

Spunbonded Rowcover and Calcium Fertilization Improve Quality and Yield in Bell Pepper

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Abstract. A 2-year study was conducted in eastern Oregon to evaluate the effects of hooped spunbonded polypropylene rowcovers and Ca fertilization on yield and quality of drip-irrigated bell pepper (*Capsicum annuum* L. Grossum group) grown on black plastic mulch. The experiment was a complete factorial with four replications of two cultivars, covered and uncovered plots, and three levels of supplemental Ca fertilization at 0, 34, and 68 kg·ha⁻¹ applied through the drip irrigation system as Ca(NO₃)₂. Rowcovers increased marketable yields both at the first harvest and over the season. Blossom-end rot and sunscald were reduced substantially by rowcovers; the effect was greatest during the earlier harvests. First-harvest and season total yield of fancy grade peppers increased linearly as rate of supplemental Ca increased, as did total marketable yield at the first harvest. Both yield of fruit with blossom-end rot and the percentage of fruit with blossom-end rot at the first harvest decreased as Ca rate increased. Yield of fruit affected by sunscald decreased linearly as supplemental Ca rate increased at the first harvest; overall, yield of sunscalded fruit was reduced by application of Ca at either rate.

Blossom-end rot (BER), commonly found in tomato (*Lycopersicon esculentum* Mill.) and bell pepper fruit, is a physiological disorder linked to localized low Ca levels in fruit tissues. Despite adequate availability of Ca in the soil, fruit can develop the condition when the transpiration stream carrying Ca is interrupted, or when leaves transpire heavily enough to divert Ca from the fruit (Bangerth, 1979). Economic losses due to BER can be substantial for fresh-market growers. Growers commonly use fertilizers with supplemental Ca, such as Ca(NO₃)₂, or apply sprays of Ca salts, with varying degrees of success. First-harvest losses >50% have occurred in the Columbia basin despite supplemental Ca fertigation.

Reductions in BER with the use of Ca(NO₃)₂ sprays are well documented in tomatoes (Geraldson, 1956; Shear, 1975). In greenhouse-grown bell peppers, Ca sprays decreased BER, but also decreased yield when peppers were harvested at the red ripe stage (Schon, 1993). Calcium fertilization and foliar/fruit sprays, while significantly increasing the Ca content of plant tissues, are not always effective in reducing BER because of the inefficient distribution of Ca to the areas of greatest need, the developing fruit tissues (Kirkby, 1979).

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Leaf transpiration determines the movement of Ca in the plant and the availability of Ca to the fruit in times of rapid growth (Bangerth, 1979). Environmental factors that affect leaf transpiration are more likely to cause BER than is inadequate soil Ca. In two tomato cultivars, the incidence of BER increased linearly with an increase in the product of daily solar radiation and temperature (Ho et al., 1993). In bell pepper, increasing the rate of fruit transpiration relative to the leaves was more effective in increasing fruit Ca uptake than was increasing the Ca content of the soil solution (Marschner, 1983). Antitranspirants are one method of reducing leaf transpiration. Antitranspirants sprayed on pepper foliage reduced BER and increased fruit Ca concentration, but at the expense of total fruit production (Schon, 1993).

Spunbonded polypropylene rowcovers reduce solar radiation, thus lowering leaf temperatures (Roberts and Anderson, 1994). Although rowcovers generally increased air temperatures, average midday leaf temperatures decreased from 33.1 °C over bare soil alone to 31.9 °C under rowcover over bare soil. Rowcovers also reduce wind velocity (Schloup et al., 1991) and this may reduce transpiration.

In Arizona, Harper (1989) observed decreases in the number of BER-affected bell peppers under spunbonded polyester rowcovers. No BER developed in fruit under the rowcovers, as compared to a 9% to 15% incidence in plots without rowcovers. On the farmlands of the Columbia Plateau, high light intensity, high midsummer temperatures, low humidity, and strong winds also create an environment conducive to the development of BER.

This research was conducted to determine the effect of spunbonded polyester rowcover, Ca fertilization, and cultivar on blossom-end rot, yield, and quality of bell pepper.

Materials and Methods

The experiment, conducted in 1995 and 1996 at the Hermiston Agricultural Research and Extension Center in Hermiston, Ore., was a complete factorial with four replications of two varieties, with and without rowcovers, and with three levels of supplemental Ca: 0, 34, and 68 kg·ha⁻¹.

Bell pepper cultivars Vidi (Vilmorin, Empire, Calif.) and Ranger (Asgrow, Salinas, Calif.) were seeded into a commercial soilless peat-based medium [Sunshine Mix Number 3 (3 peat : 1 vermiculite); dolomitic lime added for pH adjustment; Fisons Western, Downers Grove, Ill.] in 96-cell trays (24.6 cm³/cell) in the first week of April, and grown to transplant size in a greenhouse covered with a double layer of polyethylene.

Soil type was an Adkins fine sandy loam (coarse-loamy, mixed mesic Xerollic Camborthidx. Field plots were rototilled and sub-soiled, leaving 15-cm-wide strips of winter wheat (*Triticum aestivum* L.) as windbreaks. Metam sodium (560 L·ha⁻¹) was incorporated to a depth of 15 cm with a rototiller. Preplant soil test pH was 6.9, with soluble salts at 0.20 dS·m⁻¹ and Ca at 5.1 meq·L⁻¹. Fertilizer (89N–112P–179K–45S–4.5Cu–3.4Zn–1.7B kg·ha⁻¹) was broadcast in a 0.8-m band in the bed center and rototilled to a 15-cm depth. Plots were covered with 0.0254 mm black polyethylene mulch (1.2 m wide) and a single drip irrigation line (0.20-m emitter spacing, 4.97 L·h⁻¹ per meter at 51.6 kPa) was buried 5 cm in the bed center. Drip lines were plumbed separately according to Ca treatment so that the treatment blocks could be fertigated independently. Twenty plants/plot were transplanted by hand, two rows per bed, 0.4 m between rows, 0.31 m between plants, on 27 May 1995 and 18 May 1996. A polypropylene spunbonded rowcover ('Gro-shield', partially opaque, 20 g·m⁻², 80% to 90% solar transmittance; Gromax Plasticulture, Pensacola, Fla.) was applied immediately after transplanting. Galvanized wire (3.57 mm in diameter) was used as a support hoop for the rowcover, with center height and hoop spacing at ≈0.45 and 1.52 m, respectively. Covers remained in place until the first harvest, when they were removed. Recommended commercial production practices were followed.

In July 1995, hail caused 60% to 80% defoliation, loss of many plant stems, buds, and branches, and damage to the fruit. Damaged fruit were removed and rowcovers were replaced. Immediately after transplanting in 1996, a severe hailstorm caused an 80% to 90% stand loss. The peppers were reseeded in the greenhouse on 18 May, and seedlings were transplanted and rowcovers put in place on 25 June 1996.

Weekly fertigation began ≈4 weeks after transplanting. Plots were fertigated equally three times to receive a total of 0, 34, or 68

kg-ha⁻¹ Ca [Solution Grade Ca(NO₃)₂] plus urea ammonium nitrate (UAN-32), providing 22 kg-ha⁻¹ N per application. Additional N at 22 kg-ha⁻¹ (UAN-32) was applied twice in 1995 and once in 1996.

Fruit were harvested weekly at the mature green stage, sorted according to U.S. Dept. of Agriculture (USDA) standards (U.S. Dept. of Agriculture, 1963), counted, and weighed. Fruit with defects were sorted into three categories: blossom-end rot, sunscald, and other (primarily insect damage, misshapen fruit, and bacterial rot). Sunscald (SS) was identified by the dry, papery consistency and the light color of the affected area. At the early stages, SS appears water-soaked, and can be difficult to distinguish from other disorders, including BER (Barber and Sharpe, 1971). In 1996, pepper fruit were sorted into BER and SS categories in the field during harvest, based on the position of the fruit on the plant (sun exposure) and the above criteria. This gave an added degree of confidence in the cause of the injury. Data were analyzed with SAS GLM, using orthogonal contrasts for Ca treatment effects (SAS Institute, 1988).

Results and Discussion

Early (first harvest) yields of fancy, No. 1 and 2 grade, and total marketable bell pepper fruit were lower in 1995 than in 1996 (data not shown), probably because of damage from the July 1995 hailstorm, and the late transplanting date in 1996. Total fancy-grade, marketable, and total yield also were lower in 1995 than in 1996 (data not shown).

'Ranger' had lower early (first harvest) fancy, total marketable, BER-affected, total cull, and total fruit yields than did 'Vidi' (data not shown). Although 'Vidi' produced greater total-season yield of fancy-grade fruit than 'Ranger' (12.9 and 6.2 t-ha⁻¹, respectively), 'Ranger' yielded 22.3 t-ha⁻¹ No. 1 and 2 fruit as compared with 18.6 t-ha⁻¹ for 'Vidi', and the total seasonal yield of marketable fruit did not differ by variety. 'Vidi' had greater yields of BER- and SS-affected fruit than 'Ranger', and produced 42.9 t-ha⁻¹ total fruit yield as compared with 36.7 t-ha⁻¹ for 'Ranger'.

Rowcovers increased early yield of USDA fancy and No. 1 and 2 grades and total marketable fruit, and decreased yields of BER and SS fruit (Table 1), but the difference was nonsignificant for USDA fancy-grade fruit in 1996. Rowcovers reduced early BER fruit yield more in 1996 than in 1995 (data not shown), perhaps due in part to the severe hailstorms that delayed the harvest in 1995 and caused a late replanting in 1996. Plants fruited later the 2nd year because of the delayed planting, and may have been under greater temperature stress during early fruit development. Rowcovers reduced the yield of sunscalded fruit from 0.45 to 0.04 and 0.20 to 0.11 t-ha⁻¹ for 'Vidi' and 'Ranger', respectively, but the difference was nonsignificant for 'Ranger'. Rowcovers have been used successfully in the South to reduce solar injury in bell peppers (Roberts and Anderson, 1994). Daytime temperatures generally increase under rowcover, but light intensity

decreases, as the fabric transmits ≈80% of available light. The Umatilla Basin has high light intensity, infrequent cloud cover, long summer days with very low humidity, and high wind velocities, occasionally >40 km-h⁻¹. These factors combine to increase leaf transpiration and water loss, and each of these factors is influenced by rowcovers. Reducing large fluctuations in leaf transpiration is crucial to maintaining balanced Ca distribution between fruit and leaves.

Season-long yield of No. 1 and 2 and total marketable yields increased with rowcover (Table 1), but rowcovers did not affect season-long yield of fancy-grade fruit. Rowcovers reduced yields of BER- and sunscald-affected fruit, but yield of fruit with sunscald depended on year and variety. Rowcovers reduced the total yield of sunscald fruit from 3.21 to 1.60 t-ha⁻¹ in 'Ranger' in 1995 and from 2.98 to 1.11 t-ha⁻¹ in 'Vidi' in 1996. The total combined yield (marketable + cull fruit) was not affected by rowcover; rowcover seems to have had a prophylactic effect on fruit that would have otherwise developed BER, but no effect on the potential yield of the plants.

Average fruit weight of fancy, No. 1 and 2-grade, and BER-affected fruit was not affected by rowcovers (data not shown). Gent (1989) reported that rowcovers reduced average fruit weight of bell pepper 5% to 15%, but others have reported no effect of rowcovers on fruit weight (Gaye et al., 1989; Maurer and Frey, 1987).

Early yield of fancy-grade fruit increased linearly as rate of supplemental Ca fertilization increased; a 0.06 *P*-value suggests a linear increase in total early marketable yield as Ca rate increased (Table 1). First-harvest BER yield decreased linearly as Ca rate increased. The NO₃⁻ : NH₄⁺ ratio increased with Ca rate

from 0 to 0.75 to 0.83 for the 0, 34, and 68 kg-ha⁻¹ Ca treatments, respectively. These results agree with those of Marti and Mills (1991), who found that any increase in the NO₃⁻ : NH₄⁺ ratio decreased BER due to reduced cation competition with Ca and the positive effect of NO₃⁻ on Ca uptake. First-harvest yield of sunscalded fruit also decreased as Ca rate increased.

Calcium nitrate fertilization increased the early yield of larger, fancy-grade fruit but did not significantly increase the early yield of total marketable fruit (USDA fancy and No. 1 and 2-grade fruit combined). The total first-harvest yield was not affected by Ca(NO₃)₂ fertilization, suggesting that Ca did not increase overall productivity. Perhaps more large fruit, which might have been culled due to BER or sunscald, remained free of the disorders until harvest. Calcium nitrate may have a disproportionate effect on fruit with faster growth rates. More rapid growth has been linked to susceptibility to localized Ca deficiencies because of increased ratio phloem to xylem import (Bangerth, 1979; Shear, 1975). Use of Ca(NO₃)₂ may increase Ca concentration in the xylem enough to compensate for the increased phloem/xylem import ratio in faster growing fruit.

Total yield of fancy-grade fruit also increased linearly as Ca fertilization rate increased (Table 1), but yields of total marketable and BER fruit were not affected. The total yield of sunscalded fruit was lower in plots fertigated with 34 and 68 kg-ha⁻¹ Ca than in those receiving no supplemental Ca. In a study of 15 bell pepper cultivars, no difference was found in tissue Ca concentration between sunscald-affected and unaffected fruit tissue (Morley et al., 1993). Clearly, more research is needed to determine

Table 1. Bell pepper early (first harvest) and total (season) yields as affected by rowcover and Ca fertilization.

	Marketable			Nonmarketable			Total
	Fancy	No. 1 & 2	Total	BER ²	SS ²	Total	
<i>Early yield (t-ha⁻¹)</i>							
Rowcover							
Gro-shield	2.99 ^y	1.71	4.70	1.65	0.07	1.82	6.52
None	2.32	1.11	3.45	4.09	0.32	4.51	7.96
	***	**	***	****	****	****	**
Ca rate (kg-ha ⁻¹)							
0	2.32	1.40	3.72	3.27	0.28	3.65	7.37
34	2.66	1.35	4.01	2.70	0.18	2.96	6.97
68	2.98	1.51	4.50	2.69	0.13	2.93	7.43
	L**	NS	NS	L*	L*	L**	NS
<i>Total yield³ (t-ha⁻¹)</i>							
Rowcover							
Gro-shield	9.56	22.8	32.2	3.99	1.91	6.47	38.8
None	9.47	18.1	27.6	9.87	2.87	13.1	40.7
	NS	**	**	****	****	****	NS
Ca rate (kg-ha ⁻¹)							
0	8.92	21.1	30.1	7.39	2.85 a	10.7	40.8
34	9.50	19.9	29.4	6.74	2.15 b	9.41	38.8
68	10.2	20.3	30.4	6.74	2.18 b	9.38	40.7
	L*	NS	NS	NS	**	L*	NS

²BER = blossom-end rot; SS = sunscald.

^yAverage for 2 years and two varieties.

³Combined total for six harvests in 1995, four harvests in 1996.

ns, L, *, **, ***, **** Nonsignificant, linear regression significant, or significant at *P* = 0.05, 0.01, 0.001, or 0.0001, respectively. Means followed by different letters significantly different at *P* = 0.05 (Duncan's multiple range test).

whether nutrition and sunscald are related.

Spunbonded rowcover reduced BER and increased yields with and without supplemental Ca, and had a similar effect on both varieties. This suggests that rowcovers provide one or more of several benefits. 1) They may provide conditions conducive to increased uptake and/or distribution of Ca to the fruit. Rowcovers may reduce evapotranspiration, resulting in more consistent soil water availability. 2) They may increase fruit Ca accumulation. Leaf transpiration may decrease under rowcovers because of reduced leaf irradiation and temperature. Physiological changes occur with shading, such as reduced numbers of leaf stomates (Schoch, 1972) which may lead to reduced transpiration and increase Ca distribution to the fruit. 3) Fruit Ca requirements may be reduced. Since no consistent change in average fruit size could be attributed to the rowcover, how fruit Ca requirements might have been affected by the rowcover is difficult to determine. Reduced solar irradiation or anatomical or physiological changes may result in reduced Ca requirements, but one can only speculate with the limited information available.

The proportions of fruit with BER and sunscald were greatest at the first harvest, and declined as the season progressed. The amelioration of these disorders by rowcovers and supplemental Ca also decreased with time. A longer, more favorable growing season would increase total yields, but the early-season use of rowcovers probably would not provide additional benefit.

The number of factors involved in the de-

velopment of BER is daunting. There were fewer rowcover interactions with variety and supplemental Ca than expected, and the rowcover consistently reduced blossom-end rot, which suggests that in the Columbia Basin, environment and leaf/fruit transpiration ratio play a large role in the development of BER. Results similar to those observed in this study probably can be obtained in other regions with intense solar radiation, high air temperatures, low relative humidity, and/or high winds.

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