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Rowcover-removal Timing Affects Yield of Tomatoes Planted on Fall-prepared Beds

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ADDITIONAL INDEX WORDS. *Lycopersicon esculentum*, economics, microclimate modification

SUMMARY. Spring-planted 'Pilgrim' tomatoes (*Lycopersicon esculentum*) were grown under slitted clear polyethylene rowcovers on beds prepared in the fall with black plastic mulch and trickle irrigation. Fall beds allowed for earlier planting and a corresponding earlier harvest. Plastic mulch and trickle irrigation remained intact during the winter. There was no significant advantage to leaving covers on past the time of the traditional planting date for the area. It was estimated that the additional cost for this system would be about \$1000 per acre. The profitability of this system will be determined by the price growers receive for their earliest fruit. An early season price of \$0.60/lb is the approximate break-even figure. Higher early season prices will lead to much greater profits. For heat-sensitive crops like tomatoes, using rowcovers on fall beds may effectively maximize early yield and profitability.

To maximize farm profitability, vegetable growers often try to bring crops to

market earlier. Early harvests usually result in price premiums of two to three times that which is received just a few weeks or even days later. Plastic mulches have been used by growers to enhance earliness for many years (Bonanno and Lamont, 1987; Perry and Sanders, 1986). In the past decade, there has been an increase in the use of rowcovers to enhance early yield. The protected conditions under the cover have resulted in early yield increases for muskmelons (Hemphill and Mansour, 1986; Wells and Loy, 1985;) and other cucurbits (Hemphill and Crabtree, 1988) but has had a mixed effect on peppers, (Gent, 1989) and tomatoes. Perry and Sanders (1986) demonstrated early yield of tomatoes was reduced, possibly due to high temperatures under the covers. Reiners and Nitzsche (1993) found increased early yields of tomatoes using floating spunbonded covers and slitted clear plastic covers. Wolfe et al. (1988) estimated that temperatures >95 °F can have detrimental effects on tomato yield. Peterson and Taber (1991) found a correlation between early yield loss and a sustained high temperature >104 °F for ≥3 consecutive hours. Apparently, the yield loss in tomatoes grown under plastic may be related to insufficient pollination at high temperatures (Shelby et al., 1978), blossom drop (Sugiyama et al., 1966), or fruit abortion (Peterson and Taber, 1991).

For rowcovers to be effective they must be managed according to the temperature requirements or limitations of individual crops. A possible reason for the failure to increase early yield in some studies may be due to the lateness of planting. Tomato plants set near the time of traditional spring plantings for a region and covered had reduced early yield (Wolfe et al., 1989). Gent (1989) found that 16 pepper varieties planted early (21 Apr.) and covered matured 10 d earlier than unprotected plants. When planted at the more traditional time 1 month later, all varieties of protected peppers exhibited an early yield loss, with the first harvest delayed 9 d. Clearly, later plantings of tomatoes and peppers do not benefit from protection and may be damaged by high temperatures. The best advantage of rowcovers may be that they allow growers to plant several weeks earlier than traditional planting dates. The challenge encountered when trying to plant tomatoes

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Table 1. Early and total yield of tomatoes grown on plastic covered beds with trickle irrigation as influenced by rowcovers and the timing of their removal.

Treatment	Marketable				Cull
	Medium (lb/acre)	Large (lb/acre)	Jumbo (lb/acre)	Total (lb/acre)	Percent of total yield
Early season (3 July–25 July)					
13 Apr. planting: No protection	903	1,425	103	2,432	23
13 Apr. planting: Cover removed 20 May	3,824	3,057	651	7,533	23
13 Apr. planting: Cover removed 10 June	4,047	3,911	359	8,318	25
20 May planting: No protection	0	0	0	0	---
LSD ^z	1,029	882	195	2,495	NS
Total season (3 July–10 Aug.)					
13 Apr. planting: No protection	13,982	13,574	3,064	30,620	36
13 Apr. planting: Cover removed 20 May	16,350	11,268	1,415	29,033	35
13 Apr. planting: Cover removed 10 June	14,878	14,442	2,579	31,899	34
20 May planting: No protection	6,007	6,531	815	13,352	39
LSD	3,924	3,755	858	7,337	NS

²Protected LSD at $P = 0.05$.^{NS}Nonsignificant.

several weeks early is the inability to work the soil, prepare beds, and lay plastic when the soil is still wet from spring rains. This is especially true with soils that drain slowly. To overcome this limitation, an experiment was conducted to determine if beds (with plastic mulch and trickle irrigation) could be prepared in the fall and planted early the following spring. In addition, rowcovers were removed at two different times to examine the effect of timing cover removal on early and total yield.

Materials and methods

Fields were prepared at the Snyder Research and Extension Farm, Pittstown, N.J., on 10 Oct. 1992. The soil was a Quakertown silt loam (fine loamy mixed mesic, Typic Hapludults) with 80N–35P–66K lb/acre (90N–39P–74K kg·ha⁻¹) broadcast and incorporated by disking. Black polyethylene mulch (1 mil, embossed) and trickle irrigation were applied on 5-ft (1.5-m) centers on 4-inch (10-cm) raised beds that were 30 inches (0.76 m) wide. The plots were left in the field unprotected for Winter 1992–93.

On 22 Feb. 1993, 'Pilgrim' tomatoes were seeded in plastic cell packs (48 cells/flat, each cell 130 cm³) containing a 1 peat : 1 vermiculite mix (v/v). Plants were irrigated weekly with 0.6 g fertilizer (15N–6.5P–12.4K)/L. Plants were watered to runoff as needed and placed in a glass greenhouse with air temperature ranging from 65 to 75 °F.

Tomatoes were set into plastic

mulch at a 2-ft (0.6-m) spacing. Plant protection systems were installed immediately following planting. Slitted clear polyethylene (Agway, Elizabethtown, Pa.) supported by wire hoops spaced over every other plant was placed over treatment plots. The treatments included 1) 13 Apr. planting, rowcover removed 20 May (37 d after transplanting); 2) 13 Apr. planting, rowcover removed 10 June (57 d after transplanting); 3) 13 Apr. planting, no protection; and 4) 20 May planting, no protection. The date of 20 May was chosen to remove covers and make a second planting since this is about the time tomatoes are traditionally planted in this area of the state. Rowcovers were removed on 10 June as the daily air temperatures consistently exceeded 85 °F, even in unprotected plots. Pesticides and trickle irrigation were applied according to the New Jersey commercial vegetable production recommendations (Reiners and Garrison, 1993). Temperatures were recorded in each plot using a micrologger (21-X; Campbell Scientific, Logan, Utah) with thermocouples placed 3 inches (7.5 cm) above the plastic mulch.

Harvest of breaker-stage fruit began on 3 July and continued twice weekly until 10 Aug. Fruit harvested from 3 July through 25 July were considered early. Fruit were sized into four categories: Jumbo, >3.5 inch (8.9 cm) in diameter; Large, 3.0–3.5 inch (7.6–8.9 cm) in diameter; Medium 2.5, 3.0 inch (6.4–7.6 cm) in diameter, and cull, which included cracked, misshapened, and small [<2.5-inch-

diameter (6.4-cm-diameter)] fruit. Once sized, all fruit were weighed.

The experiment was a randomized complete block with five replications. The experimental unit consisted of a 20-ft (6.1-m) row. Data were subjected to analysis of variance and means separated by the protected least significant difference (LSD).

Results and discussion

Fall bed preparation allowed for the earliest possible planting of tomatoes in the spring. The plastic mulch and trickle tubing survived the winter intact. If the field had been prepared in the spring, as is customary, it is estimated that the planting would have been delayed at least 2 weeks, possibly negating the effect of early planting.

Early yield of tomatoes was increased significantly by the use of slitted clear plastic rowcovers (Table 1). Except for the yield of jumbo sized tomatoes with the early rowcover removal (20 May), there were no differences in early marketable yield due to rowcover removal timing. Planting tomatoes early without any protection resulted in >2400 lb tomatoes/acre compared to no early production for those planted at the traditional planting date. It should be pointed out, however, that there was no frost in the area after the early planting, although temperatures fell below 40 °F on 9 of the first 18 nights. The average last killing frost date in the area is 18 May. In an average year, the early unprotected planting could have been killed by frost. Despite the chance of a killing frost, growers may wish to take a chance

Fig. 1. Maximum daily temperatures under slitted clear plastic rowcovers (Δ) and no rowcovers ($\circ$) recorded by thermocouples placed 3 inches (7.5 cm) above the plastic mulch. Rowcovers removed on 20 May correspond to 37 d after transplanting.

(Fig. 1). Temperatures $>95^{\circ}\text{F}$ (Wolfe et al., 1989) or 100°F (Peterson and Taber, 1991) have been blamed for yield losses in the past. There was no advantage to leaving covers on past the time when tomatoes were traditionally planted. In fact, the date of traditional planting may indicate when to remove the rowcovers to avoid the possibility of problems from heat.

Total marketable yields of all rowcover treatments exceeded that of the later, unprotected planting (Table 1). This effect may not have been due to the rowcovers directly, rather to the greater level of disease in the field at the time the later planting was maturing. The early protected plants apparently served as a source of disease inoculum, particularly for early blight (*Alternaria solani*) and septoria leaf spot (*Septoria lycopersici*) for later plantings. Growers should be advised that their early plantings should be separated from later plantings to slow the spread of disease.

Growers need to know if the monetary return on these early tomatoes will offset the additional costs for supplies and labor. It is estimated that

with a small number of plants planted early and without protection. Although yield was significantly smaller than that achieved with protection, no additional cost was required for rowcovers and the labor for installation in the unprotected plots.

The positive effect on early tomato yield agrees with earlier work (Reiners and Nitzsche, 1993). Studies that have found negative correlations generally had higher temperatures under the covers than we experienced in this experiment. Out of the first 50 d, on 3 d temperatures under the cover exceeded 95°F and on 1 d the maximum temperature exceeded 100°F

Table 2. Return per acre in dollars based on marketable yield of rowcover treatments at varying early season prices and a single middle to late season price of \$0.20/lb.

Rowcover treatment	Early season return per acre at [price/lb (\$)]				
	0.20	0.40	0.60	0.80	1.00
13 April planting: No protection	486	973	1,459	1,946	2,432
13 Apr. planting: Cover removed 20 May	1,507	3,013	4,520	6,026	7,533
13 Apr. planting: Cover removed 10 June	1,664	3,327	4,991	6,654	8,318
LSD	497	995	1,492	1,989	2,486
Middle to late season return per acre at \$0.20/lb					
13 April planting: No protection	5,638	---	---	---	---
13 Apr. planting: Cover removed 20 May	4,300	---	---	---	---
13 Apr. planting: Cover removed 10 June	4,716	---	---	---	---
LSD	NS				
Total season return per acre based on various early season prices and a middle to late season price of \$0.20					
13 April planting: No protection	6,124	6,611	7,097	7,584	8,070
13 Apr. planting: Cover removed 20 May	5,807	7,313	8,820	10,326	11,833
13 Apr. planting: Cover removed 10 June	6,380	8,043	9,707	11,370	13,034
LSD	NS	NS	1,665	1,903	2,141

NS Nonsignificant.

the clear plastic rowcover will cost about \$348/acre (based on \$.04/linear ft and 8712 ft of row). The cost for the wire hoops necessary to support the rowcovers is about \$458/acre (2178 hoops @ \$.21/hoop). The additional labor will approach \$192 per acre (4 people @ \$6/h for 8 h). The total cost for this technique is about \$1000/acre. The return per acre based on the total marketable yield of the rowcover treatments is shown in Table 2. The profitability of the system will be determined by the price for the early season tomatoes. Based on the results of this 1-year trial, it would seem that an early season price of about \$0.60/lb would be the break-even point, assuming that later season prices are about \$0.20/lb. Actual wholesale prices received for 1993 and 1994 averaged \$0.46 and 0.71, respectively, for tomatoes from July 3 through July 25, the time considered early in this experiment (R.J. Battaglia, N.J. Agricultural Statistics Service, personal communication). Prices fell to about \$0.20/lb for most of the rest of the season before rising again in September. Based on these prices, it seems that using rowcovers is a very cost-effective means to improve early season yield.

This experiment clearly demonstrates that rowcovers, if used at the proper time, can increase the early yield of tomatoes. Their effectiveness, however, seems to be related to allowing earlier planting rather than accelerating the ripening of later planted tomatoes. The higher temperatures under rowcovers may decrease the yield in plantings made at traditional times. The traditional planting date for tomatoes in a particular area may indicate when rowcovers should be removed. Fall bedding seems to be a viable option for growers interested in maximizing the ability to plant very early in the spring.

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Response of Bean and Broccoli to High-sulfate Irrigation Water

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ADDITIONAL INDEX WORDS. *Brassica oleracea* L., *Phaseolus vulgaris*, electrical conductivity

SUMMARY. Groundwater contaminated with sulfate (SO_4^{2-}) at concentrations greater than allowed for drinking water may be suitable for irrigation. Our objectives were to determine the growth response and mineral uptake of two vegetables grown with high SO_4^{2-} irrigation water. Bean (*Phaseolus vulgaris*) and broccoli (*Brassica oleracea* L.) were grown in a calcareous sandy loam soil irrigated with water containing 175 to 1743 mg SO_4^{2-} /L. Plants were harvested and growth was measured at 4, 8, or 12 weeks. Soil paste and dried ground plant tissue extracts were analyzed for elemental composition at each harvest by inductively coupled plasma spectroscopy. Bean shoot dry mass decreased as SO_4^{2-} concentration increased. Although pod number at 4 weeks decreased as SO_4^{2-} concentration increased, pod number at 12 weeks was not affected by irrigation treatments. Broccoli growth was not affected by increasing SO_4^{2-} concentration at any of the harvest dates, although head diameter decreased as SO_4^{2-} increased. Magnesium, sodium, and sulfur accumulated in shoot tissue (leaves and stems) of both species in proportion to their concentration in the irrigation water. Soil Na and electrical conductivity levels increased as SO_4^{2-} concentration increased even with a 20% leaching fraction. These results suggest that bean and broccoli can be successfully grown with high- SO_4^{2-} irrigation water.

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