USE OF PLASTIC FILMS FOR WEED CONTROL DURING FIELD ESTABLISHMENT OF MICROPROPAGATED HARDWOODS

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Abstract: This study compares the use of plastic films to conventional methods for establishing hardwoods on a recently cultivated old field site using 1-year-old micropropagated plantlets of white ash (*Fraxinus americana* L.) and silver maple (*Acer saccharinum* L.). After one growing season in the field, height of plantlets with all weed control treatments exceeded the height of the plantlets in the non-weeded control. After two growing seasons, plantlets of both species established with plastic films were taller than plantlets with conventional methods of weed control or in the non-weeded plots. No differences were found in plantlet height growth when established with opaque white film, solid black plastic, or porous black plastic. Silver maple plantlets were taller than the white ash plantlets after the first (47 vs 35 cm), second year (114 vs 72 cm), and third years (179 vs 101 cm). Soils under the plastic films had more available moisture in the spring and less available moisture during the summer than the other treatments. During the late fall, soil moisture was again near field capacity in all treatments. After three growing seasons, the solid plastic films had begun to disintegrate. Our results suggest that plastic films can be an effective alternative to chemical or mechanical weed control when establishing hardwoods.

INTRODUCTION

Successful establishment of hardwood seedlings usually requires good site preparation, weed control, and other cultural practices to maintain adequate soil moisture and fertility during the growing season. Lack of weed control during seedling establishment usually results in reduced survival and slowed tree growth (Van Sambeek and Rietveld 1983b). Currently, the most common methods used to achieve adequate weed control have included the use of mechanical cultivation or registered herbicides to control competing vegetation. Unfortunately, hardwoods such as white ash are extremely sensitive to most herbicides (Bey and Williams 1977). In addition, effective herbicides have not been registered for trees such as silver maple.

Recent evidence suggests that micropropagated plantlets are more sensitive to herbicides than conventionally propagated plants (Mudge et al. 1987; Neal et al. 1990). Micropropagated plantlets offer several advantages over the use of seed-produced seedlings for research and field plantings. Use of clonal planting stock can reduce genetic variability and experimental error thus allowing for greater precision in research studies (Libby 1974).

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In addition, micropropagation has the potential to produce a high number of genetically improved plantlets inexpensively in a short period for field plantings.

With declining public acceptance of herbicide use, mulching with plastic or polyethylene films is being reevaluated as a promising technique for enhancing transplant survival and early growth (Windell 1993). Mulches can provide more or less permanent control of weeds during hardwood establishment, as well as more favorable soil conditions through reduced evaporative loss of soil moisture, reduced leaching of nutrients, and reduced soil erosion (Truax and Gagnon 1993). Plastic films are becoming more popular because equipment is available to mechanically lay these materials. Ashby et al. (1992) and Huetteman et al. (1992) both reported successful establishment of silver maple plantlets under droughty conditions using mechanically-laid opaque white-on-black plastic mulch.

Plastic films can have a wide range of optical properties that can markedly modify soil and air temperatures (Ham et al. 1993). Air temperatures immediately above plastic films can be 3 to 5° C higher than 1.5 m above the film. Recently, Trinka and Pritts (1992) recorded higher air temperatures immediately above white film than above black film. Depending on the type of film, midday soil temperatures under plastic films can be as much as 10° C higher than in adjacent uncovered soils (Heiskanen and Raitio 1992). Fritschen and Shaw (1960) reported that soil surfaces under clear films had higher mid-day temperatures than either black plastic or black plastic painted white. They also found temperature differences between bare soil and soil covered with plastic films tended to decrease as soils become drier.

Because plastic films can significantly alter the microenvironment, it is not clear what effect they would have on hardwood establishment, especially the establishment of containerized, micropropagated hardwoods or how the use of plastic films would compare to the conventional methods of weed control. The purpose of our study was to evaluate plantlet growth of white ash and silver maple and to compare changes in soil moisture potential and soil temperature when using three different plastic films and the more traditional methods of weed control for establishing hardwoods.

METHODS

The research planting was established on an old field site at the Southern Illinois University's Horticulture Research Center near Carbondale, IL. The study area measured approximately 25 x 50 m and was located along a mid-slope position with an eroded Hosmer silt loam (fine-silty, mixed, mesic Typic Fragiudalfs, pH 5.5). The tall fescue hay field, which previously was mowed annually, was plowed in April 1992 and cultivated twice before laying out the study in mid-May 1992. The research planting consisted of five rows, 4 m apart, oriented from west to east along the south-facing slope. Each row was treated as a block and marked off into six 1.0 m-wide by 7.5 m-long plots.

Six treatments were randomly assigned within each block: (a) non-weeded check, (b) clean cultivation, (c) herbicide treatment, (d) porous black plastic film, (e) solid black plastic film, and (f) solid white plastic film. The porous black film (VisPore tree mats) consists of approximately 60 microfunnels per cm^2 designed to allow rainwater and air to penetrate the 2.5 mil-thick plastic film. The solid plastic film was a highly reflective, opaque white-on-black 1.25 mil-thick polyethylene film that could be installed either white side up or black side up. The solid white film was laid with a tractor-pulled mulch laying machine in mid-May 1992. The two black films were manually laid in trenches formed with the mulch laying machine. When laid, the outside 15 cm of the 1.3 m wide plastic films was buried resulting in 1.0 m wide experimental plots.

The clean cultivated plots were hand-hoed twice in 1992 and rototilled twice in 1993 and 1994. The herbicide plots were sprayed with 55 ml/ha sulfometuron (Oust) and 6.4 L/ha glyphosate (Roundup) in June 1992. Glyphosate only at 6.4 L/ha was used in August 1993 and June 1994. Hardwoods were protected from direct application of herbicides using a stove pipe. The area between each row of plots was mowed twice in 1992, 1993, and 1994. The plantlets were protected from deer browse with a portable 3-wire electric fence. Some rabbit damage occurred on the smaller plantlets during the 1992-1993 winter.

Two white ash and three silver maple plantlets were randomly assigned to each plot and planted 1.5 m apart. Silver maple clones were planted as dormant containerized stock overwintered in a cooler and as plantlets in leaf from a shadehouse. White ash clones were planted as containerized plantlets in leaf from a shadehouse. Height of the white ash and silver maple plantlets averaged 24 and 28 cm, respectively, at the time of planting. Plantlets were established using KBC planting bars on 27 May 1992. A 9 gram starter (Agriform) fertilizer tablet (22 N - 8 P_2O_5 - 2 K_2O with 3% Ca, 1% S, 0.5% Fe, and 0.1% Zn) was placed in the first closure hole of each plantlet. Because the soils were relatively dry at the time of planting, approximately 2.5 cm of irrigation water was applied to the entire area on 29 May 1992. The plantlets received no subsequent fertilization or irrigation.

A soil moisture tensiometer was installed in each plot from June to October, 1992 and 1993. The 50-cm-long tensiometers were installed at a 45° angle with the ceramic cup approximately 30 cm deep located midway between a silver maple and a white ash plantlet. Tensiometers were nominally read twice a week during the growing season until soil moisture returned to field capacity in the fall. Because fine silica was used to reinforce the soil-ceramic cup interface, soil water potential readings between -80 and -90 kPa could be reliably obtained in most cases. To compare effects of vegetation management treatments on soil moisture potential during the growing season, we quantified the number of days each month soil moisture potential was less than -33 kPa (little or no moisture stress), -34 to -67 kPA (moderate moisture stress), and less than -67kPA (severe moisture stress) for each plot. These values are based on previous research growing hardwood seedlings under different moisture regimes (Rink and Van Sambeek 1985, 1987a).

One soil thermocouple was also installed 15 cm deep midway between two plantlets near the middle of each plot. Soil temperatures at 0400 and 1600 hours were recorded daily for a two week period from 26 August to 12 September 1992. Daily minimum and maximum air temperature and rainfall were recorded at the Horticulture Research Center weather station located 0.5 km southeast of the planting site.

Plantlet height was measured at planting and two or three times during the first three growing seasons. The amount of winter dieback and length of the spring flush were measured during May 1993. The number and length of all lateral shoots were determined after the first growing season. During July and/or August of the first and second growing seasons, the terminal shoots of each plantlet were examined to determine if they were still actively producing new growth.

Treatment means by species were computed from individual plantlet data and subjected to analysis of variance (ANOVA) to test for effects of weed control treatments, species of plantlets, and their interaction. We used a randomized complete block with split plots design with weed control treatments as main plots and species of plantlets as the subplots. Comparison of treatment or species means were based on Fisher's protected LSD (1% and 5% t-test values). The five planned allowable orthogonal contrasts were comparison of (1) non-weeded check against the five other treatments, (2) conventional weed control (herbicide and cultivation) against the plastic films, (3) herbicide against cultivation, (4) solid plastic films against porous plastic film, and (5) solid white-on-black against solid black-on-white film.

RESULTS

Plantlet Response to Vegetation Management Practices

Plantlet survival averaged 90 percent after the first growing season with no statistical differences between the non-weeded control or plots where vegetation was controlled chemically, mechanically, or with plastic films (Table 1). All the white ash plantlets survived while mortality exceeded 20% for silver maple plantlets after the first growing season. Most of the dead silver maple plantlets were of a single clone planted as containerized stock in leaf. The spring application of sulfometuron and glyphosate killed a few additional silver maple plantlets. Little additional mortality has occurred for either species during the second and third growing seasons.

Table 1.--First year mortality, lateral shoot growth, winter dieback, and spring flush of white ash and silver maple plantlets under six different weed control practices.

Treatment and species	Mortality	Lateral shoot Number	Lateral shoot Length	Plantlets with dieback	Spring flush 1993
	- % -		- cm -	- % -	- cm -
SPECIES MEANS:					
White ash	0	1.6	11.7	35	19
Silver maple	21	1.9	27.0	77	34
Significance[a]:	**	ns	**	**	**
TREATMENT MEANS:					
Check	20	0.7	1.5	67	24
Cultivate	17	1.4	15.9	65	26
Herbicide	10	1.3	16.2	72	34
Black Film	7	3.1	34.6	45	27
White Film	6	2.1	23.1	38	26
Porous black	5	1.9	24.7	52	29
Significance[a]:	ns	*	*	*	ns
5% t-test value:		2.4	17.5	28	
1% t-test value:		3.2	23.9	40	
Tested Contrasts:					
Check vs Others:		*	**	ns	
Conv. vs Plastic:		*	*	*	
Cultv. vs Herb.:		ns	ns	ns	
Solid vs Porous:		ns	ns	ns	
Black vs White:		ns	ns	ns	

[a] Nonsignificant (ns) or significant effects at the 5% (*) or 1% (**) according to F-test for 1 and 24 df (species) and for 5 and 20 df (treatments).

Plantlets established with plastic film for vegetation control had significantly more lateral shoots than plantlets without plastic films after the first growing season (Table 1). In addition, these plantlets also had the greatest cumulative length of lateral shoots. Silver maple plantlets produced over twice the length of lateral shoots as the white ash plantlets. All the plantlets receiving some type of weed control had significantly more and longer cumulative lenght of lateral shoots than plantlets in the non-treated check plots.

Terminal shoot dieback or winter-kill occurred on many of the silver maple and white ash plantlets in all treatments (Table 1). The lowest incidence of dieback occurred in plots with plastic mulch (38 to 52%) and the highest under the conventional cultural practices (65 to 72%). Winter dieback on the silver maple plantlets averaged 3.6 cm compared to only 1.7 cm on the white ash plantlets. No differences in the amount of winter dieback were found with respect to weed control practice.

The silver maple plantlets outgrew the white ash plantlets during the first three growing seasons (Table 2). After the first growing season, height of plantlets in all weed control treatments exceeded that of the plantlets in the non-weeded check treatment. This also remained true throughout most of the second growing season. By the end of the second growing season, plantlets established with plastic films were taller than those established with conventional methods of weed control.

Table 2.--Height of white ash and silver maple plantlets through three growing seasons under six different weed control practrices.

Treatment and Species	Oct. 1992	May 1993	July 1993	Oct. 1993	July 1994	Oct. 1994
	----------	----------	---------- cm	----------	----------	----------
SPECIES MEANS:						
White ash	34	54	64	73	102	101
Silver maple	46	79	92	114	170	179
Significance[a]:	**	**	**	**	**	**
TREATMENT MEANS:						
Check	23	43	48	49	91	89
Cultivate	46	67	79	96	140	140
Herbicide	37	74	80	84	126	144
Black Film	47	73	89	111	148	150
White Film	47	71	83	105	143	144
Porous black	51	79	95	118	55	158
Significance[a]:	**	**	**	**	**	**
5% t-test value:	11.5	12.6	16.2	16.4	25.9	27.8
1% t-test value:	15.7	17.21	22.1	22.4	35.3	37.8
Tested Contrasts:						
Check vs Others:	**	**	**	**	**	**
Conv. vs Plastic:	ns	ns	ns	**	**	ns
Cultv. vs Herb.:	ns	ns	ns	ns	ns	ns
Solid vs Porous:	ns	ns	ns	ns	ns	ns
Black vs White:	ns	ns	ns	ns	ns	ns

[a] Nonsignificant (ns) or significant effects at the 5% (*) or 1% (**) according to F-test for 1 and 24 df (species) and for 5 and 20 df (treatments).

During July of the first growing season, over 90 percent of the plantlets in the plots with plastic film had actively elongating shoots while only 65 percent of the plantlets in the non-weeded control plots had actively elongating terminal shoots. In addition, 88 percent of the silver maple plantlets had elongating shoots compared to 70 percent of white ash plantlets. Similar observations were made in July of the second growing season. The percentage of plantlets with some type of weed control having elongating shoots decreased to 50 percent or less during August of the second growing season; however, only 12 percent of the plantlets in the non-weeded plots still had elongating terminal shoots. In August, nearly four times more silver maple plantlets (57 percent) still had elongating shoots compared to the white ash plantlets (15 percent).

Effectiveness of Vegetation Management

During the first growing season, the non-weeded check plots quickly developed a heavy cover of broadleaved annuals in the spring which was followed by a dense stand of foxtail (*Setaria* spp.). During the second and third growing seasons, the non-weeded check plots had a dense cover of broadleaved annuals, biennials, and perennials with fewer grasses. Mechanical cultivation generally provided short term control of competing vegetation and needed to be repeated several times during each growing season. Sulfometuron and glyphosate effectively controlled vegetation throughout the first growing season and into the second growing season before a second application of glyphosate was applied to control emergent vegetation.

Essentially no vegetation grew within the 1 x 7.5 m plots when covered with porous black, solid black, or solid white plastic film for the first two growing seasons. What vegetation there was grew mostly through the planting hole and not the plastic film. The solid black and solid white films began to disintegrate after the second growing season. The thicker porous black film remained largely intact throughout the third growing season.

The method of weed control altered soil moisture depletion and recovery during both the first and second growing seasons (Fig. 1). In general, soil moisture potential decreased most rapidly in the check plots covered with dense vegetation. Soil moisture potentials declined more slowly under the plastic film than in the other treatments; however, they were also the last to return to field capacity at the end of the growing season. All three plastic films were laid with the edges slightly higher than the center of the plots where the trees were planted. During thunderstorms, precipitation tended to initially sheet across all three films and enter through the planting holes at the base of each plantlet. Water also readily penetrated the porous black film once the micropores were wetted.

During the spring of the first and second growing seasons, plantlets in plots with weed control experienced more days with little or no soil moisture stress (soil water potentials from 0 to -33 kPa) than the non-weeded control (Table 3). Near the beginning of the first growing season, plots with the plastic mulch had more days with adequate soil moisture than the plots with conventional weed control; however, no differences were found during the fall of the first or second growing season.

Table 3.--Number of days plantlets experienced little or no moisture stress[a] during the first and second growing season under six different weed control practices[b].

Weed control	First growing season			Second growing season			
Treatment	July	Aug.	Sept.	June	July	Aug.	Sept.
	------ days --------			--------- days ---------			
Check	0	1	23	9	0	0	9
Cultivate	2	0	18	12	14	5	16
Herbicide	2	1	27	12	6	1	12
Black film	6	1	17	19	17	7	17
White film	5	1	20	19	10	1	12
Porous black	3	0	26	24	12	0	8
Significance[c]:	*	ns	ns	*	*	ns	ns
5% t-test value:	4.2			10.6	8.9		
1% t-test value:	5.8			14.6	12.2		
Tested Contrasts:							
Check vs Others	*			*	**		
Conv. vs Plastic:	*			*	ns		
Cultv. vs Herb.:	ns			ns	ns		
Solid vs Porous:	*			ns	ns		
Black vs White:	ns			ns	ns		

[a] Soil moisture potentials between 0 and -33 kPa.
[b] Monthly precipitation from May through September was 3.30, 2.85, 6.71, 6.58, and 17.63 cm, respectively, in 1992 and was 12.52, 12.24, 8.97, 6.25, and 22.83 cm, respectively, in 1993.
[c] Nonsignificant (ns) or significant effects at the 5% (*) or 1% (**) according to F-test for 1 and 20 df (species) and for 5 and 20 df (treatments).

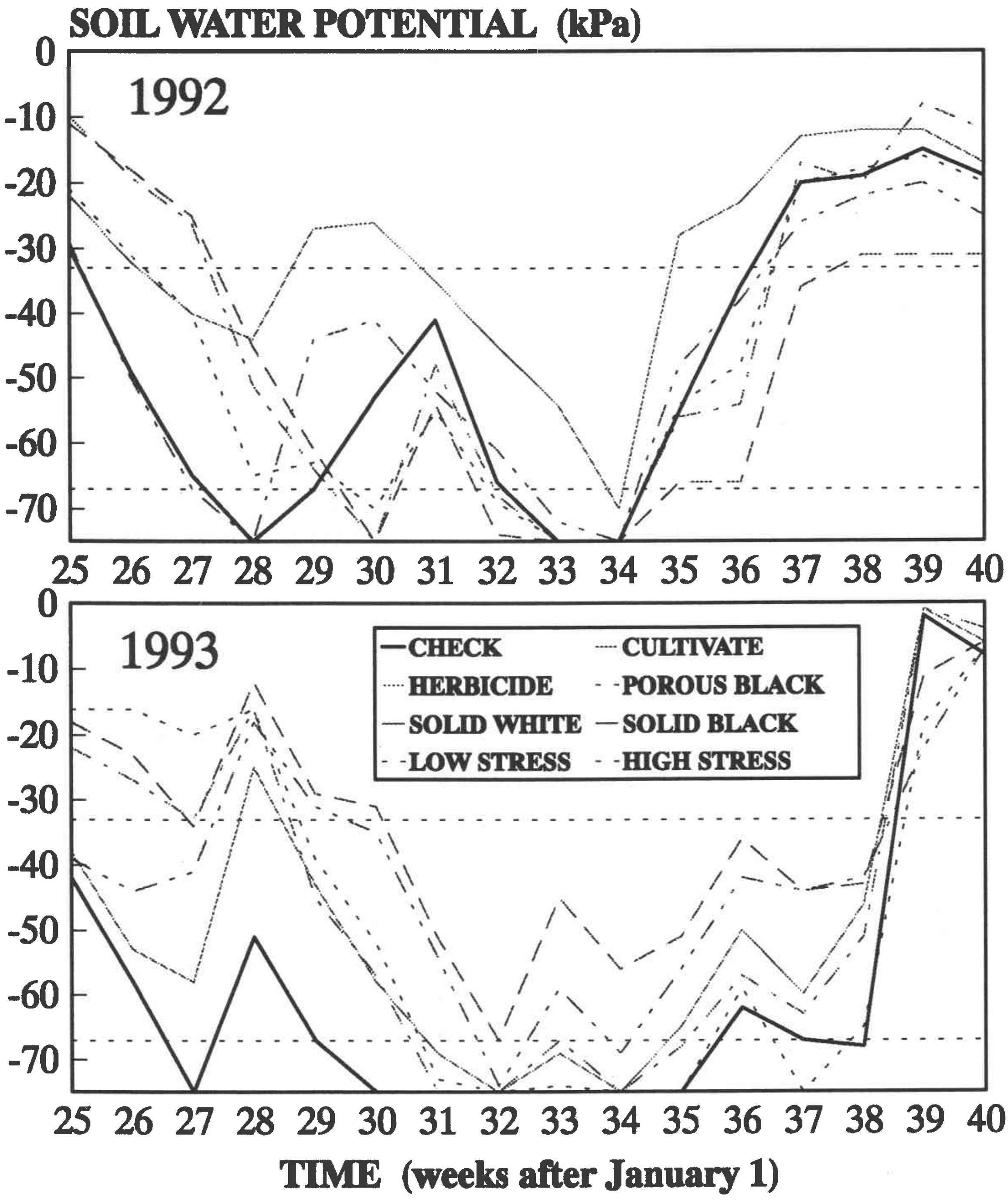

Figure 1.--Soil moisture potential under six weed control treatments for the first and second growing seasons after plantlet establishment.

During both the first and second growing seasons, plantlets in all treatments experienced 18 or more days with severe moisture stress (soil moisture potential less than -67 kPa) (Table 4). The number of days with severe moisture stress was highest in the non-weeded check plots at the beginning of each growing season. In general, the greatest number of days with severe moisture stress was least in the herbicide-treated and cultivated plots, intermediate in plots covered with plastic mulches, and highest in the check plots.

As found in other studies, the type of weed control can significantly alter the daily changes in soil temperature under both dry and wet soil conditions (Table 5). During a week of relatively clear days in late August when soil moisture potentials were under -67 kPa, the greatest daily change in soil temperatures occurred under the solid black plastic film. The same pattern was seen during a week of relatively cloudy days in early September; however, the magnitude of the daily changes under solid black plastic was not as great. The micropores in the porous black plastic may have allowed greater heat exchange, so that daily soil temperature changes were more nearly equal those for daily changes in other plots without dense vegetation. The daily change in soil temperature was least for the solid white plastic film under both clear and cloudy weather conditions. The lowest soil temperatures were found in the non-weeded control where the dense vegetation significantly reduced the amount of solar radiation reaching the soil surface.

DISCUSSION

Growth rates of the micropropagated silver maple trees were similar to that reported in other studies where height tended to double each year during the first three years (Ashby et al. 1992). This is the first report on growth rates of field-planted white ash plantlets; however, their height growth was similar to what would be expected from small bare-root seedlings of white ash.

The reduced incidence of terminal shoot dieback on plantlets in the plots using plastic films for weed control may have long-term consequences on tree form and development. Both silver maple and white ash have opposite phyllotaxy and frequently develop multiple stems following damage to the terminal bud. Because multiple stems are less desirable than a single stem for most forestry applications, the use of plastic films should have beneficial growth effects well beyond plantation establishment.

Past studies on black walnut have shown a strong correlation between the cumulative length of lateral shoots after the first growing season and rapid terminal shoot growth the second growing season (Rink and Van Sambeek 1987b). This pattern also appears to be true for white ash and silver maple, because the plantlets with the greatest cumulative lateral shoot growth after the first year tended to be the tallest after the second year.

The amount of soil warming under the solid black plastic was significantly higher than under the porous black plastic. Rapid heat exchange through the micropores appears to another important property of the porous black plastic in addition to allowing moisture to penetrate the plastic film. The changes in soil temperature we found under the solid black plastic were not as great as reported by other researchers. The rough soil surface under the black plastic or relatively dry soil conditions may have reduced the heat transfer (Ham et al. 1993, Heiskanen and Raitio 1992).

Although no root excavations were done, results from an unpublished study suggest that lateral root elongation on field-planted silver maple plantlets occurs very rapidly in moist soil and should extend beyond the edges of the plastic film late during the first growing season. With good weed control and adequate soil moisture, lateral root extension on black walnut seedlings has been shown to exceed 1.0 m after one growing season (Van Sambeek and Rietveld 1983a). The percentage of plantlets with elongating shoots in late summer and height growth of both silver maple and white ash were higher for plantlets established with plastic films than without plastic films. Increased plantlet growth early in the growing season may have resulted from a longer period without significant soil moisture stress. The solid plastic films apparently conserved the soil moisture by reducing the amount of evaporative losses when compared to changes found in soil water potentials found in the herbicide or cultivation treatments.

Table 4.--Number of days plantlets experienced severe moisture stress[a] during the first and second growing season under six different weed control practices[b].

Weed control Treatment	First growing season July	Aug.	Sept.	Second growing season June	July	Aug.	Sept.
	-------- days	-------		-------- days	---------		
Check	17	20	1	3	20	29	9
Cultivate	13	20	0	4	2	20	5
Herbicide	10	16	0	4	6	24	5
Black film	10	25	4	0	0	16	2
White film	15	22	2	1	8	27	8
Porous black	11	22	2	0	5	27	12
Significance[c]:	*	ns	ns	ns	**	ns	**
5% t-test value:	9.8				8.2		5.8
1% t-test value:	13.4				11.3		8.1
Tested Contrasts:							
Check vs Others:	*				**		ns
Conv. vs Plastic:	*				ns		ns
Cultv. vs Herb.:	ns				ns		ns
Solid vs Porous:	ns				ns		**
Black vs White:	ns				*		*

[a] Soil moisture potentials less than -67 kPa.
[b] Monthly precipitation from May through September was 3.30, 2.85, 6.71, 6.58, and 17.63 cm, respectively, in 1992 and was 12.52, 12.24, 8.97, 6.25, and 22.83 cm, respectively, in 1993.
[c] Nonsignificant (ns) or significant effects at the 5% (*) or 1% (**) according to F-test for 1 and 20 df (species) and for 5 and 20 df (treatments).

Table 5.--Soil temperature 15 cm below soil surface at 0400 and 1600 hours under six different weed control practices from 28 August to 12 September 1992.

Weed control Treatment	28 August to 4 September[a] 0400	1600	Diff.	5 September to 12 September[b] 0400	1600	Diff.
	------°C	-----		----- °C	-----	
Check	16.2	17.6	1.33	14.9	15.6	0.71
Cultivate	17.3	19.0	1.68	15.7	16.8	1.12
Herbicide	17.4	19.0	1.56	15.8	16.9	1.14
Black film	16.4	20.1	3.71	15.5	18.4	2.83
White film	16.6	17.1	0.52	15.9	16.2	0.31
Porous black	16.2	18.3	2.06	15.2	16.8	1.64
Significance[c]:	**	**	**	**	**	**
5% t-test value:	0.26	0.24	0.34	0.33	0.53	0.57
1% t-test value:	0.35	0.33	0.46	0.44	0.72	0.77
Tested Contrasts:						
Check vs Others	**	**	**	**	**	**
Conv. vs Plastic:	**	**	**	*	ns	*
Cultv. vs Herb.:	ns	ns	ns	ns	ns	ns
Solid vs Porous:	*	**	ns	**	*	ns
Black vs White:	*	**	**	*	**	**

[a] Clear days with an average air temperature of 21.9 °C.
[b] Cloudy, rainy days with an average air temperature of 23.4 °C.
[c] Nonsignificant (ns) or significant effects at the 5% (*) or 1% (**) according to F-test for 5 and 30 df.

Preliminary estimates suggest costs to establish hardwood seedlings using repeated mechanical cultivation for only one year will exceed that for laying plastic films. Costs for applying herbicides for two years are comparable to laying plastic films. Although thicker plastic films will cost slightly more, the cost should be recovered quickly through improved tree growth if the plastic film provides three or more years of weed control. Technologies already exist for manufacturing plastic films capable of giving three or more years of weed control under continual exposure to sunlight. Conversely, soil can be used to partially cover the plastic film or higher density plantings can be established that will result in more rapid canopy closure and prolong life of the plastic mulch. Future research is needed on developing the most appropriate methods for laying plastic films for forestry applications and their effects on tree growth.

SUMMARY

We found the use of plastic films to control competing vegetation to be as effective as the conventional methods currently used when establishing hardwood plantings. Plastic films slowed changes in soil moisture potential during the spring, thus prolonging the period before plantlets were exposed to moisture stress. Soil moisture potential returned to field capacity relatively quickly under all treatments late in the fall. Overall the best tree growth occurred in plots where competing vegetation was controlled with plastic films. Because the plastic mulches remained intact for 2 or 3 years, they also reduced maintenance costs following plantation establishment. We expect with closer spacings and more rapid accumulation of leaf litter the durability of plastic mulches can be further increased.

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