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Impact of Floating Rowcovers on Bell Pepper Yield and Virus Incidence

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Aphid-transmitted viruses are of great economic importance in bell pepper (*Capsicum annuum* L.) crops. The most damaging viruses in Spain are potato virus Y (PVY, Potyvirus group), and cucumber mosaic virus (CMV, Cucumovirus group) (Luis, 1989). These nonpersistently transmitted viruses can be acquired and inoculated by aphids during superficial brief probes within the plant epidermis lasting <60 s (Lopez-Abella et al., 1988). Therefore, traditional control methods, such as insecticide applications, have often failed to prevent virus spread (Raccah, 1986).

Rowcovers have prevented access of virus vectors to zucchini squash (*Cucurbita pepo* L.) (Natwick and Durazo, 1985; Webb and Linda, 1992) and cantaloupe (*Cucumis melo* L.) (Perring et al., 1989). Harrewijn et al. (1991) showed that polyethylene and polypropylene covers prevent aphids from inserting their stylets into potato (*Solanum tuberosum* L.) leaves.

Preliminary results we obtained in 1992 indicated that covering pepper plants immediately after transplanting would increase marketable yield. Therefore, our objective was to evaluate the effect of two commercial polypropylene covers on yield and virus incidence in bell pepper, based on optimal timing of covering.

Field experiments were conducted at "La Poveda" experimental farm (CSIC, Arganda del Rey, Madrid, Spain) during 1993. 'Yolo Wonder' pepper seeds were sown in beds the first week of March and covered with plastic microtunnels plus polypropylene Reicrop (Texnovo, S.A., Barcelona, Spain) covers to avoid insect damage and virus infection. Pepper seedlings were transplanted 75 d after sowing to experimental plots at a spacing of 0.85 × 0.3 m.

The polypropylene covers Reicrop and Lutrasil (Texinter, S.A., Barcelona, Spain) were compared. They have similar air and water permeability and light transmission. Reicrop was less resistant to tearing than Lutrasil, but the latter was less regularly woven. We used 2-m-wide covers that were large enough to allow space for normal plant growth. The second factor considered was the date of cover establishment.

A randomized complete block design was used with four replications. Each randomized block had three control (uncovered) plots to obtain a good estimate of virus incidence under uncovered conditions (a total of 12 control plots were used). Each 6 × 3-m plot had three rows of peppers and were 6 m long. Covers were placed on 13 May (T1, immediately after transplanting), 2 June (T2, at blossom stage and soon after the first aphid population peak), and 23 June (T3, beginning of fruit formation and just after hilling practice). Covers were fixed to the soil by metal staples and removed on 29 July.

Preplant fertilizer was applied to the soil surface with NPK at 30, 50, and 150 kg·ha^{-1}, respectively. Also, α,α,α-trifluoro-2,6-dinitro-*N,N*-dipropyl-p-toluidine (trifluralin) was used as a preemergence herbicide at 0.86 kg·ha^{-1}. Plants were hilled 6 weeks after transplanting. The herbicide 2,4-bis(isopropilamino)-6-(methylthio)-s-triazine (prometryn) was applied at 1.0 kg·ha^{-1} after hilling to improve weed control. Floating covers from T1 and T2 were removed just before hilling and then replaced. Peppers were furrow-irrigated weekly and N was applied twice at 50 kg·ha^{-1}.

Artificially infected plants were transplanted on the perimeter of the experiment to provide a nearby source of CMV and PVY. Source pepper plants for CMV (Val-CMV-24, Garcia-Luque et al., 1984) were mechanically inoculated using phosphate buffer (disodium phosphate 0.03 M, 0.2% of diethyl dithio carbamic acid, DIECA). For PVY, nightshade (*Solanum nigrum* L.) plants were inoculated with a pepper-PVY isolate (pathotype 0) (Fereres et al., 1993). Virus-inoculated plants were grown under greenhouse conditions and checked by DAS-ELISA for virus infection according to Fereres et al. (1993). A monoclonal antibody (10E3, Ingenasa, Madrid, Spain) was used for PVY detection, and a polyclonal antibody for CMV (Agdia, Elkhart, Ind.). Healthy leaves were obtained from plants grown in virus-free environmental chambers. Infected-source plants were transplanted 4 weeks after inoculation at 1.25 plants/m.

PVY and CMV incidence were assessed by observation of symptoms at harvest and by DAS-ELISA of plants with unclear symptoms. Each plant was individually labeled and yield components (total and marketable fruit mass/plant and total and marketable number of fruits/plant) were recorded separately for each plant on 8 and 9 Sept. and 28 and 29 Sept.

All data were transformed to reduce heterocedasticity. The transformation used was arcsin $\sqrt{x}$ for percentage of infection, and $\sqrt{x}+1$ for the other dependent variables. Transformed data were subjected to analysis of variance (Abacus Concepts, 1989). Multiple mean comparisons were made among treatments using the Fisher's protected LSD test (Abacus Concepts, 1989). Individual plot data for virus incidence (% of infection) and marketable pepper yield were linearly regressed and the correlation coefficient and regression slope determined (Abacus Concepts, 1989).

The highest total marketable yields (TMY) were obtained when plots were covered immediately after transplanting (Reicrop T1 and Lutrasil T1, Table 1). Plants in the control plots provided the highest TMY in the first harvest. Covers promoted vegetative growth (data not shown) but delayed flowering and maturation of fruit. Flowering and fruit set could have been delayed as well because of the high temperatures (usually above 35 °C) generated under the covers during June and July. Temperatures exceeding 35 °C reduce pepper pollination and fruit set (Aloni et al., 1994). Hence, peppers of the covered plots matured later than those of the control plots, and were

Table 1. Effect of rowcovers on the marketable yield of bell pepper.

Rowcover and time of application		Marketable yield/plant (g)		
		Harvest		
		1	2	Total
Reicrop	T1[z]	306 bc[y]	1165 a	1471 a
	T2	354 bc	830 bc	1184 bc
	T3	302 c	815 bc	1117 c
Lutrasil	T1	445 b	1002 ab	1447 a
	T2	365 bc	1024 ab	1389 ab
	T3	389 bc	720 cd	1109 c
Control		610 a	640 d	1250 bc

[z]Reicrop and Lutrasil are the brands of rowcovers used. The dates of covering were immediately after transplanting (T1), at the blossom stage and soon after aphid peak (T2), and at the beginning of fruit formation (T3).
[y]Mean separation within columns by Fisher's protected LSD test, $P < 0.05$.

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harvested mostly at the end of the experiment (second harvest).

No significant differences between treatments were obtained for the total number of fruits per plant [range, 12.4 (control) to 13.6 (Reicrop T1)]. T1 treatments produced more ($P \leq 0.05$) marketable fruits per plant (8.0) than did the control (7.0). Treatment differences were not significant for the marketable mass per fruit [range, 166 g (Lutrasil T3) to 189 g (Lutrasil T2)].

Virus incidence did not vary significantly with treatment [values ranged from 3% (Reicrop T1) to 17% (control)]. However, the regression analysis indicated a strong relationship ($P = 0.0022$) between degree of virus infection in individual plots and reduction in marketable pepper yield ($t = -3.31$; $ß = -6.53 \pm 1.98$; $r = 0.49$). The lack of significant differences by ANOVA between treatments for virus incidence can be explained by the high variation detected between experimental blocks and similar response among all but the T1 treatments. This high variation was probably due to the kind of dispersion pattern associated with nonpersistent virus diseases. Nonpersistent viruses usually spread starting from the edge of the field to the inner parts (Broadbent and Martini, 1959). While blocks 1 and 4 (external plots) had several infected plants, blocks 2 and 3 (internal plots) were almost virus-free.

Our results indicate that floating covers may be helpful in controlling virus infection in the field, although for them to be economically profitable, they must be used in areas of high virus pressure and under high yield expectations. To obtain virus control and to enhance growth of pepper crops, the covers must be placed immediately after transplanting.

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