In: Olesen, Ole; Rexen, Finn; Larsen, Jorgen, eds. Research in industrial application of non food crops, I: plant fibres: Proceedings of a seminar; 1995 May; Copenhagen, Denmark. Lyngby, Denmark Academy of Technical Sciences: 79-86.

7. Geotextiles - A Specific Application of Biofibers [1]

Brent English
Industrial Specialist

Forest Products Laboratory, Forest Service
United States Dept. of Agriculture
1 Gifford Pinchot Drive, Madison
WI 53705-2398, Wisconsin, USA

Abstract

Geotextiles are any textile like material used to enhance soil structural performance. Biobased geotextiles are used for short term (6 months to 10 year) applications where biodegradability is a positive attribute, such as mulching and erosion control. Fiber options for biobased geotextiles include cereal straws, coir, jute, kenaf, flax, sisal, hemp, cotton, woodfiber and others. This report documents research the USDA Forest Service is conducting using biobased geotextiles to increase tree seedling survival rates, establish vegetation, and control erosion.

Introduction

Geotextiles are any textile like material, either woven, non-woven, or extruded, used in civil engineering applications to improve soil structural performance. The main functions geotextiles provide are aggregate separation, soil reinforcement and stabilization, filtration, drainage, and moisture or liquid barriers (Dewey 1993). The market for geotextiles is growing, with world wide sales of over 700 million square meters annually of which about 2% is biobased (Gupta 1991). Most geotextile applications are permanent, and the use of bio-degradable materials would have adverse results. Other applications though, are temporary or short term, and the use of bio-based, biodegradable materials is worthy of investigation.

Research in the area of bio-based geotextiles is warranted for several reasons. Concerns for the environment have made product biodegradability an issue. In addition, the United States Department of Agriculture (USDA) is interested in the development of non-food, non-feed alternative agricultural crops, and in the better utilization of agricultural residues, many of which can be used in the production of geotextiles. With these trends in mind, various research projects have been conducted at the USDA Forest Service, Forest Products Laboratory (FPL), in cooperation with private industry, the USDA Agricultural Research Service, and others in the

Forest Service (English 1992, 1993a, 1993b). These research efforts have focused on temporary applications such as sheet mulches for seedling survival and plant seed establishment, erosion control, and the related applications of filtration and absorption. In addition, the use of kenaf as a staple fiber for these applications has been explored. This manuscript is a synthesis of these research efforts, and most of this information has been previously published (English 1994).

Methods for Bio-Based Geotextile Production

Commercially, there is a good variety of geotextiles available that contain a majority percentage of bio-based materials. The bio-based materials are selected for their low cost and biodegradability. Most of the geotextiles are used in erosion control where they serve to stabilize the soil surface while natural vegetation is established. Some of them contain seeds to accelerate and control the re-growth. Most of these geotextiles, though, contain some portion of synthetic material to hold the geotextile together. This is normally polypropylene nets or polyester scrim sheets that sandwich the bio-based component. With occasional exception, it was the goal of Forest Service research to make geotextiles from entirely bio-based materials. For this purpose, FPL's Rando-Webber[2] air-laid mat making equipment was chosen.

In the Rando-Webber process, blended fibers are introduced into a high speed airstream by a toothed rotor, or lickerin. The air stream passes through a moving screen conveyor, depositing the fibers in a random fashion. From there, the fibers are mechanically entangled with barbed needles in **a** needle loom, producing a finished mat. To facilitate the needling process in FPL's simple needle loom it is necessary to provide a scrim, or backing sheet for the mat. For most of the research recycled kraft paper was used.

Production of Geotextiles using Kenaf as a Staple Fiber

Early attempts at FPL to use kenaf as a staple fiber in non-woven geotextiles were unsuccessful because the fibers broke during processing. Jute, a fiber similar to kenaf, is retted and oiled to make it pliable enough for woven and non-woven fabrics. Environmental factors do not allow kenaf to be retted in the United States, but they do not preclude oil treatments. In addition, machine modifications were suggested to further improve processing. To produce mats from kenaf, the following steps were taken

1. Soy oil was sprayed on the kenaf fibers in a paddle mixer. The fibers were aged in closed plastic bags for two weeks to allow the oil to penetrate and provide lubricity.

2. A coarse lickerin (1 tooth/2cm^2) was installed in FPL's Rando-Webber and operated at about 20 percent of normal operating speeds. Retained fiber length increased from 1.2 cm to about 8 cm.

3. Relatively coarse needles of the type used to produce jute carpet backing were installed in the needle loom.

---

2 The use of trade names is for information only and is not intended to be an endorsement by the USDA Forest Products Laboratory.

4. Optimum soy oil treatment levels were determined by making runs at 5, 10, 15, and 20 weight percent soy oil levels. Evaluation was based on the ability of the treated kenaf to be needle punched, handleability, water absorption and tensile testing.

Needlepunch evaluation was made by visually noting the amount of fiber breakage caused by the needles. Kenaf treated with 15 and 20 weight percent soy oil shows almost no breakage. At 10% treatment, some fiber. breakage was noted but the amount did not appear excessive. At 5% , though, about one half of the fibers were broken. Handleability of all of the mats was about the same. Water absorption was not affected by the treatment levels tested.

Tensile testing was carried out according to ASTM standard D-4632 (1986). Specimens of mat were cut into 10 x 20 cm rectangles and placed within a pair of 2.5 x 5 cm grips and tom apart at a machine rate of 30.5 cm/minute. Specimens were tested in both machine direction (md) and cross-machine direction (cmd). In addition, strengths were examined at ambient moisture content and after 24 hrs. of soaking in water. Time and scheduling constraints did not allow examination of a complete matrix. Results are shown in Table 1.

Table 1. **Tensile test results of non-woven kenaf geotextiles.**[1]

Percent Soy Oil	Direction	Dry	Wet	Load to Failure, kg
5	md	x		6.3
10	md	x		6.7
10	md		x	7.9
10	cmd	x		7.2
10	cmd		x	8.4
15	md	x		4.5

[1] **Values are the average of five specimens.**

Notable is that tensile strength increased when the mats were soaked for 24 hrs. The deciding factor for choosing a treatment level, however, was the ability of the kenaf to be needle punched. As noted earlier, at 10% the kenaf fiber exhibited only limited breakage and this was the treatment chosen for the bulk of the research reported here. While soy oil was chosen for the application discussed here, other oils would certainly perform satisfactorily.

Selected Bio-Based Geotextile Research Materials

In addition to kenaf, The following materials have been used by FPL in the production of various bio-based geotextiles.

- *Old corrugated containers* (OCC) were shredded into .8 cm wide strips and subsequently hammermilled using a 9.5 cm screen. OCC was chosen over old newspapers because of concerns about heavy metals in Sunday supplement inks.

- *Construction waste wood* (CWW) *is* wood waste from construction sites. It has hammermilled and reduced to fibers and fiber bundles by refining.

- *Recycled jute* fibers were obtained from old woven spice bags.

  Dahoma (Piptadensiastrum africanum), a tropical wood, was chosen for its rot resistance. It was fiberized by refining. Dahoma has an undetermined toxic effect, and its reuse is not recommended.

- *Cotton* fiber was used primarily as a staple fiber and was recycled post-industrial scrap from the garment industry.

- *Acetylated kenaf* is more resistant to rot and decay than un-acetylated kenaf However, acetylated kenaf fibers are very brittle and they cannot be used as a staple fiber. While relatively expensive, and not UV stable, the process may help extend geotextile service life to some degree.

- *Automotive carpet trim waste*, a blend of polyester and polypropylene, was used only as a staple fiber, and was the only non-lignocellulosic fiber selected for study. It was selected primarily for its stable dark color.

Other materials, like bagasse or coir, are also applicable.

Sheet Mulches for Tree Seedling Survival

The survival of tree seedlings is a major concern to the United States Forest Service and to tree growers everywhere. Commonly, seedlings are overplanted and thinned as they mature. In low survival rate areas, seedlings may have to be replanted. These practices are costly and time consuming. Environmental factors that affect seedling survival include moisture, temperature, light, chemical presence or absence, and mechanical damage. Mulches can be used to control most of these factors. A mulch is defined as "an application or creation of any soil cover that contributes a barrier to the exchange of heat or vapor" (Rosenberg 1974). Mulches work mainly by suppressing weed growth. This enables the sapling to make full use of light, moisture, and nutrients. The mulch also acts as a soil insulator and as a vapor block. As a soil insulator, the mulch helps keep the soil warm in the early and late part of the growing season. As a vapor barrier, the mulch acts to suppress evaporation.

Historically, the effectiveness of mulches on seedling survival have varied widely. Soil conditions, light, and the longevity of the mat contribute to this. In especially adverse conditions, survival has increased from near 0% to over 90%. In more typical situations, survival increases from 40% to 60% (McDonald and Helgerson 1990). To examine the use of mulches more closely, the Forest Service established a “Seedling Mulch Guidance Group”. The group was represented by foresters and researchers from many National Forests, Research Stations, and the Forest Products Laboratory.

Mulch materials can be categorized two ways, loose mulches and sheet mulches. Successful application of loose mulches, like bark, sawdust, or straw is largely dependent on application thickness. Because they are bulky, loose mulches are most successful when seedling access is good, such as in an orchard or nursery. As such, their application in remote sites is limited.

Sheet mulches on the other hand, can be rolled up or folded to allow packing into remote sites. Sheet mulches consist of woven or non-woven materials, or plastic film. Film mulches and most woven plastic mulches are less bulky than non-woven mulches based on lignocellulosic materials, but they have several disadvantages. Plastic mulches need to be very well anchored to keep them from being dislodged by wind or animals. If this happens, the mulch litters the forest or folds over and smothers the seedling. Plastic mulches suppress weed growth reasonably well, but if not perforated, rain fall can be diverted from the seedling. Degradability of the plastics is also limited.

Key mulch characteristics for seedling survival have been identified. The mulch should be opaque to prevent weed growth and possess good insulative characteristics. The mulch should be porous for water infiltration yet still retard water loss from underneath it. The mulch should be strong and durable enough to last until the seedling is well established usually about three years. Good ground conformance would keep the mat from being dislodged. A biodegradable mulch will limit forest litter, save removal costs and may increase mulch effectiveness. In addition, the mulch should be low in cost and light weight for ease of transportation and installation.

The Forest Service Seedling Mulch Guidance Committee decided to examine seedling survival, installation techniques, and associated costs with a variety of commercial and prototype sheet mulch materials. The Forest Products Laboratory's efforts focused on the production of a variety of bio-based sheet mulches using FPL's Rando-Webber. With minor exception, all of the mulches were approximately 90 cm x 90 cm with an "X" slit in the center for seedling placement. The mulches were held down with five metal staples, one on each comer and one in the center near the seedling. All of the sheet mulches, both experimental and commercial, were placed by foresters at the Southern Forest Experiment Station, Pineville, Louisiana; Wallowa-Whitman National Forest, Baker City, Oregon; Ochoco National Forest, Hines, Oregon; and the Lolo National Forest, Missou1a, Montana. Mulches were placed in 1990,1992 and 1993.

Performance of Bio-based Sheet Mulches

First and foremost, the successful application of mulches to enhance seedling survival is site specific. If the site is especially remote, the bulkiness of the non-woven bio-based sheet mulches was a hindrance, and the plastic mulches were preferred for installation, although they are more difficult to anchor. If reasonably accessible, bio-based mulches offered good ground conformance and biodegradability. Few of the mats that are durable enough to last until the seedling is established have had any adverse effect on seedling survival, although if improperly installed, some plastic mulches will abrade the seedling stem and kill it. All of the FPL bio-based sheet mulches are considered durable enough to last until the seedling is established, although some of the commercial bio-based mats did not last one season. Becuase mulch installation procedures are very site specific, there is much variability in the economics of installation. Sheet mulch installation costs range from under $800 US to over $4,000 US per hectare. Generally, if survival rates are reasonably good and the site is accessible for maintenance, there is no reason to apply mulches. However, if the site has an inherently low survival rate, and is not readily accessible, the use of mulches has merit.

Determination of a Seed Incorporation Method in Sheet Mulches

The purpose of seed incorporated sheet mulches is to provide a vehicle for the distribution of seeds and to prevent erosion during seed establishment and early plant growth. Commercial seed impregnated kenaf sheet mulches are available that use non-woven polyester scrim sheets on both sides of the kenaf to hold the seeds in place. Other seed incorporated sheet mulches are made using cereal straw, kraft paper, and polypropylene netting. Since the objective of our research was to make completely bio-based, biodegradable sheet mulches, alternative materials and seed incorporation techniques were examined. After preliminary examination a blend of 50% kenaf (treated with 10% soy oil) and 50% cereal straw was chosen for sheet mulch production. Three methods of seed incorporation were considered; 1) incorporating in the air-laying process, 2) incorporating prior to needle punching, and 3) pre-applying to a kraft paper backing sheet using a starch-based adhesive.

Incorporating the seeds into the air-laying process resulted in the seeds gravitating to the bottom of the mulch, which is where they should be, but the seeds tended to fall out during mat production. Incorporating the seeds prior to needling was also ineffective because the seeds did not become sufficiently entangled within the fibers to remain with the mat. Pre-applying the seeds to the kraft paper backing though, was quite successful. This was accomplished by spreading a thin layer of starch based adhesive onto the backing, applying the seeds, and then feeding the mat onto the glued side. The combined backing and mat were then mechanically fastened together during the needlepunching operation. Gluing the seeds onto the backing not only helped the production process, it also insured that the seeds will not be dislodged during shipping or handling. Fertilizers and herbicides can be applied in the same way.

Seed type and application rates where selected by an industrial cooperator and foresters in the Mount Baker-Snoqualmie National Forest (MBSNF) in Washington state. The MBSNF suggested rates of 2,000 to 4,000 wildflower seeds/m^2. The industrial cooperator selected a variety of different rates for a plethora of different grass and wild flower seeds. Twenty nine different varieties of these sheet mulches were placed in a green house by the cooperator for evaluation. Seventeen different mulches were placed at high elevations in the MBSNF in the fall of 1993 with germination to take place naturally in the spring of 1994. In total, 14 different seed types were used.

Evaluation was made with visual inspection of germination rates and plant health. Evaluation of the cooperator mulch mats showed that the heavier mats (680 gm/m^{2f}) were marginally effective at establishing plant growth. The lightest weight mats (340 gm/m^{2s}) however, performed very well, with excellent germination rates and plant health. Specific results are confidential to the cooperator.

Other Related Applications

Other related applications of bio-based geotextile are absorption, filtration, and erosion control. Geotextiles are used as soil filters, that is, they are installed to filter sediments from moving water. This function can be for both surface and ground water. Bio-based geotextiles have application for surface water around construction sites where run-off may be a problem and for industry where they can be used in waste water treatment. Use of bio-based materials for absorption is also expanding, with the largest use at this time is to clean up oil and chemical spills.

The erosion control function of geotextiles is very important because sediment accounts for roughly two thirds of the pollution in United States waterways. Most commercial bio-based geotextiles target this problem along with providing the previously described function of establishing vegetation. The testing and evaluation of erosion control properties is quite site specific, where factors such as the inherent soil type, slope, and others, can be considered.

Conclusions

* A wide variety of lignocellulosic materials are applicable to the production of bio-based, biodegradable geotextiles.

* The market for bio-based geotextiles is small but growing. It is driven by the environmental benefits of the use of these types of products, and by the need to make these products biodegradable.

* Kenaf fibers can be treated with soy oil and successfully used as a staple fiber in the production of bio-based geotextiles.

* Depending on site specific variables, bio-based geotextiles are effective in increasing tree seedling survival rates.

* Seeds, fertilizers and herbicides can be incorporated into bio-based sheet mulches by adhering the seeds to a kraft paper backing using a starch based glue and needle punching the backing to the mulch material.

* Bio-based geotextiles can be effectively used to control erosion while plant growth is established.

References

ASTM (1986). Breaking Load and Elongation of Geotextiles (Grab Method)
ASTM D 4632 in 1986 Annual Book of ASTM Standards Volume 4.08, American Society of Testing and Materials, Philadelphia, PA, USA.

Dewey, C.S. (1993). Use of geotextiles on Federal lands highway projects.
Engineering Field Notes, Volume 26, May-June. pp. 17-22.

English, B. (1992). Mulch mats from kenaf fiber, Part I - The feasibility of making mulch mats from kenaf fiber and other biobased fiber using a non-woven web fiber processing technology. Internal FS report on Interagency Agreement No. FP-91-1639.

English, B. (1993a). Mulch mats from kenaf fiber, Part II - Forest Service mulch mats from kenaf and other fiber. Internal FS report on Interagency Agreement No. FP-91-1639.

English, B. (1993b). Kenaf mulch mats for seed establishment and erosion control. Forest Products Laboratory report in completion of Collection Agreements FP-93-2031 and FP-93-2032.

English, B. (1994). Biobased, biodegradable geotextiles: USDA Forest Service research update. In: Proceedings, Second Pacific Rim Bio-Based Composites Symposium, Vancouver BC, Canada. Nov. 6-9. pp. 204-212.

McDonald, P.M, Helgerson, O.T. (1990). Mulches aid in regenerating California and Oregon Forests: Past present and Future. USDA General Technical Report PSW-123.

Sen Gupta, A.K. (1991). Geotextiles: Opportunities for natural-fibre products. International Trade Form, Jan.-Mar., 1991. pp. 10-15.

Rosenberg, N.J. (1974). Microclimate: The biological environment. New York, Wiley Interscience. pp. 150-157.