harrowing could be eliminated for young bur oak plantations on a stony sandy loam soil, when 120 cm strips of black plastic mulching or wick application of glyphosate are used as post-planting weed control treatments during the first 5 years of growth. However, the combination of simazine herbicide application with the mechanical soil preparation allows an increase in the beneficial effects of post-planting weed control treatments on bur oak growth. The single application of a persistant preemergence herbicide like simazine, once in an 100 year rotation hardwood plantation system, resulted in a significantly divergent young tree growth curve, which forecasts a permanent effect on productivity. Post-planting weed control treatment by the plastic mulch produced larger oak seedling diameter and height when compared to those obtained with the wick application of glyphosate. However, the high survival rate and the year to year size increment of trees treated by wick application of glyphosate were sufficient to declare this treatment a success as well.

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