Brushing for Frost Protection

method and materials studied to determine ability to protect desert grown specialty vegetables against hazard of freezing

S. A. Hart and F. W. Zink

Even in desert regions of mild climate, frost is often a hazard to specialty vegetables for the winter market.

One method of protecting the vegetable plants from freezing is by brushing—placing shields of brown kraft wrapping paper, attached to a framework of lath and wire or of arrowweed stalks, on the north side of east-west rows, so they lean over the plants.

The brushing shields act as windbreaks during the day to reduce convectional heat transfer from plant and soil to the air. At night they act as radiation shields, reducing radiation loss to the sky. No experimental determination has been made of the over-all heat balance or of the contribution of each factor, though measurements indicate that daytime convectional heat transfer is probably the more important mode of heat loss in limiting the storage of solar energy by the soil. The resulting low soil temperature makes frost injury more likely because there is less heat energy in the soil to meet the subsequent demand of nighttime outward radiation and convectional heat transfer.

Reflective materials have been proposed for brushing shields because calculations show that a highly reflective material—such as aluminum foil—might be expected to concentrate 20–25 BTU/ft^2 hr—British thermal units per square foot per hour—more solar energy into the soil at plant locations, nearly a 10% increase. However, reflective shields are less effective than kraft paper in conserving heat at night, for being mirrors, they do not decrease radiation heat loss to the sky; but the over-all effect of aluminum foil has nevertheless been supposed to be beneficial. Two experiments, separately conceived, were run to determine whether such reflective materials would actually improve brushing benefits.

In the first study, five stations were located at 12′ intervals along north-south rows of chrysanthemum plants. At each station, heat-flow meters were buried one half inch deep. Air temperature thermocouples were placed within the foliage of the plants 15″ above the ground. Four pairs of portable shields were used. One shield of each pair was placed 1′ north of the test station, the other shield 5′ south of the station, as if protecting an adjacent plant row. The shields, 10′ long and 3′ high, were positioned on east-west axis, and were sloped to the south 30° from the vertical. They were similar to commercial brushing shields except for the materials to be tested: kraft paper, aluminum foil, aluminum coated kraft paper and a shield made with aluminum foil on the south—sunfacing—side and brown kraft paper on the north—skyfacing—side. Automatic instruments recorded temperatures, heat flows, and air drift velocity. Air movement was quite low during the whole of the test period.

Air temperature at the 26′ elevation was compared to the ground air temperature as an indication of the nocturnal radiation level. A greater temperature at the higher elevation usually means clear sky and high radiation rate. After each night's run, the shields were moved so that each shielding system in turn protected each station. One station was unshielded each night in rotation. Data were taken for 24 nights.

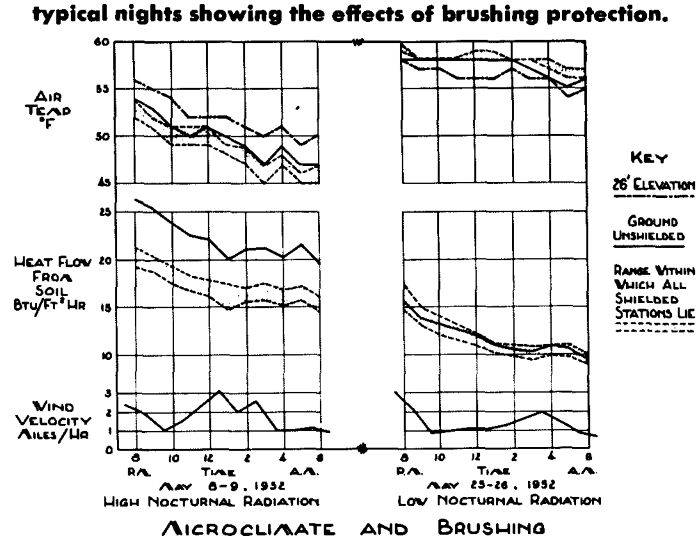
On the nights when the sky was clear—as indicated by higher air temperatures at 26′ than at the ground—the shields reduced the rate of heat loss from the soil. Under conditions of low nocturnal radiation—ground air temperature equal to or greater than air temperature at 26′—shielding did not appreciably modify the rate of heat loss from the soil. The average rates of soil heat loss with the brushing materials tested are shown in the table at the left on page 15.

There was no significant difference between the air temperatures in the foliage of the shielded and unshielded stations, and no significant differences between the air temperatures under the various materials.

Results from the 10′ test shields are not exactly comparable to commercial

Continued on page 15

Air temperature, heat flow from soil, and wind velocity on typical nights showing the effects of brushing protection.

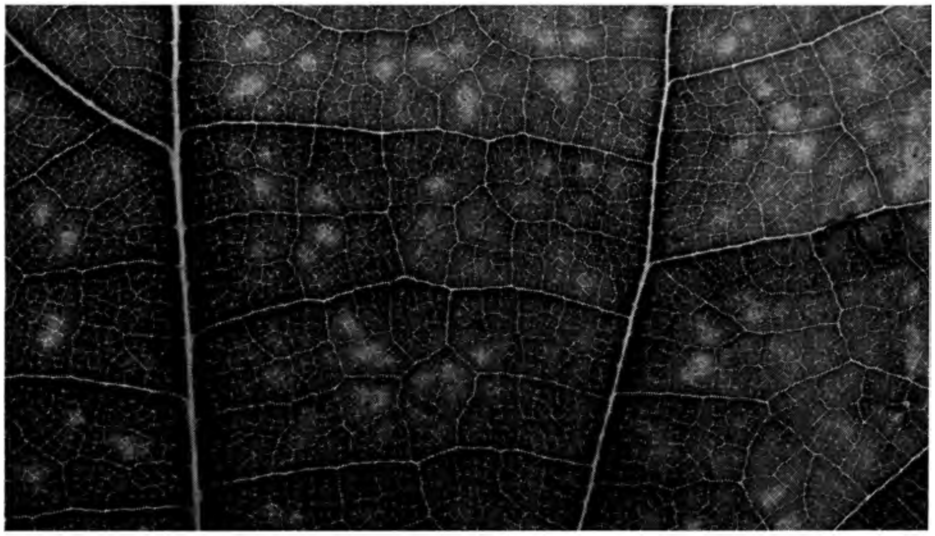


Bell pepper field in Coachella Valley protected by 2′ kraft paper brushing shields. Rows are 5′ apart.

number of spots with corresponding raised spots—that turn reddish-brown—on the under surface. Evidently the loss of affected leaves is hastened by the appearance and increased number of the spots. Not until the new leaves are approximately of full size do the spots put in their appearance. This type of leaf spot occurred on leaves of seedlings in various soil cultures—as well as in silica sand—and on leaves of many varieties on various rootstocks. Such a leaf blemish might conceivably affect the health of the tree because of the loss of green color and premature loss of leaves.

Outdoors in full sunlight or under partial shade no such leaf symptoms were found on Fuerte-Carr-Hybrid trees budded on various rootstock varieties in silica sand or soil cultures. Several of these outdoor cultures were brought into the glasshouse. The new leaves when of full size and some of the older leaves showed the symptoms as though the cultures had always been grown in the glasshouse. No recovery of affected leaves occurred by the transfer of affected cultures from the glasshouse to the outdoors. However, the removal of affected cultures from the glasshouse to the outdoors permitted new leaves to develop to full size without the appearance of any of the symptoms, even though leaves severely affected and in poor condition while in the glasshouse were allowed to be in contact with the new growth produced while outdoors.

Appearance, when highly magnified, of leaf spots on underside of avocado seedling.



From the general occurrence of these avocado leaf symptoms in the glasshouse and in leaves of trees transferred to the glasshouse from outdoors and the failure of symptoms to appear in new leaves produced following the tree removal from the glasshouse to the outdoors, it would appear that possibly the increased humidity in the glasshouse under reduced light may be a factor in the initiation of this leaf malady.

Whether a sprinkler system that contacts tree foliage would be sufficiently continuous as to affect leaves in this manner is not known.

A. R. C. Haas is Plant Physiologist, Emeritus, University of California, Riverside.

Joseph N. Brusca is Principal Laboratory Technician in Plant Biochemistry, University of California, Riverside.

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BRUSHING

Continued from page 8

brushing, where several acres are protected. The short shields of the test did not seem to act as sufficient windbreaks to reduce the convectional heat transfer. However, results from the test shields are indicative of reduction of nocturnal outward radiation as measured by heat flow from the soil. The heat loss was significantly less with brushing, although no material was significantly better than any other.

The second study was conducted in the Imperial Valley to evaluate the effect on plant growth and frost protection of the color of brushing paper. Four colors were studied: brown kraft wrapping paper, black and red papers, and aluminum foil backed with brown kraft paper. An unshielded station was included for comparison.

All stations were replicated four times in a randomized block design. The shields were 3′ high and sloped to the south 30° from the vertical. Each plot consisted of 15 hills of tomatoes 1′ apart on the south side of a 5′ wide raised tomato bed. The beds ran east-west. In each hill 10 Pearson tomato seeds were planted one half inch deep. Irrigation was started January 11, 1951. Data on per cent and rate of emergence in the center 10 hills of each plot were used as a biological assay of soil temperature.

Daytime air temperatures as measured by mercury thermometers one half inch above the soil surface at the plant locations were approximately the same at all shielded stations and higher than at the unshielded station. Daytime soil temperatures were highest under the aluminum foil shield.

Percentage emergence was significantly greater under the aluminum foil shield than the other shields on January 20. Differences in per cent emergence under the various shields were not significant on January 25, but the difference between shielded and unshielded stations was highly significant. The data on rate and per cent emergence substantiate the temperature records observed under the various shields.

Concluded on next page

Air Temperature at Plant and Loss of Soil Heat Associated with Various Kinds of Protection

Protection	Heat flow BTU/ft.² hr. from soil*	Air temperature at plant* °F
Unshielded	14.6	55.2
Kraft paper shield	13.3	55.5
Sisalation shield	13.3	55.3
Aluminum foil shield	13.5	55.4
Aluminum and kraft paper shield	13.3	55.7
L.S.D. 5%	0.55	not sig.
1%	0.74	

*Average of 24 nights test, from 9 p.m. to 5 a.m.

Soil and Air Temperatures Associated with Different Brushing Protection on a Typical Morning

	7 a.m.	8 a.m.	10 a.m.	12 noon
	Soil temperatures on Jan. 16 ½" deep			
Unshielded	36	41	53	64
Brown	38	44	57	67
Red	37	44	56	68
Black	38	43	56	68
Aluminum	40	45	63	73
	Air temperatures on Jan. 16 ½" above soil surface			
Unshielded	33	40	59	62
Brown	34	42	60	64
Red	34	42	60	64
Black	34	42	60	64
Aluminum	34	42	61	66

Effect of Color of Paper Shield Brushing on Rate and Per Cent Emergence

Date	Paper color					L.S.D.**	
	N*	Br*	Rd*	Bl*	Al*	5%	10%
1/16	0	0	0	0	0	..	..
1/20	0	35	29	32	47	6.95	9.76
1/25	18	73	68	62	78	19.8	27.8

*N: none; Br: brown; Rd: red; Bl: black; Al: aluminum.

** Least significant difference.

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BRUSHING

Continued from preceding page

No frost damage was observed in any of the shielded treatments although there was a small amount of leaftip burning on the unshielded plots. When the shields were removed, seven weeks after planting, the plants under the various paper treatments showed no difference in size, while those in the unshielded plots were smaller because of late emergence.

Brushing helps maintain a warmer environment at the plant. However, these studies indicate that reflective or colored shields are of only little benefit. Increased daytime soil temperatures and speed of emergence of tomato seedlings indicate that aluminum foil shields increase the heat input to the soil, but this did not result in more favorable nighttime conditions when frost usually occurs.

Although the germination rate of tomato seedlings was speeded under aluminum foil brushing, the plants did not subsequently grow faster or larger. As the brushed plants grow, they shade out the underside of the shielding so that reflective materials become of decreasing importance with time.

The effect of any brushing material for frost protection is positive, due to reductions in both radiational and convectional heat losses, but the effectiveness of brushing depends upon plant size and causation of the frost damage. Small plants may be protected from a certain frost condition while large plants that are nearly as high as the brushing paper will be frosted back on their more exposed south and top sides. Also, strictly radiational frost conditions—very calm and clear—can be better controlled with brushing than cold air front frost conditions.

S. A. Hart is Assistant Professor of Agricultural Engineering, University of California, Davis.

F. W. Zink is Associate Specialist in Vegetable Crops, University of California, Davis.

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Contributions to the University of California for research by the Division of Agricultural Sciences, accepted in August, 1957

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