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Effect of combined seasonal coverage on northern production of strawberry (*Fragaria ananassa* Duch)

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Abstract

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Two field trials with five strawberry cultivars planted on a woven black polyfibre ground cover sheet with or without translucent sheet plant coverage during winter and the growing season as combined treatments were started in 2004 and 2005. In total, nine different cultivars were included in the two fields. One early cv. 'Polka' and one late cv. 'Korona' acted as standard cultivars, while the other cultivars were new, named or labelled selections from Norwegian, Finnish and Swedish breeding programs. Winter survival, spring vigour, earliness, saleable and total berry yield, berry size and berry quality were registered for three years. The cultivars differed in earliness, berry size, yield (gram per plant) and total production (sum of all years). A combination of fibre sheet winter and spring coverage and more open net sheet harvest season coverage showed favourable results for overwintering, earliness and berry yield, and enhanced the ripening process in all cultivars.

Keywords: cultivars; winter survival; earliness; berry yield; berry size

The cultivated strawberry (*Fragaria ananassa* Duch), a hybrid of *Fragaria chiloensis* and *Fragaria virginiana*, is an important and very popular soft fruit produced mostly in temperate areas worldwide. The genetic background of the cultivated strawberry suggests that it is not an optimal crop for cultivation in Northern Scandinavia. Strawberry production is limited by low temperatures during the whole life cycle of the plants. Floral buds are initiated under shorter photoperiods in autumn (Heide 1977; Sønsteby, Heide 2006). When temperatures reach below 9°C floral bud initiation in the cultivar 'Korona' eventually stops (Sønsteby, Heide 2006). Frost damage during winter, e.g. due to lack of snow cover, damage crowns resulting in poor spring growth while low spring temperatures may damage flowers and delay anthesis and fruit ripening (Gast, Pollard 1989).

Most commercial varieties are physiologically adapted to more southerly growth conditions than Northern Scandinavia and need short days and relatively high temperatures in autumn to produce flower buds/initials for next season's flowers (Sønsteby, Heide 2007). Hence, the short growing season with low temperatures in the north poses a challenge for the growers when choosing cultivars and growing methods. However, cultivars respond differently to varying photoperiod and temperatures, and some cultivars, like the Nordic 'Zephyr' and 'Glima', are able to initiate flower buds even

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under climatic conditions with long days and low temperatures (Heide 1977; Samuelsen, Nilsen 1995).

Northern growth conditions with low temperatures and 24-hour photoperiod during ripening were shown to produce sweeter fruits in several berry fruits such as bilberries (Uleberg et al. 2012). An early Finnish study (Hårdh, Hårdh 1977) found that sugar and dry matter contents were higher in strawberries grown in the northern than in the southern part of Finland. Similarly in a Norwegian study (Davik et al. 2006) the total sugar content increased with decreasing temperature for 10 different strawberry cultivars, among them 'Korona', 'Polka', 'Babette', 'Carmen' and 'Hanibal' – five of the cultivars in our field trials.

In Norway, 50% of the primary value of the fruit and berry industry originates from strawberry (Davik et al. 2000). However, strawberry production is very low in Northern Norway. In order to increase and stabilize commercial production and make the production more predictable and profitable in Northern Norway it is crucial to develop northerly-adapted cultivars and cultivation methods that improve the growing conditions. Frost-injured plants are one of the factors that most strongly influence strawberry fruit yield and size in Norway (Nestby, Bjørgum 1999). Frost injuries may occur during winter as well as during the flowering period in spring or early summer. Translucent sheet covering during the growing season increase temperature and enhance growth and development of the plants. Nestby et al. (2000) reported promising response of winter coverage on the traits overwintering and berry yield. Differences between cultivars and selections for winter survival, earliness and berry yield have also been reported previously (From, Davik 2003). The aims of our trials were to evaluate a combined winter and growing season coverage to different cultivars and breeding selections under the climatic conditions of Tromsø, Norway.

MATERIAL AND METHODS

Test fields. Two test fields were established at Bioforsk Nord Holt, Tromsø, Norway, 69°39'N and 18°56'E in 2004 and 2005. The fields were positioned in a 20% westerly slope 20 m a.s.l. with soil type mr saSI-siMS (3–6% ignition loss, sandy silt/sandy loam). In 2004 fresh plug plants of five cultivars ('Hanibal' (Norway), 'Polka' (Netherlands), 'Carmen' (Norway), PK97.62.2 (Norway) and 'Babette' (Norway)) were planted on woven black polyfibre ground cover sheet with or without translucent sheet plant coverage during the winter and the growing season as combined treatments. The combination of cultivar and coverage had two replicates. Each subplot consisted of 7 plants, and observations were recorded on 5 of these plants. A paralleled field trial with five cultivars ('Kaunotar' (Finland), 'Polka' (Netherlands), 'Kulkuri' (Finland), Bfr.949603 (Sweden) and 'Korona' (Netherlands)) and the same treatment combinations was established in 2005.

One early ('Polka') and one late cultivar ('Korona') acted as standard cultivars, while the other cultivars were new, named or unnamed (labelled) selections from Norwegian (Davik 2003; Davik et al. 2005), Finnish and Swedish breeding programs. The cultivars were selected based on available information on earliness, berry size, disease resistance and winter hardiness (From, Davik 2003).

Plant and row distances varied between the years with 0.325×0.95 m^2 and 0.325×1.20 m^2 for the plants established in 2004 and 2005, respectively. Surface area per plant was 0.30 m^2 in 2004 and 0.48 m^2 in 2005. Plants from additional cultivars and selections ('Korona', PL98.115, PK97.62.2, 'Babette', 'Hanibal', 'Zephyr', 'Glima' and 'Kulkuri') were planted as border plants in the fields.

Spring vigour, earliness, saleable and total berry yield, berry size and berry quality were registered in 2005, 2006 and 2007, while winter survival was registered in 2006, 2007 and 2008.

Soil preparation and fertilization. The fields were sprayed by glyphosate (Roundup ECO Felleskjøpet) and the soil was ploughed, harrowed and fertilized (Fullgjødsel® 11-5-18 NPK micro (Norsk Hydro, Norway) and Borax (Neobor – US. Borax Inc., USA – Felleskjøpet)) the planting year to add the following amounts of macronutrients; N: 49.5 kg/ha; P: 22.5 kg/ha; K: 81 kg/ha; Mg: 8.1 kg/ha and Ca: 11.2 kg/ha. No fertilizers were added in the berry production years 2005–2007 and the fields were not irrigated.

Establishment of the field. The planting dates were July 27, 2004 and June 20, 2005, with one exception. Plantlets of the Swedish selection Bfr.949603 were received as late as August 31, 2005, but were well rooted and planted in the field on 14 September

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Table 1. Overview of the field trial characteristics from 2004–2008

Year	P	WU	SFC	SFU	SNC	SNU	WC	FS-free	Temp. (°C)	Precip. (mm)	Ann. precip. (mm)
2004	27 Jul	–	–	–	–	–	28 Oct	–	–	–	–
2005	20 Jun	10 May	10 May	13 Jun	30 Jun	12 Oct	27 Oct	1/5–21/10	9.46	480	1,044
2006	–	12 May	12 May	15 Jun	10 Jul	29 Sep	5 Dec	16/5–21/9	9.62	292	1,009
2007	–	14 May	14 May	20 Jun	12 Jul	4 Oct	6 Dec	26/4–9/11	9.70	332	943
2008	–	2 Jun	–	–	–	–	–	–	–	–	–

P – planting; WU – winter uncovering; SFC – spring fibre sheet covering; SFU – spring fibre sheet uncovering; SNC – season net sheet covering; SNU – season net sheet uncovering; WC – winter covering; FS-free – snow free season, Temp. – mean temperature May 1–Sept 30; Precip. – precipitation May 1–Sept 30; Ann. precip. – annual precipitation

and covered with translucent fibre sheet for three weeks at the end of the planting year season.

Covering. The ground was covered with woven black polyfibre cover sheet (MyPex; LOG, Norway) and the soil surface was kept flat. The plants on the covering treatment plots were covered with fibre sheet (Agryl P17; LOG, Norway) from field cleansing at growth start in spring till flowering start, to enhance both growth and flowering. The spring fibre sheet replaced the winter cover and was kept on average 34 days (min. 31 days in 2006 and max. 37 days in 2007). After spring the fibre sheet coverage was removed and a period without coverage followed to secure good pollination; on average 21 days (min. 17 days in 2005 and max. 25 days in 2006). After the uncovered period a net sheet (Agrocover; LOG, Norway) was applied and kept during the harvest season in order to improve the ripening temperature and protect the berries from bird attacks (Table 1). The net sheet was removed after the last harvest date, varying from Septemeber 29 in 2006 to October 12 in 2005. The plots were then kept uncovered until the winter season coverage was applied with a thicker fibre sheet (Agryl P30; LOG, Norway), from first autumn frost till growth start the following spring. Winter season coverage aimed to protect the plants from frost injury. Winter coverage was commenced in the end of October in 2004 and 2005, and as late as the beginning of December in 2006 and 2007. The winter covering was removed earliest on May 10 (2005) and latest on June 2 (2008). An overview of the established field plots with dates and year of planting and covering are summarised in Table 1.

Overwintering. Plant vigour (1–9, where 9 was the best score) and the number of winter surviving plants (0–5, of the observed plants in each plot) were recorded each spring and these recordings formed the basis for the plant overwintering index (POI = (plants surviving winter/5) × (spring vigour/9) × 100).

Statistical analysis. Data were analysed by the General Linear Model (GLM) procedure in Minitab 17 (Minitab, USA) to evaluate the main effects of variety, cover treatment, plant year and harvest year and date, as well as their interactions, on the evaluated traits.

RESULTS AND DISCUSSION

Earliness

Earliness is one of the main factors affecting northern berry production. In these trials earliness of flowering was strongly improved by the cover treatment and enhanced the first day of flowering (mean of all cultivars) with 7 days, 13 days and 10 days in 2005, 2006 and 2007, respectively (Table 2). All cultivars responded to the covering treatment and there were no significant differences between cultivars. Covering increases both the spring temperatures during flower development and autumn temperatures (Pietilä et al. 2002). Increment of autumn temperatures enables the developmental stages of the flower initials to reach a higher level (Sønsteby, Heide 2007), and thus accelerate flower development in spring. The cumulative effect is reflected by significantly earlier flowering. The positive effect of covering on the first flower date was reflected in the date for 50% harvested yield. In 2005 covered plants reached 50% harvest 11 days earlier than uncovered plants, while the difference were 13 and 5 days in 2006 and 2007, respectively. Pietilä et al. (2002) did a study on covering with non-woven fabrics from 18th Sep-

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Table 2. Earliness of the cultivars expressed by the flowering start dates and by the dates for 50% saleable berry yield with and without combined seasonal coverage in 2005, 2006 and 2007. Flowering start and 50% harvested berries were not recorded in 2005 for cultivars planted in 2005

Cvs	Flowering start						50% harvested					
	2005		2006		2007		2005		2006		2007	
	uncovered	covered	uncovered	covered	uncovered	covered	uncovered	covered	uncovered	covered	uncovered	covered
Babette	20 Jun	11 Jun	4 Jul	24 Jun	5 Jul	26 Jun	13 Aug	25 Jul	30 Aug	17 Aug	13 Aug	8 Aug
Carmen	23 Jun	19 Jun	7 Jul	17 Jun	28 Jun	12 Jun	13 Aug	3 Aug	27 Aug	16 Aug	2 Aug	30 Jul
Hanibal	20 Jun	11 Jun	9 Jul	19 Jun	4 Jul	14 Jun	15 Aug	8 Aug	30 Aug	14 Aug	9 Aug	28 Jul
PK 97.62.2	25 Jun	18 Jun	8 Jul	28 Jun	2 Jul	29 Jun	8 Aug	29 Jul	29 Aug	17 Aug	9 Aug	6 Aug
Polka	21 Jun	17 Jun	8 Jul	24 Jun	29 Jun	18 Jun	13 Aug	6 Aug	27 Aug	18 Aug	9 Aug	6 Aug
Mean	21 Jun	15 Jun*	7 Jul	22 Jun***	1 Jul	19 Jun***	12 Aug	1 Aug.***	28 Aug	16 Aug***	8 Aug	3 Aug*
Bfr 949603[z]	–	–	30 Jun	18 Jun[B]	8 Jul[A]	2 Jul	–	–	22 Aug	9 Aug	20 Aug	11 Aug
Kaunotar [z]	–	–	6 Jul	30 Jun[A]	4 Jul[AB]	23 Jun	–	–	29 Aug	15 Aug	10 Aug	4 Aug
Korona [z]	–	–	11 Jul	3 Jul[A]	4 Jul[AB]	23 Jun	–	–	30 Aug	19 Aug	13 Aug	8 Aug
Kulkuri [z]	–	–	7 Jul	18 Jun[B]	29 Jun[B]	18 Jun	–	–	2 Sep	16 Aug	10 Aug	4 Aug
Polka [z]	–	–	11 Jul	28 Jun[A]	2 Jul[AB]	24 Jun	–	–	30 Aug	15 Aug	9 Aug	8 Aug
Mean	–	–	7 Jul	25 Jun***	3 Jul	24 Jun***	–	–	28 Aug	14 Aug***	12 Aug	7 Aug*

[z]flowering start and 50% harvested berries were not recorded in 2005 for cultivars planted in 2005; [A,B] – different letters indicate that the values differ significantly at $P \leq 0.05$; $^{*}P \leq 0.05$, $^{***}P \leq 0.001$

tember to 27th May in North Finland (64°N) and found that covering promoted early yields and also concentrated the yield in a shorter season. For the cultivar 'Polka' our results confirmed the results reported by Pietilä et al. (2002), that 'Polka' is a cultivar that responds to winter cover protection by producing an earlier yield. The time of 50% harvest is determined both by early flowering and by a reduction in time between flowering and ripening. Ferguson (1971) screened for earliness in as many as 40 different strawberry cultivars and concluded that earliness of flowering and the rate of fruit development should be considered as two independent processes. The number of days between flowering and 50% harvest were longer with cover than without it (49.5 versus 46.5 days on average over all three harvest years) for Field 1, while the number of days were equal in Field 2 (46 versus 47 days on average over all three harvest years). Thus, the positive effect of covering on 50% harvest time was mainly due to an earlier season start. These results could however be shaded by the fact that covered plants developed higher numbers of flowers and berries and higher berry yields than uncovered plants. As a result the covered plants might have needed more time to complete berry development, ripening and harvest, compared to uncovered plants.

Yield

Number of berries, and saleable yield per plant. The number of berries and the saleable berry yield increased during the observation years as the plants grew older (Figs 1 and 2, Table 3). Coverage did not increase the yield the first harvest season, where the yield was equal between treatments in Field 1 while uncovered plots yielded highest in Field 2. Coverage showed a favourable effect on yield the second and third harvest year, and the differences in berry production increased with plant age (Fig. 2). Both fields showed a significant effect of covering on berry yield the last harvest year (2007), and also on total berry production over three (Field 1) and two (Field 2) years (Fig. 1). 'Polka' produced most berries the third year (Field 1) both without (62.7 berries per plant) and with coverage (99.8 berries per plant), and was the cultivar that seemed

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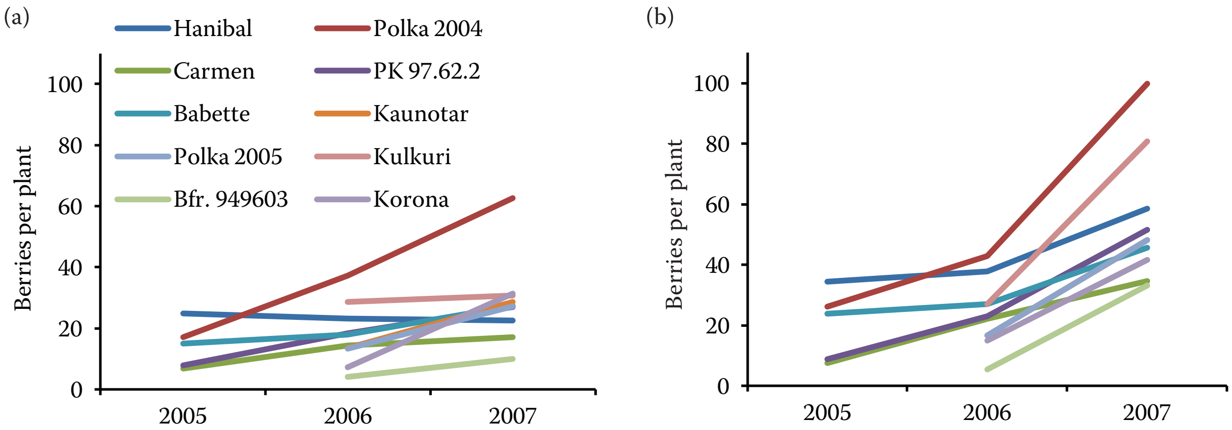

Fig. 1. Berry production per cultivar expressed as number of berries per plant (a) without cover and (b) with cover for the years 2005, 2006 and 2007

to be less affected by the northern climate. The Finnish cultivar Kulkuri produced most berries in Field 2 after two years with cover (80.8 berries per plant), while without cover all cultivars except Bfr.949603 produced equal berry numbers. Accumulated saleable yields (g/plant) for all harvest years (Table 3) were the highest for 'Hanibal' and 'Polka' (Field 1) the different cultivars respond differently to different growing methods as expressed by earliness and total yield, while the berry size is mainly determined by the cultivar (genetic factors). Different cultivars did not differ in percentage of saleable yield in any of the production years. However, the total production varied a lot between cultivars, and they also responded differently to the covering treatments.

Berry size. Berry size decreased with plant age and increasing berry number per plant. The reduction was small between the first and second harvest year for most cultivars, but profound between the first and third year, indicating that also environment influenced the reduction. In general, berry size is affected by environmental conditions like temperature (Døving, Måge 2001), water status (Peñuelas et al. 1992), UV radiation (Tsormpatsidis et al. 2011) and nutrition (Opstad, Sønsteby 2008) during berry development from flowering to ripening, in addition to the genetic background (Opstad et al. 2011). In addition, berry size will also change during the season, and as the plants develop and grow older from season to season, due to increasing numbers of berries (Hortyński et al. 1991). The mean berry size was significantly reduced with plant covering, and the size reduction was more or less obvious for all cultivars. The highest reduction between 2005 and 2007 was observed for 'Carmen' (39%) and 'Hanibal' (32%). 'Carmen' had very large berries (26.3 g) in the first harvest year 2005, while the other cultivars had quite even berry weights (between 15.8 and 17.5 grams). The amount of small berries increased under coverage, probably due to increased temperature, as reported by several (Hellman, Travis 1988; Miura et al. 1994; Wang and Camp 2000; Josuttis et al. 2011). Small berries are not included in our observations of saleable yield, but the saleable yield proportion of the total yield was equal with and without coverage. This is explained by an increase in both the saleable and total yield with coverage.

Overwintering

The plants developed satisfactorily during both planting years, and all plants survived through the relative mild first winter 2004–2005. Only two young, uncovered plants of the late planted Swedish selection Bfr.949603 died during winter 2005–2006, and most of the plants survived until spring 2008.

Effect of covering and cultivar. Uncovered plants had decreasing overwintering indices during the three observation years, whereas covered plants kept their high indices or increased them (Table 4). This was clearest expressed in 2008, when uncovered plants scored very low overwintering indices. Among cultivars the highest overwintering indices were achieved by the control cultivars 'Polka' and 'Korona'. Low overwintering index for Bfr.949603 in spring 2006 may partly be explained as a result of late planting and hence a short plant establishing period in autumn 2005 (Table 4). Late spring frost

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Table 3. Saleable berry yield in 2005, 2006 and 2007

Cvs	Saleable yield per plant (g/plant)											
	2005			2006			2007			total		
	uncovered	covered	mean	uncovered	covered	mean	uncovered	covered	mean	uncovered	covered	mean
Babette	218.2^{B}	276.0^{AB}	247.1^{B}	208.5^{B}	317.7	263.1^{AB}	341.0	436.4	388.7	767.6^{AB}	1,030.2^{AB}	898.9^{AB}
Carmen	152.4^{B}	146.5^{B}	149.4^{BC}	237.5^{AB}	392.0	314.7^{AB}	251.7	473.4	362.6	641.6^{AB}	1,011.9^{AB}	826.7^{AB}
Hanibal	406.3^{A}	449.2^{A}	427.7^{A}	249.8^{AB}	402.2	326.0^{AB}	266.8	541.9	404.3	922.9^{AB}	1,393.2^{A}	1,158.0^{A}
PK 97.62.2	95.4^{B}	96.8^{B}	96.1^{C}	180.1^{B}	268.1	224.1^{B}	255.1	450.2	352.6	530.6^{B}	815.1^{B}	672.9^{B}
Polka	167.9^{B}	210.0^{B}	188.9^{BC}	453.3^{A}	398.7	426.0^{A}	369.1	580.9	475.0	990.3^{A}	1,189.6^{AB}	1,089.9^{A}
Mean	208.0	235.7	221.9	265.8	355.7*	310.8	296.7	496.6***	396.6	770.6	1,088.0***	929.3
Bfr 949603^{z}	–	–	–	25.5^{B}	46.3^{B}	35.9^{C}	64.9^{B}	379.0	222.0^{AB}	90.4^{C}	425.3	257.9^{C}
Kaunotar^{z}	–	–	–	95.5^{B}	103.0^{AB}	99.3^{BC}	170.3^{AB}	202.4	186.3^{B}	265.8^{BC}	305.4	285.6^{BC}
Korona^{z}	–	–	–	121.9^{B}	145.0^{AB}	133.4^{BC}	352.2^{A}	340.4	346.3^{AB}	474.0^{AB}	485.4	479.7^{AB}
Kulkuri^{z}	–	–	–	293.5^{A}	172.2^{AB}	232.8^{A}	295.1^{A}	465.8	380.5^{A}	588.6^{A}	638.0	613.3^{A}
Polka^{z}	–	–	–	170.3^{AB}	223.9^{A}	197.1^{AB}	209.6^{AB}	387.5	298.5^{AB}	379.9^{AB}	611.3	495.6^{AB}
Mean	–	–	–	141.3	138.1	139.7	218.4	355.0**	286.7	359.7	493.1**	426.4

^{z}cultivars planted in 2005 (lower part of table) have no recorded yields before 2006; ^{A,B} – different letters indicate that the values differ significantly at $P \leq 0.05$; $^{*}P \leq 0.05$, $^{***}P \leq 0.001$

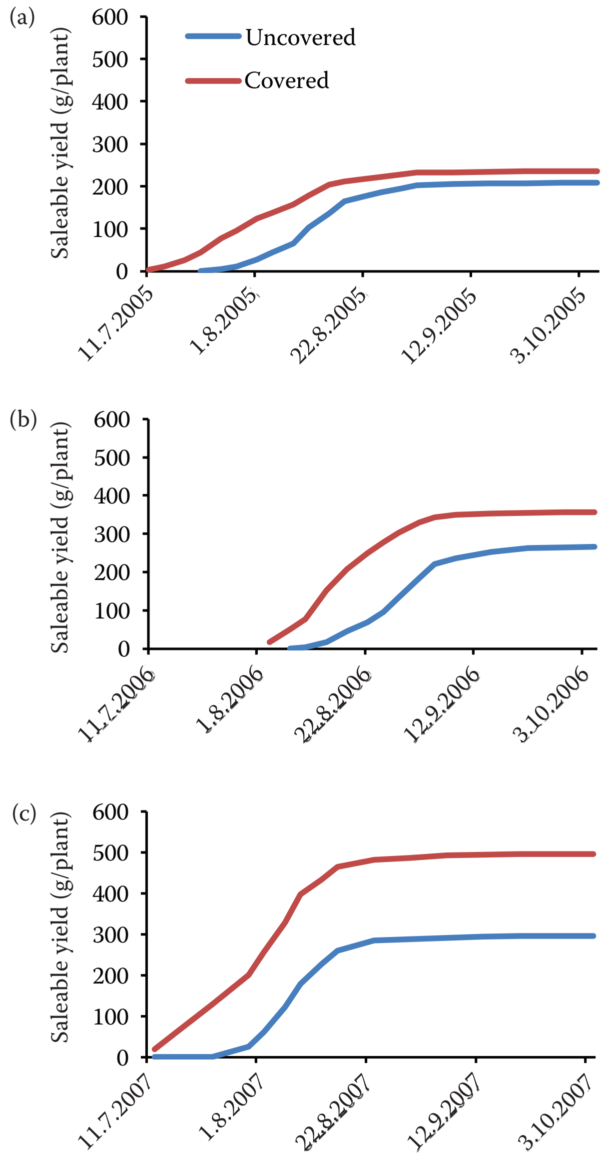

Fig. 2. Effect of coverage on accumulated saleable yield (mean of all cultivars for each of three years 2005, 2006, and 2007

causes injuries to flowers and reduces yields (Shokaeva 2008), and covering during spring might protect against frost and thus reduce the damages. However, late spring frost was not observed in these trials, and is neither considered a crucial limitation for strawberry growing along the Norwegian coastal districts. Our findings confirmed the results of Nestby et al. (2000), who concluded that use of winter cover reduced freezing injuries of strawberries in a coastal and continental climate. However, these studies included only winter season covering.

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Table 4. Plant overwintering index (POI; 0–100 %) at Holt, Tromsø 2006–2008, POI = (plants surviving winter/5) × (spring vigour/9) × 100

	2006		2007		2008		Mean	
	uncovered	covered	uncovered	covered	uncovered	covered	uncovered	covered
Babette	78	83	56	78^{AB}	33	81	56	81
Carmen	50	72	40	67^{B}	44	89	45	76
Hanibal	56	78	39	78^{AB}	18	83	38	80
PK 97.62.2	61	67	50	72^{B}	33	83	48	74
Polka	67	89	74	94^{A}	42	84	61	89
Mean	62	78^{*}	52	78^{***}	34	84^{***}	49	80^{***}
Bfr. 949603	29	39	46^{B}	78	33	67	36	61
Kaunotar	61	72	50^{B}	67	33	61	48	67
Korona	72	67	78^{A}	72	44	89	65	76
Kulkuri	72	72	44^{B}	78	39	72	52	74
Polka	61	72	61^{AB}	94	42	84	55	83
Mean	59	64	56	78^{**}	38	75^{***}	51	72^{***}

^{A,B}different letters indicate that the values differ significantly at $P \leq 0.05$; $^{*}P \leq 0.05$, $^{***}P \leq 0.001$

Covered plants had significantly higher overwintering indexes than uncovered for both fields in 2007 and 2008 and totally for all years. In 2006, there was a significant effect of coverage in Field 1, but no effect in Field 2. The positive effect of coverage was the highest in 2008. In total over the three years there were no significant differences between the cultivars, but in 2007 covered plants of 'Polka' had a significantly higher index than 'Carmen' and PK 97.62.2 (Field 1), while uncovered plants of 'Korona' had a significantly higher index than Bfr. 949603, 'Kaunotar' and 'Kulkuri' (Field 2).

CONCLUSION

A combination of a translucent fibre sheet winter and spring coverage and a more open net sheet harvest season coverage showed favourable results for earliness of all cultivars, and for berry yield of the three highest yielding cultivars. The cultivar 'Polka' was the all-over best performing cultivar. Covering treatment enhanced vegetative and flower development and the ripening process in all the cultivars. Optimal types of plant coverage still have to be developed, and their optimal practical utilization has to be studied in future laboratory and field experiments. The field trials demonstrate that strawberries can be produced also in northern Scandinavia when combining knowledge about cultivars, growing techniques and market demands.

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