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Durability of selected mulches, their ability to control weeds, and influence growth of loblolly pine seedlings*

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Abstract. Several mulches of natural, synthetic, or blends of natural and synthetic fibers were tested around newly planted loblolly pine (*Pinus taeda* L.) seedlings on a sheared and windrowed site in central Louisiana, USA. The vegetation was primarily winter annuals, some residual grasses and forbs, and sparse woody regrowth. Study 1 was rotary mowed just prior to planting in March 1992, and 35 mulches and an untreated check were established. In Study 2, 15 mulches and an untreated check were established in a 1-year-old rough in March 1993. In both studies, a single loblolly pine seedling formed each plot established in a randomized complete block design, with 10 blocks as replicates. Each block was planted with a separate open-pollinated loblolly pine family.

Nearly all mulches had deteriorated to some extent after three growing seasons. Synthetic mulches were generally more durable than the natural or natural/synthetic mulches. Mulching eliminated the established vegetation and germinants, and vegetation did not readily reestablish following the deterioration of a mulch. The soil seed bank apparently was not sufficient to regenerate areas that were once covered with mulch and many of the natural materials deteriorated into a fibrous cover that acted like a natural litter layer. Both of these residual weed control effects – insufficient soil seed bank and formation of a fibrous cover – were important in stopping vegetation from reestablishing after a mulch had deteriorated. After three growing seasons, the loblolly pine seedlings generally grew better if mulches were used.

Key words: *Pinus taeda* L., plantation establishment, mulch, competition control

Introduction

Mulching is a weed control method used in agriculture and forestry throughout the world (Dao 1987; Gale et al. 1993; Gupta 1991; Mahajan and Kanwar 1993; McDonald and Helgerson 1990). Mulching provides a means to passively control vegetation and thereby reduces the need for mechanical and chemical weed control. Where labor for continual weeding is scarce,

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machines cannot operate, and the use of chemicals restricted or not desired, mulching may be an attractive alternative which will also conserve soil moisture, improve water infiltration, and reduce sedimentation (Crutchfield et al. 1985; Mahajan and Kanwar 1993; Walker and McLaughlin 1989; Zuzel and Pikul 1993). Forest litter and logging debris can be shredded on site to form a mulch or it can be transported from another site. Another strategy is to use manufactured mulches.

An ideal manufactured mulch for silvicultural use should be opaque to prevent weed growth, dark to create temperatures hot enough to kill germinants and sprouts, porous enough to allow water to infiltrate through the mulch but still retard loss of water from under it, have thermal characteristics to maintain a favorable soil temperature regime, be durable enough to last until the seedling is established and growing well, easy to transport, have sufficient tear strength to allow easy handling and fast installation, be a color that blends into the landscape, and non-toxic (McDonald and Helgerson 1990). Additional properties might include being biodegradable and unattractive to animals. Also, natural and natural/synthetic mulches are often heavier and bulkier than synthetic mats, which makes them more difficult to transport and handle in hilly or mountainous terrain (McDonald and Helgerson 1990).

Many mulches are marketed but few may actually meet enough of these criteria to be useful. To assist forest managers in selecting mulches, two studies were established to determine the ability of a large selection of mulches to remain intact and in place under field conditions (durability), control weeds, and influence the growth of planted loblolly pine (*Pinus taeda* L.) seedlings. Attempts were made to include all mulches commercially available when the studies were installed plus several experimental materials.

Methods

Establishment and design

The two studies are on the same site in central Louisiana, USA. The site is approximately located at 92°30′ W longitude and 31° N latitude at an elevation of 50 m. The soil is a Beauregard silt loam (fine-loamy, siliceous, thermic Plinthic Paleudult) and has a level slope of 0 to 3%.

The original forest stand was clearcut harvested in the mid 1980's. The site was left fallow until it was sheared and windrowed in the summer of 1991. Following mechanical preparation, the vegetation was primarily winter annuals, some residual grasses and forbs, and scattered blackberry (*Rubus* spp.), southern bayberry (*Myrica cerifera* L.), American beautyberry

(*Callicarpa americana* L.), and sweetgum (*Liquidambar styraciflua* L.). The vegetation was rotary mowed in March 1992.

Weather can influence the durability of a mulch. Weather data were available from continuously recording electronic weather stations located 3 and 19 km from the sites. Daily ambient temperature at 1.5 m above the surface and precipitation data were used to calculate monthly values. Average yearly ambient temperatures were below normal from 1992 through 1995 (Louisiana Office of State Climatology 1995). However, 1995 was the warmest year since 1990, due in part to above average temperatures in July and August.

Precipitation was variable during both studies. Precipitation was below the 44-year average in the 1992 and 1994 growing seasons (March–September) and above average in the 1993 and 1995 growing seasons, largely because of late winter and spring rains (Louisiana Office of State Climatology 1993, 1995). Droughts occurred in August and September 1993 and in August 1995.

For both studies, a single pine seedling formed each plot to which treatments were assigned in a randomized complete block design. There were 10 blocks, as replicates, and each block was planted with a separate loblolly pine family. The blocks were spaced 2.4 m apart, and the 36 single-tree plots were spaced 2.4 m apart within each block.

The 10 loblolly pine families used in both studies were open-pollinated collections from a first generation loblolly seed orchard in central Louisiana. These families are widely planted in the southern United States and are used in a national site productivity study (Tiarks et al. 1991). Twenty-eight-week-old container grown seedlings from the 10 families were planted with a punch of the correct size for the root plug in March 1992 on Study 1 and in March 1993 on Study 2.

I was not concerned with a treatment × family interaction (the error term) because I had already used some of these open-pollinated families in another study as the subplot treatment – planting stock (Haywood et al. 1997). In that work, there were no significant treatment × family interactions, and the treatments were herbicide, litter (mulch), and fertilization.

Treatments

Study 1. In March 1992, 35 mulches and an untreated check were established. The mulches were placed around the planted seedlings, and the mats were anchored with large staples. The 36 treatments in Study 1 were as follows:

Check. No treatment after rotary mowing in March 1992.

Fourteen natural mulches:

Cotton shoddy. A 1.0-m^2 non-woven high density cotton (*Gossypium hirsutum* L.) shoddy from Conwed Fibers (P.O. Box 357, Riverside NJ 08075 USA).

CWW-475. A 1.0-m^2 mat of 90% hammer-milled and refined construction wood wastes (CWW) blended with 10% cotton fibers weighing 475 g/m^2 from the U.S. Department of Agriculture, Forest Service, Forest Products Laboratory (FPL) (One Gifford Pinchot Drive, Madison WI 53705 USA).

CWW-830. A 1.0-m^2 mat of 90% hammer-milled and refined CWW blended with 10% cotton fibers weighing 830 g/m^2 from FPL.

Dahoma. A 1.0-m^2 mat of intertwined fibers of 90% dahoma (*Piptadensiastrum africanum*) blended with 10% cotton weighing 1,200 g/m^2 from FPL.

HortoPaper®.[1] A 0.9-m^2 peat and cellulose mixture pressed into a sheet from Nordstrom Enterprises (2504 West San Bruno, Fresno CA 93711 USA).

Jute-475. A 1.0-m^2 mat of intertwined jute (*Corchorus* spp.) fibers treated with mineral oil weighing 475 g/m^2 from FPL.

Jute-830. A 1.0-m^2 mat of intertwined jute fibers treated with mineral oil weighing 830 g/m^2 from FPL.

Kenaf-360. A 1.0-m^2 mat of intertwined fibers of 80% kenaf (*Hibiscus cannabinus* L.) blended with 20% cotton weighing 360 g/m^2 from FPL.

Kenaf-720. A 1.0-m^2 mat of intertwined fibers of 80% kenaf blended with 20% cotton weighing 720 g/m^2 from FPL.

OCC-475. A 1.0-m^2 mat of 90% hammer-milled old corrugated containers (OCC) blended with 10% cotton fibers weighing 475 g/m^2 from FPL.

OCC-950. A 1.0-m^2 mat of 90% hammer-milled OCC blended with 10% cotton fibers weighing 950 g/m^2 from FPL.

Pine straw. About 9 kg of air-dried needles taken from opened bales of pine straw and placed around the seedling covering about a 1.0-m^2 area.

PS15-W®. A 0.2-m^2 single layered Bermuda grass (*Cynodon dactylon* (L.) Pers.) mulch with filter paper on one side from ProSeed USA (P.O. Box 1250, San Marcos TX 78667 USA). The mulch contains a slow release 6-18-6 (N-P-K) fertilizer.

PS30®. A 0.2-m^2 double layered Bermuda grass mulch with filter paper between the two layers from ProSeed USA. The mulch contains a slow release 6-18-6 (N-P-K) fertilizer.

Eleven natural/synthetic fiber blends:

Cellulose mat. A 1.0-m^2 non-woven secondary cellulose fiber mat encapsulated with a non-woven meltblown polypropylene blanket from Conwed Fibers.

[1] Use of trade names is for the convenience of the reader and does not constitute recommendation of their use by the U.S. Department of Agriculture.

Cellulose-plastic netting. A 1.0-m^2 non-woven high density cellulose fiber mat with lightweight polypropylene net on one side and polyethylene and lightweight polypropylene net on the other side from Conwed Fibers.

Cellulose-polypropylene. A 1.0-m^2 non-woven secondary cellulose fiber mat with lightweight polypropylene netting on one side from Conwed Fibers.

Cotton-polyethylene. A 1.0-m^2 non-woven high density cotton shoddy with polyethylene backing on one side from Conwed Fibers.

Ecomat®. A 0.8-m^2 continuous-spun needle-punched mat of hemlock (*Tsuga* spp.) and polyester fibers from Canadian Forest Products Ltd (430 Canfor Avenue, New Westminster, BC, Canada).

Excelsior-polypropylene. A 0.8-m^2 mat of woven wood excelsior on one side and non-woven continuous filament polypropylene on the other wrapped with a fine mesh polypropylene netting and attached to the mat with a plastic adhesive from PPS Packaging Co (204 North Seventh Street, P.O. Box 56, Fowler, CA 93625 USA).

Fortifiber®. An 0.8-m^2 asphalt laminated kraft paper sheet reinforced with a fiber glass scrim from Fortifiber Corporation (300 Industrial Drive, Fernley, NV 89408 USA).

Nelson-Ball® Paper. An 0.8-m^2 asphalt laminated kraft paper sheet reinforced with a nylon scrim from Nelson Ball Paper Products, Inc (P.O. Box 3016, Longview, WA 98632 USA).

Poplar/synthetic mat. A 1.0-m^2 non-woven embossed poplar (*Populus* spp.)/synthetic mat with lightweight polypropylene net on one side from Conwed Fibers.

Secondary fiber mat. A 1.0-m^2 non-woven secondary fiber mat with polypropylene net and polyester scrim on both sides from Conwed Fibers.

Synthetic/cellulose mat. A 1.0-m^2 non-woven high density synthetic/cellulose mat from Conwed Fibers.

Ten synthetic mulches:

Black polyethylene. An 0.8-m^2 embossed black polyethylene sheet from Edison Plastics Co (706 Wildwood Drive, Aberdeen, NC 28315 USA).

Sunbelt®. A 0.8-m^2 woven black polypropylene mat from DeWitt Co (Highway 61 South, Rural Route 3, P.O. Box 31, Sikeston, MO 63801 USA).

Sunfilm®/Brush Blanket®. A 0.8-m^2 perforated translucent green plastic sheet that allows only infrared light through sold under the trade name Sunfilm from AEP Enterprises (20 Knickerbocker Road, Depart-

ment A-1, Moonachie, NJ 070774 USA); also sold under the trade name Brush Blanket from Arbortec Industries, Ltd (P.O. Box 130, Oroville, WA 98844 USA).

Super Mulch®. A 0.8-m^2 black polyethylene sheet with scattered perforations from Easy Gardener (P.O. Box 21025, Waco, TX 76702 USA).

Terra Mat "E"®. A 0.8-m^2 non-woven needle punched polyester mat (seconds from the geotextile industry) from Terra Enterprises (P.O. Box 9485, Moscow, ID 83843 USA).

Thermat®. A 0.8-m^2 plastic laminate mat with green on one side and brown on the other, that was installed green side up, from Treessentials (Riverview Station, P.O. Box 7097, St. Paul, MN 55107 USA).

Vispore® A 0.8-m^2 black polyethylene sheet with funnel-shaped pores from Tredegar Film Products (1100 Boulders Parkway, Richmond, VA 23225 USA).

Weed Barrier®. A 0.8-m^2 woven black polypropylene mat with a non-woven polypropylene cap from DeWitt Co.

Weed Block 6+®. A 0.8-m^2 black polyethylene sheet with many perforations from Easy Gardener. Weed Block 6+ is a thicker material than Super Mulch.

White on black film. An 0.8-m^2 extruded white on black polyethylene sheet from Tredegar Film Products.

Difficulties in installing mulches can be a serious obstacle to their continued use, and managers want prior knowledge of potential installation problems. HortoPaper tore easily and was difficult to re-anchor unless the mat corners were rolled around a tongue depressor before stapling. Other than the HortoPaper, the mulches were not difficult to install at a freshly mowed site on a calm day.

A potential problem with several of the natural and natural/synthetic mulches is the weight and bulk of the mats, which makes them difficult to transport and handle in steep terrain (McDonald and Helgerson 1990). However, handling these materials was not a problem at this flatwoods site in central Louisiana.

Study 2. Based on the preliminary results from Study 1, several of the mulches were again tested in Study 2. Other mulches not available when Study 1 began were also included in Study 2. The site was not re-mowed prior to establishment, and in March 1993, 15 mulches and an untreated check were established in the one-year-old rough in Study 2. The mulches were placed around the planted seedlings, and the mats were anchored with large staples. The 16 treatments in Study 2 were as follows:

Check. No treatment after rotary mowing in March 1992.

Four natural mulches:

Acetylated kenaf. A 1.0-m^2 low-density mat of intertwined fibers of 80% acetylated kenaf and 20% cotton from FPL.

Cardboard. A 1.2-m^2 layered disk of recycled cardboard from Snowy Pines Reforestation (Route 3, Box 95, Browerville, MN 56438 USA).

Kenaf-oil. A 1.0-m^2 low-density mat of intertwined fibers of 100% kenaf treated with soybean oil from FPL.

Pine straw. About 3.6 kg of air-dried needles taken from opened bales of pine straw and placed around the seedlings covering about a 0.8-m^2 area.

Four natural/synthetic fiber blends:

CWW-carpet waste. A 1.0-m^2 mat of 70% hammer-milled and refined CWW blended with 30% carpet waste from FPL.

CWW-polyester. A 1.0-m^2 blend of CWW and polyester fibers from Wood Recycling, Inc (300 Forest Street, P.O. Box 6087, Peabody, MA 01961 USA).

Ecomat®. Same mulch as in Study 1.

Kenaf-carpet waste. A 1.0-m^2 low-density mat of intertwined fibers of 70% kenaf and 30% carpet waste from FPL.

Seven synthetic mulches:

Black polyethylene. Same mulch as in Study 1.

Sunbelt®. Same mulch as in Study 1.

Sunfilm®/Brush Blanket®. Same mulch as in Study 1.

Terra Mat "P"®. A 0.8-m^2 black non-woven needle punched polypropylene mat from Terra Enterprises.

Thermat®. Same mulch as in Study 1.

Vispore®. Same mulch as in Study 1.

Weed Block 6+® Same mulch as in Study 1.

The 1-year-old rough and steady 24 km/h winds interfered with installing most of the mulches used in Study 2. Among the natural and natural/synthetic mulches, the acetylated kenaf mulch was the most tear resistant and stiff enough to install under windy conditions. The CWW-carpet waste and CWW-polyester mulches were readily torn by the grass stubble and small woody stems during installation. Loose fibers were an irritant when installing the kenaf-oil, CWW-carpet waste, Ecomat, and kenaf-carpet waste mulches, but the Ecomat fibers were the most irritating.

Among the synthetic mulches, black polyethylene, Sunfilm/Brush Blanket, Vispore, and Weed Block 6+ were easily torn on the grass stubble and small woody stems and were difficult to install in the wind because they are lightweight and too flexible. Thermat was also easily punctured but was

stiff enough to handle under windy conditions. Sunbelt and Terra Mat "P" were easier to install than the other synthetic mulches because they are more puncture resistant and stiff enough to handle in the wind.

Cardboard was the easiest mulch to install. The layered cardboard circles were bulky and stiff and this helped to push down the grass stubble and small woody stems. Pine straw was the next easiest mulch to install because bales, which are formed by compressing layers of straw together, dissect easily and there is no fabric to puncture. The straw handled well in the wind.

Measurements and data analysis

In both studies, 3-year-old loblolly pine total heights were measured to the nearest centimeter and groundline diameters to the nearest millimeter. Weed cover was estimated to the nearest percent within the area originally covered by the mulch or within a 0.5-m radius of the seedling on the checks. The percentage of weed cover was the amount of surface that would be shaded by weeds if the sun were directly overhead. Vegetation leaning or spreading over a mulch that was still in place was not included in these estimates. Plants growing through the planting slit and staple holes of a mulch were included in the estimates.

Total height, groundline diameter, and weed cover results were analyzed by analysis of variance ($\alpha = 0.05$) (SAS Institute 1985). If there were significant treatment differences in the analysis of variance, mean differences were determined by Duncan's multiple range tests ($\alpha = 0.05$). Duncan's multiple range tests often separate treatment means into more classes than other means separation tests. Therefore, the power of the test is increased when a Duncan's test is used to avoid Type II errors. The false acceptance of the null hypothesis is a major concern in ecological studies because natural variation is always and issue regardless of the care taken to reduce it (Peterman 1990; Thomas 1997).

Mulch durability (ability to stay intact and in place) for three growing seasons was visually estimated and classed as follows:

1 **Excellent** – no damage to the mulch occurred
2 **Good** – 0.1 to 5.0% of the mulch deteriorated
3 **Fair** – 5.1 to 15% of the mulch deteriorated
4 **Poor** – over 15% of the mulch deteriorated
5 **Missing** – no mulch present.

These classes were developed after several years of personal experience in estimating mulch durability. Block effects on mulch durability were ignored, and the results were analyzed using nonparametric procedures (NPAR1WAY) (SAS Institute 1985). The Kruskal-Wallis test results were reported (probability $> \chi^2 = 0.05$). The final mean rankings were the averages of the 10

durability values for each mat treatment evaluated. The rankings were derived from the nonparametric analysis.

Results and discussion

Mulch durability and weed cover

Revegetation occurs quickly in central Louisiana after site preparation and rotary mowing. Shading by vegetation at the edge of the mulches as well as by the loblolly pine seedlings reduced the effects of direct sunlight on the mulch fabrics. However, the ability of ultraviolet radiation to deteriorate fabrics was probably a factor in these studies.

In Study 1, all of the mulches, except for Thermat, deteriorated to some extent (Table 1). Pine straw had fair durability, but the other natural mulches had poor durability or were missing after three growing seasons. Among the natural/synthetic mulches, cotton-polyethylene and synthetic/cellulose mats had good durability, and excelsior-polypropylene mulch had fair durability. The other natural/synthetic mulches had poor durability or were missing. Eight of the 10 synthetic mulches had good or excellent durability: black polyethylene, Sunbelt, Sunfilm/Brush Blanket, Thermat, Vispore, Weed barrier, Weed Block 6+, and white on black film. Terra Mat "E" had fair durability, and Super Mulch had poor durability.

In Study 2, all of the natural mulches had fair durability after three growing seasons (Table 2). Among the four natural/synthetic mulches, CWW-carpet waste, Ecomat, and kenaf-carpet waste had fair durability. The CWW-polyester mulch was less durable than the CWW-carpet waste mulch. Five of the seven synthetic mulches had good or excellent durability: Sunbelt, Terra Mat "P", Thermat, Vispore, and Weed Block 6+. Black polyethylene and Sunfilm/Brush Blanket had only fair durability in Study 2.

Because of improvements in design, the mulches from the FPL were more durable in Study 2 than in Study 1. For example, the acetylation process made the kenaf fibers more dimensionally stable and resistant to decay. Nevertheless, the synthetic mulches generally had better durability than the natural or natural/synthetic mulches in both studies.

However, the deterioration of the natural or natural/synthetic mulches was not necessarily bad because some of the deteriorating fabric formed a fibrous cover over the soil which continued to suppress weeds after the mulch was apparently gone. Therefore, this fibrous cover acted like a natural litter layer. This was especially true with several mats from Conwed Fibers and the FPL, such as CWW-830, dahoma, OCC-475, OCC-950, and cellulose mat.

Table 1. Total height and diameter at groundline of 3-year-old loblolly pine seedlings, weed cover, and mulch durability for Study 1.

Mulches	Total height (m)	Groundline diameter (cm)	Mean class for mulch durability	Weed cover (%)
Check, no mulch	1.34de[1]	2.85e	Missing[2]	86a
Natural mulches				
Cotton shoddy	1.80abc	4.01abc	Poor	34ef
CWW-475	1.70abcd	3.66abcde	Poor	40ed
CWW-830	1.56abcde	3.45abcde	Poor	10gh
Dahoma	1.63abcde	3.43abcde	Poor	12gh
HortoPaper	1.88a	4.01abc	Missing	59bc
Jute-475	1.57abcde	3.76abcd	Missing	41ed
Jute-830	1.66abcde	3.68abcde	Poor	39ed
Kenaf-360	1.68abcd	3.66abcde	Poor	23efgh
Kenaf-720	1.61abcde	3.68abcde	Poor	28efg
OCC-475	1.48bcde	3.28cde	Poor	12gh
OCC-950	1.57abcde	3.63abcde	Poor	11gh
Pine straw	1.60abcde	3.71abcde	Fair	7h
PS15-W	1.71abcd	3.66abcde	Missing	66bc
PS30	1.46bcde	3.30bcde	Missing	72ab
Natural/synthetic fiber blends				
Cellulose mat	1.70abcd	3.96abc	Poor	16fgh
Cellulose-plastic netting	1.47bcde	3.56abcde	Poor	28efg
Cellulose-polypropylene	1.41cde	2.90de	Missing	70abc
Cotton-polyethylene	1.83ab	4.09abc	Good	4h
Ecomat	1.75abc	3.56abcde	Poor	17fgh
Excelsior-polypropylene	1.70abcd	3.63abcde	Fair	6h
Fortifiber	1.80abc	3.99abc	Missing	60bc
Nelson-Ball Paper	1.68abcd	3.71abcde	Missing	52cd
Poplar/synthetic mat	1.28e	2.94de	Missing	69abc
Secondary fiber mat	1.52abcde	3.45abcde	Poor	27efg
Synthetic/cellulose mat	1.72abcd	3.86abc	Good	6h
Synthetic mulches				
Black polyethylene	1.78abc	4.15abc	Good	4h
Sunbelt	1.73abcd	3.96abc	Good	3h
Sunfilm/Brush Blanket	1.60abcde	3.53abcde	Good	5h
Super Mulch	1.74abc	3.68abcde	Poor	64bc
Terra Mat "E"	1.79abc	4.19ab	Fair	7h
Thermat	1.73abcd	3.61abcde	Excellent	5h
Vispore	1.56abcde	3.56abcde	Good	9gh
Weed Barrier	1.69abcd	3.91abc	Good	3h
Weed Block 6+	1.77abc	4.24a	Good	11gh
White on black film	1.79abc	4.29a	Good	4h

[1] Treatment mean differences were determined by Duncan's multiple range tests. Means followed by the same letter are not significantly different ($\alpha = 0.05$).

[2] Mulch durability (ability to stay intact and in place) for three growing seasons were classed as follows: excellent – almost no damage to the mulch, good – 0.1 to 5.0% deterioration, fair – 5.1 to 15% deterioration, poor – over 15% deterioration, and missing – no mulch present. A Kruskal-Wallis test was carried out to determine differences among mulches: $\chi^2 = 291.72$ and probability $> \chi^2 = 0.0001$.

Table 2. Total height and diameter at groundline of 3-year-old loblolly pine seedlings, weed cover, and mulch durability for Study 2.

Mulches	Total height (m)	Groundline diameter (cm)	Rankings for mulch durability	Weed cover (%)
Check, no mulch	1.52	3.49	Missing[1]	94a[2]
Natural mulches				
Acetylated kenaf	1.77	4.32	Fair	6d
Cardboard	1.70	4.09	Fair	4d
Kenaf-oil	1.66	3.91	Fair	25b
Pine straw	1.51	3.45	Fair	20bc
Natural/synthetic fiber blends				
CWW-carpet waste	1.78	4.25	Fair	4d
CWW-polyester	1.83	4.29	Poor	28b
Ecomat	1.76	4.04	Fair	8d
Kenaf-carpet waste	1.76	4.22	Fair	6d
Synthetic mulches				
Black polyethylene	1.66	3.67	Fair	13cd
Sunbelt	1.81	4.00	Excellent	5d
Sunfilm/Brush Blanket	1.72	4.11	Fair	11cd
Terra Mat "P"	1.66	4.03	Good	8d
Thermat	1.79	4.08	Excellent	4d
Vispore	1.53	3.68	Good	3d
Weed Block 6+	1.57	3.95	Good	3d

[1] For each mulch, durability (ability to stay intact and in place) was estimated and classed as follows: 1 – excellent – almost no damage to the mulch, 2 – good – 0.1 to 5.0% deterioration, 3 – fair – 5.1 to 15% deterioration, 4 – poor – over 15% deterioration, or 5 – missing – no mulch present. A Kruskal-Wallis test was carried out to determine mean rank differences in durability among mulches: $\chi^2 = 104.49$ and probability $> \chi^2 = 0.0001$. The mean rankings were the average of the 10 numerical durablity values for each mat treatment evaluated and those mean rankings fell within the above classes.

[2] Treatment means for weed cover that are followed by the same letter are not significantly different based on Duncan's multiple range tests ($\alpha = 0.05$). There were no differences in pine total height and groundline diameter at $\alpha = 0.05$.

Pine straw forms a natural litter layer, but it had not completely deteriorated after three growing seasons. Other manufactured mulches should also form fibrous covers, but they had not deteriorated enough in 3 years to observe this: acetylated kenaf, CWW-carpet waste, Ecomat, kenaf-carpet waste, and synthetic/cellulose mat.

In certain cases, residual weed control was also observed without the formation of a fibrous cover because mulch initially kills established vegetation and germinants and there may not be a sufficient soil seed bank to quickly reestablish the plant cover once a mulch is gone (Haywood and Youngquist 1991; McDonald and Helgerson 1990).

To illustrate these observations, pine straw had fair durability and only 7% weed cover after three growing seasons in Study 1 (Table 1). The three natural/synthetic mulches with fair to good durability averaged 5% weed cover – cotton-polyethylene, excelsior-polypropylene, and synthetic/cellulose mat.

Percentage of weed cover was similar on the check (86%) and three of the mulches that had completely deteriorated – PS30, cellulose-polypropylene, and poplar/synthetic mat (an average of 70% weed cover) (Table 1). However, other mats having poor durability or which were missing were still associated with some weed control. For example, the CWW-830, dahoma, kenaf-360, OCC-475, OCC-950, cellulose mat, and Ecomat had less than 25% weed cover, and the cotton shoddy, CWW-475, jute-475, jute-830, kenaf-720, cellulose-plastic netting, and secondary fiber mat had less than 50% weed cover.

In Study 2, all of the natural and natural/synthetic mulches had significantly less weed cover than the checks (Table 2). These kinds of mulches had 28% or less weed cover while the check had 94% weed cover.

Greater weed cover with less mulch durability seemed more apparent among the synthetic mulches which do not form a fibrous cover as they deteriorate. In both studies, the synthetic mulches with fair to excellent durability averaged 6% weed cover (Tables 1 and 2). Super Mulch had poor durability and 64% weed cover in Study 1.

Therefore, the formation of a fibrous cover might be important in residual weed control. The initial death of established vegetation and germinants and an insufficient soil seed bank had its own lasting effect beyond the useful life of the mulch. I concluded that both of these residual weed control effects were important.

Loblolly pine

Loblolly pine is a good test species for short-term studies because it is known to respond to different kinds and levels of vegetation management practices at young ages, and loblolly pine has responded to mulch in other studies. Bilan (1960) found that pine straw mulch conserves soil moisture in the upper portion of the soil profile and causes a larger proportion of loblolly pine roots to grow near the surface when compared to the roots of non-mulched seedlings.

Walker and McLaughlin (1989) reported that a perforated black polyethylene mulch caused an increase in spring soil temperatures. After 3 years, unfertilized and mulched loblolly pine seedlings were somewhat larger than non-mulched ones, and by age 6, these pines were significantly taller than non-mulched saplings.

Ninety-six percent of the seedlings survived through three growing seasons in Study 1. In Study 2, a hard freeze in March 1993 killed several of the newly planted seedlings, and survival averaged 72% after three growing seasons. Mulch treatment did not affect pine survival in either study.

In Study 1, the mulched pine seedlings were generally larger than the checks after three growing seasons. Loblolly pine seedlings were significantly taller when treated with two of the natural mulches (cotton shoddy and HortoPaper), three natural/synthetic mulches (cotton-polyethylene, Ecomat, and Fortifiber), and five synthetic mulches (black polyethylene, Super Mulch, Terra Mat "E", Weed Block 6+, and white on black film) than were the check seedlings (Table 1).

Groundline diameters were significantly larger when the pines were treated with three of the natural mulches (cotton shoddy, HortoPaper, and jute-475), four natural/synthetic mulches (cellulose mat, cotton-polyethylene, Fortifiber, and synthetic/cellulose mat), and six synthetic mulches (black polyethylene, Sunbelt, Terra Mat "E", Weed Barrier, Weed Block 6+, and white on black film) than were the check seedlings in Study 1. Both height and diameter were significantly greater than the checks when cotton shoddy, HortoPaper, cotton-polyethylene, Fortifiber, black polyethylene, Terra Mat "E", Weed Block 6+, or white on black film mulches were used. Therefore, these eight mulches might be considered the best of the 35 mulches tested. However, after three growing seasons, the HortoPaper and Fortifiber mulches were missing and the durability of the cotton shoddy was poor (Table 1).

In Study 2, there were no significant treatment differences in pine height and groundline diameter (Table 2). Therefore, my findings were similar to Walker and McLaughlin (1989). In general the mulched trees were somewhat larger in stature than the unmulched trees by age 3. Unfortunately, a wildfire destroyed my research studies after the third growing season, so the effect of mulch at 6 years cannot be determined as was possible in Walker and McLauglin's (1989) study.

Residual weed control often observed after the mulches apparently deteriorated may be an important result. Mats which are biodegradable would have an advantage when used with fast growing species such as loblolly pine. Once the residual weed control effect was no longer evident, the sapling root system should have extended beyond the mulched area and the tree should be shading the mulched area. On lands where non-decomposed materials would have to

be collected after the useful life of the mulch, biodegradable mulches may be the only option. If biodegradability is not a management issue, other mulch properties such as ease of transport and installation as well as durability may become more important.

References

Bilan, M.V. 1960. Root Development of Loblolly Pine Seedlings in Modified Environments. Stephen F. Austin College, Dept. Forestry, Nacogdoches, Texas; Bull. 4.

Crutchfield, D.A., Wicks, G.A. and Burnside, O.C. 1985. Effect of winter wheat (*Triticum aestivum*) straw mulch level on weed control. Weed Sci. 33: 110–114.

Dao, T.H. 1987. Crop residues and management of annual grass weeds in continuous no-till wheat (*Triticum aestivum*). Weed Sci. 35: 395–400.

Haywood, J.D., Tiarks, A.E. and Sword, M.A. 1997. Fertilization, weed control, and pine litter influence loblolly pine stem productivity and root development. New Forests 14: 233–249.

Haywood, J.D. and Youngquist, J.A. 1991. Mulching effects of plant fiber-polyester mats combined with fertilizer on loblolly pine seedlings. USDA Forest Serv., Tree Planters' Notes 42(3): 32–35.

Gale, W.J., McColl, R.W. and Fang, X. 1993. Sandy fields traditional farming for water conservation in China. J. Soil Water Conserv. 48: 474–477.

Gupta, G.N. 1991. Effects of mulching and fertilizer application on initial development of some tree species. For. Ecol. Manage. 44: 211–221.

Louisiana Office of State Climatology. 1993. Louisiana Monthly Climate Review, Vol 13. Louisiana Office of State Climatology, Department of Geography and Andropology, Louisiana State University, Baton Rouge, Louisiana.

Louisiana Office of State Climatology. 1995. Louisiana Monthly Climate Review, Vol 15. Louisiana Office of State Climatology, Department of Geography and Andropology, Louisiana State University, Baton Rouge, Louisiana.

Mahajan, K.K. and Kanwar, B.B. 1993. Effect of pine (*Pinus* species)-needle mulch on maize (*Zea mays*)-wheat (*Triticum aestivum*) cropping system. Indian J. Agron. 38: 515–518.

McDonald, P.M. and Helgerson, O.T. 1990. Mulches Aid in Regenerating California and Oregon Forests: Past, Present, and Future. USDA Forest Serv., Pac. Southwest Res. Sta., Berkeley, California. Gen. Tech. Rep. PSW-123.

Peterman, R.M. 1990. Statistical power analysis can improve fisheries research and management. Can. J. Fisheries Aquatic Sci. 47: 2–15.

Thomas, L. 1997. Retrospective power analysis. Conserva. Bio. 11: 276–280.

Tiarks, A.E., Kimble, M.S. and Elliott-Smith, M.L. 1991. The first location of a national, long-term forest soil productivity study: Methods of compaction and residue removal. Proc. Bienn. South. Silvicultural Res. Conf. 6: 431–442.

SAS Institute Inc. 1985. SAS® User's Guide: Statistics, Version 5 Edition. SAS Institute Inc., Cary, North Carolina.

Walker, R.F. and McLaughlin, S.B. 1989. Black polyethylene mulch improves growth of plantation-grown loblolly pine and yellow-poplar. New For. 3: 265–274.

Zuzel, J.F. and Pikul, J.L., Jr. 1993. Effects of straw mulch on runoff and erosion from small agricultural plots in northeastern Oregon. Soil Sci. 156: 111–117.