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Grass Living Mulch for Strawberries

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Abstract. **'Sparkle' and 'Honeoye' strawberries (*Fragaria* ×*ananassa* Duchesne) were planted into plots of newly seeded perennial ryegrass (*Lolium perenne* L.), Kentucky bluegrass (*Poa pratensis* L.), winter wheat (*Triticum aestivum* L.), or no grass. After a 1985 windstorm during the green fruit stage, yield was higher in living mulch plots than in control plots and fruit from control plots were small and dark relative to those from the ryegrass plots. In 1986, all plots had similar yields. All plants grew at similar rates during the establishment year. Later, strawberry plants in living mulch plots had smaller leaves than plants in control plots. Plants in all treatments contained above the critical concentrations of leaf N on most sampling dates. Soil under grass was less compacted and was cooler than cultivated soil. Living mulch prevented annual weed establishment after the first and improved winter survival of flower buds. A tillering type of ryegrass was the best living mulch of the three species tested. It quickly covered the ground but did not spread into the crop rows, and grew tall enough to afford wind protection.**

Traditional strawberry cultural practices include herbicide use and cultivation to maintain weed-free areas within and between matted rows. This soil management practice may present problems. Reliance on residual chemicals to kill weeds is not only expensive, but also creates ecological hazards. High soil temperatures (19), soil compaction, and subsequent poor soil aeration often slow root growth (9). Bare ground also is susceptible to water and wind erosion. Wind may damage leaves (13), flowers (11), and fruit; may limit fruit size and yield (10, 14, 20); and, over long periods of time, may inhibit plant growth (8, 15). Convection heat loss in winter may lower plant temperatures to lethal levels (3). Nonmulched plants also undergo greater temperature fluctuations (17).

A living mulch is "a crop production technique in which a food crop is planted directly into an established cover crop" (1). Under many conditions, living mulch may be a more effective technique than traditional methods to produce a quality crop and sustain high yields over many years (1, 5). Little information is available on the use of a living mulch system to solve problems associated with clean cultivation in strawberry production. The recent availability of selective postemergence grass herbicides may present a new option for crop management (5).

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Materials and Methods

'Regal' perennial ryegrass (a bunch-type grass that spreads by tillering); 'Park' Kentucky bluegrass (rhizomatous); 'Kenosha' winter wheat (an annual, tillering grass), and a clean cultivated control were maintained between strawberry rows during a 3-year field study.

One of the four cover crop treatments was applied to each plot (4.5 m wide × 12.2 m long), each of which contained one row of 'Sparkle' and one row of 'Honeoye' strawberry plants. Plants were set 76 cm apart in rows 1.5 m apart. Soil type was Plano silt loam (Typic Argiudoll, fine-silty, mixed, mesic well-drained) with 3.0% to 4.5% organic matter and a pH of 6.0. Plots formed a randomized complete block design with four replicates. All mean separations were performed on only analysis of variance significant effects.

Turfgrass seed was broadcast 11 May 1984, at the rates of 90 $kg\cdot ha^{-1}$ for ryegrass, 30 $kg\cdot ha^{-1}$ for bluegrass, and 135 $kg\cdot ha^{-1}$ for winter wheat. On 21 May 1984, strawberry plants were set by hand into each experimental plot and allowed to form matted rows 38 cm wide. With the exception of sod management and weed control, the field was treated as a commercial strawberry planting (16).

(±)-2-[4-[[5-(trifluoromethyl)-2-pyridinyl]oxy]phenoxy]propanoic acid (fluazifop) was sprayed in a 36-cm-wide band over strawberry rows on 7 June 1984 at 0.56, on 18 July 1984 at 0.28, on 28 May 1985 at 0.9, and on 8 May 1986 at 0.49 kg a.i./ha. Broadleaf weeds were controlled during the establishment year by hand cultivation. An application of 2-(α-naphthoxy)-N,N-diethylpropionamide (napropamide) was made 22 Oct. 1984 at 4.5 kg a.i./ha. Between strawberry rows, (2,4-dichlorophenoxy)acetic acid (2,4-D) at 0.56 kg a.i./ha was sprayed in a 1.2-m band on 15 June 1984 to control annual dicotyledons. Dandelions were controlled by periodic applications of 1.12 kg a.i. 2,4-D/ha sprayed in a 1.5-m-wide band over the strawberry rows during the growing season and by hand cultivation. *N*-(phosphonomethyl) glycine (glyphosate) (8% solution) was used occasionally between strawberry rows as a spot treatment wipe on Canada thistle. Population counts of annual weeds were made in three areas selected at random between strawberry rows on various dates during the 1984 through 1986 growing seasons.

Nitrogen was applied as NH_4NO_3 or urea at various times during the season and either broadcast over the field or applied in a narrow strip along the strawberry rows. Total N applications included 33.8 kg N/ha in 1984 (split applications in June, July, and August), 33.6 kg N/ha in 1985 (applied at renovation), and 78.4 kg N/ha in 1986 (split applications in May, August, and September).

The strawberry planting was renovated on 19 July 1985 by mowing the strawberry plants and narrowing rows to 36 cm.

Grass was mowed to a height of 5 to 7 cm on 12 and 23 July and 9 Aug. 1984, 2 May and 19 July 1985, and on 4 June, 3 July (renovation), and 18 Aug. 1986.

In 1985, all fruit from a 3-m section of each row was harvested and weighed. Mean fruit weight was calculated from the weight of 25 fruit randomly selected from each treatment on each harvest date. During 1986, two 3-m-long sections of 'Sparkle' and one 3-m section of 'Honeoye' were harvested on six dates. Data from the two harvest areas in each 'Sparkle' row were averaged for statistical calculations.

A windstorm at 16.5 $m \cdot s^{-1}$ from the south–southwest that lasted for 12 hr, with gusts to 21.5 $m \cdot s^{-1}$, hit north–south plant rows at about a 30° angle on 31 May 1985. Fruit produced on 30 trusses in each plot were harvested, weighed, and counted separately from the other harvested area in the row on 10, 17, 25, and 28 June 1985.

A Hunterlab D 25 Optical Sensor was used 17 June 1985 on 'Sparkle' fruit. Three 200-ml samples of rinsed, ripe, unbruised fruit were randomly selected from each plot. Calyces were removed, fruit was sliced in half longitudinally, and halves were placed skin side down in a plexiglass sensor cup until they formed two layers, 1.5 to 2.0 cm deep. Lightness was measured on a scale of 0 (black) to 100 (white). Hue and color value (amount of pigment) were calculated from the *a* (redness) and *b* (yellowness) readings (7).

One 'Honeoye' plant selected randomly from each row was uprooted each month from June through Oct. 1984. All leaves of the main crown and of each of the five largest runners were harvested, measured with an optical planimeter (LI-COR Model LI-3100), dried, and weighed before analysis of total percent N according to the modified Kjeldahl technique described by Murneek and Heinze (18), and used by Liegel et al. (12). Five recently matured 'Sparkle' leaves were collected from five areas randomly selected within each plot on 10 dates during 1985 and 1986. Leaves were measured, dried, weighed, and total percent N was determined.

Five core samples from the top 15.2 cm of soil were collected from random locations in the center of the 'Sparkle' row on the same dates as the leaf samples in 1985 and 1986. Parts-per-million of ammonium (NH_4) and nitrate (NO_3) were determined according to the micro-Kjeldahl procedures of Bremner and Keeney (4).

Soil temperature was measured with an electric current thermistor at 5 and 10 cm below the soil surface in three randomly selected areas within the strawberry rows on several dates during each growing season.

Soil compaction was measured 17.8 cm below the soil surface on five dates in five areas randomly selected between strawberry rows. A cone penetrometer (U.S. Army Corps of Engineers Model LA 328) was used.

After a mild, wet autumn, air temperatures rapidly dropped to −16.7C during the week of 9 Nov. 1986. Twenty-five randomly selected 'Sparkle' strawberry crowns from each of the ryegrass plots and the control plots were collected 19 Nov. and dissected under a ×10 power microscope to estimate cold injury as indicated by discolored tissue.

Results and Discussion

Ryegrass and wheat plots produced higher yields than bluegrass or control plots in 1985 (Table 1). Living mulch did not affect total 'Sparkle' yield for the 1986 harvest or total yield of 'Honeoye' in either year.

Ryegrass plots produced heavier strawberries than other plots in 1985, but, during 1986, strawberries from ryegrass plots were similar in weight to those from control plots (Table 1) and bluegrass and winter wheat plots produced smaller strawberries than other plots.

After the windstorm of 31 May 1985, strawberry plants in control plots showed symptoms of wind damage: desiccated fruit, torn leaves, bent petioles and peduncles, and black lesions on leaves and fruit. Strawberry plants grown in living mulch plots had few of these symptoms. Individual 'Sparkle' trusses from control plots produced fewer fruits than plants grown in living mulch (Table 2). On the first harvest date, all strawberry plants in living mulch plots produced heavier fruit than those in control plots, but weights were similar at the second and fourth picking, and variable at the third (Table 2). These results suggest that the windbreak effect of living mulch limited damage to primary berries and may also have protected later fruit. Fruit was more susceptible to wind damage than open flowers. Yield data for 'Sparkle' suggest that a cold winter and a spring wind storm limited yield in 1985. Snow covered plants during the winter of 1985–86 and additional protection from living mulch did not affect yield in 1986 (Table 1).

Strawberries from control plots appeared dark and dull after

Table 1. Total yield (kg fresh weight per 10 m of row[z]) and mean fruit weight (g) of 'Sparkle' strawberry from living mulch and control plots, 1985 and 1986.[y]

	1985		1986	
Mulch	Yield	Fruit wt	Yield	Fruit wt
Ryegrass	8.30 a	7.8 a	13.55 a	11.0 a
Bluegrass	6.00 b	6.2 b	9.97 a	6.4 b
Wheat	9.02 a	6.7 b	10.89 a	8.0 b
Control	5.90 b	6.0 b	9.97 a	10.0 a

[z]Rows were 38 cm wide.
[y]Means within columns separated by Student–Newman–Keuls' multiple range test, $P = 0.05$.

Table 2. Number and weight of strawberries from 30 labeled 'Sparkle' inflorescences, 1985.

Mulch	Total no. of fruits	Individual fruit weight (g) Date 10 June	17 June	25 June	28 June	Total yield (g)
Ryegrass	219 a[z]	10.8 a	7.5 a	4.8 a	3.5 a	1248 a
Bluegrass	205 a	8.3 a	6.8 a	3.8 bc	2.8 a	1032 b
Wheat	192 a	8.8 a	5.8 a	4.3 ab	3.0 a	973 b
None	148 b	5.0 b	4.5 a	3.0 c	2.5 a	544 c

[z]Means within columns separated by Student–Newman–Keuls' multiple range test, $P = 0.05$.

Table 3. Hunterlab color difference meter measurements of light quality of 'Sparkle' strawberries in relation to living mulches, 1985.

Mulch	Color characteristics[z,y] Lightness	*a*	*b*	Hue	Value
Ryegrass	21.7 a	22.2 a	9.4 a	1.17 a	24.1 a
Bluegrass	21.2 a	14.0 b	8.9 a	0.99 b	16.6 b
Wheat	21.4 a	14.0 b	9.4 a	0.97 b	16.9 b
Control	18.3 b	17.1 b	6.7 b	1.20 a	18.3 b

[z]Means within columns separated by Student–Newman–Keuls' multiple range test, $P = 0.05$.
[y]Lightness is measured on a scale of 0 (black) to 100 (white); *a* quantifies redness and *b* yellowness.

Table 4. Total leaf area (cm^2) and dry weight (g) of 25 newly mature 'Sparkle' strawberry leaves in relation to living mulches.[z]

Mulch	1985 Leaf area	1985 Dry wt	1986 Leaf area	1986 Dry wt
Ryegrass	1400 c	13.0 c	1560 b	16.2 b
Bluegrass	1570 b	15.1 b	1320 c	13.4 c
Wheat	1700 b	15.7 b	1570 b	16.6 b
None	1870 a	18.0 a	1740 a	18.5 a

[z]Means within columns separated by Student–Newman–Keuls' multiple range test, $P = 0.05$.

the windstorm of 31 May 1985, while those from living mulch plots (especially ryegrass plots) were shiny, bright red with yellow achenes, and had a glossy finish. These color differences were also reflected in the Hunterlab Optical Sensor data (Table 3). Strawberries grown in living mulch plots were lighter in color than strawberries grown in control plots, fruit from ryegrass plots was more red (higher *a* reading) than fruit from other plots, and fruit from mulch plots was more yellow (higher *b* reading) than fruit from control plots.

Living mulch-grown plants also had less strawberry leaf scorch infection than plants in control plots, perhaps because the windbreak action reduced abrasion and particulate damage to the leaf cuticle and epidermis.

Compared to control plots, strawberry plants in bluegrass and ryegrass plots appeared to have smaller, lighter green leaves with shorter petioles. During 1984, no differences among treatments were found in plant dry weight or leaf area. During 1985, ryegrass plots produced leaves with the least dry weight and smallest leaf area, with those from the other living mulch plots being intermediate (Table 4). However, plants with strong growth the previous fall (those in control plots) did not yield more the next spring (1985) than did plants with less vegetative growth (Table 1) in living mulch plots. The intensity of visual stress symptoms corresponded to sod density in ryegrass and bluegrass plots. Leaf area and dry weight of strawberry plants were highest in the control plots and lowest in the bluegrass plots in 1986 (Table 4). Compared to other plots, plants in bluegrass plots appeared to be the most stressed and continued to have symptoms of stress throughout the season.

All strawberry plants during 1984 contained N at levels within the range of the critical concentration (2, 6). The levels during 1985 were slightly low overall, but not below the critical concentration (except on 4 Nov.). A Student–Newman–Keuls' mean separation test ($P = 0.05$) revealed that plants from control plots averaged the most N (2.02%), those from ryegrass (1.69%) and bluegrass (1.65%) had the lowest N content, and plants from wheat plots were intermediate (1.85%). By late Fall 1985, strawberry leaves in bluegrass plots showed some bright red, symptomatic of late season N deficiency. In spite of low tissue N levels the previous fall, yield the next year was not affected.

During 1986, all treatments had similar tissue N levels, except on 1 Aug. and on 2 Sept., when leaves from control plots contained the most N (2.31% on 1 Aug. and 2.49% on 2 Sept. vs. 1.92% and 2.15% in ryegrass and 1.84% and 1.96% in bluegrass). There were no differences among treatments in soil NO_3 or NH_4 levels within the 'Sparkle' strawberry rows on any sampling date.

Soil penetrometer readings in Oct. 1985 supported the observation (9) that a sod cover deters soil compaction and improves soil tilth relative to clean-cultivated soil (Table 5). Subsequent measurements confirmed this result.

When strawberries had not yet formed a complete row canopy but ryegrass had formed a dense sod, soil temperature averaged 1.9C cooler in the strawberry rows grown in ryegrass than in other plots (Table 5). After a solid matted row of strawberry plants formed (by mid-July 1984), no differences were found in soil temperature within the rows.

Exposure to low air temperatures and high wind in Nov. 1986 killed 64% of the strawberry crowns from control plots and 21% of the crowns from ryegrass plots.

Ryegrass formed a dense sod by June 1984, earlier than the other mulches, and contained the fewest weeds between strawberry rows on 19 June and 11 July 1984 (Table 6). All mulch plots contained similar low weed counts on 23 Aug. Wheat died the first winter and was replaced by volunteer wheat the following season, although these plots never regained a solid stand. Therefore, 1985 and 1986 weed counts were high in wheat plots (Table 6). Ryegrass and bluegrass plots contained similar low weed counts compared to control plots throughout 1985 and 1986 (Table 6). After strawberries formed a matted row and

Table 5. Soil temperature (°C) within strawberry rows and soil compaction (kPa) between rows in relation to living mulches.[z]

Mulch	Soil characteristics[y] Temperature	Compaction
Ryegrass	27.0 c	827 b
Bluegrass	28.8 ab	820 b
Wheat	28.3 ab	924 b
None	29.6 a	1124 a

[z]Means within columns separated by Student–Newman–Keuls' multiple range test, $P = 0.05$.
[y]Temperature measured 10 cm below surface on 20 June 1984; compaction measured 2 Oct. 1985.

Table 6. Number of new annual weeds per square meter in area between strawberry rows.[z]

Date	Mulch[y] Ryegrass	Bluegrass	Wheat	None[x]
1984				
19 June	20 b	83 a	71 a	---
11 July	0 c	15 a	3 b	---
23 Aug.	6 a	14 a	14 a	---
1985				
28 June	0 b	0 b	31 a	50 a
16 July	13 c	4 c	205 a	85 b
22 Aug.	58 b	12 c	147 a	97 ab
1986				
4 June	1 b	0 b	265 a	163 a
3 July	0 b	0 b	N.C.[w]	68 a
1 Aug.	0 b	0 b	N.C.	46 a

[z]Weed population was composed of purslane (*Portulaca oleracea* L.), common lambsquarters (*Chenopodium album* L.), redroot pigweed (*Amaranthus retroflexus* L.), and other species.

[y]Means within rows separated by Student–Newman–Keuls' multiple range test, $P = 0.05$.

[x]During 1984, control plots were regularly cultivated; thereafter, they were cultivated the day following each weed count.

[w]Not counted, since wheat was totally replaced by weeds in 1986.

grass mulches formed a dense sod (August of the establishment year), weed control in treatment plots was unnecessary, with the exception of dandelion control in the strawberry rows. Dandelions established in the rows at the same rate whether or not grass was grown between rows.

Living mulch is a useful system in areas where strawberry production is limited by wind or cold temperatures. When wind during strawberry blossom damaged plant tissues, living mulch plots produced the highest yields; without wind stress, living mulch did not affect yield. Plant competition from living mulch limited strawberry growth after the establishment year, but did not prevent high yields. Living mulch was effective at preventing weed growth between rows and should eliminate the need for tillage. Perennial ryegrass (tillering) was the best living mulch of the three species tested; it quickly covered the ground but did not spread into the crop rows and its leaf blades and inflorescences grew tall enough to afford wind protection.

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