Evaluation of Synthetic Mulches on the Establishment and Growth of Cottonwood

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ABSTRACT. Soil microclimatic conditions created by various weed-control mulches and the resulting survival, diameter, and height growth of cottonwood seedlings were studied in central Kansas. The treatments compared the effects of six synthetic plastic mulches often used in horticultural practices with the effects of cultivation or a herbicide. One-year-old seedlings were planted with either clear plastic, blue and yellow waste plastics, black or gray/black polyethylene, or polypropylene fabric weed barrier; cultivation; or herbicide weed-control treatment. After five years, sapling survival was more than 85% for all mulch types except the clear plastic (82% survival). Differences among weed-control

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treatments were significant for survival, height, stem diameter, and biomass. Sapling growth was best with sulfometron methyl herbicide, slightly less for cultivation, and nearly the same for all other materials for weed control. Stem temperature had no relationship to first year height growth. Soil temperature and moisture had a slight relationship to second year height. Use of herbicides or cultivation was clearly less expensive than synthetic mulch for weed control.

KEYWORDS. Herbicide, mulch, polyethylene, polypropylene, *Populus deltoides*, weed control

INTRODUCTION

Tree barriers are an important tool for land managers in a total system of wind erosion control in the Great Plains area of the United States of America (Cunningham 1982). Shelterbelts and farmstead wind breaks are planted to protect soils, crops, buildings, people, livestock, wildlife, and highways from environmental extremes since the Plains was settled. The sustainability of these entities is frequently enhanced by tree barriers. Establishing trees is a challenge as the Plains environment is not hospitable to trees. Effective weed control is needed for establishment of hardwood tree seedlings in a prairie environment to maintain conditions favorable for survival and growth as grassy vegetation is a major competitor to newly established woody plants. Weed-control strategies include cultivation; application of herbicides; or use of woodchips, ground covers, or weed-barrier mulches, including plastic or polyethylene sheets and woven landscape fabrics or geotextiles (Appleton et al., 1990; Stevenson, 1994; Van Sambeek et al., 1995). Mulches have several advantages over herbicides and cultivation. Herbicides often are toxic and require repeated application. Other benefits of mulches can include conserving soil moisture and reducing soil erosion and nutrient leaching (Truax and Gagnon,1993). On poorly drained sites, mulch may contribute to anaerobic conditions by limiting evaporation (Davies, 1988). In studies with forest tree seedlings, several researchers (Ashby et al., 1992; Huetteman et al., 1992; Van Sambeek et al., 1995) reported successful establishment of silver maple and white ash with synthetic mulches. Black polyethylene and black-woven polypropylene mulch were shown to improve growth of green ash in a semi-arid environment (Stepanek et al., 2002). Although there is scant use of plastic mulches in traditional forestry, landscape mulches are used widely in horticulture and agroforestry. Various new types of plastics and fibers appear frequently on the market and are continually being evaluated (Windell and Haywood, 1996).

Early studies with weed-barrier materials were done with 1.5- to 6-mil black polyethylene films that were impermeable to water unless mechanically punctured. Weed barriers of woven-polypropylene fabrics are now being marketed, including Sunbelt and Earthmat, manufactured by the DeWitt Company in Sikeston, MO. Sunbelt woven fabric was one of the first permeable weed-barrier fabrics marketed. Sunbelt is 8 mils thick, weighs 110.2 7 g m^{-2}, and has a high infiltration rate of 491 L m^{-2} min^{-1}. It is long-lasting in the field and contains carbon black as an UV light stabilizer. Newer products are lighter and cheaper.

The objective of this study was to investigate the effects of weed-barrier fabrics and plastic mulches as alternatives to conventional herbicides and cultivation for controlling competing vegetation in newly planted cottonwood in the central Great Plains.

MATERIALS AND METHODS

The planting was established on a flat, alluvial, old-field site in the central Great Plains near Manhattan, Kansas. Precipitation averages about 30 inches (76 cm) per year, with 75 percent coming during the growing season. The soil was classified in the Eudora silt loam series (coarse-silty, mixed, mesic, Fluventic Hapudolls) and consisted of 9.8 inches (25 cm) of silt loam soils underlain by very fine sandy loam. The tall fescue sod was treated with Roundup and later cultivated before planting. The research planting consisted of four 400-foot-long (122 m) rows, spaced 12 feet (3.6 m) apart, for a total of 800 trees. Each row was divided into eight, 6 feet (1.8 m) wide by 50 feet (15.2 m) long plots with 25 trees each. Grass strips were left between the rows. A randomized complete-block planting design was used, with each row considered a block. In this study, 1:0 age seedlings of cottonwood (*Populus deltoides* Bartr. Ex Marsh) were hand-planted two feet (0.6 m) apart. Every other tree in the mulch treatments was planted in a tight-fitting hole punched in the plastic with a rod or in four-inch X-crossed slits. Roots were trimmed heavily for easy access through the plastic.

Weed-control treatments were 0.6-mil clear commercial waste plastic, 3.5-mil yellow or blue commercial waste plastic (silicon covered), 1.25-mil gray/black polyethylene plastic mulch (Edison Plastics), 3.0-mil black polyethylene plastic mulch (Tredegar Film Products), DeWitt Sunbelt woven polypropylene fabric, bi-monthly cultivation, and 0.5 oz (14 ml)/a sulfometron methyl (Oust) herbicide applied after cultivation. The films (6 feet/1.8 m wide) were manually laid, with a four-foot (1.2 m) exposed width after the sides were trenched and covered with soil. The area between the plots was mowed often during the growing season for accessibility.

Variables Studied

Weed-control treatments were tested for survival and growth of the trees. Survival in percentile, height in feet, and diameter at the ground line in inches of the cottonwood saplings were recorded each year and at the end of the fifth growing season. Tree weight was calculated by using D^2H, where D is diameter in inches, H is total tree height in feet and expressed as pounds oven dry weight (OVD). This mathematical model is frequently used and has high correlation with tree weight (Geyer et al., 2000). Planting hole types, soil moisture, soil temperature, and stem temperature were also evaluated for the first two growing seasons.

To determine volumetric water content of the soil in the root zone, time-domain reflectometry (TDR), metal rods were inserted at the 6-inch (15 cm) and 12-inch (30 cm) levels, in the center of each treatment plot, and water volume was measured weekly at 1500 hours for two growing seasons. Soil temperatures were measured with thermocouples at the same depths and location within the strip as TDR wave-guides.

During the period of July10 to September 9, 1997, weekly surface temperatures of selected cottonwood seedling stems and their corresponding treatment plastics were measured by an infrared thermometer (Omega model OS 520) outfitted with a laser spotter, and air temperature at three feet (0.9 m) above the ground was also measured. The OS520 integrates a surface temperature over an area enclosed by a 0.5-inch (1.3 cm) diameter circle when the instrument is positioned within three inches (7.62 cm) of the surface to be measured. Care was taken to locate the instrument within the 1- to 3-inch (2.5 to 7.6 cm) range to keep the spot size at its minimum. Most of the seedlings measured had stem diameters greater than 0.5 inches (1.3 cm). Therefore their measurements contain a small, probably insignificant, error. Measurements were recorded for four seedlings in each of the eight treatments. All temperatures were measured on the southwest side of the stem at approximately 1500 hours on measurement days, two for closed holes and two for open holes. The plastic surface temperature was recorded adjacent to each seedling that was measured.

Data were analyzed by analysis of variance by using SAS General Linear Model procedure (SAS, 1985). Duncan's procedure was used to separate treatment means when significantly different at the P = 0.05 level. Survival differences were determined by using the chi-square test. Simple correlation was used to analyze the linear relationship between soil moisture and temperature and seedling height.

Cost Comparisons

To analyze the economic impact of the use of mulches, the costs to prepare the ground, purchase and apply a six-foot wide strip of herbicide or mulch, and establish the tree seedlings at eight-foot in-row spacing were used to calculate the cost per 100 linear foot of treatment and those costs were compared with the cost of three years of cultivation only. Custom rates for farming practices taken from various K-State Research and Extension publications (Beaton et al., 2003 and Kansas Forest Service communication) were used to develop costs.

RESULTS AND DISCUSSION

Significant differences existed after five growing seasons among weed-control treatments for survival, height, stem diameter, and biomass (Table 1). Weed-barrier fabrics have been shown to improve the soil environment in several similar studies. Polyethylene weed barriers have been shown to increase soil temperatures during the growing season and to preserve soil moisture at depths of 6 and 10 inches (40.6 and 25.4 cm) (Appleton et al., 1990; Ham et al., 1993; Truax and Gagnon, 1993; USDA-Agriculture Research Service, 1993). Ham and Kluintenberg (1994) have developed mathematical models relating optical properties and soil contact resistance of various plastic mulches to soil heating. The models suggest that plastic mulches increase early spring soil temperature. Warmer soil temperatures when soil moisture is still near field capacity presumably leads to improved tree growth.

Survival

Weed control is usually required for successful tree seedling establishment (Boysen and Strobl,1991; Geyer, 2003), and we found overall survival of the mulched cottonwood trees after five years was 85% with a range of 75 to 94% between the mulches. Mortality remained essentially the same from one to five years (mortality increased <1 %). The chi-square test for survival revealed a significant difference ($P < 0.001$) between treatments during the first growing season. Survival under clear plastic was less than the others. No difference in first-year survival was found between the closed or open holes used in planting.

Height

Cottonwood saplings treated with the sulfometron methyl weed-control treatment, had the best growth (37.6 ft/11.5 m) followed closely by cultivation (35.5 ft /10.8 m) after five years (Table1). Clear plastic was the shortest at 30.1 (9.2 m) feet, while the average height for saplings, although not significantly different, with the other four polyethylene or polypropylene mulches, was about 88% (33.3 feet /10.2 m) of the height of the herbicide treatment. Hole type did not significantly affect seedling height growth the first year.

TABLE 1. Fifth-year survival and growth in a cottonwood planting with eight weed-control methods.

Treatment	Survival	Tree height	Stem diameter	Tree weight
	–%–	–ft(m)–	–in (cm)–	–lbs (kg)OVD–
Clear plastic	75b	30.1(9.2)e	3.3(8.4)c	18.7(8.5)c
Blue waste	90a	31.0(9.5)de	3.5(8.9)bc	20.9(9.5)c
Gray/black plastic	80b	32.7(10.0)cd	3.6(9.1)cb	21.6(9.8)c
Black plastic	94a	33.2(10.1)c	3.7(9.4)b	23.1(10.5)c
Sunbelt fabric	91a	33.0(10.1)c	3.6(9.1)cb	22.1(10.0)c
Yellow waste	87a	33.3(10.2)c	3.7(9.4)b	22.1(10.0)c
Bi-monthly cultivation	86a	35.5(10.8)b	4.1(10.4)a	29.8(13.5)b
Sulfometron methyl	84ab	37.6(11.5)a	4.4(11.2)a	34.2(15.8)a
Mean	**85**	**33.3(10.2)**	**3.7(9.4)**	**24.1(11.0)**
Sign.	**1%**	**1%**	**1%**	**1%**

Values followed by the same letter are not significantly different at the p = 0.05 level.

Stem Diameter and Biomass Index

Stem diameter followed a similar pattern to height, however, diameter for saplings grown with the plastic mulches was 80 to 90% of the diameter of the saplings grown with the cultivation treatment, while the herbicide was 107%. Trees grown with plastic mulches had about 56 to 85% of the biomass index (tree weight) with the standard cultivation treatment, while herbicide was 112% (Figure 1). Biomass index was calculated by converting D^2H to pounds OVD weight of individual trees times the number of trees per plot times survival. In a similar study (Geyer, 2003) cottonwood saplings grown in a tall fescue sod, had only 20% of the biomass of those grown with cultivated weed-control.

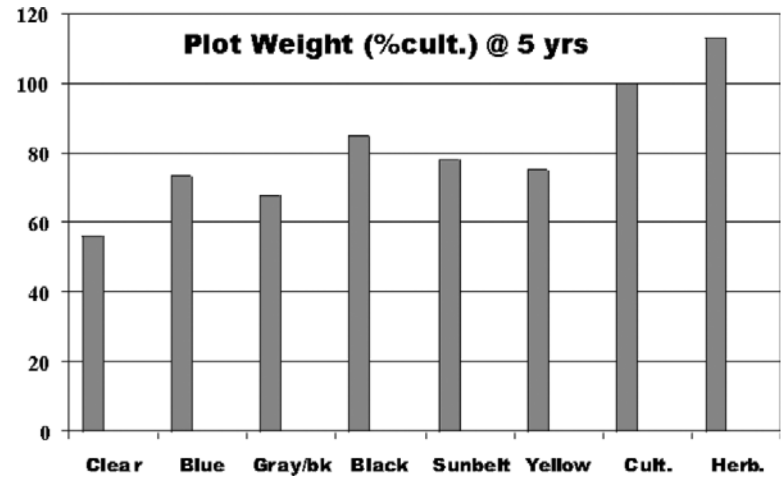
Durability

Resistance of the commercial plastic mulches in this study to degradation by ultra violet (UV) light was minimized by tree leaf litter and grassy vegetation at the barrier edge. The mulches without UV filters–clear, yellow, and blue–broke down within two years. The other commercial mulches remained durable for more than 5 years. Rodents did not seem to damage tree trunks. Cutting of the plastics may be required for longer periods to prevent girdling.

Seedling Stem/Plastic Interface Temperature

Stem temperatures during the first growing season ranged from a high of 167°F (75°C) for black to 88°F (31°C) for clear plastic. The clear plastic degraded early in the summer, and measurements were discontinued. Stem temperatures differed significantly between mulch treatments ($P < 0.001$). Stems in black plastic were significantly warmer than all other mulch types (137.5°F/ 58.6°C). Sunbelt fabric and gray plastic had mean stem temperatures of 125.1°F (51.7°C) and 124.5°F (51.4°C), respectively. Temperatures of blue, yellow, and clear mulches were significantly different than those of the other treatments, with means of 113.6°F (45.3°C), 108.8°F (42.7°C), and 108.3°F (42.4°C), respectively. A similar temperature of 113.0°F (45°C) was found for bi-monthly cultivation. First year height growth had no significant relationship to stem temperature variation among the mulch treatments. Sunbelt fabric and gray/black plastic had intermediate temperatures. Stem temperatures differed ($P < 0.005$) between the hole types. Seedlings planted in the open holes (cut with an X) had significantly lower stem temperatures than those in closed

FIGURE 1. Biomass production from various weed-control treatments.



(punched) holes (114.2°F/45.7°C vs. 129.3°F/54.1°C). The higher stem temperature did not affect seedling mortality. Blue waste was the only plastic for which hole type had a significant ($P < 0.008$) effect on temperature. The clear and yellow plastics deteriorated rapidly and were not measured consistently. Air temperatures during the 3-month period ranged from 75 to 100°F (23.8 to 37.8°C).

Soil Temperature and Moisture Variation

Average soil temperature at the 6-inch (15 cm) depth of the nine weekly measurements taken during the first growing season showed a range of 78.0 to 81.8°F (24.8 to 27.7°C). Average soil moisture temperatures for different mulch types were significantly different ($P < 0.0001$). Blue waste and black plastics were the warmest whereas gray plastic was the coolest (Table 2). During the second growing season, the soil-temperature range was from 74.5 to 76.6°F (23.6 to 24.8°C), for herbicide and clear plastic, respectively. The soil temperature of other treatments did not differ. Average soil moisture differed slightly between treatments (Table 2). Although there was little difference between the treatments, herbicide and cultivation were the driest ($P < 0.001$). Data for the first month (when seedling establishment is critical and all plastic types were intact) was used to test the relationship of treatments to first-year, total seedling-height. Neither soil temperature

TABLE 2. First- and second-year soil temperature and moisture measurements at the 6-in (15 cm) and 12-in (30 cm) levels under various mulch types.

Treatment	Temperature (°F/°C)			Volumetric moisture (%)		
	15 cm		30 cm	15 cm		30 cm
	1st year	2nd year	2nd year	1st year	2nd year	2nd year
Clear plastic	81.0 (27.2)a	76.6 (24.8)a	73.3 (24.1)b	15.1a	27.4a	27.5b
Blue waste	81.8 (27.7)a	75.9 (24.4)b	75.0 (23.9)bc	12.2b	25.3bc	26.8b
Gray/black plastic	76.6 (24.8)bc	75.9 (24.4)b	75.1 (23.9)bc	15.3a	24.9ab	26.1b
Black plastic	81.7 (27.6)a	75.9 (25.3)b	76.7 (24.8)a	16.5a	26.6ab	29.9a
Sunbelt fabric	78.1 (25.6)b	75.9 (24.4)b	75.0 (23.9)bc	16.8a	26.2abc	27.9ab
Yellow waste	80.5 (26.9)a	76.1 (24.5)b	75.1 (23.9)bc	15.4a	24.5cd	25.8b
Bi-monthly cultivation	78.0 (25.6)b	75.8 (24.3)b	74.9 (23.8)bc	11.3b	22.8d	25.6b
Sulfometron methyl	–	74.5 (23.6)c	74.2 (23.4)c	–	23.0d	25.8b
Sign.	**1 %**	**1 %**	**1%**	**1%**	**1%**	**1%**

Values followed by the same letter are not significantly different at the p = 0.05 level.

or moisture was correlated to height ($r = 0.0014$ for temperature and 0.02 for moisture) during the first year. Mean moisture and temperature values over the entire nine-week period were negatively correlated with total height after the one growing season (-0.89 and -0.75, respectively).

Average soil temperature at the 12-inch (30 cm) level was not recorded during the first growing season. During the second growing season, black plastic was significantly warmer than the other mulches, 76.7°F (24.8°C), and retained the most moisture at 29.9%. Mean moisture and temperature values over the entire nine week period were not significantly correlated with total height after two growing seasons. Cottonwood grows best in sandy, well-drained soils; the heavy soil at this site seemingly restricted growth.

Economic Comparisons

The high cost of some weed-control methods restricts their use to situations when tree survival and growth and/or convenience (conservation agency turn-key operation of establishment) are factors. Establishment and three-year maintenance costs were least with Oust herbicide. Bimonthly cultivation increased costs by a factor of three. The synthetic mulches were very expensive to use. Costs per 100 feet of treatment were $1 for Oust, $3 for cultivation, $20 for polyethylene mulches, and $48 for the polypropylene fabric. The difference between the synthetics resulted from the cost of material and the laying of mulch, which was expensive. Using waste plastics would likely reduce the cost by 25%.

Weed Control

The blue, clear, and yellow plastic mulches deteriorated during the first growing season, thus they did not control herbaceous weeds as well as the others. Sulfometron methyl applied after cultivation each spring controlled weeds effectively for three months and was applied for three years. Some weeding is necessary using the synthetics mulches, and was necessary within the X-crossed planting hole slits. After a few years, weed mats did grow over the edges of the material.

CONCLUSIONS

The value of tree barriers for wind erosion is an established sustainable agricultural agroforestry practice in the savanna regions of the world. Weed control is necessary for tree seedling establishment, especially cottonwood, in the Plains States. Proper selection and application of an herbicide is worthwhile if conditions are favorable. Often, in field applications, herbicides are applied later in the spring than desired or receive less than adequate amounts of moisture for activation. Late-spring application to dry soils in the Great Plains may compromise weed control significantly, reducing the growth of many tree species. Site preparation in the previous fall and the use of pre-emergent chemicals will eliminate this problem. At times, Sunbelt-fabric or plastic-sheet weed barriers can yield better results than herbicides do (Geyer, 2003). They can be installed over weeds that may have already germinated, killing competitive vegetation and minimizing subsequent germination of weed seeds. Even with the use of weed-barrier fabrics, some weeding around the tree may be necessary within the planting hole.

In this study, five-year growth was best with sulfometron methyl (Oust) herbicide. Cultivation is the next best alternative, but requires frequent application. Soil temperature and moisture differed under the different types of mulch, but had no relationship to first-year seedling height growth. Synthetic mulch-weed barrier plastic sheets and fabrics have many positive attributes. Although these UV-resistant materials initially may be more expensive to establish, they are practical to use under limited conditions. The commercial landscape materials, black or gray /black plastic polyethylene, and polypropylene fabric weed barriers work well for a long period of time. They are especially valuable in areas of more limited precipitation than found at the study site.

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