# Effects of duration of coverage with spunbonded polyester rowcovers on growth and yield of bell pepper (*Capsicum annuum* L.)

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Waterer, D. 2003. **Effects of duration of coverage with spunbonded polyester rowcovers on growth and yield of bell pepper (*Capsicum annuum* L.).** Can. J. Plant Sci. **83**: 387–391. Transparent rowcovers installed at transplanting and removed as growing conditions improve are commonly employed to promote development of warm-season vegetable crops. In regions with a brief and cool growing season, short-stature warm-season crops such as peppers could potentially benefit from being kept under the rowcovers for extended periods after transplanting. This study examined the influence of duration of coverage with spunbonded polyester rowcovers on vegetative growth, fruit yields and degree of fruit maturity of bell peppers over the 1999, 2000 and 2001 cropping seasons in Saskatchewan, Canada. Eight-week-old transplants of several cultivars of pepper were covered for 6 wk or 10 wk after transplanting or for the duration of the growing season. All growth and yield responses to the duration of coverage were consistent across the cultivars tested. In 1999, extending the period of coverage reduced aboveground vegetative growth of the crop, otherwise vegetative growth was not influenced by the duration of coverage. During the relatively cool 2000 cropping season, the duration of coverage had no effect on fruit yields or the proportion of the fruit that matured to red prior to frost. By contrast, in the warmer 1999 and 2001 cropping seasons, fruit yields declined as the duration of coverage increased. Excessively high temperatures interfere with fruit set in peppers. These results suggest that the risk of exposing the crop to excessively high temperatures may be increased by extending the period of coverage into the warmer periods of the growing season. Extending the period of coverage beyond the standard 6 wk also required additional labor and occasionally exacerbated problems with weeds and insect pests.

**Key words**: Rowcovers, microclimate, ripening, pepper, *Capsicum annuum*

Waterer, D. 2003. **Usage de tapis en polyester filé-lié et effet de la période de protection sur la croissance et le rendement du poivron (*Capsicum annuum* L.)**. Can. J. Plant Sci. **83**: 387–391. On utilise couramment des tapis transparents qu'on retire quand les conditions climatiques s'améliorent pour aider les légumes de la belle saison à se développer au repiquage. Les cultures estivales à port bas comme le poivron pourraient bénéficier d'une plus longue période de protection sous ces tapis après le repiquage, dans les régions où la période végétative est courte et fraîche. L'auteur a tenté de déterminer dans quelle mesure la durée de la protection avec des tapis de polyester filé-lié influe sur la croissance végétative, le rendement fruitier et le degré de maturité des poivrons pendant la saison de croissance en 1999, 2000 et 2001, en Saskatchewan (Canada). Des plants de plusieurs cultivars repiqués à l'âge de huit semaines ont été recouverts d'un tapis pendant 6 ou 10 semaines ou toute la période végétative. Les cultivars testés réagissent tous de manière cohérente au niveau de la croissance et du rendement. En 1999, la prolongation de la période de protection a réduit la croissance des organes aériens de la plante, mais pas celle des autres organes végétatifs. Pendant la saison de croissance relativement fraîche de 2000, la durée de la protection n'a eu aucune incidence sur le rendement fruitier ni sur la proportion de poivrons qui avaient rougi avant la première gelée. Lors des saisons plus chaudes de 1999 et de 2001 cependant, une protection plus longue a diminué le rendement fruitier. En effet, les températures trop élevées nuisent à la nouaison chez le poivron. Selon ces résultats, les risques d'exposition à une température trop élevée pourraient s'accroître si on maintient la protection jusqu'aux moments plus chauds de la période végétative. Prolonger la période de protection au-delà des six semaines habituelles demande aussi plus de main-d'œuvre et exacerbe à l'occasion les problèmes que posent les mauvaises herbes et les insectes.

**Mots clés**: Tapis de protection, microclimat, maturation, poivron, *Capsicum annuum*

Growers of warm-season vegetable crops such as bell pepper commonly employ soil mulches and rowcovers to produce beneficial changes to the microclimate in the vicinity of the crop (Wells and Loy 1985). Tunnels constructed of transparent rowcover material supported above the crop by wire hoops produce a greenhouse-like environment that accelerates growth and enhances fruit maturity of the pepper crop (Wells and Loy 1985; Waterer 1992; Gaye et al. 1992; Alexander and Clough 1998). Rowcovers may provide some frost protection, allowing earlier establishment of the crop (Waterer 1992), while also protecting the crop from wind damage and attack by insects (Avilla et al. 1997). Rowcovers are typically installed at the time of transplanting and are kept in place until: (a) improved growing conditions render them unnecessary, (b) the covers begin to physically interfere with growth of the crop, (c) the covers must be removed to allow access by the insects required for crop pollination, (d) control of weed or insect pest problems is required (Wells and Loy 1985). Depending on the crop, the region and prevailing weather conditions, rowcovers are typically removed 4–8 wk after transplanting (Gaye et al. 1992; Waterer 1992; Reiners and Nizsche 1993).

On the Canadian Prairies, temperatures, even at the peak of the growing season, are typically well below the optimum for warm-season crops such as peppers (21–25°C) (Lorenz and Maynard 1988). This suggests that the crop may benefit by prolonging the period of protection by rowcovers. The relatively short stature of the pepper plants makes them suited to extended periods of growth within the confines of a tunnel constructed with rowcover. Although field-grown peppers are both insect and self-pollinated (Cochran 1932; Dempsey 1961), fruit set is not greatly impaired by the absence of flying pollinators (Dempsey 1961); thus fruit set does not depend on the removal of the rowcovers. Although rowcovers decrease light transmittance to the crop by up to 20% on sunny days (Loy and Wells 1982; Wells and Loy 1985), peppers are tolerant of partial shading (Wells and Loy 1985). Partial shading may actually increase marketable yields of peppers by reducing the incidence of fruit malformation (Gerber et al. 1988), fruit damage by sunscald (Roberts and Anderson 1994; Alexander and Clough 1998) and blossom end rot (Alexander and Clough 1998).

While the benefits of short-term use of rowcovers have been well established, the impact of longer term coverage is less clear. Alexander and Clough (1998) showed that a crop kept under spunbonded polypropylene rowcover from transplanting until the first fruit were mature produced greater early and total fruit yields than when no rowcover was used. Avilla et al. (1997) showed that total fruit yields increased with the duration of coverage by polypropylene rowcovers through to the maximum period tested (76 d after transplanting), but that flowering and fruit maturity were delayed by the rowcovers. They attributed this delay in fruiting to impairment of pollination and fruit set by the high temperatures generated under the covers. Delayed fruit set is a concern as early mature-green fruit often command a price premium as do mature-red fruit, which necessarily set early. Gerber et al. (1988) showed that pepper yields increased as the duration of crop coverage with spunbonded polyester rowcovers increased from 22 d through to the maximum period of coverage tested (52 d after transplanting). By contrast, leaving clear polyethylene rowcovers in place beyond about 32 d after transplanting reduced yields. This difference was again attributed to flower abortion caused by excessive temperatures within the clear polyethylene tunnels.

This study examined how the duration of coverage with spunbonded polyester tunnels influenced yields of bell pepper. The trials were conducted in a region with a short, cool growing season, with periods of coverage ranging from a few weeks to the entire growing season. Spunbonded polyester tunnels were selected as they had produced superior fruit yields in both short- and long-term coverage trials (Gerber et al. 1988; Waterer 1992) relative to tunnels constructed of perforated clear polyethylene.

## MATERIALS AND METHODS

Trials were conducted in 1999, 2000 and 2001 at the University of Saskatchewan Horticulture Field Research plots in Saskatoon, Saskatchewan. The site features a Sutherland series clay soil and is protected by an established shelterbelt system. Two weeks before transplanting the crop, the trial site was disced to incorporate the nitrogen and phosphorous fertilizers required to bring the soil fertility levels up to the requirements for peppers [110 and 120 kg ha$^{-1}$, respectively (Millar 1988)]. Two days prior to transplanting, pre-plant herbicides [trifluralin (1.0 L a.i. ha$^{-1}$) and napropamide (2.2 kg a.i. ha$^{-1}$)] were sprayed onto the soil surface and then shallow-incorporated with a rotovator. A wavelength-selective plastic mulch (IRT-76, Ken-Bar Inc. Reading, MA) was used to warm the soil and provide additional weed control. In early June, when the risk of spring frost was minimal, 8-wk-old greenhouse-grown seedlings were transplanted into the field. The rows were 1.5 m apart, with 30 cm between plants within a row. Cultivars tested were Valencia (1999), Staddon's Select (1999 and 2000), New Ace (2000 and 2001), Redstart (2000 and 2001), Superset (2000) and King Arthur (2001). These cultivars were selected based on superior performance in previous field trials in Saskatchewan (Waterer and Bantle 1995). Each plot, which consisted of 10 plants within a row, was covered immediately after transplanting with a 50 cm tall tunnel constructed of spunbonded polyester row covering (21 g m$^{-2}$, Reemay, Reemay Inc, Nashville, TN), supported on wire hoops.

Drip irrigation lines running under the plastic soil mulch were used to maintain soil moisture potentials above –30 kPa, as measured by tensiometers positioned in the root zone. Six weeks after transplanting, 50 kg N ha$^{-1}$ was applied through the drip irrigation system. Every 3 wk the covers were briefly removed to allow inspection of the crop and hand removal of any weeds developing along the edges of the mulch or in the holes cut in the mulch for the crop. The row covers were permanently removed 6 wk after transplanting (standard treatment), 10 wk after transplanting or were kept in place for the duration of the cropping season. The trial was arranged in a randomized complete block design, with three replicates. The crop was once-over harvested in mid-September just prior to the first killing frost. The fruit were graded based on local market standards for size, degree of maturity and freedom from defects. Number and fresh weight of fruit in each market category (mature green, mature red or culls = immature or damaged) were determined. Fruit were considered mature red if more than 50% of the fruit surface had turned red by the time of harvest. Fresh weights of the aboveground vegetative components of the crop were also determined at the final harvest.

### Statistical Analyses

Error variances for the three cropping seasons were homogeneous. As the cultivars tested were not consistent across the 3 yr, the cultivar main effect was not evaluated. When the analysis of variance indicated significant treatment effects ($P < 0.05$), Fishers protected LSD test ($P < 0.05$) was used to compare treatment means.

## RESULTS

Mean daily temperatures during the 2000 growing season were near the 30-year norm, while in 1999 and in 2001 temperatures were above normal for much of the growing season (Table 1). Extending the duration of coverage by the rowcovers had no obvious impact on the rate of crop development, plant morphology or vigor. When the rowcovers were left in place throughout the growing season, the plant

**Table 1. Mean monthly temperatures (°C) over three growing seasons and the 30-yr average temperature for Saskatoon, Canada**

| | May | June | July | Aug | Sept | Average |
|---|---|---|---|---|---|---|
| 1999 | 13.0 | 14.5 | 18.7 | 20.6 | 13.3 | 15.9 |
| 2000 | 10.5 | 14.3 | 18.7 | 16.8 | 11.7 | 14.4 |
| 2001 | 11.6 | 15.9 | 19.2 | 19.7 | 13.7 | 16.0 |
| 30 yr[z] average | 11.2 | 15.6 | 18.4 | 17.2 | 11.5 | 14.8 |

[z]Average from 1965 to 1995 (Saskatchewan Research Council 1998).

**Table 2. *F* test probabilities and main effect means for the influence of duration of coverage by rowcovers on vegetative growth and fruit yields for several cultivars of bell pepper over 3 crop years**

| | Vegetative growth | Mature red fruit | | Mature green fruit | | Cull fruit | | % mature |
|---|---|---|---|---|---|---|---|---|
| | (wt) | (wt) | (no.) | (wt) | (no.) | (wt) | (no.) | red fruit |
| Year (Y) | ** | *** | ** | *** | ** | * | *** | * |
| Duration of coverage (D) | * | * | ** | *** | NS | NS | NS | NS |
| Cultivar (C) | *** | *** | *** | *** | ** | *** | ** | *** |
| D × Y | ** | ** | ** | * | * | NS | NS | NS |
| D × C | NS | NS | NS | NS | NS | NS | NS | NS |
| C × Y | ** | ** | * | * | ** | NS | NS | NS |
| D × C × Y | NS | NS | NS | NS | NS | NS | NS | NS |
| | (kg plant$^{-1}$) | (kg plant$^{-1}$) | (no plant$^{-1}$) | (kg plant$^{-1}$) | (no plant$^{-1}$) | (kg plant$^{-1}$) | (no plant$^{-1}$) | (%) |
| *Year* | | | | | | | | |
| 1999 | 0.36*b* | 0.14*b* | 0.9*b* | 0.54*b* | 4.1*c* | 0.27*a* | 4.2*a* | 15*b* |
| 2000 | 0.27*c* | 0.10*b* | 0.9*b* | 1.17*a* | 10.2*a* | 0.08*b* | 2.4*b* | 6*c* |
| 2001 | 0.46*a* | 0.53*a* | 3.2*a* | 1.12*a* | 6.7*b* | 0.26*a* | 2.5*b* | 26*a* |
| *Duration of coverage* | | | | | | | | |
| 6 wk | 0.41*a* | 1.14*a* | 2.1*a* | 1.14*a* | 8.1*a* | 0.22*a* | 3.4a | 17*a* |
| 10 wk | 0.34*b* | 0.90*b* | 1.7*b* | 0.90*b* | 6.8*a* | 0.17*a* | 2.5a | 17*a* |
| Full season | 0.35*ab* | 0.97*b* | 1.5*b* | 0.97*b* | 7.1*a* | 0.18*a* | 2.8a | 14*a* |

*a–c* Values within columns for each variable followed by the same letter are not significantly different at $P = 0.05$.
*, ** Significant at $P = 0.05$ and $P = 0.01$, respectively; NS = non-significant.

canopy fully occupied the available space within the tunnels, with no obvious growth distortions or other abnormalities. Extending the period of coverage with rowcovers reduced the aboveground fresh weight of the vegetative tissues in 1999 but had no effect in the 2000 or 2001 trials (Table 2 and Fig. 1). These treatment responses were consistent across the cultivars tested in each year (Table 2).

Yields of mature green fruit (number and weight) in 1999 were substantially lower than in 2000 and 2001 (Table 2) . Yields of mature red fruit (number and weight) and the proportion of the crop maturing to red prior to harvest were higher in 2001 than in the other seasons (Table 2). Less fruit was culled in 2000 than in the other years (Table 2). In 2000 most of the culls were immature, whereas in the two warmer growing seasons abnormal shape was the basis for culling most fruit. Blossom end rot was more prevalent in fruit that set early in the growing season, and sunscald was rare.

The impact of time of removal of the rowcovers on yields (number and weight) of mature red and mature green fruit varied between years (Table 2). In 2000, the time of removal of the rowcovers had no impact on any of the fruit yield parameters measured (Fig. 1). By contrast, in 1999 and 2001, yields of both mature green and mature red fruit were higher when the covers were removed at 6 wk after transplanting than for the later removal treatments (Fig. 1). These treatment responses were consistent across the cultivars tested in each year (Table 2). Fruit cullage rates were not influenced by the duration of coverage (Table 2).

## DISCUSSION AND CONCLUSIONS

Within the past two decades, rowcovers have been widely adopted as a means to enhance vegetative growth and yields of warm-season vegetable crops such as bell pepper (Gerber et al. 1988; Joliffe and Gaye 1995). The benefits of rowcovers are most apparent when high-value, warm-season vegetable crops are grown in regions with a short, cool growing season. Rowcovers may be particularly useful when price premiums are available for early crops or more mature fruit as in the case of red peppers. As installation and removal of rowcovers involves significant commitment of both capital and labor, growers must strive to obtain maximum benefits from the rowcovers. Determining when to remove the covers involves balancing the potential benefits of extending the period of coverage with any associated drawbacks. Removing the covers too early represents a waste of resources and effort, particularly as re-installing the covers is not generally practical. Potential risks associated with leaving the rowcovers in place too long include restriction of growth due to limitations in available space or development of adverse conditions within covered areas. This balance between risk and benefit would be influenced by the crop and cultivar, growing conditions, the type of rowcover used and the yield objectives.

In this study, which was conducted over three cropping seasons at a site with a relatively short and cool growing season, extending the period of coverage beyond the standard period of 6 wk either reduced or had no effect on vegetative growth and fruit yields of several cultivars of bell

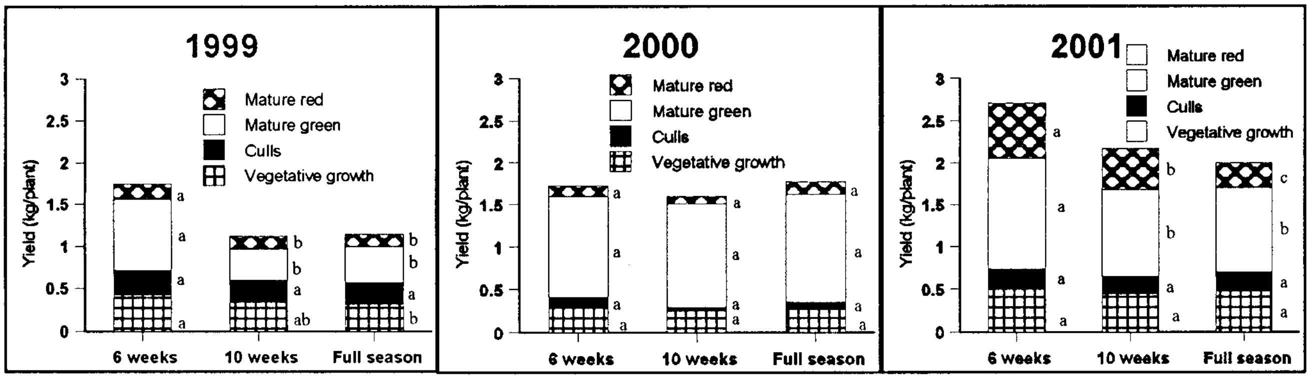


**Fig 1.** Vegetative growth and fruit yields during three cropping seasons for bell pepper as a function of the duration of protection by rowcovers. Within each year and yield component, values followed by the same letter are not significantly different ($P < 0.05$).

pepper. There is little evidence that the amount of shade cast by lightweight spunbonded rowcover materials significantly interfere with growth or fruit yields of peppers (Wells and Loy 1985; Roberts and Anderson 1994; Alexander and Clough 1998). The negative effects associated with extended periods of coverage were more pronounced in the two cropping seasons that were warmer than normal. Development of excessively high temperatures within the confines of a rowcovered area can reduce or retard fruit set (Gerber et al. 1988; Aloni et al. 1994). The likelihood of high temperatures interfering with fruit set would be increased in treatments kept covered through mid-July, as this is the warmest period in a typical Saskatchewan growing season (Table 1) and coincides with the peak of the flowering period. The risk of the rowcovers interfering with fruit set due to overheating would likely be heightened in warmer regions and by the use of less porous or opaque rowcover materials (Gerber et al. 1988). In trials conducted in a relatively warmer region (Madrid, Spain), Avilla et al. (1997) did obtain yield benefits from extending the period of coverage further into the growing season, but attributed the positive yield response to the rowcovers protecting the crop from insect-borne viral disease.

Any benefits to the crop obtained by extending the period of use of the rowcovers could be negated if these treatments also exacerbated problems with crop competitors such as weeds or insect pests. In the 2000 trial, the seedlings carried a light infestation of aphids from the greenhouse into the field. The aphid populations increased in the warm, sheltered environment of the tunnels. Extending the period during which the crop was protected by the rowcovers also extended the period of time during which an aphid problem could develop, while the aphid problems disappeared soon after removal of the rowcovers. In this study, the higher aphid populations associated with increased durations of coverage with the rowcovers had no obvious negative effect on vigor of the crop or fruit yields based on comparisons to the two cropping seasons with no aphid problems. Nonetheless, the implications of extending the period of crop coverage on insect pest populations need to be considered prior to adoption of this practice, particularly as the rowcovers may also interfere with detection and control of insects. In the 1999 trial, the herbicide treatments failed to completely control the red root pigweed, Canada thistle and lambsquarters along the edges of the mulch and the holes punched into the mulch for the pepper transplants. These weeds appeared to thrive in the warm, sheltered microclimate of the tunnels, achieving a considerable size within the 3-wk intervals between hand weeding operations. These weeds may have competed with the crop, potentially contributing to the observed reduction in vegetative growth and fruit yields associated with increased durations of crop coverage in 1999. In the 2001 trial, fruit yields also declined as the duration of coverage increased, despite the absence of any significant weed pressure. This suggests that weed competition was not the sole factor contributing to the yield suppression associated with increased durations of crop coverage. As mechanical control of weeds within the tunnels is not possible and hand-weeding a covered crop is labor intensive, growers must identify effective and persistent chemical or cultural methods of weed control before considering extending the period of crop coverage.

In summary, leaving rowcovers in place beyond the standard 6 wk either provided no benefit or was detrimental to pepper yields and fruit maturity over three cropping seasons in Saskatchewan. Greater benefits of extended periods of coverage might be expected in years or regions characterized by more consistently cool conditions or in crops adapted to warmer conditions. As the rowcovers appeared to delay fruit set, partial or complete removal of the rowcovers at this developmental stage may be warranted, particularly if prevailing growing conditions are warm. Once an adequate fruit set has been achieved, re-establishing some form of cover over the crop may be warranted if it accelerates development of the pepper fruit. Lightweight porous crop covers that can be temporarily installed over multiple rows of an established crop may represent a convenient and practical means to achieve this objective (Waterer et al. 1992).

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