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Biological Mulches for Managing Weeds in Transplanted Strawberry (*Fragaria × ananassa*)[1]

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Abstract: Diminishing availability and increasing costs of herbicides cause strawberry growers to seek both chemical and nonchemical alternatives, especially for within-row weed control soon after strawberries are transplanted. Several weed control treatments for strawberry establishment were examined during 2 yr in Minnesota. Treatments included: woolen landscaping fabric centered over the crop row; as above, but 2-ply fabric; spring canola incorporated into soil when 30 cm tall; as above, but canola killed with burndown herbicide and left as mulch; standard herbicide, DCPA; hand weeded; and no weed control. Areas between all strawberry rows were cultivated. Measurements included weed densities and weights, numbers of strawberry daughter plants, and fruit yield 1 yr after transplantation. The best alternative treatment was the 1-ply woolen fabric. It nearly eliminated weeds from rows, promoted daughter plant rooting, and allowed maximum fruit yields, equivalent to those of the DCPA and hand-weeded treatments. Canola mulch controlled weeds inconsistently and achieved only modest to low production of daughter plants and fruit. Weed control and fruit yield with incorporated canola were similar to the weedy check treatment.

Nomenclature: DCPA; canola, *Brassica napus* L.; strawberry, *Fragaria × ananassa* Duchesne 'Glooscap'.

Additional index words: Cover crop, landscape fabric, weed control, weed management.

INTRODUCTION

Strawberry typically is grown in 3-yr cycles in northern regions such as Minnesota. During April or May of the first growing season, strawberries are established using bare-root transplants. Transplants must grow vigorously during June through September to produce abundant runners that are able to form roots and establish themselves because the number of rooted daughter plants determines fruit yields during the next growing season.

Weed competition affects transplant establishment and daughter plant production. The length of time during which weeds must be suppressed was aided in the past by the use of soil fumigants and residual herbicides (Hartz et al. 1993; Zandstra et al. 1995). However, many of the chemicals that have been used traditionally for weed control at this time are being eliminated or their costs are rising considerably. For instance, the cost of using the standard herbicide, DCPA, has more than doubled in the past few years, from about $200/ha to over $400/ha. Few herbicide options are available (Smith et al. 2001). Furthermore, new potential replacement herbicides often cause crop injury (Starke et al. 1999), although some alternatives recently have been labeled for use on strawberry, e.g., clethodim and sulfentrazone (Baron 2001). In any event, managing weeds is a problem during the establishment year of strawberry, and many growers are seeking alternatives that will allow them to attain adequate weed control at reasonable costs during strawberry establishment. Alternatives include both herbicides and nonchemical forms of weed management.

Various types of mulches have shown promise for controlling weeds, with plastic mulches being the most commonly used category in strawberry production (Kasperbauer 2000; Poling 1994). Although plastic mulches are very effective, problems exist with postharvest disposal of these long-lasting materials. Furthermore, solid plastic mulches are not conducive to rooting of strawberry daughter plants in northern production regions. Porous plastic mulches, or landscaping fabrics, exist, but suffer from the same disposal limitations as solid plastic mulches. Biodegradable landscaping fabrics may serve a

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Table 1. Dates of management operations for strawberry plants established in 1999 and 2000.

Operation	Establishment year	
	1999	2000
Soil tilled	April 19	April 7
Nitrogen fertilizer applied	NA[a]	April 7
Canola sown	April 20	April 7
Herbicides applied	June 8	May 24
Canola incorporated, wool mulch established, and strawberry transplanted	June 9	May 25
Early weed assessment	July 13	July 13
Late weed assessment	August 16	August 23
Third daughter plant assessment	September 15	September 27
Napropamide application	November 5	November 10
Straw applied	November 6	November 11

[a] Abbreviation: NA, not available.

role as replacements for less degradable mulches in strawberry, but little information is currently available.

Mulches also can be developed from living plant materials. For instance, canola has been used in potato production. These living mulches can be incorporated into the soil during seedbed preparation (Boydston and Huang 1995), at which time compounds apparently exude from the dying tissues and inhibit weed seed germination (Eberlein et al. 1998). Roots are thought to contain the most effective chemicals (Gardiner et al. 1999). Alternatively, living mulches can be killed by mowing or with herbicides, leaving aboveground plant materials on the surface of the seedbed. Use of living mulches, or cover crops, to suppress weeds has been limited in strawberry production (Whitworth 1995).

Our objectives were to examine the effects of canola and sheep's wool mulch on weed abundance and strawberry daughter plant production during the establishment year of strawberry transplants as well as strawberry fruit yield during the next year.

MATERIALS AND METHODS

Field experiments were conducted during 1999 through 2001 at the horticultural garden of the West Central Research and Outreach Center, University of Minnesota, Morris, MN. The soil was a Barnes loam (Pachic Udic Haploboroll, course, mixed, mesic) on a well-drained 4% slope with an eastern aspect. Soil between 0- and 20-cm depth had sand, silt, clay, and organic matter percentages of 45, 35, 20, and 3.7%, respectively. The site was a sward of mixed herbaceous vegetation for several years before autumn 1998, at which time it was tilled in preparation for the experiments.

Field Plot Management. The same basic experiment was conducted twice, the first commencing in 1999 and the second in 2000, in adjacent areas of the same field. In both years, treatments were established in randomized complete block designs with three replications. Individual plots were 3.2 m long and 3.7 m wide. Blocks were separated by alleys 2 m wide. The entire experimental area was tilled with a field cultivator before canola was sown, and most areas were tilled again with a rototiller before strawberry transplantation. Dates for managing plots and establishing treatments are shown in Table 1.

The seven treatments in the experiments were as follows: (1) 1-Ply matting made of low-quality sheep wool. The wool underwent an aggregation process known as needle punching, which created matting that was 4 mm thick and weighed about 240 g/m^2. Mats were cut into strips that were 46 cm wide and 320 cm long. Strips were centered over the prospective strawberry rows, of which there were three per plot, each separated by 122 cm. At 46-cm intervals, 10-cm-long slits were cut into the center of the wool strips, through each of which a single 'Glooscap' strawberry transplant was buried so that its crown was even with the soil surface. There were eight transplants per row, three rows per plot, for a total of 24 transplants per plot. Wool fabric was held in place on the soil surface by 15-cm staples driven through the fabric and into the soil. (2) 2-Ply wool mulch, otherwise identical to treatment 1. (3) Seeds of 'Dwarf Essex' (1999) and 'Polaris' (2000) canola were broadcast in early spring at 8 kg/ha (about 2,000,000 seeds/ha) and subsequently cultipacked to ensure good soil–seed contact. Canola was allowed to grow until canopy closure, at which time it was 30 to 40 cm tall. It was killed with glyphosate in 1999 and glufosinate in 2000, both applied at 0.5 kg ae/ha. Strawberry was transplanted through the standing canola mulch 1 d later. (4) Canola was sown as in treatment 3, but killed by use of a rototiller that incorporated all plant materials within the top 5 to 10 cm of soil. (5) A standard herbicide, DCPA (Zandstra 1995), was applied at 9 kg ai/ha after transplanting and then incorporated with overhead irrigation. Hand weeding supplemented herbicide control in this treatment, as is common practice among strawberry producers. (6) Hand weeding, where weeds were controlled manually by hoes and by hand pulling after transplanting strawberry. (7) Weedy check, where weeds were not controlled after transplanting strawberry.

A 77-cm-wide interrow area of each plot was tilled in late July each year to control between-row weeds, as is standard practice by producers. Napropamide was applied at 3.6 kg ai/ha in early November each year after establishment of daughter plants. Subsequently, established plants were covered by 10 cm of wheat straw. Straw was removed from rows and placed in interrows to a depth of 15 cm in April to suppress weeds during fruit production years of 2000 and 2001. During fruit production years, grass weeds, including volunteer wheat, were controlled with sethoxydim at 0.3 kg ai/ha, and broadleaf weeds were managed by hand pulling as needed in May and early June. All herbicides were applied using backpack sprayers delivering about 187 L/ha at 280 kPa.

Plots were irrigated through drip tubes that ran along each strawberry row. The drip tubes were under the wool mats in wool-treated plots. Water was supplied whenever soil water potential at a 5-cm depth dropped below −0.03 MPa according to sensors that measured water potential hourly under a central strawberry row in one plot of each treatment. Although drip-line irrigation ensured that transplants never underwent water stress, high evaporation rates during summer may have dried adjacent soil surfaces sufficiently to inhibit rooting of daughter plants. Soil temperatures were measured hourly with thermocouples buried at 1 cm in a central strawberry row in one representative plot of each treatment. Urea ammonium nitrate fertilizer was applied at a rate equivalent to 85 kg/ha in April 2000 for the second experiment. No fertilizer was applied for the first experiment.

Data Collection. Weeds were sampled only during the strawberry establishment years. Sampling dates were mid-July and mid-August (Table 1). In mid-July, weeds were sampled by placing five 0.1 m^2 quadrats along a diagonal line across each plot. Three of these quadrats were within strawberry rows and the remaining two were in interrow areas of each plot. Within-row and between-row data were kept separate. Data included the weed identity, density, and dry weight within each quadrat. For dry weights, weeds were clipped at ground level, placed into paper bags, and dried for at least 1 wk at 70 C. Weeds were categorized as grass or broadleaf weeds, but they were primarily green foxtail [*Setaria viridis* (L.) Beauv., #[3] SETVI] and redroot pigweed (*Amaranthus retroflexus* L. # AMARE). In mid-August, weeds were sampled only within strawberry rows but otherwise in a similar manner as in July.

Rooted strawberry daughter plants were counted at the time of weed sampling as well as in September and October. These counts were made for daughter plants emanating from each of two original transplants in each row (i.e., six transplants per plot). Data were aggregated within each plot.

During the fruit production season (June and early July), all ripe fruit were harvested from the central 3 m of the middle row of each plot on Monday, Wednesday, and Friday each week. Fresh fruit weights were recorded, and they were aggregated across harvest dates within plots. As a simple index of fruit quality, 20-fruit weights also were recorded for each plot at each harvest in 2000.

Statistical Analyses. All data were analyzed by ANOVA ($P \leq 0.05$). Because of significant year by treatment interactions, data for each year were analyzed separately. Bartlett's test (Anonymous 1996) indicated that variances for weed densities and dry weights were not homogeneous among treatments. Consequently, data for these variables were log-transformed before ANOVA and calculation of LSD, as advised by Steel and Torrie (1980). Means were back transformed for presentation. Transformations were unnecessary for ANOVA of daughter plant and fruit yield data.

RESULTS AND DISCUSSION

Early-Season Weed Control. Densities and dry weights of weeds within strawberry rows during early July were always lowest in the wool mulch treatments compared with other treatments (data not shown). As expected, weeds were as abundant between rows in the wool mulch treatments as in the weedy check. The treatment in which canola was managed with a burndown herbicide had reduced weed densities between rows, but where canola was incorporated, weed densities and dry weights were high.

Late-Season Weed Densities. Differences among weed management treatments were more apparent in mid-August for both the broadleaf and grass weeds (Table 2). Weed densities within rows were negligible in both the 1-ply and 2-ply wool treatments, and neither of these

[3] Letters following this symbol are a WSSA-approved computer code from *Composite List of Weeds,* Revised 1989. Available only on computer disk from WSSA, 810 East 10th Street, Lawrence, KS 66044-8897.

Table 2. Effects of seven weed management treatments for strawberries transplanted in 1999 and 2000 on densities of broadleaf and grass weeds, total weed dry weight, daughter plant production, and fruit yield (fresh weight) during the next year.[a]

Treatment	Broadleaf		Grass		Dry-weight		Daughters		Fruit yield	
	1999	2000	1999	2000	1999	2000	1999	2000	2000	2001
	no./m²				g/m²		no./plant		Mg/ha	
Wool 1-ply	0 c	5 c	0 b	0 c	0 b	3 b	9.9 a	9.9 a	6.6 a	11.7 a
Wool 2-ply	0 c	5 c	1 ab	0 c	0 b	2 b	11.2 a	7.4 ab	4.3 abc	6.6 bc
Canola incorporated	37 a	73 ab	10 a	10 ab	6 b	239 a	1.2 b	3.5 bc	2.4 c	6.6 bc
Canola + burndown	11 ab	172 a	1 ab	3 bc	141 a	65 a	2.9 b	6.3 ab	2.5 c	5.2 c
DCPA	1 c	28 b	1 ab	0 c	1 b	2 b	2.9 b	7.4 ab	4.1 bc	7.9 abc
Hand weeded	2 bc	2 c	0 b	0 c	1 b	0 b	9.8 a	8.4 a	5.9 ab	10.0 ab
Weedy check	37 a	205 a	12 a	25 a	219 a	198 a	1.1 b	1.7 c	3.0 c	3.8 c

[a] Values within a column without a common letter differ significantly ($P = 0.05$).

treatments differed from the hand-weeded check. Very few weeds were found growing directly through the wool mulch, which was centered on the strawberry row. Those weeds that were in the strawberry row grew in the narrow openings cut in the wool for the strawberry transplants. Weed emergence through these openings could be minimized with minor engineering modifications, e.g., small flaps that cover the openings.

Weed densities were high, especially for grasses, in the treatment in which spring-sown canola was incorporated into the soil (Table 2). This contrasts with the results for potato production, wherein incorporated canola decreased weed densities (Boydston and Huang 1995). Perhaps differences in weed species composition and sensitivity to allelochemicals within canola cover crops explains the divergence in results. In any case, soil disturbance during incorporation of canola mulch stimulated germination of many weed seeds after strawberry transplantation in our experiments.

Weed densities were variable in the treatment in which the canola mulch was killed with burndown herbicides (glyphosate or glufosinate). The variability was not due to differences between the herbicides because all living vegetation was killed or suppressed greatly after herbicide application. Instead, the very high level of broadleaf weeds (primarily redroot pigweed) encountered in the second experiment (2000) appeared to overwhelm the ability of canola mulch to suppress their growth. When broadleaf weeds were not as dense, as in 1999, the canola mulch suppressed growth of these weeds, as it did for grass weeds in 2000 (Table 2).

DCPA, a standard preemergence herbicide used in northern strawberry production, controlled weeds well for both years. In an attempt to mimic standard farming practices, large broadleaf plants that occasionally escaped control were removed with supplemental hand weeding in this treatment. There were no differences in grass weed densities among DCPA, the wool mulch treatments, and the hand-weeded check. The same was true for broadleaf weed densities in 1999 but not in 2000. Nevertheless, DCPA reduced broadleaf weed densities below those of the canola plus burndown and weedy check treatments (Table 2).

Total Weed Dry Weight. Weed dry weights here highest in the weedy checks, the canola burndown treatment, and the incorporated canola treatment in 2000 (Table 2). Other treatments minimized weed dry weights to levels equivalent to that of the hand-weeded treatment.

Although weeds were more numerous in 2000 than in 1999, they grew larger in 1999, possibly because of higher temperatures that year. Accumulated growing degree-days (base 10 C) in Morris for June plus July, when summer annual weeds tend to accumulate most of their dry weight, were 639 in 1999 and 572 in 2000 (data not shown). Regardless of the cause, a few large individual plants within sampled quadrats accounted for the high values for dry weights in 1999.

Daughter Plant Production. Production of rooted daughter plants increased during the growing season, as expected, from near 0 plants per transplant in July to about 9 plants per transplant in September (data not shown). The final assessment of daughter plant production in autumn (Table 2) suggested that this variable was associated with levels of weed control in August (Table 2). In other words, highest levels of daughter plant production occurred in the wool mulch treatments and the hand-weeded check. Daughter plant numbers in the DCPA treatment in 1999 were lower than those in the hand-weeded check but similar in 2000. Canola treatments produced only low to modest numbers of daughter plants, and the weedy check had the fewest.

High numbers of daughter plants in the 1-ply wool mulch treatment indicated that the 4-mm-thick fabric did not unduly restrict establishment of rooted daughter plants. In fact, the cooler and possibly wetter soil surface

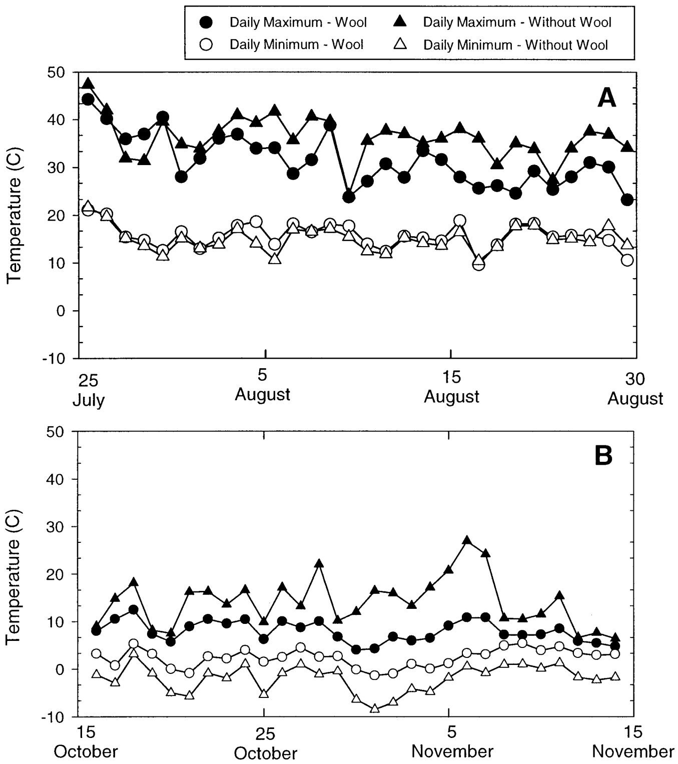

Figure 1. Soil temperatures at 1-cm depth in 2000 under 1-ply wool mulch and without wool mulch (A) during late July through August, the time of strawberry daughter plant rooting; and (B) mid-October to mid-November, the time when strawberry plants enter dormancy.

under wool mulch may have compensated for any restrictions imposed by the mulch or perhaps even promoted establishment of daughter plants. Soil temperatures under wool mulch differed from those without wool (Figure 1A) at the peak time of daughter plant rooting (late July and August). Daily maximum and minimum temperatures at 1-cm depth during this time averaged 31 and 18 C under wool mulch and 36 and 16 C without wool. Thus, wool mulch moderated soil surface temperature, especially the daily amplitude of soil temperature, and this may be partially responsible for higher daughter plant production in this treatment. Wool mulch also moderated soil temperature in autumn when strawberry plants entered dormancy (Figure 1B); moderate temperatures induce deeper levels of dormancy (Fujime and Yamasaki 1988), which may be beneficial in northern climates with variable spring weather.

Fruit Yield. Strawberry fruit yields 1 yr after establishment of transplants were considerably higher in 2001 than in 2000, but otherwise followed the same trends in response to weed management treatments (Table 2). High yields in 2001 were a regional phenomenon (unpublished data). Regardless of yearly variability, fruit yields were correlated closely with daughter plant production, as expected, each year.

Although the yearly fruit yields were highest in the 1-ply wool mulch treatment, they were not significantly different from yields in the hand-weeded treatment in either year and the DCPA treatment in 2001. Lowest yields occurred consistently in the weedy check and herbicide-treated canola treatments, which always differed significantly from the 1-ply wool mulch and hand-weeded treatments but not necessarily from other treatments (Table 2).

The type of weed management used during strawberry establishment did not influence fruit quality (data not shown). Production of consistently high quality fruit among treatments probably was due to the uniform management that occurred during the second year of each experiment rather than treatments in the establishment year.

The success of the 1-ply wool mulch treatment in producing abundant and high-quality fruit partly reflects the high level of weed control it achieved. However, it also allowed for vigorous rooting and establishment of daughter plants. The low yield in the 2-ply wool mulch treatment, compared with the 1-ply wool treatment, probably resulted from rooted but otherwise poorly established daughter plants. Poor establishment may have been due to the thickness of the two layers of wool fabric.

The comparable yields between the 1-ply wool mulch treatment and the hand-weeded check might be explained not only by a lack of weeds but also through protection by the wool mulch of the soil from desiccation and thermal extremes in immediate proximity to the strawberry plants. Strawberry is known to be sensitive to high temperatures and low water potentials (Bish et al. 2002; Darnell et al. 2003). In addition, the decomposing wool mulch may have provided nutrients, such as nitrogen, to the strawberry plants. Most of the wool had decomposed after 1 yr.

Canola was not effective as mulch for strawberry establishment. Although when killed and left on the soil surface, it did have transient effects on weed control, these effects were too short lived to represent a viable management alternative to standard herbicides in a crop such as strawberry. The effects of incorporated canola were not apparent or were inconsistent be used as a green manure that suppresses weeds in strawberry. However, canola may have some value as surface mulch between strawberry rows before interrow cultivation.

Wool landscaping fabric can serve as mulch that suppresses weeds during strawberry establishment. It reduces weed growth at least as effectively as hand weeding and is at least equal to standard herbicides. Wool mulch also maintains high strawberry fruit yield. This occurs not only through good weed control but also by permitting high rates of daughter plant establishment and possibly by keeping the soil surrounding young plants cooler and wetter during warm and dry weather through the establishment year of strawberry.

The questionable feature of wool mulch is cost. Its price is high, presently about $1,000/ha. The high price is not due to the inherent value of the wool but due to the expenses associated with new product development and transportation. Commercial costs may decrease if mats can be manufactured in quantity. Establishment of more manufacturing facilities using wool from locally raised sheep also may lower prices and provide a market for wool that currently has little value.

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