Europ.J.Hort.Sci., **71** (6). S. 262–266, 2006, ISSN 1611-4426. © Verlag Eugen Ulmer KG, Stuttgart

Watermelon Response to Plastic Mulch and Row Covers

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Summary

Cucurbit species respond better to small tunnels than Solanaceous species but this declaration is not always true. Watermelon *Citrullus lanatus* (Thunb.) Matsum & Nakai on plastic mulch is well documented in North latitudes, however, small tunnels have not been well evaluated in Mexican conditions. The outlined hypothesis is that plastic mulch plus small tunnels will increase early and total yield. Watermelon plants were grown on plastic mulch alone or plus small tunnels to study their effect on air and soil temperature in growth, early and total yield. Treatments were: a) clear plastic mulch (C), b) black plastic mulch (B), c) B plus a Vispore cover of polypropylene (15 g m^{-2}) (BV), d) B plus a white cover of perforated polyethylene (BW), e) B plus a clear perforated polyethylene (BC), f) B plus an Agribon cover of polypropylene (17 g m^{-2}) (BA), and g) bare soil Control. Total yield was higher compared to the Control ($p<0.05$) by 46 t ha^{-1} (170 %), 43 t ha^{-1} (159 %), 42 t ha^{-1} (153 %), 36 (132 %), 36 t ha^{-1} (131 %), and 13 t ha^{-1} (49 %) on C, B, BW, BA, BV, and BC, respectively; the Control recorded 27 t ha^{-1}. Results on this study indicate total yield is increased using soil mulch alone, while higher accumulation of degree days air and soil under small tunnels, had no positive effect in growth, early and total yield of watermelon plants.

Key words. *Citrullus vulgaris* – degree days air – degree days soil – growth – small tunnels – temperature – mulch – row cover

Introduction

In 1995, the area with plastic mulch in Mexico was of 5.600 ha, in 1996 the area was 35.000 ha, and in 2001 of 50.000 ha (Garza 2001). The main horticultural crops have been, cucumber and eggplant 33 %, summer squash 24 %, pepper 28 %, tomatoes 22 %, asparaguses 16 %, and watermelon 14 %. Main effect on soil mulch has resulted in a total yield increase and saved water when soil mulch plus drip irrigation is used.

Mulch modifies the environmental conditions, energy balance at the soil surface, creating more favorable conditions for plant growth. Mulches keep soil moisture by retarding evaporation, but soil temperature varies depending on the mulch properties (Ham et al. 1993). In general, polyethylene mulch raised maximum and minimum temperatures compared to unmulched soil (Díaz and Batal 2002).

In addition to polyethylene mulches, to promote early and total yield of horticultural crops, small tunnels or row tunnels are used. Environmental factors modified by row covers include: Light, soil and air temperature, humidity, and air movement (Wells and Loy 1985). Small tunnels are reported to increase early and total yield in watermelon, Soltani et al. (1995). Cucurbits species respond better to small tunnels than Solanaceous species (Reiners et al. 1989) but responses differ (Wells and Loy 1985). Baker et al. (1998) found that watermelon respond better to plastic mulch than small tunnels, Wilson et al. (1988) found opposite results.

Soil mulch marketing in Mexico has been increased rapidly while small tunnels market is only 6000 ha (Garza 2001). Information on soil mulch plus small tunnels is low, and more research is needed on Mexican conditions in order to have a more clear understanding of their application. The outlined hypothesis is that plastic mulch plus small tunnels will increase early and total yield respect to plastic mulch alone. The objective of this study was to measure changes induced by soil mulch alone or combined with row covers in growth, early and total yield of watermelon plants.

Materials and Methods

This work was carried out under the semi-arid conditions of the Experimental Field of the Centro de Investigacion en Quimica Aplicada (CIQA), in Saltillo, Coahuila, Mexico (25° 27‘ N, 101° 02‘ W) at a 1610 m altitude. Soil composition was clay (47 %), silt (32 %), and sand (21 %) with a pH of 7.7–7.9.

All the beds except the unmulched treatment were covered with black or clear plastic mulch 1.20 m wide and 37.5 μm thick. Treatments were: 1) bare soil, control, 2) Clear polyethylene plastic mulch (C), 3) black polyethylene plastic mulch (B), 4) B plus a Vispore cover of poly-

propylene (15 g m^{-2}) (BV), 5) B plus a clear cover of perforated polyethylene (BC), 6) B plus a white cover of perforated polyethylene (BW), 7) B plus an Agribon cover of polypropylene (17 g m^{-2}) (BA).

Treatments were arranged in a randomized complete block design with four replications. Data were tested using the analysis of variance; treatment means were compared using the Tukey procedure operating at P=0.05.

Jubilee watermelon seeds cultivar were sown on June 9, 2000. The experimental unit consisted of 3 rows 5.0 m long with 5.0 m between bed centres; distance between plants within the row was 0.50 m. Initial fertilization consisted on 100-84-84 kg ha^{-1} of N, P K before seeding, followed by 60 kg ha^{-1} of N applied, through the drip irrigation system during the vegetative growth period to make a total of 160N-84P-84K kg ha^{-1}. Irrigation was applied via drip irrigation system according to the crop needs.

Semicircular tunnels of wire 0.55 m height and 1.0 m wide were used and separated at 1.5 m within beds. The covers were placed above the tunnel, the edges of row covers were held with soil and the covers were laid 2 days after seeding (DAS) and removed at flowering. During the treatment period of row covering (40 DAS), air and soil temperatures were recorded with sensors copper-constantan 10 cm depth and 15 cm above soil. Sensors were connected to a data logger (LI-21X, Li-Cor, Lincoln, Nebraska), programmed to record readings every 10 seconds. Air temperatures were taken with sensors placed in a wood sentry- box (covered temperatures). Air degree-days and soil degree days were calculated as:

$$DD_{air} = (TA_{max} + TA_{min})/2 - T_{base}$$
$$DD_{soil} = (TS_{max} + TS_{min})/2 - T_{base}$$

Where TA_{max} is the maximum daily temperature of the air, TA_{min} the minimum daily temperature of the air, TS_{max} the maximum daily temperature of the soil, and TS_{min} the minimum daily temperature of the soil, and T_{base} is the base temperature (10 °C) × (physiologic zero).

For plant growth measurement, 2 plants per treatment were cut at soil level of the guard rows, row end plants were avoided and dry weights of leaves and stem were determined, whereas the fruit was excluded. The samples were taken at 40, 60, and 80 DAS. For dry weight determination the samples were dried at 70 °C for 48 h in a stove of hot air.

Plots were harvested every 7 days during 70 days. Early yield was considered the total production until the second harvest.

Results

Air temperatures were averaged during the period that row covers were placed, B and C recorded higher maximum and minimum air temperature 15 cm above mulch, when compared to the Control ($p<0.05$) (Table 1).

Maximum, minimum, and mean soil temperature under all mulches and small tunnels treatments were significantly higher than mean soil temperature under bare soil (Table 1). Mean soil temperature under mulch/cover treatments ranged from 3.6 to 6.0 °C higher than Control. Clear plastic mulch increased soil temperature significantly, compared to black plastic mulch.

Watermelon plants grew on plastic mulch alone or plastic mulch plus row cover-tunnel overcame those grown in bare soil in the accumulation of shoot biomass (stem and leaves), number of leaves per plant, and length stem (Fig. 2). However, plants under row cover tended to grow in a similar way than those grown on plastic mulch alone.

Early yield was similar among treatments, either in soil mulch alone or soil mulch plus small tunnels ($p<0.05$)(Fig. 1a). Nevertheless these treatments were greater than the Control. Marketable and Total yields were increased by soil mulch and small tunnels except with BC ($p<0.5$) (Fig. 1b and 1c), this treatment recorded the highest accumulation of degree days air with 839 during the row cover period. Also was the third place in accumulation of degree days soil with 808, and recorded one of the biggest frequency days over 35 °C with 29 days (data not shown).

Table 1. Effect of row covers/plastic mulch on air and soil temperatures.

Treatment	Mean air temperature (°C)			DD_{air}	Mean soil temperature (°C)			DD_{soil}
	Max.	Min.	Mean		Max.	Min.	Mean	
Control	24.8 e [y]	16.2 b	22.4 b	614 e	31.5 f	21.1 c	22.7 c	595 f
B	27.9 d	17.3 a	22.8 b	647 d	33.9 e	22.3 e	26.9 b	768 d
C	27.5 d	17.3 a	22.2 b	625 e	35.2 d	24.2 ab	28.7 a	853 a
BV	30.1 bc	17.4 a	23.8 ab	707 c	35.6 d	25.1 a	27.0 b	760 d
BW	29.3 c	17.2 a	25.4 a	773 b	39.3 b	24.5 a	26.3 b	718 e
BC	32.0 ab	17.3 a	25.7 a	839 a	41.3 a	25.7 a	28.2 a	808 c
BA	32.9 a	17.8 a	22.8 b	768 b	37.9 c	24.8 a	28.7 a	833 b
Tukey (0.05)	2.34	0.60	2.30	15.76	1.08	2.04	1.13	14.61

DD_{air}= Degree days air; DD_{soil} = Degree days soil

[y]Means within columns followed by the same letter are not significantly different at P=0.05

B= black plastic mulch; C= clear plastic mulch; BV= Black plastic mulch plus a row cover Vispore; BW= black plastic mulch plus a row cover white; BC= Black plastic mulch plus a row cover clear; BA= Black plastic mulch plus a row cover Agribon

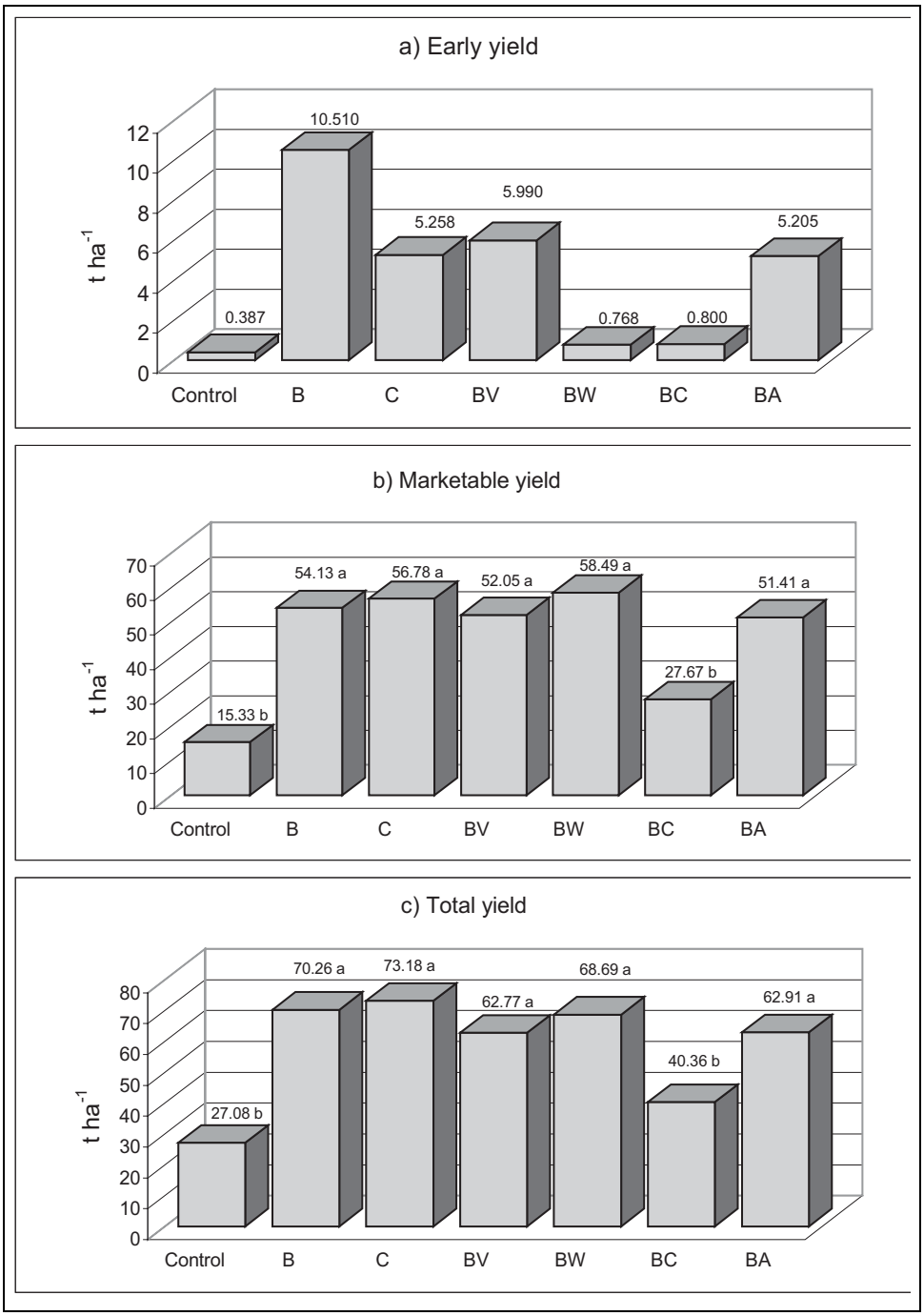


Fig. 1. Early yield in a), marketable yield in b), and total yield in c) for different treatments of covers/plastic mulch. Treatments with different letter in b) and c) are statistically different at P=0.05. B= black plastic mulch; C= clear plastic mulch; BV= Black plastic mulch plus a row cover Vispore; BW= black plastic mulch plus a row cover white; BC= Black plastic mulch plus a row cover clear; BA= Black plastic mulch plus a row cover Agribon.

Control low yield contributed to differences among treatments ($p<0.05$). Fruit total yield was higher than the Control by 46.09 t ha^{-1} (170 %), 43.18 t ha^{-1} (159 %), 41.59 t ha^{-1} (153 %), 41.6 (154 %), 35.85 t ha^{-1} (132.3 %), 13.27 t ha^{-1} (49 %) with C, B, BW, BA, BV, and BC, respectively (Fig. 1c).

Discussion

Clear plastic mulch increased soil temperature significantly, compared to black plastic mulch. Clear plastic transmits most of the incoming solar radiation to the soil, and retards the heat soil lost. However, black mulch re-radiates most of the solar energy as sensible heat to the air or to the soil (Wolfe et al. 1989). Black polyethylene mulch increased mean soil temperature over that of bare ground by 2.4, 1.2, and 4.2 °C in maximum, minimum, and mean temperature, respectively. These results are generally similar to those found by other investigators (Hemphill and Mansour 1986; Hemphill and Crabtree 1988) soil temperature in small tunnels plus black plastic were 0.1, 1.4, and 1.3 °C up on bare ground.

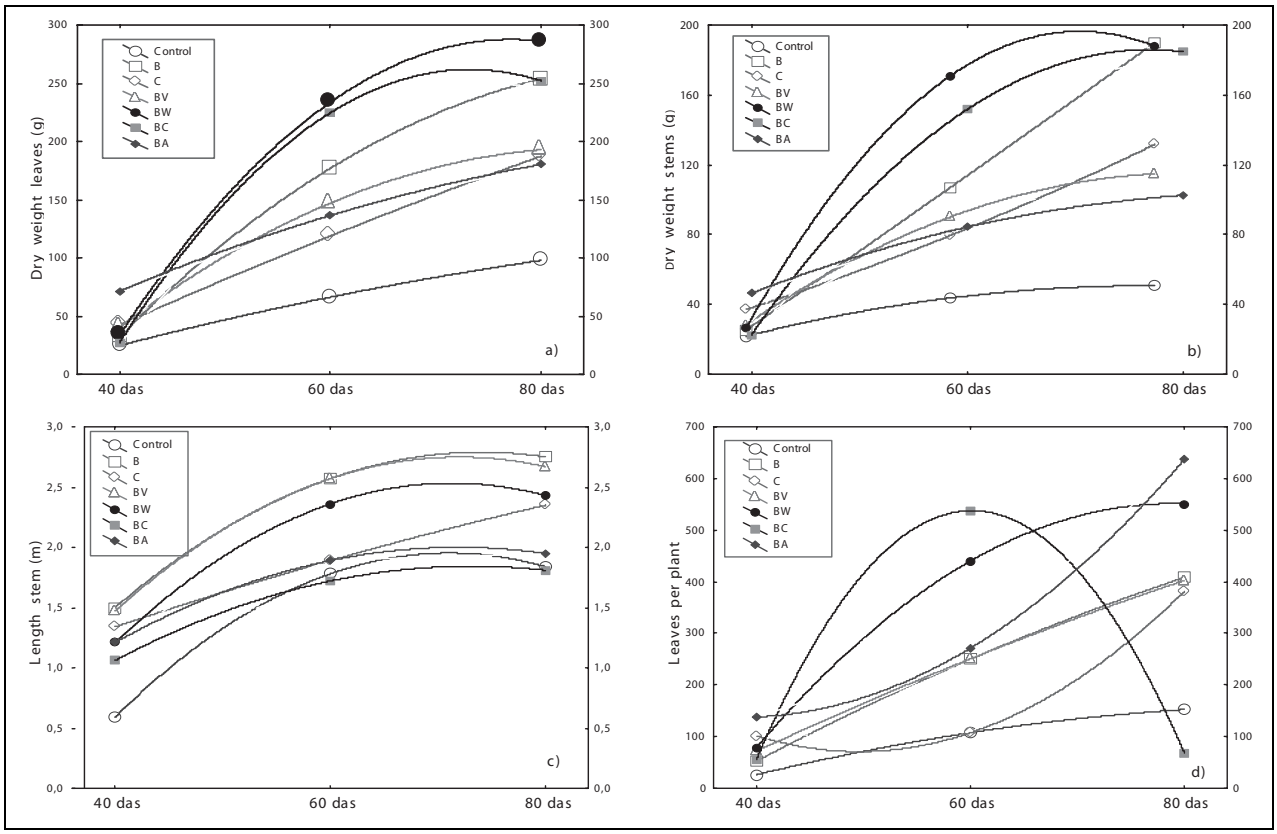


Fig. 2. Dry weight of leaves in a), dry weight of stems in b), length stem in c), and number of leaves in d) at 40, 60, and 80 das, respectively on watermelon plants. B= black plastic mulch; C= clear plastic mulch; BV= Black plastic mulch plus a row cover Vispore; BW= black plastic mulch plus a row cover white; BC= Black plastic mulch plus a row cover clear; BA= Black plastic mulch plus a row cover Agribon.

Some authors have used different formulas on air or soil Degree Days (DD) in an attempt to obtain a straight line relationship between air or soil DD, dry weight and early and total yield in cucumbers (WOLFE et al. 1989), muskmelons (JENNI et al. 1996). In both cases there was a positive response of the crop to row covers in early and total yield. In this study air or soil DD did not present a positive correlation with dry weight, early or total yield.

Light intensity at the plant level under row cover was lower than for uncovered treatments transmitting from 70 to 80 % of the photosynthetic photon flux (PPF). However, as WELLS and LOY (1985) reported, the reduction in transmittance should not limit plant growth in full or partial sun, since under these conditions PPF often exceeds the light saturation point of the plants.

The exposition to row covers did not affect the vegetative development of the watermelon crop. Although protection with row cover during the first 40 days after seeding (Fig. 2d), was enough so that plants continue growing in a remarkable form, even after removing the row cover.

Treatments on plastic mulch and plastic mulch plus row cover were statistically similar in yield among treatments, however they were greater than the Control. Increase in yield using plastic mulch plus row cover respect to plastic mulch alone are reported in muskmelon (HEMPHILL and MANSOUR 1986; BONANO and LAMONT 1989), in cucumber (HEMPHILL and CRABTREE 1988; WOLFE et al. 1989), and in watermelon by SOLTANI et al. (1995).

The optimum air temperature for growth in watermelon is around 23–28 °C (MAROTO 1989) which was closer to soil mulch treatments that recorded the highest yield values overcoming 70 t ha^{-1}. Many authors have emphasized in air temperature as an optimum growth and yield of different crops (i.e. MAROTO 1989) but very little is mentioned respect to soil temperatures requirements. Like other biological processes, root growth increase with temperature until an optimum is reached, then declines if temperature rises further (SINGH 1998). We did not determine the optimum temperature in the soil, but watermelon plants tended to record the higher total yield in C and B treatments. Soil mulch plus row cover treatments yielded 40 to 69 t ha^{-1}. It is possible that highest air and soil temperature had detrimental effects in watermelon plants, specially by row cover effect in both soil and air temperatures. It is the case in treatment BC where the maximum temperatures in the ground reached 41.3 °C, which was undoubtedly prejudicial for the roots. Different results to this study in early and total yield have been obtained by (WILSON et al. 1987; MANSOUR 1989; MILLER 1989; MARR et al. 1991; SOLTANI et al. 1995).

Polyethylene mulches were effective in increasing total yields. Soil and air temperature examination, may help to explain this effect. Soil temperatures measured

over the 40 days after seeding, indicated that maximum, minimum, and mean temperatures, tended to be the highest. However, the greatest differences were noted in air temperatures (Table 1).

Watermelon plants grown on plastic mulch alone or plastic mulch plus row cover-tunnel overcame those grown in bare soil in the accumulation of shoot biomass, and stem length. The dramatic low number of leaves per plant in the treatment BC at 80 DAS maybe was caused by the excessive heat generated with this treatment (Fig. 2d). However, plants under row cover tended to grow more than plastic mulch alone plants, the exposition to row covers did not affect the vegetative development of the watermelon crop.

Conclusion

Under the conditions of this test, the small tunnels improve neither early nor the marktable and total yields. The temperatures of the ambient air and the ground in the mulching treatments alone, are already sufficient to ensure an optimal yield.

Acknowledgement

We acknowledge support of Juanita Flores Velásquez in Tables and Figures.

References

BAKER, J.T., D.R., DEARTH, M.L. BAKER, F.J. DAINELO and V.A. HABY 1998: Interactions of poultry litter, polyethylene mulch, and floating row covers on triploid watermelon. HortScience **33**, 810–813.

BONANO, A.R. and W.J. LAMONT 1987: Effect of polyethylene mulches, irrigation method, and row cover on soil and air temperature and yield of muskmelon. J. Am. Soc. Hort. Sci. **112**, 735–738.

DÍAZ-PÉREZ, J.C. and K.D. BATAL 2002: Colored plastic mulches affect tomato growth and yield via changes in root-zone temperature. J. Am. Soc. Hort. Sci. **127**, 127–136.

GARZA, R. 2001: Aportación del polietileno al incremento de la productividad agrícola. Contribuciones del CIQA en Agroplásticos. pp. 1–50

HAM, J.M., G.J. KUITENBERG and W.J. LAMONT 1993: Optical properties of plastic mulches affect the field temperature regime. J. Am. Soc. Hort. Sci. **118**, 188–193.

HEMPHILL, D.D. and N.S. MANSOUR 1986: Response of muskmelon to three floating row covers. J. Am. Soc. Hort. Sci. **111**, 513–517.

HEMPHILL, D.D. and G.D. CRABTREE 1988: Growth and weed control in slicing cucumbers under row covers. J. Am. Soc. Hort. Sci. **113**, 41–45.

JENNI, S., D.D. CLOUTIER, G. BOURGEOIS and K.A. STEWART 1996: A heat unit model to predict growth and development of muskmelon to anthesis of perfect flowers. J. Am. Soc. Hort. Sci. **121**, 274–280.

MANSOUR, N.S. 1989: Floating row covers on vegetable crops. The Grower, 47–50.

MAROTO, J.V. 1989: Horticultura herbácea especial. Ediciones Mundi Prensa. Madrid, España. p. 425–437.

MARR, C., W.J. LAMONT and M. ALLISON 1991: Row covers improve seedless watermelon yields in an intensive vegetable production system. HortTechnology **1**, 103–104.

MILLER, G.A. 1989: Effect of row covers on harvest date of watermelon. Proceedings of the National Agricultural Plastics Congress **21,** 123–125.

REINERS, S., P. J. NIETZSCHE and W.H. TIETJEN 1997: Row cover-removal Timing affects yield of tomatoes planted on fall-prepared beds. HortTechnology **4**, 426–429.

SINGH, B.P. 1998: Soil and root growth: Introduction to the Colloquium. HortScience **33**, 946–947.

SOLTANI, N., L. Anderson and A.R. HAMSON 1995: Growth analysis of watermelon plants grown with mulches and row covers. J. Am. Soc. Hort. Sci. **120**, 1001–1009.

WELLS, O.S. and J.B. LOY 1985: Intensive vegetable production with row covers. HortScience **20**, 562–568.

WILSON, M.A., P. MOLAHLANE, V. KHAN and C. STEVENS 1987: Muskmelons on row covers and black plastic mulch. Proceedings of the National Agricultural Plastics Congress **19**, 122–125.

WILSON, M.A., P. MOLAHLANE, V. KHAN and C. STEVENS 1988: Influence of earliness and yield of watermelons on row covers and black plastic mulch. Proceedings of the National Agricultural Plastics Congress **20**, 264–269.

WOLFE, D., L.D. ALBRIGHT and J. WYLAND 1989: Modeling row cover effects on microclimate and yield l. Growth response of tomato and cucumber. J. Am. Soc. Hort. Sci. **114**, 562–568.

Received November 29, 2004 / Accepted December 29, 2005

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