11. Rose, A.J. and G. Yelenosky. 1978. Citrus trunk wrap evaluations. Proc. Fla. State Hort. Soc. 91:14–18.
12. Turner, W.C. and J.F. Malloy. 1981. Thermal insulation handbook. McGraw-Hill, New York.
13. Turrell, F.M. 1973. The science and technology of frost protection, p. 338–446. In: W. Reuther (ed.). The citrus industry, vol. III. Univ. of California, Berkeley.
14. Yelenosky, G. 1981. A new insulator wrap to protect young citrus trees during freezes. HortScience 16:44–45.
15. Young, R.H., J.E. Fucik, and R.A. Hensz. 1967. Tests of insulating materials for citrus tree trunk freeze protection using controlled freeze conditions. J. Rio Grande Valley Hort. Sci. 21:74–79.

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Over-wintering Strawberry Plants under Rowcovers Increases Fruit Production

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Abstract. **Over-wintering strawberry (*Fragaria* ×*ananassa* Duch.) plants under rowcovers applied in early Fall 1983 through 1985, and removed in spring at first bloom, significantly increased production of marketable fruit. Spunbonded rowcovers of nylon or polyester were more effective than those of slitted polyethylene. In years when winter injury affected fruit production in noncovered controls, addition of a winter-protective mulch to rowcovered treatments in early December had no effect on fruit production, compared to rowcovered treatments without winter mulch. In years when winter injury was not a factor affecting production, addition of winter mulch to rowcovers nullified the rowcover effect on production. Accumulation of degree days (base 10°C) in soil and air in rowcovered plots was significantly greater than in noncovered plots. The rowcover effects influencing fruit production appeared to occur in winter and/or spring rather than in the fall.**

Cultural systems that use light-weight perforated plastic films and spunbonded textiles as rowcovers to modify microclimates and improve production of high-value horticultural crops are being developed in Europe, Japan, and North America. The primary objective of recent rowcover research has been to develop economical cultural systems for vegetables and fruits that can increase production where productivity is limited by a short growing season and/or by low-temperature stress or frost during winter or spring (6, 10).

Strawberry fruit production may be limited by low temperatures during autumn, winter, or spring in many temperate regions. Low temperatures during bloom and in the fall and winter can destroy flowers and buds (2, 8). In addition, many cultivars raised in these regions are obligate short-day plants with specific photoperiod and temperature requirements for flower bud initiation (1, 3, 7). In many regions, flower bud initiation is restricted to the short days of autumn because temperatures are too low for initiation during the short days of winter and spring. Moderation of low temperatures during critical periods for flower bud initiation and survival may attenuate some of the factors limiting production (9).

The objectives of these experiments were to determine the effects of overwintering plants under fall-applied rowcovers on accumulation of heat units during autumn and spring and on fruit production in short-day strawberries.

Plants were set in early May 1982, 1983, and 1984 in single rows on 25-cm-high ridges at 10 cm between plants and 91 cm between rows. The cultivars were 'Darrow' in 1982 and 1983 and 'Earliglow' and 'Sparkle' in 1984. A mulch of salt marsh hay was applied to the soil at 4.5 $t \cdot ha^{-1}$ 2 weeks after planting. All stolons and flowers were removed during the first growing season. Application of nutrients, herbicides, pesticides, and irrigation were consistent with recommendations of the New Hampshire Cooperative Extension Service for commercial strawberry plantings (5). A winter-protective mulch of salt marsh hay was applied to appropriate treatment plots in early December of each year at 4.5 $t \cdot ha^{-1}$ and remained in place until late April. Irrigation for frost control was applied during bloom. Data were collected for marketable fruit from the maiden harvest in each planting. Marketable fruit were defined as disease-free, uniformly shaped, mature berries with a mass ≥ 5.0 g.

Treatments were fall-applied rowcovers with and without winter-protective mulch and no rowcovers with and without winter-protective mulch. Four types of rowcovers were evaluating during this period. They were spunbonded nylon and slitted polyethylene in 1982–83, spunbonded polypropylene in 1984–85, and spunbonded polyester in all 3 years 1982–83 through 1984–85.

Rowcovers were applied in mid-September and remained in place until first bloom the next spring. All spunbonded rowcovers were of 20 $g \cdot m^{-2}$ material. Slitted polyethylene rowcovers were of 100-μm-thick material with two rows of slits 25 cm apart. Slits were 15 cm long spaced 10 cm apart. All rowcovers were supported by the plant canopy and were secured to the soil with U-shaped wire pins or with a shovelful of soil about every 2 m.

Temperatures from copper–constantan thermocouples were recorded hourly on a Doric Minitrend 205 (Doric Scientific, San Diego, Calif.) in Fall 1985 (8 Sept.–23 Nov.) and Spring 1986 (17 Mar.–7 May) in separate plots covered with spunbonded polypropylene (4). Air temperatures were measured at 5 cm above the soil surface. These thermocouple junctions were shielded from direct sun with chrome-painted, T-shaped polyvinylchloride pipe joints. Soil temperatures were measured 5 cm below surface. To avoid confounding temperature data, no irrigation was applied for frost control in this experiment. Three frosts during bloom severely damaged blossoms and fruit set; therefore, no fruit production data were collected from these plots.

Experimental designs for fruit production and degree-day experiments were either completely randomized or randomized complete block with six replications.

All rowcovers increased production of marketable fruit over the noncovered mulched control (Table 1). In 1983, spunbonded nylon and spunbonded polyester treatments were equally effective at increasing production above the control, and both produced more fruit than slitted polyethylene. In 1985, spunbonded polypropylene and spunbonded polyester treatments were equally effective in increasing production above controls.

Spunbonded polypropylene was not available for evaluation in 1983 and 1984. Spunbonded nylon was omitted from experiments in 1984 and 1985 because, in 1983, it was no more effective for increasing production than spunbonded polyester, it was suscepti-

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Table 1. Effect of type of rowcover of marketable fruit.

Rowcover type	Marketable fruit[zy] (g/plot) 1983	1984	1985
Spunbonded nylon	785 a[x]	---	---
Spunbonded polyester	723 a	1383 a	988 a
Spunbonded polypropylene	---	---	1009 a
Slitted polyethylene	561 b	---	---
Noncovered mulched control	460 c	1067 b	774 b

[z]Disease-free, uniformly shaped, mature berries ≥ 5 g.
[y]Cultivars: 1983–84, 'Darrow'; 1985, 'Earliglow' and 'Sparkle'.
[x]Mean separation within columns by Duncan's multiple range test, $p = 5\%$.

Table 2. Marketable fruit after fall application of spunbonded polyester rowcovers with and without winter mulch, 1983–85.

Treatment	Marketable fruit[zy] (g/plot) 1983	1984	1985	Total
Rowcovered nonmulched	723 a[x]	1383 a	988 a	3094
Rowcovered mulched	785 a	1002 b	826 b	2613
Noncovered mulched	460 b	1067 b	774 b	2301
Noncovered nonmulched	339 c	1005 b	746 b	2090

[z]Disease-free, uniformly shaped, mature berries ≥ 5 g.
[y]Cultivars: 1983–84, 'Darrow'; 1985, 'Earliglow' and 'Sparkle'.
[x]Mean separation within columns by Duncan's multiple range test, $p = 5\%$.

Table 3. Cumulative degree days (base 10°C) for rowcovered and noncovered strawberries, 1985–86.

Treatments and thermocouple locations	Degree days Fall 1985 (8 Sept.–23 Nov.)	Spring 1986 (17 Mar.–7 May)	Total (Fall + spring)
Soil (5 cm)			
Noncovered	94 a[y]	7 a	101 a
Rowcovered[z]	153 b	117 b	270 b
Air (5 cm)			
Noncovered	103 a	55 a	158 a
Rowcovered	156 b	157 b	313 b

[z]Spunbonded polypropylene.
[y]Mean separation between treatments within soil or air by analysis of variance Table F test, $p = 5\%$.

ble to photodegradation in the field, and it was unlikely to be improved for agricultural applications by the manufacturer. Slitted polyethylene was omitted from experiments in 1984 and 1985 because, in 1983, it was less effective for increasing production than either of the spunbonded materials and it caused scorching of foliage and flowers.

Fruit production was greater for rowcovered nonmulched plants than for either noncovered mulched plants or noncovered nonmulched plants (Table 2). In 1983, production was greater from noncovered mulched plants than from noncovered nonmulched plants, indicating that winter injury was probably a factor affecting production in this year. Production was also greater for row covered mulched plants than for noncovered mulched plants, indicating that production was increased in this year by a rowcover effect in addition to a mulch effect. There was no difference in production between the rowcovered nonmulched treatment and the rowcovered mulched treatment. These results suggest that for conditions prevailing in 1983, the rowcover may have provided protection from winter injury equal to that provided by mulch, or a rowcover effect on berry numbers and/or size may have compensated for any loss of production from winter injury in the rowcovered nonmulched treatment. A rowcover effect was the dominant factor producing increases in yield among treatments in all 3 years.

In 1984–85, there was no difference in fruit production between noncovered mulched plants and noncovered nonmulched plants, indicating that winter injury was probably not a factor affecting production in these years (Table 2). When rowcover and mulch were combined in a single treatment, increased production attributable to a rowcover effect disappeared. It is suggested that total fruit production over a period of several years of overwintering strawberry plants under rowcovers only is greater than overwintering plants under mulch or a combination of rowcover and mulch, especially in regions where risk of winter injury is only moderate.

Increased fruit production in the rowcovered nonmulched treatments compared to the rowcovered mulched treatments in 1984 and 1985 indicates that the rowcover effect responsible for these increases probably occurs in the winter and/or spring rather than in the fall. In both treatments, plants were covered with rowcovers from September until April; however, in the rowcovered mulched treatment, a layer of mulch over the rowcover excluded light from December through April, whereas in the rowcovered nonmulched treatment rowcover and plants were exposed to light during this period.

Spunbonded polypropylene increased degree-day (base 10°C) accumulation in soil and air in Fall 1985 and in Spring 1986 (Table 3). The magnitude of the difference in total degree-day accumulations between rowcovered and noncovered treatments was approximately the same for soil or air; however, the differences between rowcovered and noncovered treatments for both soil and air were greater in the spring than in the fall. Increased accumulation of degree days in the fall and spring may affect flower bud initiation and development occurring at these times. An increase in the number of flowers initiated and/or an increase in receptacle size as a result of increased heat and enhanced growth during periods of flower initiation and development could increase production by increasing the total number and/or size of berries. Such an effect may be partially responsible for the increases in production seen in rowcovered treatments reported herein. In addition, the greater number of degree days accumulated in rowcovered treatments in the spring compared to the fall supports the hypothesis that rowcover effects occurring in the spring may be an important factor affecting increases in fruit production.

Literature Cited

1. Austin, M.E., V.G. Shutak, and E.P. Christopher. 1960. Responses of Sparkle strawberry to inductive cycles. Proc. Amer. Soc. Hort. Sci 77:372–375.
2. Boyce, B.R. and R.A. Reed. 1983. Effects of bed height and mulch on strawberry crown temperatures and winter injury. Adv. Strawberry Prod. 2:12–14.
3. Darrow, G.M. 1966. The strawberry: History, breeding and physiology. Holt, Rinehart & Winston. New York.
4. Dethier, B.E. and M.T. Vittum. 1963. Growing degree days. Northeast Reg. Res. Publ. Bul. 801. New York State Agr. Expt. Sta. Geneva.
5. Lord, W.G. Growing strawberries in New Hampshire. New Hampshire Coop. Ext. Serv. Info. Guide no. 21.
6. Loy, J.B. and O.S. Wells. 1982. A comparison of slitted polyethylene and spunbonded polyester for plant rowcovers. HortScience 17:405–407.
7. Moore, J.N. and L.F. Hough. 1962. Relationships between auxin levels, time of floral induction and vegetative growth in strawberry. Proc. Amer. Soc. Hort. Sci. 81:255–264.
8. Ourecky, D.K. and J.E. Reich. 1976. Frost tolerance in strawberry cultivars. HortScience 11:413–414.
9. Scheel, D.C. 1982. Effect of clear polyethylene winter mulch on growth and yield of strawberries. Adv. Strawberry Prod. 1:29–30.
10. Wells O.S. and J.B. Loy. 1985. Row Covers: A changing landscape. HortScience 20:800.