

# The effects of a non-woven cover in combination with different soil mulches in strawberry cultivation

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The effects of a non-woven cover and three different soil mulches on the timing of harvest and on the yield of strawberry were examined in two field experiments in northern Finland during 1989–1993. The non-woven cover was used either in spring or in both autumn and in spring. Non-covered plants served as controls. Depending on the year, plants covered in spring alone gave a significantly earlier (4 to 9 days) marketable yield than did uncovered plants. The non-woven cover had no effect on marketable yield at Sotkamo but at Rovaniemi it increased the yield, especially in cold years. The use of cover decreased the amount of mouldy berries. At both experimental sites, a significantly higher yield was obtained from beds covered with soil mulches than from uncovered beds. White-on-black film delayed the yield by 2 to 4 days in comparison with black or Mypex film.

*Key words:* black film, early harvest, Mypex film, quality, timing, white-on-black film

## Introduction

Non-woven covers are mostly used under cool conditions to advance strawberry crop growth early in the season (Laurinen and Säkö 1987, Davies 1992). A non-woven type of cover, such

as Agryl or Lutrasil, provides a barrier against pest attack (Davies 1992). Begin (1988) found that plants ripened more quickly on plots covered with polypropylene-polyamide net (Agronet) in spring than on uncovered plots. According to Polling et al. (1991), overwinter covers improved early yields, but not the total

marketable yield. Laurinen and Säkö (1987) reported that non-woven covers have, however, certain disadvantages, e.g. a slightly poorer crop quality and a large percentage of small berries (less than 1.5 cm in diameter), both of which reduce the quantity of the marketable yield. Pollard (1990) noted that Agronet row covers (extruded polypropylene-polyamide mesh) enhanced conditions in autumn and spring, thus possibly contributing to greater flower initiation and berry development. Clear polyethylene plastic over plants in spring creates a greenhouse effect, which advances the start of growth in early spring. This early growth results in earlier bud development and, subsequently, an earlier harvest, which, as shown by experience, is approximately 7 to 10 days earlier than that for organically mulched plants (Scheel 1982).

The most widely used soil mulch is black PE film. One disadvantage of black film is that it warms up the soil surface. The strawberry roots are then drawn closer to the soil surface than in uncovered soil, making the plants more susceptible to freeze injury (Leskinen 1977). The surface temperatures of clear, black and white plastic mulches were 17, 19 and 15°C higher, respectively, than the surface temperature of bare soil. Both clear and black mulches advanced the earliness of the crop, increasing the potential danger from late spring frosts (Himelrick 1982). The temperature under mulch alone was highest for clear polyethylene and lowest for aluminium-coated paper, with black polyethylene being intermediate between the two. Row covers over black polyethylene gave a higher soil temperature than did black polyethylene alone (Voth 1968). Generally, the superiority of plants on black polyethylene mulch was well sustained in the second year, the average yield being almost 90% higher than that from plants grown on bare soil (Laughlin 1968). Clear mulch increased fruit maturity by about 1 week, and black mulch by about 3 days, whereas white mulch had no effect on the time of maturity (Hopen and Oebker 1976). Pollard et al. (1987), Pollard and Cundari (1987), Pritts et al. (1989), Lieten (1991) and Himelrick et al. (1993) reported that in northern

areas with short growing seasons and/or low-temperature stress during winter or spring, spunbonded row covers of clear or black polyethylene advanced the strawberry harvest and improved strawberry yields in matted rows by increasing the growing degree units and by reducing heat loss from beneath the covers.

The main aim of this study was to answer the following questions:

- 1) Does the use of a non-woven cover or soil mulches or their combination advance harvest?
- 2) Is the yield of a crop protected by a non-woven cover in spring or in both autumn and spring greater than that of an uncovered crop?
- 3) Does the use of soil mulches increase the marketable yield?
- 4) Does black polyethylene mulch cause strawberry roots to grow nearer the soil surface than in bare soil?

## Material and methods

Field studies were conducted in 1989–1993 at two stations in northern Finland, Sotkamo (64°06'N, 28°20'E) and Rovaniemi (66°35'N, 26°01'E). The characteristics of the experimental soils are presented in Table 1. At Sotkamo fertilizer was applied to the rows before bed shaping at rates of N 0, P 0, K 206 kg/ha, and at Rovaniemi at N 112, P 168 and K 184 kg/ha in accordance with the general recommendations of the Soil Analysis Service of Finland.

The most commonly cultivated early strawberry in northern Finland is 'Zefyr', a variety of Danish origin. Plants of this variety were planted in June 1989 in rows of about 15 cm high and 5 m long. The rows were spaced 130 cm on cen-

Table 1. Characteristics of experimental soils.

	Sotkamo	Rovaniemi
pH	6.7	6.8
P, mg/l soil	35.0	39.7
K, mg/l soil	214.0	225.0
Ca, mg/l soil	2025.0	2027.0
Mg, mg/l soil	231.0	438.0

Table 2. The periods that strawberry plants were protected with a non-woven cover in spring and autumn.

Station	1991	1992	1993
Sotkamo	5 May – 17 June	13 May – 11 June	7 May – 31 May
	12 Aug – 16 Sept	11 Aug – 23 Sept	30 Aug – 1 Oct
Rovaniemi	14 May – 24 June	18 May – 9 June	15 May – 9 June
	5 Sept – 5 Nov	1 Sept – 1 Nov	31 Aug – 23 Sept

tre, and were covered with three different soil mulches: woven cloth (Mypex film), black plastic film and white-on-black plastic film. The Mypex film is woven from polypropylene plastic strips and provide effective protection against UV-radiation. Water penetrates the film, which is 200  $\mu$  thick, weighs 95 g/m<sup>2</sup> and is 100 cm wide. The black film, which is of UV-protected polyethylene is 60  $\mu$  thick. The white-on-black film is coextruded polyethylene, 100  $\mu$  thick. Non-covered plants served as controls. In combination with mulches, a non-woven cover (Lutrasil 17 g/m<sup>2</sup>, white in colour with 92% light infiltration) was applied at two different times. The first application was in spring after the snow had melted and immediately after spring cleaning; this cover was left in place until flowering began. The second application was in autumn, and was used to extend the autumn season and protect the plant from early frosts. This cover was applied in August, after the harvest, and left in place until October; it was put back on again in spring. Table 2 shows the periods that the strawberry plants were covered with the non-woven cover in spring.

### Calculation and observation methods

An early harvest was established by calculating how many days had elapsed from the first harvest day until the day when at least half of the marketable yield had been harvested. The total yield was classified into marketable yield, small berries, mouldy berries and others. Berries less

than 1.8 cm in diameter were considered small. The quantity of small berries in the early harvest and the total yield were calculated. At the end of the experiment, the plants were removed carefully with their roots intact to find out whether roots under mulches grow at the soil surface or deeper down. The roots were washed and their length was measured. The region of root branches was examined and each root was assessed on a scale from 1 to 5. If the roots were mostly branching on the upper side, they were rated 1 and if they were mostly branching on the down-side, they were rated 5.

### Weather conditions

The plants received sufficient moisture from rainfall, and irrigation was therefore unnecessary. During the growing season, temperature and precipitation were monitored. Table 3 lists the monthly mean precipitation during growing seasons, Figure 1 shows the average temperatures from May to October in 1991–1993, and Figure 2 the sum of effective temperature (base °C) at Sotkamo and Rovaniemi.

### Soil temperature measurement

At Rovaniemi, the temperature of the soil was measured under cover and under mulches. The measurements were made at 7.00 am, at a depth of about 15 cm. The differences in temperature between soils under cover and uncovered soils dur-

Table 3. Monthly mean precipitation during growing seasons in 1991–1993 and long-term averages.

Station	Month	Precipitation, mm			
		1991	1992	1993	1961–1990
Sotkamo	May	50.7	19.5	20.8	38.4
	June	149.0	26.9	56.7	55.5
	July	45.5	71.2	112.3	67.8
	August	60.7	139.5	77.0	88.5
	September	85.4	84.0	62.4	63.5
Sum	May–September	391.3	341.1	329.2	313.7
Rovaniemi	May	72.3	34.9	41.6	34.4
	June	94.0	109.6	59.5	54.4
	July	22.1	117.5	53.1	63.4
	August	60.3	147.4	31.5	68.6
	September	68.3	96.1	23.4	61.0
Sum	May–September	317.0	505.5	209.1	218.8

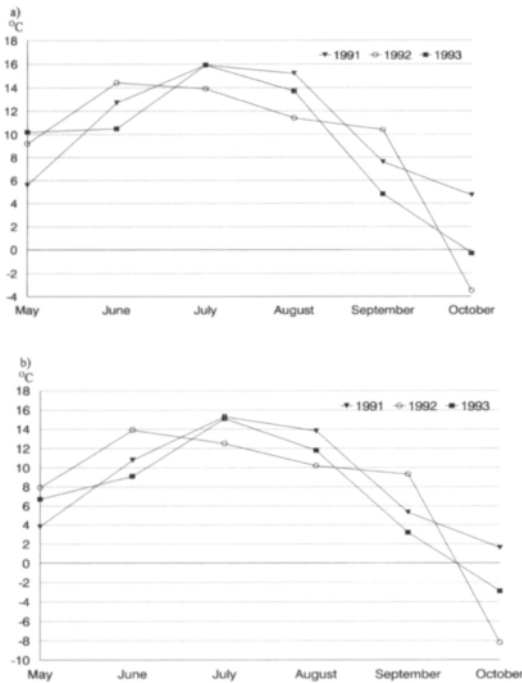


Fig. 1. Average of monthly temperature a) at Sotkamo and b) at Rovaniemi.

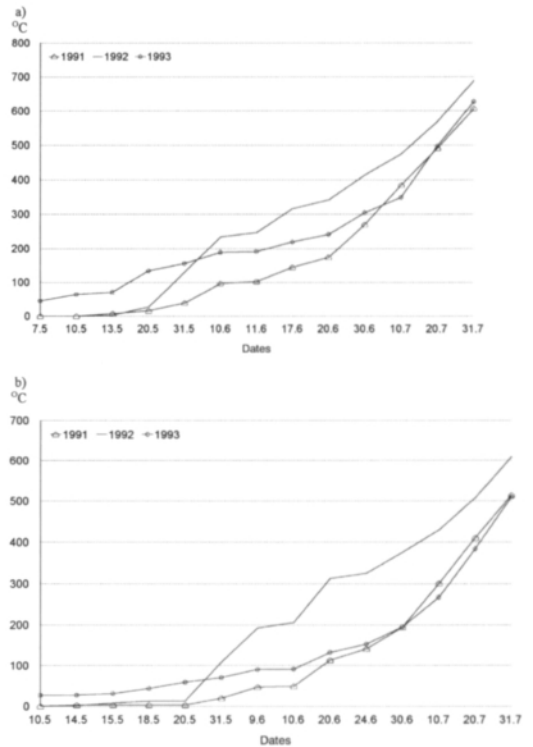


Fig. 2. Sum of effective temperature a) at Sotkamo and b) at Rovaniemi (base °C).

Table 4. The 5-day average temperature (°C) under different soil mulches and crop covers at 7.00 am at Rovaniemi in 1991 and 1992.

Treatment	16–20 May	21–25 May	26–30 May	31 May – 4 June	5–9 June
Mypex & Lutrasil	6.50	8.95	9.51	11.88	11.61
Black & Lutrasil	6.76	9.28	9.93	12.10	12.10
White on black & Lutrasil	5.90	8.16	8.87	11.12	11.18
Lutrasil	6.58	8.50	9.34	11.40	11.30
Mypex	5.30	7.39	7.80	10.25	10.36
Black	5.67	7.82	8.09	10.42	10.60
White on black	4.45	6.73	6.72	9.21	9.41
No mulch or cover	4.77	6.80	6.82	9.32	9.51

ing May and June were similar. The highest temperatures were recorded with Mypex film and the non-woven cover or with black film and the non-woven cover (Table 4).

### Pesticide use

At Sotkamo and Rovaniemi, supermetrin (Ripcord 0.05%) was used against leaf beetle (*Galerucella sagittariae*) in 1991, 1992 and 1993. At Sotkamo tridimefon (Bayleton 0.03%) was used against powdery mildew (*Sphaerotheca alchemillae*) in 1992 and 1993. At Rovaniemi there was no need to spray the plants against the above mentioned fungi and insects.

### Statistics

The day at which 50% of the marketable yield was achieved, was assessed with 2 subsequential harvest days. The first day was when 50% of the marketable yield had not yet been achieved and the second day was when it had just been achieved. The days were usually 2 to 5 days apart. A linear estimation was used to establish the time that had passed before 50% of the marketable yield was achieved.

The statistical analysis was performed using analysis of variance (ANOVA) for a split plot design. The non-woven cover was the main plot,

and the soil mulch was the subplot. The model included a time factor, the year of harvest, which was considered as a sub-subplot. The covariance structure for repeated measures was selected from unstructured, autoregressive and compound symmetry using the Akaike Information criterion (SAS 1992). The analysis was performed with the MIXED procedure of the SAS® software. The response variable was log-transformed, when necessary, to satisfy the statistical assumptions of the ANOVA. A P-value of less than 0.05 was considered statistically significant.

## Results

### Timing of the harvest

#### *Effects of non-woven cover*

The effect of the non-woven cover on the timing of harvest was significant at both experimental sites (Table 5).

#### *Effects of mulches*

The use of mulches had a significant effect on the timing of harvest at both experimental sites. At Sotkamo, in all 3 years, the effect of black film was statistically significant (P<0.01, 0.05,

*Aflatuni, A. et al. A non-woven cover and soil mulches in strawberry cultivation*

Table 5. Statistically significant effects of non-woven cover and mulch on timing of harvest, marketable yield, amount of mouldy berries, proportion of small berries and total yield at Sotkamo and Rovaniemi.

Station	Source	A	B	A x B	C	AxC	BxC	A x BxC
Sotkamo	Timing of harvest	***	***	NS	***	***	*	NS
	Marketable yield	NS	**	NS	***	NS	*	NS
	Amount of mouldy berries in the early harvest	NS	NS	*	***	NS	NS	NS
	Proportion of small berries	NS	NS	NS	***	**	NS	NS
	Total Yield	NS	**	NS	***	NS	NS	NS
	Rovaniemi	Timing of harvest	**	***	NS	***	**	**
Marketable yield		NS	***	NS	***	***	NS	NS
Amount of mouldy berries in the early harvest		NS	NS	NS	***	NS	NS	NS
Proportion of small berries		NS	NS	NS	***	*	NS	NS
Total Yield		NS	***	NS	***	***	NS	NS

A = effect of non-woven cover, B = effect of soil mulch, A x B = interaction between non-woven cover and soil mulch, C = effect of year, A x C = Interaction between non-woven cover and year, B x C = interaction between soil mulch and year and A x B x C = interaction between non-woven cover, soil mulch and year

\* = P<0.05, \*\* = P<0.01, \*\*\* = P<0.001, NS = no significant

0.05 in 1991, 1992 and 1993, respectively) in comparison with mulched plots. Black film advanced harvest by 1 to 2 days (Table 6), whereas white-on-black film delayed it, depending on the year, by about 1 to 2 days in comparison with no use of mulch, but the difference was statistically significant only in 1991 (P<0.001). At Rovaniemi, white-on-black film delayed the harvest by 3 days, on average, in comparison to no use

of film (Table 6). However, this delay was not statistically significant in 1993.

*Interactions*

There was a significant interaction between the non-woven cover and the harvest years at both experimental sites (Table 5). Depending on the year, an early market yield was obtained from

Table 6. Effect of soil mulches on timing of strawberry harvest at Sotkamo and Rovaniemi.

Station	Soil mulch	Days when 50% of marketable yield harvested		
		1991	1992	1993
Sotkamo	Mypex	13	15	15
	Black	11	14	14
	White on black	16	17	16
	No cover	13	16	16
Rovaniemi	Mypex	13	21	9
	Black	11	20	8
	White on black	16	26	10
	No cover	14	22	9

Table 7. Effect of the non-woven crop cover on advancing of marketable yield harvest at Sotkamo and Rovaniemi.

Station	Covering season	Days when 50% of marketable yield harvested		
		1991	1992	1993
Sotkamo	Spring	10	12	14
	Autumn and spring	11	15	14
	No cover	20	19	18
Rovaniemi	Spring	12	21	9
	Autumn and spring	12	21	7
	No cover	21	27	14

crops protected with the non-woven cover 4 to 9 days earlier than from crops not protected with such a cover (Table 7). There was also a significant interaction between the use of mulches and harvest years (Table 5).

### Marketable yield

#### Effects of non-woven cover

Use of the non-woven cover had no effect on marketable yield.

#### Effects of mulches

In both experiments, a significantly higher yield was obtained from beds covered with soil mulches than from uncovered beds (Table 5). At Rovaniemi, although use of the white-on-black film

increased the marketable yield, the difference was not statistically significant as compared with the yield from uncovered plots.

#### Interactions

At Rovaniemi, there was a significant interaction between the non-woven cover and the harvest year (Table 5). When the non-woven cover was used in autumn 1991 and spring 1992, the yield was significantly higher ( $P < 0.01$ ) than that from uncovered plots (Fig. 3). At Sotkamo, there was an interaction between soil mulches and the harvest year (Fig. 4). A significantly higher yield was obtained in 1991 with Mypex ( $P < 0.001$ ) and with black film cover in both 1991 and in 1992 ( $P < 0.001$  and  $P < 0.05$ ) than with no bed cover. With the white-on-black film, a significantly higher yield was obtained in all three harvest years (1991 and 1992  $P < 0.001$  and 1993  $P < 0.05$ ).

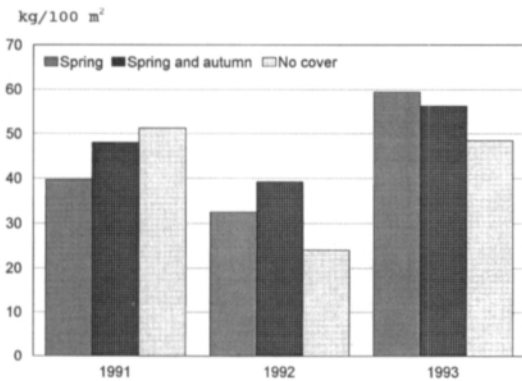


Fig. 3. Combined effect of non-woven crop cover and harvest year on marketable yield at Rovaniemi.

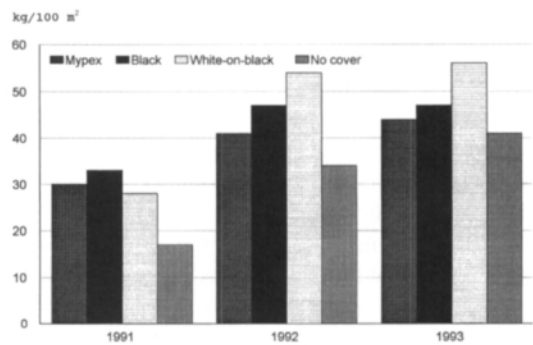


Fig. 4. The Combined effect of soil mulches and harvest year on marketable yield at Sotkamo.

## Mouldy berries

At Sotkamo, there was a significant interaction between the non-woven cover and soil mulches in the amount of mouldy berries (Table 5). When the non-woven cover was used in spring with black mulch, there were significantly fewer mouldy berries ( $P < 0.05$ ), than when no cover was used. At Rovaniemi, use of the non-woven cover in spring did not have a significant effect on the amount of mouldy berries, except in 1991 ( $P < 0.05$ ) when it decreased the amount of such berries.

## Small berries

At Sotkamo, the effect of the non-woven cover on the proportion of small berries in the early harvest significantly depended on the harvest year. In 1991, use of the non-woven cover in spring, or in autumn and spring, ( $P < 0.001$  and  $P < 0.001$ ) significantly increased the proportion of small berries in comparison with no use of the non-woven cover. At Rovaniemi, use of the non-woven cover in spring did not have a significant effect on the proportion of small berries in the early harvest in comparison with that of no use of the non-woven cover.

## Length and development of the strawberry root system

Development of the strawberry root system was evaluated to see whether the roots were better developed near the surface of the soil or deeper down in the soil. The differences in the development and density of the roots were small. At Rovaniemi, the effect of the non-woven cover and mulches on the length of the strawberry root system did not differ significantly from that of a non-woven cover or mulch. At Sotkamo, only the use of Mypex film was statistically significant ( $P < 0.01$ ). In uncovered beds, the roots were 4 cm longer than in beds covered with Mypex film.

## Discussion

In Norwegian trials, non-woven covers (Agryl p 17) advanced crop ripening by 5–6 days (Meland 1986), and in Finnish trials by 3–5 days (Laurinen and Säkö 1987). Polling et al. (1991) reported that, in general, plots covered either in spring or in both winter and spring gave higher early yields than did uncovered plots and, according to Karen et al. (1989), low temperatures in spring can damage flowers and delay anthesis and fruit ripening. Our 3-year field trial shows that use of a non-woven cover on plots in spring significantly advanced the harvest, which was 4 to 9 days earlier than in uncovered plots, depending on the year.

According to Pollard and Cundari (1987), use of a non-woven cover in autumn and in spring increases the marketable yield, and according to Wals and Loy (1985), row covers extend the season by retaining heat during periods of falling ambient temperature. Such covers are especially suitable for high-value field crops in climates where plants are exposed to low temperature stress or frost during autumn, winter or spring. In our present study, use of a non-woven cover in both autumn and spring at Rovaniemi, especially in a cold year like 1991, when the weather was exceptionally cold in September, and the frost came at the beginning of September already, led to an increase in the marketable yield. This increase suggests that the covers not only protected floral buds from early autumn frosts but that they may also extend the period of flower bud initiation. More studies should be carried out to establish whether or not non-woven covers really do have such a protective effect in autumn.

In northern latitudes non-woven covers did not have much effect on the size of berries. On the contrary, in warm years, they even reduced the marketable yield by increasing the percentage of small berries.

The present experiment showed that significantly higher marketable yields were obtained from beds covered with soil mulches than from unmulched beds. In warm years, the highest



yields were obtained from beds covered with white-on-black film, indicating that such film may be the most suitable mulch for warmer areas. Lieten (1991) and Himelrick et al. (1996) also found that the white-on-black film gave the lowest soil temperatures, about 3°C below those with black polyethylene. This delayed cropping by a few days but gave a significantly higher yield.

Himelrick et al. reported that average soil temperatures from highest to lowest were found with black, black-on-white, clear, IRT-76, ALOR brown, red, silver and white-on-black film; the temperature of bare soil was the lowest of all.

As found elsewhere (Laurinen and Säkö 1987), the use of a row cover decreased the amount of mouldy berries.

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## SELOSTUS

### Katteiden käyttö mansikanviljelyssä

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*Maatalouden tutkimuskeskus*

Maanpeite- ja kasvustokatteiden vaikutusta mansikan sadon ajoitukseen, määrään ja laatuun tutkittiin vuosina 1989–93 Pohjois-Suomessa. Harsoa käytettiin kokeessa kahdella tavalla: 1) harso levitettiin kasvuston päälle heti kevätpuhdistuksen jälkeen ja poistettiin kukinnan alkaessa, 2) edellisen lisäksi harso levitettiin uudelleen elokuussa sadonkorjuun jälkeen ja sen annettiin olla kasvuston päällä ilmojen kylmenemiseen saakka. Maanpeitteenä käytettiin Mypex-tekangasta, mustaa muovia tai valkoista muovia, jonka alapinta oli musta. Lisäksi verranteena kasvatettiin mansikkaa ilman harsoa ja katetta.

Harson käyttö aikaisti satoa 4–9 päivää. Kylminä keväinä harson käyttö lisäsi kauppakelpoista satoa hiukan, kun taas lämpiminä keväinä harso lisäsi

pienien marjojen osuutta ja sen seurauksena vähensi kauppakelpoisen sadon määrää. Harson käyttö sekä syksyllä että keväällä ja erityisesti viileänä syksynä lisäsi kauppakelpoista satoa. Syynä saattaa olla se, että mansikan kukka-aiheiden muodostuminen voi jatkua syksyllä pidempään. Maanpeitekatteista vain musta muovi aikaisti satoa 1–2 päivää ilman maanpeitettä kasvatettuun mansikkaan verrattuna. Sen sijaan valkoinen muovi hidasti sadon kypsymistä 1–3 päivää. Ylensä maanpeitekatteiden käyttö lisäsi kauppakelpoista satoa. Kuumina kesinä paras kauppakelpoinen sato saatiin valkoisen muovikatteen avulla, joten sen käyttö on yksi vaihtoehto lämpimille alueille.