recommend spring or summer planting rather than fall planting so that the rhizomes or culms can be established before winter. Usual horticultural practices generally result in a good survival rate. Bamboo tolerates a deep mulch and generally do not require addi-fertilizer once established.

A word of caution. The running bamboos are very vigorous and can spread quickly into areas where they may not be welcome. It is, therefore, best to contain these types. My recommendation is to bury fiber glass panels at least 30 in. for the taller growing types and 8 in. for the shorter growing varieties.

USING SPUNBONDED FABRICS FOR COLD PROTECTION

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INTRODUCTION

Plastics and textiles have played an increasingly important role in the continuing search for better ways to grow nursery crops. Continuous films of clear plastic have replaced glass throughout the industry. Woven polymer shadecloth provides reduced heat and light to sensitive crops, is easier to handle and has become less expensive than wooden lath. Milky white plastics have become an integral part of winter protection for container nurseries. Insulating plastic foams and laminates help nurseries overwinter more valuable or delicate stock.

Today, we are often pumping water through plastic pipe and nozzles onto plants in plastic pots on a plastic groundcover with plastic protection between the plant and the sky. Polyethylene, polypropylene, polystyrene, etc. have become familiar terms during the polymer revolution that has captured us in the past 20 years. This rapid change has occurred because the nurseries must use technology that will perform required tasks as well as or better than existing technology, at the same or less cost while fitting into existing nursery practices. It was all of these criteria that led us to investigate ways that spunbonded fabrics might be used in North Carolina mountain nurseries.

Spunbonded fabrics. Spunbonded fabrics differ from other porous polymers in that they are not woven into a regular, uniform pattern like shadecloth. Spunbonding is a continuous process in which a polymer, or several polymers, such as polyester, polypropylene, or others is fed into an extruder. As it flows from the extruder it is forced through a device with tiny holes. After cooling, the continuous filaments are laid down on a moving belt. While being laid down the desired orientation is achieved, then the fabric is bonded using combinations of heat, pressure, and chemicals.

Because of this process, every time fibers cross, they should be bonded together. This limits the unravelling and stretch characteristics found in some woven fabrics. Holes are built into the fabric. These holes permit the passage of water and gasses. This allows plants beneath a spunbonded fabric to have air exchange and permits irrigation without removing the fabric cover.

Work on vegetables, tobacco, turf, and particularly that reported at the 1984 National Agricultural Plastics Congress, stimulated us into looking for ways that spunbonded fabrics might be used in North Carolina mountain nurseries.

Spring frost protection of 2 to 5°F, with about 7°F fall frost protection was claimed in New Hampshire. This was difficult to accept from a hole-filled 5.5 mil thick fabric. Illinois data showed that soil moisture averaged 3% higher following rainfall or irrigation under a Reemay cover. Early season growth of tobacco seedlings, turf, earliness and increased yields of vegetables, plus reduced insect damage, all intrigued us so we set up a series of on-farm tests to see if spunbonded fabrics might have a use in North Carolina mountain nurseries.

Conifer seedling protection. One year old (1–0) conifer seedlings must be mulched during North Carolina mountain winters to prevent heaving. Widely fluctuating winter temperatures create hoar frost which can lift small seedlings out of growing beds. When the ice that lifted seedlings melts, roots are exposed to the air. Roots then dry out leading to seedling death. To prevent this, standard practice has been to mulch beds of 1–0 conifer seedlings with straw or locally obtained hardwood leaves in late November or early December, after seedlings have been exposed to frosty nights for 4 to 6 weeks. Beds are center crowned by stacking the mulch deeper in the middle. This acts like a thatched roof, shedding much winter rain. Mulch is secured against winter winds with either shadecloth or pea netting. Beds are usually uncovered from mid-March to mid-April, about 6 weeks before the average last frost date. Mulch is removed very carefully to avoid pulling up small seedlings.

Problems we have encountered using organic mulches include: 1) high labor cost, 2) poor moisture control, 3) introduction of pests, 4) harboring rodents, and 5) lack of light for 3½ to 4 months. In 1985 we estimated that the cost of using organic mulches was about $16 per 400 sq ft bed.

In December 1984, we set up a nursery test at 3400 ft elevation to determine whether spunbonded fabrics would provide equivalent protection to organic mulch. Seedlings (1–0) of eastern hemlock

(*Tsuga canadensis*), eastern white pine (*Pinus strobus*), and Fraser fir (*Abies fraseri*) were used as test plants. Plant population in four, 1 sq ft plots in each 100 sq ft mulch test section was determined on December 5, 1984. Each section was then covered with either organic mulch (OM), a single layer of Kimberly-Clark spunbonded polypropylene (KC6), or a single (RM1) or a double (RM2) layer of DuPont Reemay 2006 spunbonded polyester.

Nursery air temperature and air temperature under the mulch were measured using Max-Min thermometers and recorded weekly. Nursery soil temperatures and soil temperatures under the mulch were also recorded weekly from soil thermometers reading at depths of 2 or 4 in. below the soil surface.

Mulch was removed on March 19, 1985. Plant population was determined immediately and any visual differences noted. Plant height was measured on June 20, August 13 and October 1, 1985. No plant heaving or death occurred in test plots due to mulch treatments. Species response, however, was quite variable.

Fraser fir: No visual differences existed for Fraser fir at any time in the test. Plants in the KC6 plots were significantly shorter (Table 1). However, a difference of ½ inch may not be important to a grower.

Table 1. 2–0 Fraser fir height (in.) on June 20, 1985 following winter protection under selected mulches.

Mulch	Height (in.)
OM	2.5 a*
KC6	2.0 b
RM1	2.5 a
RM2	2.8 a

*R_{p05} Duncan's New Multiple Range Test

Eastern white pine. Pine foliage under both Reemay treatments was uniformly blue-green on March 19. Plants under the organic mulch were uniformly mottled brown and yellow, with many totally dead needles. Plants under KC6 ranged from blue-green to brown. The patches of discolored seedlings seemed to correspond to thicker and thinner spots in the KC6 covering. This suggests that the positive response was due either to increased light penetration or better gas exchange during the 15 week test period.

Seedlings that had been protected under a single layer of Reemay were significantly taller (Table 2) than those that had been under an organic mulch when measured on June 19. By the time they had finished height growth for the 1985 season (August 13, 1985), no significant height difference existed between plants in the organic and KC6 mulch treatments, while plants in both Reemay treatments were significantly taller.

Table 2. 1–0 Eastern white pine seedling height (in.) following winter protection under selected mulches.

Mulch	DATE June 20, 1985	August 13, 1985
OM	3.2 b*	4.5 b
KC6	3.5 ab	4.6 b
RM1	4.4 a	6.4 a
RM2	4.3 ab	6.8 a

*R_{p05} Duncan's New Multiple Range Test

Eastern hemlock. Hemlocks under either Reemay treatment were yellow-green when uncovered. This color change occurred during the last week under mulch. Within two weeks of normal spring fertilization, hemlock needles were again a normal deep green color.

This color change cannot be accounted for by heat build-up under Reemay alone (Table 3). However, a temperature fluctuation of 72°F under RM1 and 63°F under RM2 may be a contributing factor. The color change reported is characteristic of the response when sunlight shines on frost-covered hemlock needles in the spring. Since Reemay is translucent (75% light transmitted), a "frost burn" under the Reemay mulch may have caused the color change. This experiment was repeated the following winter, removing Reemay mulch in successive 100 ft. sections during March 1986 to determine whether removing the mulch earlier could prevent discoloration. No discoloration occurred regardless of when the mulch was removed in 1986.

Table 3. Air temperature (°F)* under selected mulches covering eastern hemlock.

	Mulches					
	RM1		RM2		OM	
Interval	Max	Min	Max	Min	Max	Min
2/26–3/5	66	20	68	23	66	27
3/6–3/12	80	20	72	22	68	18
3/13–3/19	86	14	79	16	81	19

*Average of three thermometers

While no visual difference was apparent on June 20, 1985, hemlocks that were discolored under Reemay in March were significantly shorter. By October 1, 1985, no significant height difference existed (Table 4).

Seedling conifer conclusions. Reemay and KC6 were as effective as organic mulches in protecting 1–0 eastern hemlock, eastern white pine, and Fraser fir seedlings from winter damage due to soil heaving. With white pines, an additional benefit in both appearance and growth occurred with either a single or double layer of Reemay 2006 mulch.

Cost factors favor using a single layer of Reemay mulch. The cost of covering a 400 sq ft bed with a single layer of Reemay was estimated at $11.50 in 1985. This was $4.50 per bed less than with an organic mulch. A tear strength of 68% was retained by a single layer of Reemay after 15 weeks exposure in this test. This suggests that the Reemay might be safely reused a second season, thus reducing costs even further.

Table 4. Eastern hemlock seedling (2–0) height (in.) following winter protection under selected mulches.

Mulch	DATE June 20, 1985	DATE October 1, 1985
OM	5.8 a*	13.5 a
KC6	5.4 ab	12.9 a
RM1	4.9 b	12.8 a
RM2	5.0 b	13.1 a

*R_{p05} Duncan's New Multiple Range Test

Temperature response. In Table 5 air and soil temperatures are shown for the coldest, second coldest, and warmest weeks of the 1984–85 winter. During both the coldest and second coldest weeks of the winter a single layer of Reemay provided superior cold protection to the organic mulch. The difference in protection of over 20°F during the week of January 15, 1985, and only 7°F during the next week is a reflection of how Reemay works.

During the week of January 15 there was no snow cover so light could penetrate the Reemay, warming the soil underneath. During the following week, a light snow blanketed the test preventing most light from reaching the soil with less heat accumulated under the mulch.

Table 5. 1985 air and soil temperatures (°F) with selected mulches of 1–0 conifer seedlings.

Interval	Mulches None	OM	RM1	RM2
1/15–1/22/85				
Max	50	57	49	50
Min	−20	3	8	20
2 in.	30	31	31	44
4 in.	34	31	32	38
1/22–1/30/85				
Max	51	50	45	48
Min	−2	2	5	6
2 in.	32	31	32	44
4 in.	31	32	32	36
3/12–3/19/85				
Max	80	78	86	79
Min	10	18	14	23
2 in.	57	49	53	49
4 in.	54	47	60	56

Rarely a winter week passes in the North Carolina mountains without temperatures rising above freezing. As a result, even though soil remained frozen for over a month, no temperature below 30°F was recorded at 2 or 4 inches deep.

Container-grown ericaceous seedling protection. To protect container-grown ericaceous plants from cold, roots must not reach temperatures as low as air temperatures. The flow of drying and cooling air around plants must be restricted. Using the temperatures shown in Table 5 and the moisture retention reported in Illinois as inspiration, we set up a test with a producer of flat and pot-grown native ericaceous liners.

All available unheated greenhouse space for winter protection was filled but, because of expansion, this same space would need to be used and heated by February for the next crop. The expense of building winter protection structures on his terraced mountainside was an option this small-scale grower did not relish.

In an attempt to find an alternative, flats of seedling ericaceous liners 1 to 4 in. tall were thoroughly watered, set on crushed rock surfaced terraces and covered with a single layer of Reemay. We hoped to prevent heaving of the smaller seedlings, plus avoiding root temperatures cold enough to kill the seedlings (estimated at below 10°F).

Plants were uncovered in mid-March. No breakage had occurred despite a 22 in. February snowfall. No rodent damage existed as it had under organic mulches in another test. Most important, all the seedlings lived and resumed normal growth slightly earlier than those in unheated white copolymer film covered houses.

Container-grown herbaceous perennials. A mail-order nurseryman was dissatisfied with the current system for protecting his herbaceous perennial crop of mostly 2¼ in. to quart container-grown plants of diverse species. His system was to cover production houses with 6 mil white copolymer film. When the coldest temperatures threatened, he placed Microfoam over plants that experience had shown were most likely to be injured.

While the Microfoam performed excellently, the variable weather in the Asheville area, plus pulling orders for shipping, required moving the Microfoam frequently. He felt the labor involved, expense, and storage of Microfoam were negative factors. Also, maintaining nearly 100% humidity and temperatures near freezing around the crowns of some crops made him uneasy.

In 1984–5, he experimented with Reemay. The Reemay was folded along side flats of pots on the floor of his crushed rock surfaced white film covered greenhouse. When cold weather was forecast, one or two people easily covered plants in a few minutes with this light weight material (67 in. wide × 100 ft. long section weighs 2.3 lbs.). In 1985–86, all plants were protected with Reemay. The ease with which it can be handled, its relatively low cost, plus "breathing" to allow leaves and crowns to dry were considered positive points.

DISCUSSION

During spring, heat can build rapidly under Reemay and KC6 and damage newly germinated sugar maple seedlings if covers are left on top of seedlings when air temperatures exceeded 80°F. In another test we had beds of Norway maples covered with KC6 or Reemay all winter. The seeds never germinated but were completely viable. Apparently, the heat building up in the soil surface almost daily prevented proper stratification.

We also tried using Reemay as a 25% summer shade. While 68% of tear strength remained after 15 weeks exposure in winter, it breaks down rapidly under August sun and wind, lasting no longer than 3 to 4 weeks before tearing. Once these fabrics are lifted from the soil surface they very effectively catch the wind.

CONCLUSIONS

Spunbonded fabrics show nursery potential in a variety of situations. Where sunlight can penetrate and build heat under a fabric mulch, a few degrees of winter protection can be expected. In Florida, tender crops have been protected from frost and cold winds simply by draping Reemay on top of foliage.

In North Carolina these fabrics hold potential as an economical mulch over hardy conifer seedlings. They may be used to protect very hardy container-grown seedling ericaceous plants as well. The limited degree of cold protection provided means growers should be cautious when trying to protect more tender plants or in a more severe climate.