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Microclimate modifications and their effect on early and total yield of 'Bigset' tomatoes.

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Microclimate modifications and their effects on early and total yield of 'Bigset' tomatoes

by

Jean Marie Bromert

A Thesis Submitted to the Graduate Faculty in Partial Fulfillment of The Requirements for the Degree of

MASTER OF SCIENCE

Major: Horticulture

Approved:

Signatures have been redacted for privacy

Iowa State University
Ames, Iowa

1979
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INTRODUCTION

The Midwest continental climate severely limits field production of vegetable crops. Efforts to extend the growing season for vegetable crops basically involve modifications of the plant microclimate.

One method involves synthetic mulches to warm the soil earlier in the season and conserve soil moisture. A variety of materials have been used to do this. Among them are plastics, both clear and opaque black, wax-coated papers, and aluminum foil. Another method involves the use of plant coverings to modify the air temperatures immediately around the plants. These include continuous row covers and individual plant covers, made of a variety of materials. Their main effect has been to raise temperatures around the plants.

Another climate factor affecting field-grown vegetables is wind. Transplants and seedlings are particularly vulnerable when they are young. Wind protection may be provided by windbreaks of vegetative material (rye strips), and plant covers. Foliar sprays of an antitranspirant applied at transplanting time may also reduce the transpiration rate caused by high winds.

These methods suggested for modifying the microclimate are subject to the early season weather conditions in the growing area. Some may be effective one year and fail the next. Others, such as mulching, have usually proven to be of benefit
to vegetable production.

The use of any of these methods involves close monitoring of soil and air temperatures in order to obtain maximum benefit. Wind speed charting may be necessary for a time to determine the effectiveness of the barrier or plant cover on the wind velocity at plant height. The goal of these plant microclimate modifications is to provide an earlier harvest for the grower since an earlier harvest is often the key to a grower's success or failure.
Environmental Stresses on Vegetables

Flowering and fruit set of tomato

Flowering and fruit set in the tomato is as much dependent on environmental factors as it is on genetic influence. Temperature seems to be the most important environmental factor involved in pollination and fruit set. Extremes of both high and low temperatures occurring either during the day or night have an effect. Low temperatures, 10 to 13°C (50 to 55.4°F), at night have increased flowering in young, stocky tomato plants (66,67). However, the pollen of flowers produced while low temperatures were occurring has been largely inviable and resulted in little or no fruit set (12). Low temperatures also delayed flowering (2). Night temperatures for optimum plant development from flower initiation through fruit set are considered to be from 15 to 20°C (59 to 68°F), (12,62,63).

Daytime temperatures are important because of their effect on pollination and fruit set in the tomato. Temperatures above 30 to 32°C (86 to 89.6°F), cause premature flower drop which reduces fruit set (1,32,45). The flower drop may be caused by low auxin levels due to inviable pollen or high ethylene levels (32,45). High temperatures may also decrease flower production by increased usage of carbohydrates for respiration (32).

These high temperatures may also cause anatomical changes
within the flower which prevent successful pollination.
Raising of the stigma higher up into the antheridial cone due
to stylar elongation is one example of these changes (1,12,32,
43,57). The pollen is less likely to land on the stigma be-
cause of the height differential. Under high temperature con-
ditions the stigma may be less receptive to the pollen or the
pollen tube growth rate may be adversely affected (1,12,57).
The optimum temperature for in vitro pollen germination and
tube growth has been found to be 27°C (80.6°F), while at 42°C
(107.6°F) no pollen germination occurs in tomato (1). High
temperatures may also cause embryo sac disintegration (1,54).

The duration of these high temperatures and the stage of
development of the tomato plant and flower during which they
occur are also important. The higher the temperature, the
shorter the exposure time needed to cause damage. One hour
exposure of tomato plants to 40°C (104°F), has been found to
be detrimental to fruit set (54). Seedlings with less than 5
expanded leaves are tolerant to high temperatures while pro-
gressively older plants are more susceptible to injury from
higher temperatures (54). Flower buds 9 to 5 days before
anthesis and flowers 1 to 3 days after anthesis are highly
susceptible to high temperature damage (54).

Wind stress

Wind may be a limiting factor in plant production on the
Great Plains. The main effects of wind on the plant are
damage from bending, abrasion from windblown particles and other plant parts, and an increase in the transpiration rate. The morphological damage may include actual loss of branches and leaves or lesions from rubbing one plant part on another or on the soil (5,34,59,65). Windblown particles, such as sand, may rupture plant cells of both leaves and stems (25, 26). All of this damage results in wounded tissue. Wounds may act as areas of entry for disease and insects (26). The plant response to this damage is an increase in respiration and a resultant decrease in photosynthesis or CO₂ assimilation (5,34,41). Carbohydrates are used for the wound healing process rather than for flower production so bloom is delayed or decreased in the damaged plant (39). Plant damage and the increase in air movement over the plant from the wind has been found to increase transpiration for a time (5,15,25). The use of irrigation to decrease transpiration after damage has occurred has been both effective (4) and ineffective (65).

Wind damaged plants of winter wheat had less dry weight due to reduced growth (5). Lower yields were recorded in snap beans and peas because of the effect of wind on bud and blossom drop (10). Reduced vegetative growth is advantageous to the plant in this situation. Less surface area is exposed to the wind by reducing leaf area and internodal length in some species (64). However, this morphological adaptation to the stress is not beneficial to the grower because of yield reduction.
In wind tunnel studies sheltered plants have been found to have higher transpiration levels than those in the open (65). This higher transpiration rate has been attributed to the larger size of the sheltered plants and less stomatal closure of these plants due to less stress. Stomata may close under stressful conditions which cause high water losses, such as the rapid movement of air across the leaf surface. This reduces transpiration but also prevents $\text{CO}_2$ uptake and photosynthesis thereby reducing growth in unsheltered plants (65).

Seedling age is of importance in the amount of damage caused by wind and windblown particles. Tomato seedlings up to 6 weeks of age are greatly damaged by wind (4,26,65). The more visible damage is caused by high speed wind (48.3 kph or 30 mph), but winds of only 9.7 kph (6 mph), can adversely affect the growth of field crops, including tomatoes (65).

Modifying the Plant Microclimate

Mulching

Mulching is a common practice used to modify the plant microclimate when growing vegetables. Materials for mulching may be either organic or inorganic compounds. Organic mulches include straw, corn cobs, wood by-products and animal manures. For the commercial grower, organic mulches require too much hand labor and handling problems because of the quantity needed. Inorganic or synthetic mulches are much more
adaptable to large scale use. Inorganic mulches can be machine applied to the field before planting, thus saving the cost of hand labor application. Synthetic mulches include Kraft paper, polyethylene or plastic (clear and black), and foils of steel or aluminum (16).

The beneficial effects attributed to mulches, particularly black plastic mulch, are numerous. Soil temperatures under black plastic mulch tend to be higher than the uncovered soil (3,9,13,16,17,24,48). Temperature increases have ranged from $4.4^\circ C$ ($7.7^\circ F$) at a 10 cm (4 inch) depth to $6.3^\circ C$ ($11.3^\circ F$) at the 5 to 7.5 cm (2 to 3 inch) depth (16,17). Early in spring, during the cooler part of the growing season, black plastic mulched soil warmed faster than unmulched and could account for the occurrence of earlier yields (13).

The soil temperature under the black plastic mulch peaked later than that of the bare soil (30,50). The black plastic mulch tends to even out temperature fluctuations throughout the day and night, providing a more uniform temperature regime for root growth and microorganism activity (16,47,50,58).

Mulch use is important in areas of limited rainfall or limited irrigation water availability. Evaporation loss from the soil is decreased by black plastic mulch, increasing the quantity of moisture available in the upper part of the soil for plant use (16,24,47). There is better nutrient retention by the soil under the black plastic mulch, nitrogen being the most important, because of reduced leaching in the
immediate area (13,16). Weed problems are eliminated near the plants and with fewer weeds less cultivation and movement is needed in the field. Less compaction and less root pruning allow for better plant growth (16,24). Black plastic mulch may also decrease disease spread and ground-spotting of the fruit (24).

Due to an increase in microorganism activity under the black plastic mulch, higher levels of CO₂ may be emitted around the plant (16). The black plastic mulch is fairly impervious to gases so the CO₂ emitted by the breakdown of the organic matter by microorganisms may be funneled along the black plastic mulch until it reaches a hole, generally where the plant is growing. This causes a temporary increase in the CO₂ level in the air around the plant and may allow for accelerated plant growth (31). In yield studies, the mulch has been found to increase both early and total yields of tomatoes by accelerating plant development and flowering (40, 55,56). The percentage of culls has also been decreased with the use of black plastic mulch (40).

There are some disadvantages to using black plastic mulch for vegetable culture. Special application equipment is required, it may be more expensive than herbicides for weed control, and it generally can be used for only one season in temperate climates (24).
Plant protection

Plant covers or protectors are used to allow a longer growing season or to overcome adverse weather conditions (24). Means of protection used for large scale vegetable production include individual plant covers, continuous row covers, foams, shelterbelts or windbreaks and antitranspirants. Some of these provide protection from low temperatures and wind damage in the field.

Early work with plant covers was done in the 1950's with glassine or wax paper caps on muskmelons (14,49,71). These studies also used individual plastic covers which were found to be no better than the standard glassine cap. Zink also found the glassine caps to provide better frost protection than individual plastic covers (71). These covers provide little protection from radiation frosts (8). The caps promoted early growth and when used in combination with a mulch paper, fruit was ripe 3 to 9 days earlier than the check plots (14). Perforating the caps is essential to prevent damage to the plants (11,14). With the possibility of damage from high temperatures caps have a short period of effectiveness and are of greatest benefit during cool seasons (11,14).

Continuous tunnels of either wax paper or clear polyethylene provided even better protection than the individual covers (49). The continuous covers were found to increase minimum air temperatures within the cover 2.2 to 4.2°C (4 to 7.5°F) higher than the ambient air temperature, while
caps only increased the temperature 1.1 to 3.4°C (2 to 6°F) (49). Cloudy weather and high winds tended to decrease the effect of the tunnels on the air temperature around the plants (24).

Ventilation is required during sunny days. Perforations may decrease the temperatures within the tunnels by 10°C (19°F) on sunny days but frost protection or increase in minimum temperatures are decreased by 1°C (2°F) (27, 28, 46, 50, 68). The perforations allow the tunnels to be in place longer (28).

Frost protection levels afforded by the covers depend on a number of factors. These include the covering material, moisture condensation on the inside of the film, thermal properties of the soil, cloud cover, wind, and other factors (29, 50). This protection may be up to 4°C (7°F) at night (33).

Plant covers also provide protection from wind and wind-blown particles (7, 11, 29, 68). This can be very important in protecting a newly transplanted seedling from excessive transpiration losses and mechanical damage. The plants grow more rapidly because of better moisture availability and less leaching loss of nutrients under the covers (49, 52).

The plant covers also increase the daytime air temperatures and both day and nighttime soil temperatures around the plant (27, 28, 29, 33, 42, 46, 50, 51, 52). These higher temperatures are most important during a cool early growing season. Accelerated seedling growth and earlier yields have been
reported for muskmelons, cucumbers, tomatoes, and lettuce with the use of continuous row covers (7,33,49,51,68).

Daytime temperatures may reach a very high level, especially inside covers without ventilation, causing flower abscission or other damage to the plant (13,27,42,46). The decision to remove the covers must be based on current environmental conditions (51).

Combining row covers with black plastic mulch has been both advantageous and deleterious to growth and yield of some crops. Earliness was enhanced 3 to 9 days by using both mulch paper and plastic caps on cantaloupe (14). Total yields of muskmelons were also greatly increased with the combination of row covers and black plastic mulch (33). Sweet peppers showed retarded growth and more culls when grown with the continuous row cover-black plastic mulch combination (46).

Foams have been used as a means of frost protection. They are most effective on frosts occurring during clear, calm nights, which are generally considered radiative frosts. Up to 6.6°C (12°F) protection has been provided by these protein-based foams. The protection is greatest near the ground. Drawbacks with their use include removal during the daytime, reapplication every night if protection is needed, and instability of the foam under windy conditions (23,53).

Tomatoes are very sensitive to moisture stress so protection from wind and its effect on transpiration can be very important, especially with newly set transplants (44,60).
Transpiration can be reduced by inducing stomatal closure or by covering the stomata or leaf surface with a thin film-forming emulsion. This film could lessen 'transplant shock' or allow a plant to survive a moisture-stress period.

Antitranspirants have shown promise in this area. Phenyl-mercuric acetate (PMA), 2-chloro-ethyl trimethyl ammonium chloride (CCC), and poly-1-p-menthen-8-9 diyl (Vapor Gard), have been found to be effective in reducing transpiration in certain plants (18,35,37,38,69,70).

The antitranspirants which induce stomatal closure (PMA and CCC), have caused damage to the plants to which they have been applied (38,70). Overcoming the phytotoxic effects of these compounds is necessary to enable their widespread use as effective antitranspirants.

Vapor Gard, a film-forming antitranspirant, has been used on woody plants to prevent desiccation during overwintering (35). It has also been used to increase fruit size of tree fruits prior to harvest by reducing transpiration losses from the fruit and leaves (6,36). The stage of leaf development and the concentration of Vapor Gard or other antitranspirants are the most important factors in their effect on reducing transpiration (21,36,61). At effective concentrations, Vapor Gard reduced transpiration significantly for 8 days in Fraxinus americana seedlings (22). In other studies, this same reduction in transpiration was found but with a concomitant reduction in photosynthesis (20,21,61). To overcome
this decrease in photosynthesis, compounds are needed which do not completely cover leaves, will eventually crack, or which will be lost by volatilization (22). A minimum resistance to passage of gases, such as CO₂, in these films would allow for less reduction in photosynthesis and a smaller yield loss (21). If the plant is under moisture stress, use of these film-forming antitranspirants may increase growth and yield in annual crops (21).

Literature Cited


CHAPTER II. THE EFFECT OF HOT TENT REMOVAL TIME AND BLACK PLASTIC MULCH ON EARLINESS AND TOTAL YIELD OF 'BIGSET' TOMATOES

Early tomatoes bring a higher market price, so it is important for the grower to set out plants as early as possible in the spring. Tomato plants are sensitive to low temperatures, and in some years protection from near-freezing or freezing temperatures may be needed. Row covers or individual plant covers provide some cold protection and may increase the ambient air temperature around the plant by 4°C (7°F) at night (6). In addition, the higher temperature around the plant during the day speeds up plant development and earlier maturity of the fruit. However, if the temperatures are too high, pollen viability and fruit set may be reduced in some tomato cultivars (8). Timing of the removal of the hot tents is important to get maximum protection and minimum damage.

Black plastic mulch is another cultural practice that increases early and total season yields of some vegetables (9). Black plastic increased early yield of several muskmelon cultivars, both with and without polyethylene row covers (6). The soil temperature increased an average of 3.3°C (5.5°F) at a 5 cm (2 inch) depth. Other favorable factors associated with black plastic are: higher levels of CO₂ emitted from the hole in the plastic at the base of the plant, soil moisture conservation, and less soil compaction (2,4). A large early yield may be the result of more flower clusters, higher
percentage of fruit set, or greater fresh fruit weight (9).

For the past 15 years, the occurrence of the last frost at Ames, Iowa has varied from April 6 to May 12. Some protection from low temperatures may be needed in this area when transplants are set into the field. This two-year study was undertaken to determine the effect of hot tent removal time and black plastic mulch on early and total yield of 'Bigset' tomato at the Horticulture Research Station, Ames, Iowa.

Procedures

Transplants were set-out on May 6, 1977 and May 12, 1978 into a silt loam soil which had a pH of 7.1 and 4.6% organic matter. Standard cultural practices for optimum yield were followed. Each plot was a single row 10 m (35 ft) long. Plant spacing was 60 cm (2 ft) within the row and 1.5 m (5 ft) between rows. The design was a 2 x 4 factorial, completely randomized block with four replications. Ground cover was none or black plastic. Plant cover was hot tents left over the transplants for 0, 11, 18, and 22 days in 1977 and 0, 7, 14, and 20 days in 1978. A small hole was punched in the west side of each hot tent to allow for ventilation.

Air and soil temperatures were monitored in all treatments by placing copper-constantan thermocouples 10 cm (4 inches) above ground level or 5 cm (2 inches) below ground level. Readings were taken at 12:30 p.m. each day while the hot tents were in place.
Plant dry weight, number of trusses, and flower development were determined at each hot tent removal time. An overhead sprinkler irrigation system maintained soil tensiometer readings at 25 to 30 centibars at the 45 cm (18 inch) depth in all treatments.

Fruit was sized according to diameter with small, <5.4 cm (<2 1/8 inches), medium 5.4 to 6.7 cm (2 1/8 to 2 5/8 inches), and large >6.7 cm (>2 5/8 inches) for marketable fruits. Tomatoes having more than 2.54 cm (1 inch) of either concentric or radial cracking or were catfaced were considered culls. Culls were not divided according to size.

Early yield in 1977 was from July 14 to July 20, while in 1978 it was from July 25 to July 28. Total yield included fruit picked from July 14 to August 11 in 1977 and from July 25 to August 14 in 1978. Culls were subtracted for each harvest period (early and total) to arrive at the marketable yields. Data was analysed using Duncan's multiple range test.

Results and Discussion

There was no significant interaction either year between the plant cover and ground cover for early or total yield.

Early yield

Covering the transplants for at least 7 days increased early marketable yields by 45%, from 13.8 MT/ha to 20 MT/ha in 1978, but not in 1977 (Fig. 1). The enhanced early yield
Figure 1. Effect of hot tent removal time on early marketable yield of 'Bigset' tomato in 1977, 1978. Mean separation within year by Duncan's multiple range test, 5% level.
in 1978 was due to an increased rate of fruit development. The hot tent treatment increased the formation of large fruit 17% and that of medium fruit 258% as compared to the control (Fig. 2). The hot tent coverage time of 7 days matured 42.3% of its' total crop during the early season compared to 34.1% for the control. This is further evidence of an increased rate of fruit development with the 7 day hot tent coverage.

Covering periods longer than a week greatly reduced early yields both years. In explanation, the hot tent air temperatures above bare ground in 1977 were much higher the first week than in 1978 (Fig. 3). The high 1977 temperatures may have prevented early fruit set in all treatments with hot tents. By the first hot tent removal time in 1978, the temperature had not exceeded 30°C (86°F), so fruit set probably was not adversely affected with the 7 day hot tent coverage (1,9).

Temperatures within the hot tents above the black plastic mulch were 4 to 8°C (7 to 14.4°F) higher than those above bare ground (Fig. 4). Further, hot tent air temperatures over black plastic mulch in 1978 averaged 8°C (14.4°F) higher than ambient air, with a maximum increase of 16°C (28°F) on May 19. The higher temperatures within the hot tent above the black plastic mulch have been noted before (1,7). There is a greater potential for flower abscission with this treatment combination. Just such a problem has occurred with sweet peppers (7).
Figure 2. Effect of hot tent removal time on early fruit development of 'Bigset' tomatoes in 1978. Mean separation by Duncan's multiple range test, 5% level.
Figure 3. Hot tent air temperatures above bare ground in 1977, 1978.
Figure 4. Hot tent air temperatures above bare ground and black plastic mulch in 1978. Ambient air temperatures are included.
The effect of the hot tents on early vegetative development was dependent on the early season weather conditions of each year. Plant dry weights taken at the hot tent removal times both years help point out the effects of the early growing conditions of each year (Table 1). In 1977, with the last hot tent coverage time of 22 days the plants had a dry weight of 11.8 gms, 10.4 branches or trusses, and 3.5 visible flower clusters. The control had 24.8 gms of dry weight, 11.9 trusses, and 9.1 visible flower clusters. This reduction in size and slower development under the tents may have been due to a very high respiration rate because of the high temperatures experienced under the tents. The duration of coverage also had a detrimental effect. The plant's growth is retarded by the continued high rate of respiration. Photosynthates are used for maintenance rather than growth and reproduction, reducing early yields.

In 1978, plant dry weight was slightly higher with the hot tents as compared to the controls (Table 1). This may be due to the cooler early season of 1978 as compared to the early season of 1977. Under the hot tents, the warmer temperatures may have increased the growth rate early in the season when compared to the controls. The black plastic mulch seemed to have no effect either year on vegetative development.

Total yield

Total yield was not significantly affected by the
Table 1. Effect of time of hot tent removal on plant dry weight, truss number, and flower development of 'Bigset' tomato.

<table>
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<td>11.9</td>
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<tr>
<td>Flower number</td>
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<td>2.0</td>
<td>3.5</td>
<td>9.1</td>
</tr>
<tr>
<td></td>
<td>7</td>
<td>None</td>
<td>14</td>
<td>None</td>
</tr>
<tr>
<td>Dry wt (grams)</td>
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<td>1.1</td>
<td>3.6</td>
<td>3.1</td>
</tr>
<tr>
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<td>7.0</td>
<td>9.0</td>
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timing of hot tent removal in either year (Figs. 5 and 6). Those plants which had the longer hot tent coverage times had greater fruit set later in the season and eventually equalled the yields of the controls.

The black plastic mulch increased total season yield 9% in 1977 and 12% in 1978 (Fig. 7). Early in the season, the plants were not demanding much moisture, so the bare ground and mulched soil were able to provide adequate moisture (Fig. 8). Later in the season with a greater demand from the larger plants and heavier fruit load, the black plastic mulch provided more moisture through less surface evaporation than did the bare ground even though the tensiometers were not reading in the stress area. Soil moisture with the black plastic mulch was more readily available near the surface for feeder roots to utilize (5). Under the bare soil, these top few centimeters may have been dry. Other explanations may involve less soil compaction and more CO₂ emission around the plant as this soil type contained 4.6% organic matter and a pH of 7.1.

Soil temperatures at the 5 cm (2 inch) depth were lower under the black plastic mulch than under the bare soil late in spring (Fig. 9). The bare soil heats up faster during the day and cools down faster at night (8). Because of the time of day when the readings were taken (12:30 p.m.), the mulched soil temperatures averaged 1 °C (1.8°F) lower, with a maximum decrease of 4 °C (7.2°F) over bare soil. Later in the day,
Figure 5. Effect of hot tent coverage time on total yield of 'Bigset' tomatoes in 1977.
Figure 6. Effect of hot tent coverage time on total yield of 'Big set' tomatoes in 1978.
Figure 7. Effect of mulch cover on total yield of 'Bigset' tomatoes in 1977 and 1978. Mean separation within year by Duncan's multiple range test, 5% level.
Figure 8. Soil moisture tensiometer readings at two depths.

*One reading. Others are average of two readings.
Figure 9. Soil temperatures 5 cm below bare ground and black plastic mulch in 1978. Ambient air temperatures are included.
temperatures under the black plastic mulch were higher and did not drop as quickly as those under the bare soil (8). Sky conditions also had an effect on temperature fluctuations. Cloudy days showed less temperature difference (3). Soil temperatures tended to be near that of the ambient air or above it on cloudy days with both mulched and unmulched soil. The hot tents and black plastic mulch thus have their greatest effect on early fruit set on sunny days.

Practical use of hot tents in the Corn Belt is dependent on monitoring the temperature under the hot tent to determine removal time. When temperatures exceed 30°C (86°F), flowers may not set fruit (9). With this temperature limit, the use of hot tents would have been feasible for only 6 of the last 15 years at Ames, Iowa. This applies even if the transplants had been set out before the occurrence of the last frost in each respective year. The mulch is of proven benefit regardless of the early season weather conditions.

Literature Cited


CHAPTER III. THE EFFECTS OF HOT TEXTS AND AN ANTITRANSPIRANT FOLIAR SPRAY ON EARLY AND TOTAL YIELD OF 'BIGSET' TOMATOES

Iowa has strong southwest winds in the spring. This rapid air movement over plants can cause increased levels of respiration and slow growth by reducing photosynthesis and causing short-term moisture stress of the exposed plants (1, 2, 8, 13, 14, 15, 16). Buds and blossoms of some crops may fall off due to desiccation, resulting in significant yield losses (5). Damage caused by the wind may also occur due to the rubbing of plant parts on one another or on the soil surface (5, 8, 10, 14, 15).

Wind-blown particles such as sand may also cause mechanical damage by rupturing cells on the plant surface (8). This damage reduces plant size and the photosynthetic rate and increases respiration (2). These wounds may become avenues for disease and insect entrance (8).

Young plants are the most susceptible to damage from wind and wind-blown particles (9, 16). Tomato transplants up to 6 weeks of age are particularly vulnerable (9). Some type of protection for these seedlings at transplant time would be beneficial to reduce respiration losses and prevent mechanical damage (16). Two means of protection for transplants are row covers or individual plant covers and application of an antitranspirant at transplanting time. Plant covers have provided wind protection for muskmelons, tomatoes, lettuce, and
cucumbers (4,6,17). They greatly decrease air movement past the plants and protect the plants from the mechanical damage caused by wind and wind-blown particles.

Rapid air movement over plants may cause desiccation and plant loss at transplanting time or during periods of moisture stress. A temporary barrier to water loss may be needed until the transplant can develop an adequate root system to provide enough water to the plant for its transpiration and metabolic needs. Vapor Gard, a film-forming antitranspirant, (poly-1-p-menthen-8-9 diyl), has been used in this capacity. Control of transpiration during transplanting of food crops and ornamentals is one of its recommended uses (11). It has been used to increase the size of tree fruits at harvest through preharvest sprays (3,12). This size increase may be the result of less transpiration losses through the fruit and leaves. This would allow for an increase in volume of the fruit at harvest. It is also used to prevent winterkill of woody ornamentals and has been found to be effective in reducing transpiration from seedlings of Praxinus americana for 8 days (7,11). This short-term residual effect would be desirable when using Vapor Gard as an antitranspirant for vegetable transplants. The substance is transformed into a chalky solid phase and is removed as the plant grows (11).

The purpose of this study was to enhance early and total yields of 'Bigset' tomatoes by reducing transpiration at transplanting time with hot tents or an antitranspirant spray.
Procedures

Transplants were either covered with hot tents or sprayed with Vapor Gard, an antitranspirant, at transplant time. The transplants were set on May 12, 1978 into a sandy loam soil at the Horticulture Research Station, Ames, Iowa. The design was a randomized block with three replications. Treatments consisted of: (1) hot tent coverage for 14 days, (2) one spray to run-off of Vapor Gard (74 ml/gal or 1 pint/6.25 gal), and (3) unprotected seedlings. Each plot was a single 6.1 m (20 foot) row. Plant spacing was 60 cm (2 ft) within the row and 1.5 m (5 ft) between rows. A small hole was punched in the side of the hot tents to allow for ventilation. All plots were mulched with black plastic and standard cultural practices were followed to insure optimum growing conditions.

Wind speed was recorded once a day at 1:00 p.m. while the hot tents were in place. The wind speed was taken at plant height on the side of the prevailing wind using a handheld anemometer. Yield data included both early (July 25 to August 2) and total season yields (July 25 to August 16). Fruit was sized according to diameter with small, <5.4 cm (<2 1/8 inches), medium, 5.4 to 7.6 cm (2 1/8 to 2 5/8 inches), and large >6.7 cm (>2 5/8 inches) for marketable fruits. Tomatoes with more than 2.54 cm (1 inch) of either concentric or radial cracking or were catfaced were considered culls. Culls were not divided according to size. Yield data was
analysed using Duncan's multiple range test at the 5% level of significance.

Results and Discussion

The wind speed data taken while the hot tents were in place is shown in Figure 1. Wind speeds ranged from 9 kph to 11.2 kph (5 mph to 7mph). These values are low. However, even winds that do not cause obvious physical damage can adversely affect plant growth (16).

The hot tents and Vapor Gard reduce transpiration loss due to air movement and allow for more rapid growth when plants are newly transplanted. A less severe shock at transplanting time should have allowed for a greater early marketable yield with the hot tent and Vapor Gard treatments when compared to the controls. The analysis of the data from the early marketable yield shows no significant difference, even though the Vapor Gard treatment outyielded the control by 12.3 MT/ha (Fig. 2).

The hot tent and Vapor Gard treatments both significantly outyielded the control for the total marketable yield (Fig. 3). As previously noted, the hot tents and Vapor Gard should have both reduced transpiration at transplant time. This would ease 'transplant shock' and allow the plant to recover sooner and produce an earlier crop. A larger total season crop is the result of the plants coming into production sooner than the control plants.
Figure 1. Wind speed at plant height at 1:00 p.m. Anemometer sensitive to speeds ≥ 8 kph.
Figure 2. Effect of plant protection on early marketable yield of 'Bigset' tomatoes. Mean separation by Duncan's multiple range test, 5% level.
Figure 3. Effect of plant protection on total marketable yield of 'Bigset' tomatoes. Mean separation by Duncan's multiple range test, 5% level.
There was no significant yield difference between the hot tent and Vapor Gard treatments but the Vapor Gard tended to be higher. Other factors can be considered in determining which is better. Vapor Gard is much easier to apply and no phytotoxicity was apparent. Any type of sprayer can be used to apply the Vapor Gard to the seedlings at the time they are set into the field. The hot tents require a number of people to set and remove them. There is also the problem of disposal of the used tents after removal. The point most in favor of using Vapor Gard instead of hot tents to increase early and total yields of tomatoes is the cost. Vapor Gard can be applied for $90/ha ($35/acre) for labor and materials. The hot tents cost $1240/ha ($500/acre) to use. This includes labor and material costs.

Literature Cited


CONCLUSIONS

Soil moisture tension was decreased by an average of 1.1 centibars at the 25.4 cm (10 inch) depth and 2.5 centibars at the 45.7 cm (18 inch) depth under the black plastic mulch. Black plastic mulch increased total yield 9% in 1977 and 12% in 1978 but early yield was not affected. Vegetative development was not affected either year by the black plastic mulch. Hot tents increased air temperatures both over bare ground and over the black plastic mulch. The average temperature increase with the hot tents and the black plastic mulch was 8°C (14°F). In 1978, the higher yield resulting from the use of hot tents for 7 days would have increased the profit $1063/ha ($430/acre).

The use of hot tents or Vapor Gard as a protection from wind and to reduce transpiration at transplanting time seemed to be effective. Both showed higher early and total yields when compared to the control and were equal to each other in effectiveness. The Vapor Gard is much less expensive to use than the hot tents. This study should be repeated to see if the same results occur before recommending the use of Vapor Gard to growers.
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