Title
Part II: Potential Usefullness of Antitranspirants for Increasing Water Use Efficiency in Plants: Applied Investigations with Antitranspirants

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POTENTIAL USEFULNESS OF ANTITRANSPIRANTS FOR INCREASING WATER USE EFFICIENCY IN PLANTS

II. APPLIED INVESTIGATIONS WITH ANTITRANSPIRANTS

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APPLIED INVESTIGATIONS WITH ANTITRANSPIRANTS

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APPLIED INVESTIGATIONS WITH ANTITRANSPIRANTS

Antitranspirants can be useful in achieving the following broad objectives: 1) soil-water conservation; 2) improvement of plant performance via increased plant-water potential; and 3) miscellaneous uses, e.g., prevention of fruit cracking.

SOIL-WATER CONSERVATION

Reduction of irrigation requirement of oleanders (in cooperation with the California State Division of Highways).

The California State Division of Highways, at the present time, spends about $3 million dollars annually (out of their landscape maintenance budget) for irrigation of ornamental plantings along California Highways. Projected costs for future years are much higher. In addition to being costly, plant-watering operations are hazardous, since oleanders grown in the dividing strip of the freeways are irrigated by slow-moving tank trucks which must maneuver in and out of the fast lanes of traffic. Any method resulting in reduced irrigation requirements of the 1,000 miles of oleander plantings on California highways would consequently be of great significance.

Initial studies on the effects of antitranspirants on oleander plants involved pot experiments in greenhouse and laboratory measurements of the rates of transpiration and photosynthesis. The latter measurements, which were presented in Table 9 in Part I (Basic Investigations) of this report, showed reductions of 15 to 50% resulting from phenylmercuric acetate (stomata closing) or CS-6432 (film-forming) antitranspirant treatment. Transpiration data from pot experiments were given in Table 16 where antitranspirants reduced daytime transpiration losses by as much as 70%. Other evidence of reduced water losses from potted oleanders in the greenhouse was shown in Figures 8 and 17 to 19. The studies involving interaction of antitranspirant effect and soil moisture suggested that antitranspirants would be most efficient in conserving soil moisture if applied soon after an irrigation, rather than when soil moisture was already severely depleted.

These preliminary studies laid the groundwork for measurements of the effects of antitranspirants on plantings along a highway during summer, 1968. In an experiment near Davis, randomized blocks of oleanders in the median strip of Interstate 80 were treated with phenylmercuric acetate (PMA, 110 ppm) or CS-6432 (3%) just after an irrigation. About 1/4 gallon of diluted spray was applied per bush by a mist blower, and particular attention was given to wetting the lower surfaces of the leaves where all of the stomata are located. Gypsum blocks at 1, 2 and 3-foot depths were used to record the changes in soil-matric suction. Three weeks after spraying, the matric suctions at the 2-foot depth in the antitranspirant-treated plots were about 40% lower than in the control plots (Table 1). The average reductions over the 3-foot depth were 25 to 30%. Because of the reduced rate of water loss from the antitranspirant-treated plants, the relative water contents of these leaves, sampled in the late afternoon, were higher than in the control plants. These experiments with oleanders on the freeway suggested that, on the basis of the rates of soil-moisture depletion, irrigation intervals may be increased by one to two weeks by the use of antitranspirants. However, it should be kept in mind that no standards have been experimentally determined for the optimum irrigation time of oleanders. Furthermore, the plants along the freeways are extremely variable because of genetic heterogeneity and varying soil textures in the back-filled trenches in which the oleanders are planted. However, the need for protection against excessive water loss is probably much greater on the freeway than in other locations because 1) the isolated (and therefore unprotected) nature of the plantings and the turbulence created by fast-moving traffic on either side of the median strip enhances water loss; and 2) the variable texture, and rooting depth of the soil, limits water availability to the plants in localized areas.

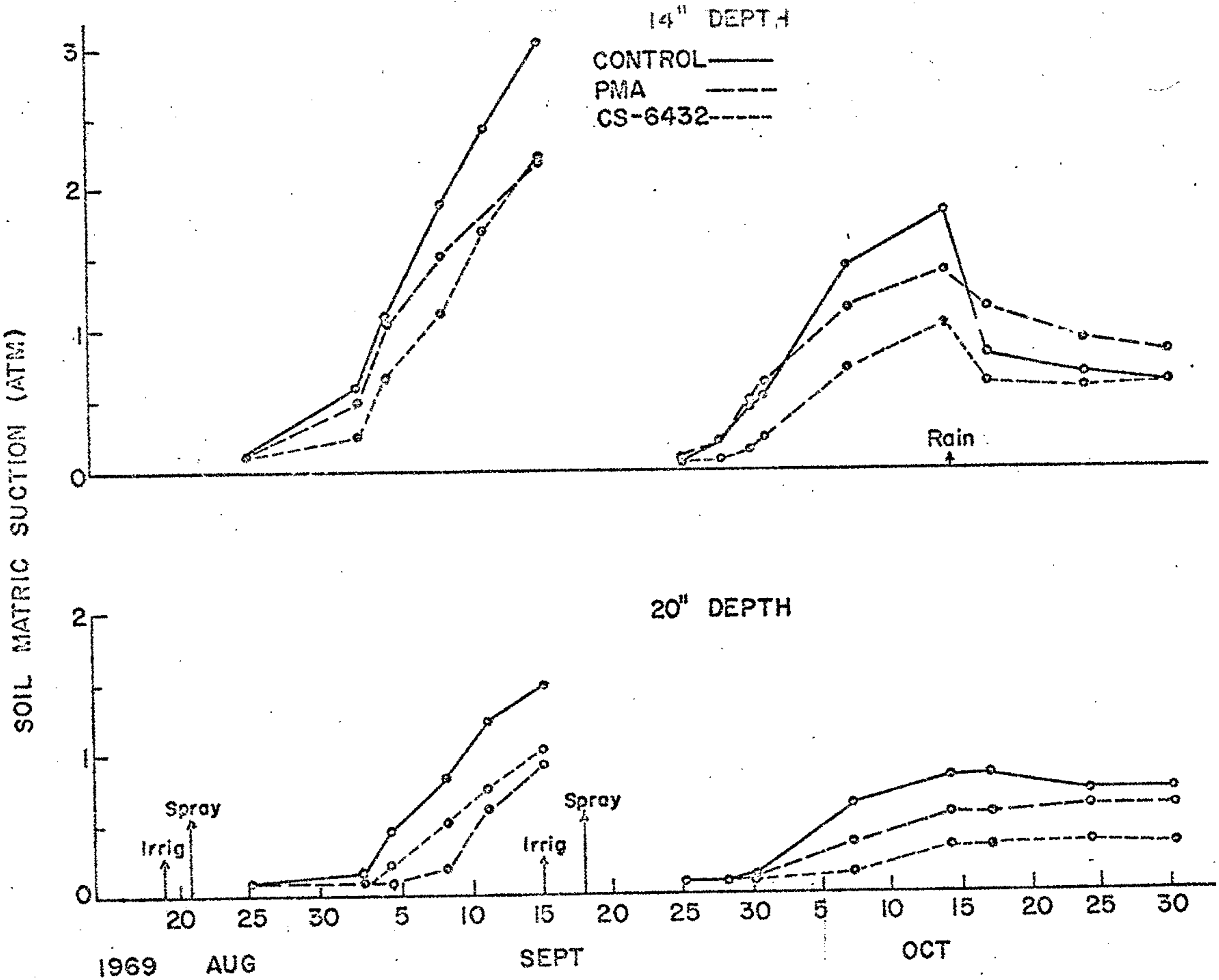
Table 1

Effects of antitranspirant sprayed on oleanders in a freeway median strip on soil-matric suctions (atm) at three soil depths, measured by gypsum blocks three weeks after application. Numbers in parenthesis are values relative to control (100).

	Matric suction (atm)			
	1 foot	2 feet	3 feet	Average (1-3 feet)
Control	2.95 (100)	2.50 (100)	1.70 (100)	2.38 (100)
PMA (110 ppm)	2.65 (90)	1.40 (56)	1.30 (77)	1.78 (75)
CS-6432 (3%)	1.80 (61)	1.45 (58)	1.75 (103)	1.67 (70)

Because of the extreme variability of soil along the freeways, a line of oleanders was planted in autumn 1968, at the Davis experimental farm, where it was known that the soil was much more uniform and would therefore enable more accurate determinations of soil-moisture extraction rates as affected by anti-transpirants. The oleanders, planted six feet apart in a single line, were divided into treatment plots. Each plot had three plants and was replicated four times. In the summer of 1969, soil-moisture extraction was measured by gypsum blocks at 8-, 14- and 20-inch depths, tensiometers at 16- and 26-inch depths, and a neutron moisture meter to a depth of three feet. Only the center plant of each plot was instrumented. The oleanders were irrigated and fertilized with NH_4NO_3 in mid May, 1969 and were given three more irrigations before spraying on August 21. The sprays were 1) control (water + X-77 surfactant); 2) PMA (110 ppm + X-77 surfactant); and 3) CS-6432 (2%), given in two light consecutive sprays. About one liter of diluted material was sprayed on each plant. The plots were re-irrigated on September 15 and resprayed on September 18.

Resistances of gypsum blocks at the 8-inch depth increased far more rapidly than those at the 14- and 20-inch depths because of soil-surface evaporation. The effectiveness of the antitranspirants in decreasing soil-water suction at the 8-inch depth was, therefore, small or nonexistent. However, at 14 and 20 inches, the antitranspirants did decrease soil-matric suction between August 21 and September 15 (Figure 1). Similarly, tensiometers (which are sensitive only in the wet soil-moisture range, up to 0.8 atm) indicated that PMA and CS-6432



<u>Figure 1</u>: Effects of phenylmercuric acetate (PMA) and CS-6432, sprayed on Oleanders, on soil matric suction measured by gypsum blocks.

decreased soil-matric suctions at the 14- and 26-inch depths (Figure 2). Thus at the 26-inch soil depth, when control plants had depleted soil moisture to a matric suction of 0.6 atm, the antitranspirant-treated plots were about 0.4 atm, i.e., a 33% decrease in soil-matric suction resulted.

Changes in soil-water content (volume percentage of P_v) with time at the 12-, 18-, 24- and 36-inch depths are shown in Figure 3, A-D. At 12 inches during the first drying cycle, CS-6432 gave the most noticeable reduction in the rate of soil-moisture depletion. Thus, P_v in the CS-6432 plots was depleted to 25 by September 15, whereas the controls had reached this level of depletion about 10 days earlier on September 4. The September 15 irrigation wetted the CS-6432 plots more thoroughly than the control and PMA plots, presumably because of the already high P_v in the former. The rate of soil-water depletion during the second drying cycle was again reduced by CS-6432. PMA appeared to have no effect.

During the first cycle, both CS-6432 and PMA decreased the rate of soil-moisture depletion, so that P_v values at the 18 inch depth on Sept. 15 for control, PMA and CS-6432 were 18, 20 and 22%, respectively. If we arbitrarily select 18% soil-water content (percent by volume) as the critical allowable depletion level at the 18-inch depth before re-irrigation of the oleanders becomes necessary, control plots reached this level on September 15. However, for the CS-6432 plots it would probably not reach this critical level until early October, i.e., about two to three weeks later than the controls (obtained by extrapolation of the CS-6432 curve). In the second drying cycle, the antitranspirants again reduced soil-water depletion rates, so that by the end of October, the CS-6432 and PMA plots had, respectively, 20 and 6% higher soil-water contents than controls.

At 24 inches, reductions in soil-moisture depletion rates were similar to those observed at the 18-inch depth. The apparent greater effectiveness of PMA was partly due to initially higher soil-water contents in these plots at both irrigations.

At 36 inches, it was obvious that insufficient irrigation water was applied to thoroughly wet the soil, except in the PMA plots. Nevertheless, the reduced rates of depletion in the CS-6432 plots, relative to controls, indicates the presence of some roots at this depth. By September 15, the roots appeared to be particularly active at the 24- and 18-inch depths where control plants depleted soil water to P_v 17 to 18%. Although there was adequate water available at 12 inches, the depletion at this depth was not as great as at 18 and 24 inches. In this soil, the roots tended to be confined to the center of the plant at shallow depths (8 to 12 inches) and to spread away from the center with increasing depth. Therefore, if the neutron probe access tube had been located closer to the plant, greater moisture depletions might have been observed at the 12-inch depth.

The amounts of soil-moisture depletion at the four soil depths measured is given in Table 2 for both irrigation cycles. In each cycle, the depletion of P_v between the day of spraying (which was usually two days after irrigation) and the last day before re-irrigation was due, was always greatest for control and least for CS-6432. The average water use (inches of water from 36 inches of soil) was reduced 36% by CS-6432 and 13% by PMA in the first cycle; corresponding reductions in the second cycle were 35 and 9%. (It should be kept in mind that the calculated soil-water depletions were based on average P_v over

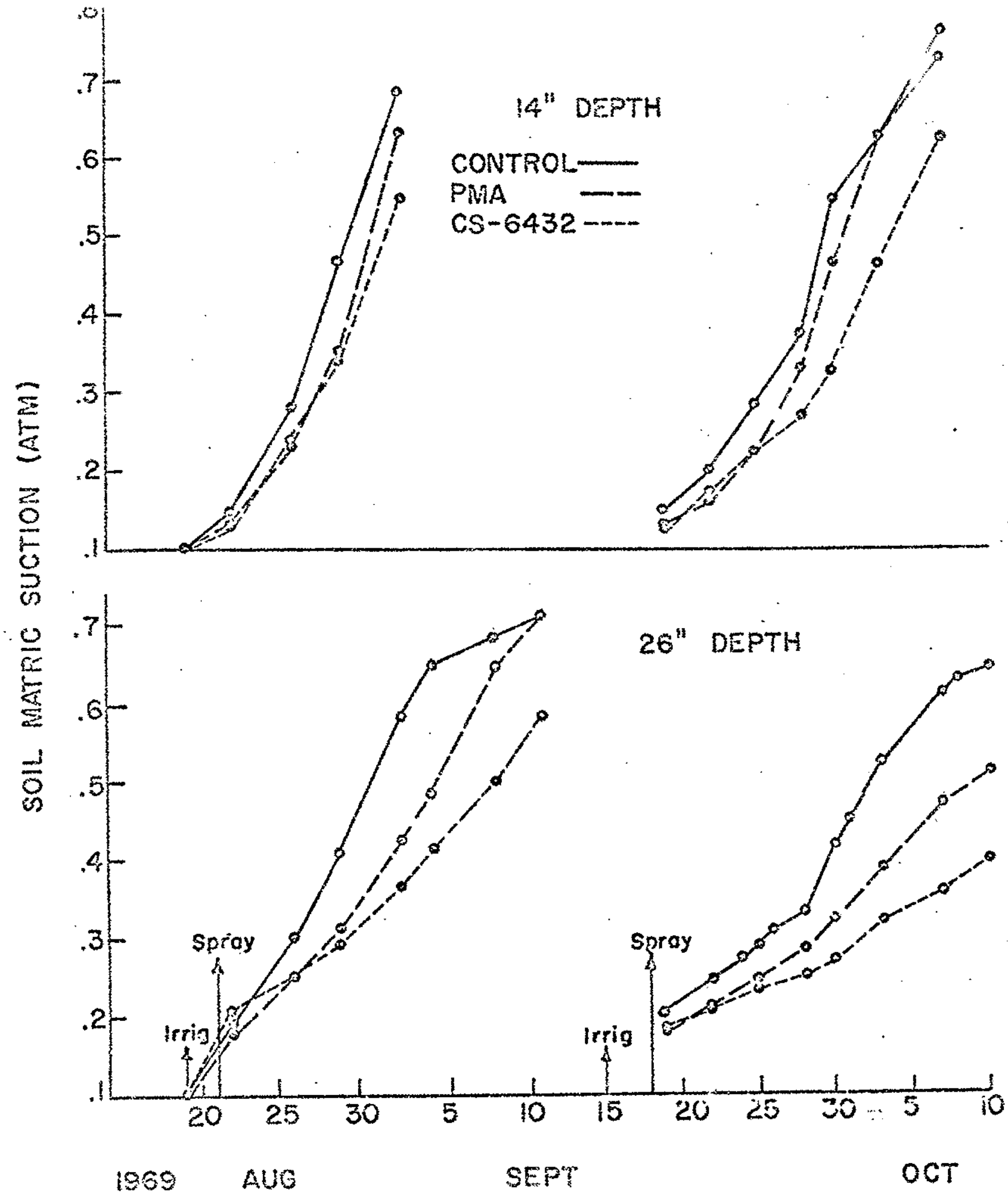


Figure 2: Effects of phenylmercuric acetate (PMA) and CS-6432, sprayed on oleanders, on soil matric suction measured by tensiometers.

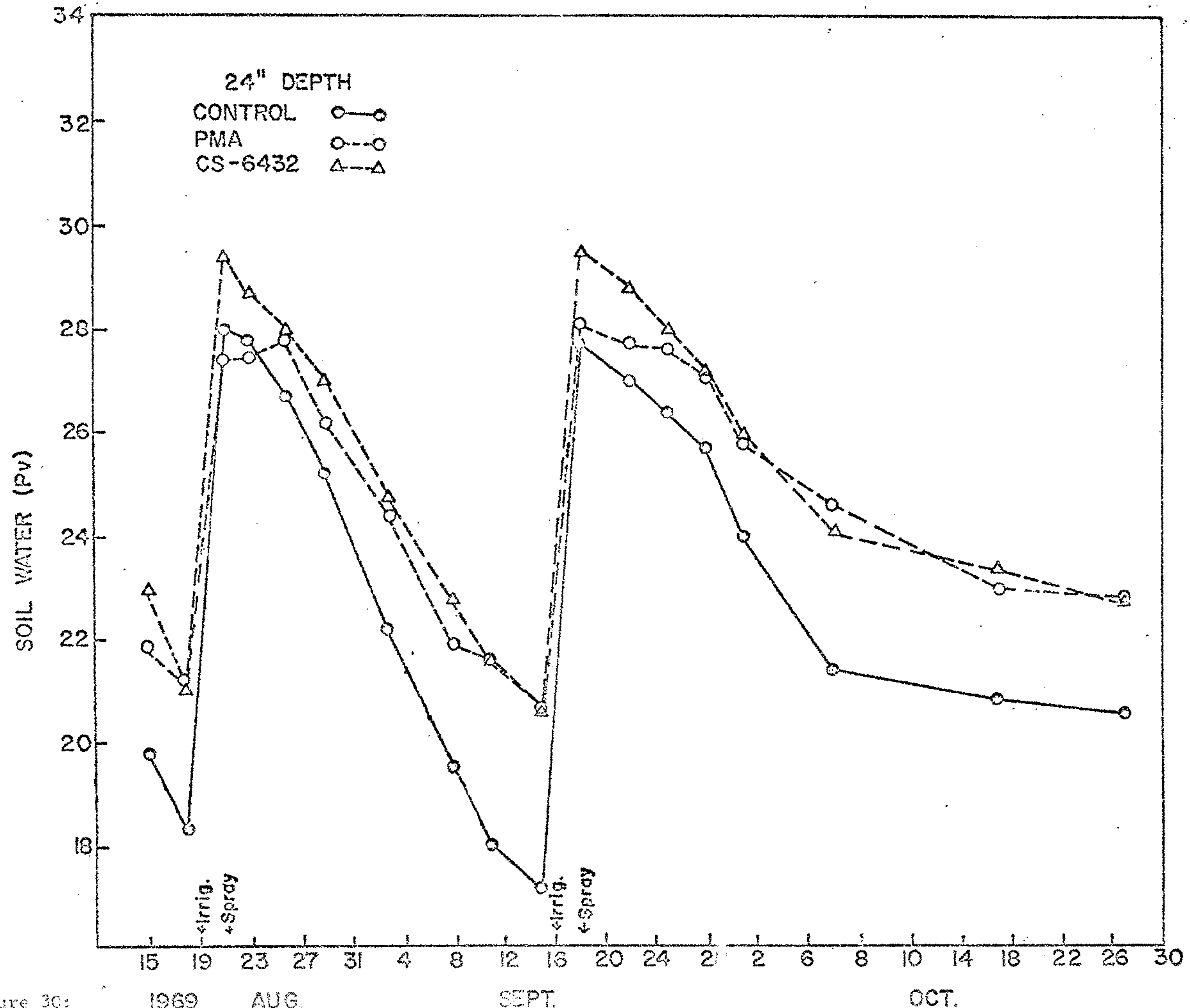

24" DEPTH
CONTROL
PMA
CS-6432
SOIL WATER (Pv)
34
32
30
28
26
24
22
20
18
←Irrig.
←Spray
←Irrig.
←Spray
15
19
23
27
31
4
8
12
16
20
24
2
6
8
10
14
18
22
26
30
1969
AUG.
SEPT.
OCT.

Figure 3C:

Figure 3 (A-D): Effects of phenylmercuric acetate (PMA) and CS-6432, sprayed on oleanders, on soil water content (volume percentage) measured by a neutron moisture meter at depths of 12, 18, 24 and 36 inches.

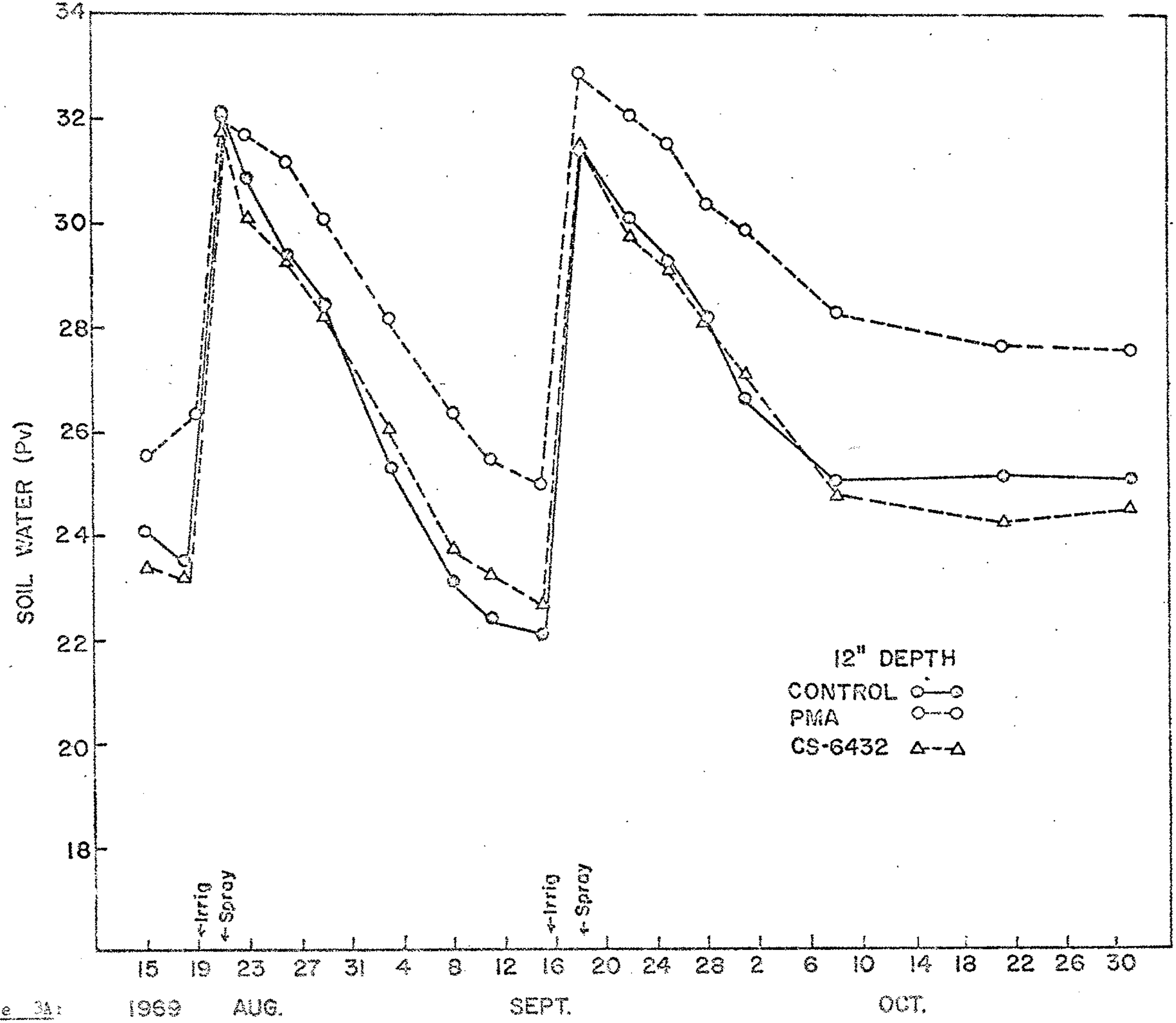

SOIL WATER (Pv)
34
32
30
28
26
24
22
20
18
12" DEPTH
CONTROL
PMA
CS-6432
←Irrig
← Spray
←Irrig
← Spray
15 19 23 27 31 4 8 12 16 20 24 28 2 6 10 14 18 22 26 30
1969 AUG.
SEPT.
OCT.

Figure 3A:

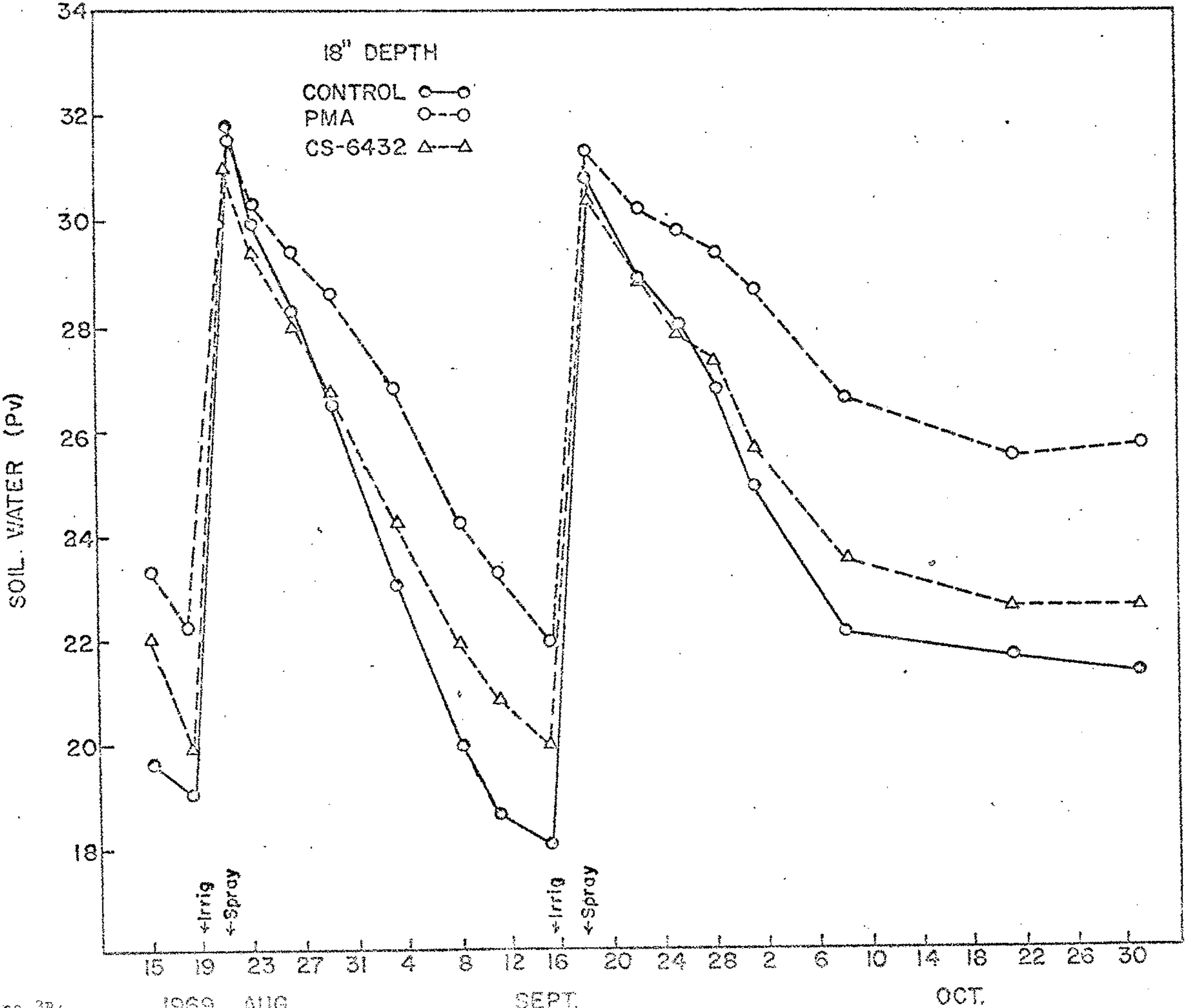

18" DEPTH
CONTROL
PMA
CS-6432
SOIL WATER (Pv)
34
32
30
28
26
24
22
20
18
←Irrig
←Spray
←Irrig
←Spray
15
19
23
27
31
4
8
12
16
20
24
28
2
6
10
14
18
22
26
30
1969 AUG
SEPT.
OCT.

Figure 3B

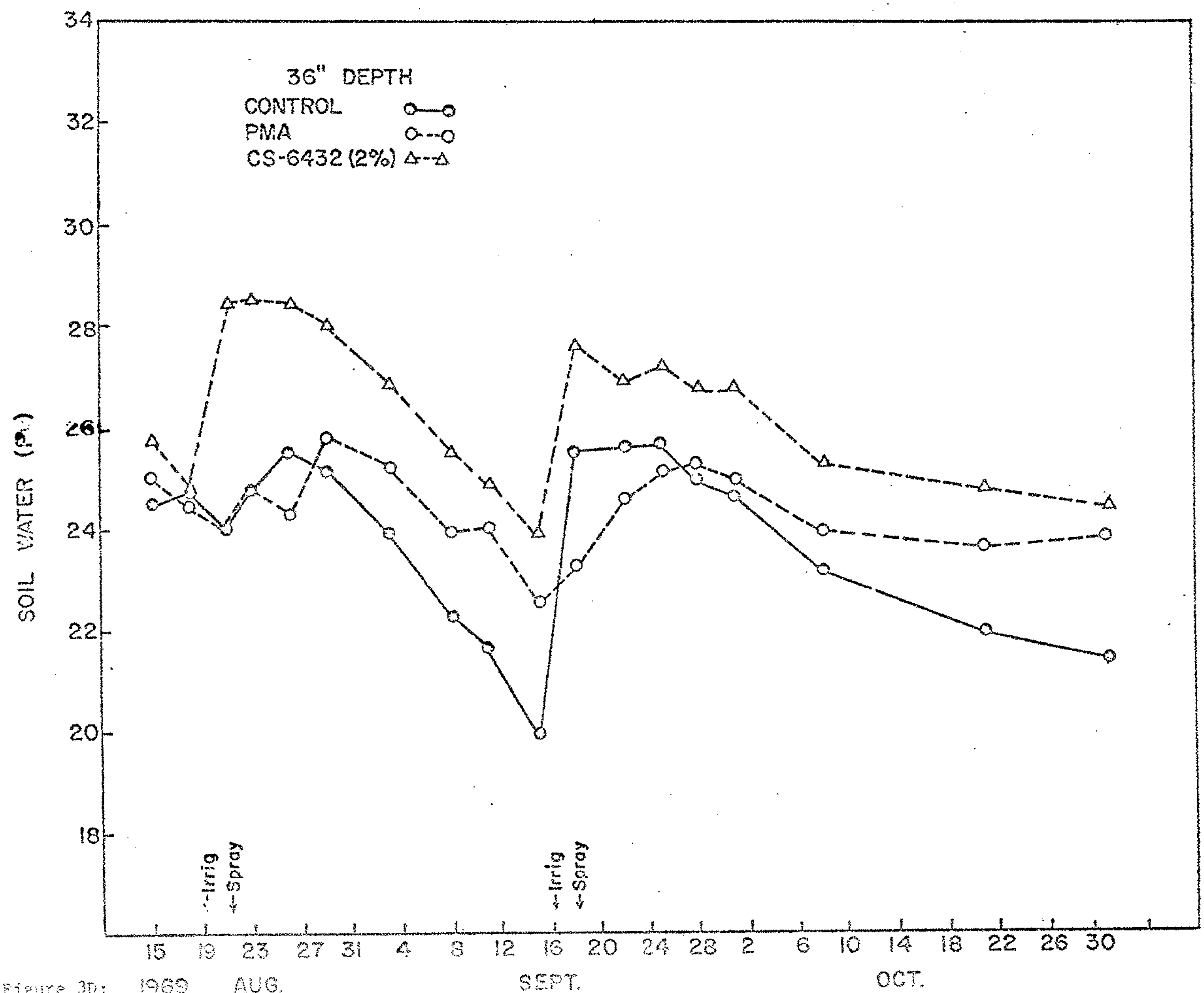

36" DEPTH
CONTROL
PMA
CS-6432 (2%)
SOIL WATER (P.)
34
32
30
28
26
24
22
20
18
←Irrig
←Spray
←Irrig
←Spray
15
19
23
27
31
4
8
12
16
20
24
28
2
6
10
14
18
22
26
30
1969
AUG.
SEPT.
OCT.

Figure 3D:

Table 2

Effects of PMA (110 ppm) and CS-6432 (2%) on soil water depletion (D) by irrigated oleanders over two drying cycles in 1969.

1st Cycle

	SOIL WATER % (P_V)								
	Control			PMA			CS-6432		
Depth (in)	8/21	9/15	D	8/21	9/15	D	8/21	9/15	D
12	32.1	22.1	10.0	31.8	22.7	9.1	32.0	25.0	7.0
18	31.8	18.0	13.8	31.0	19.9	11.1	31.5	21.9	9.6
24	28.0	17.1	10.9	29.4	20.5	8.9	27.4	20.6	6.8
36	24.1	20.0	4.1	28.5	23.9	4.6	24.1	22.6	1.5
Average P_v			9.70			8.43			6.23
Water use from 36" profile (inches)			3.49			3.04			2.24

2nd Cycle

Depth (in)	9/18	10/31	D	9/18	10/31	D	9/18	10/31	D
12	31.5	25.1	6.4	31.5	24.5	7.0	32.9	27.6	5.3
18	30.8	21.3	9.5	30.4	22.6	7.8	31.3	25.7	5.6
24	27.7	20.5	7.2	29.5	22.7	6.8	28.1	22.8	5.3
36	25.6	21.5	4.1	27.7	24.5	3.2	25.3*	23.9	1.4
Average depletion in 36" profile (P_v)			6.8			6.2			4.4
(Inches)			2.45			2.23			1.58

*P_v on 9/28, due to delayed water penetration to this depth.

all depths measured, and did not include measurements in the 0- to 12-inch layer, where water losses by surface evaporation were probably high. However, the omission does not affect the relative depletions between treatments.)

About three miles of a 3-foot-wide oleander-planted median strip is equivalent to 1 acre, and 1-acre-inch of water = 27,600 gallons. Therefore, in the first irrigation cycle, the 3.49 inches of water used by control plants is equivalent to 96,300 gallons per acre or per three miles, compared to 61,800 gallons for the CS-6432-treated plants. This is the same as 32,100 gallons per mile for control and 20,600 gallons per mile for CS-6432, i.e., a saving of over 10,000 gallons of water per mile of oleander strip. This is equivalent to a saving of nearly three trips per mile for a 4,000 gallon irrigation truck. At 1/4 gallon of diluted spray per bush and 880 bushes per mile, about 220 gallons of spray would be required per mile. The water use figures given above are based on a deep rooting depth system, and therefore probably exceed the water application rates normally applied on freeway oleander plantings. However, the real value of the antitranspirants probably lies in prolonging the interval between irrigations, rather than applying less water each time. Thus, extrapolation of the antitranspirant curves in Figures 1 to 3, indicates that antitranspirants can delay irrigations by two to three weeks.

In 1970, half the line of oleanders planted on the Davis farm were used in an experiment in which no irrigation was given throughout the summer, the only source of water being soil moisture from the winter rains. It should be kept in mind that because of the virtually unlimited rooting depth and the good moisture storage of the Davis farm soil, this experiment gave a somewhat unrealistic comparison with highway oleander plantings where soil-moisture storage capacities are poor, and where roots are usually limited by narrow, shallow trenches and impenetrable clay layers. The experiment involved periodic measurements of soil moisture from April to October 1970, using the neutron moisture probe. A film-forming antitranspirant, Mobileaf (provided by the Mobil Oil Corporation), was sprayed at a concentration of one part Mobileaf (ML) in five parts water. One liter of diluted spray was applied per plant on May 18 and again on July 15. There were four plots each of control (unsprayed) and antitranspirant-sprayed plants, each plot containing three plants.

The last major rain for the winter season occurred between March 1 to 10 (1.75 inches), bringing the total winter rain for 1969-1970 to 16.5 inches. Thus, when the first neutron meter readings were made on April 1, 1970, the soil-water content (% volume or P_V) ranged from 28.5% at the 12-inch depth to 35% at the 60-inch depth. By mid May, at the time of the first spray, soil water was depleted to 20 to 22% at the shallower depths (12 to 24 inches) and 29 to 30% at deeper depths (48 to 60 inches). The "available" range of P_V for the Davis-Yolo loam soil is from 33 to 13%, though this may vary slightly with depth. Thus, at the beginning of the spray period, over 50% of the available water was already depleted from the upper soil layers. As a result, the antitranspirant did not reduce the rates of soil-water depletion at the 12-, 24- and 36-inch depths (Figure 4, A-C) and in fact, tended to increase the rate of water use at these depths. This is in accordance with the findings in Part I of this report on the interactions with soil moisture. At the 48- and 60-inch depths, where more soil water was available at the time of treatment (May 18), the first Mobileaf spray reduced the rates of soil-water depletion (Figure 4, D and E). When over 50% of the available soil water had been depleted from these depths (around early July) the rates of soil-water depletion

Figure 4 (A-E): Effects of Mobileaf (ML), sprayed on oleanders, on soil water content (volume percentage) measured by a neutron moisture meter at depths of 12, 24, 36, 48 and 60 inches.

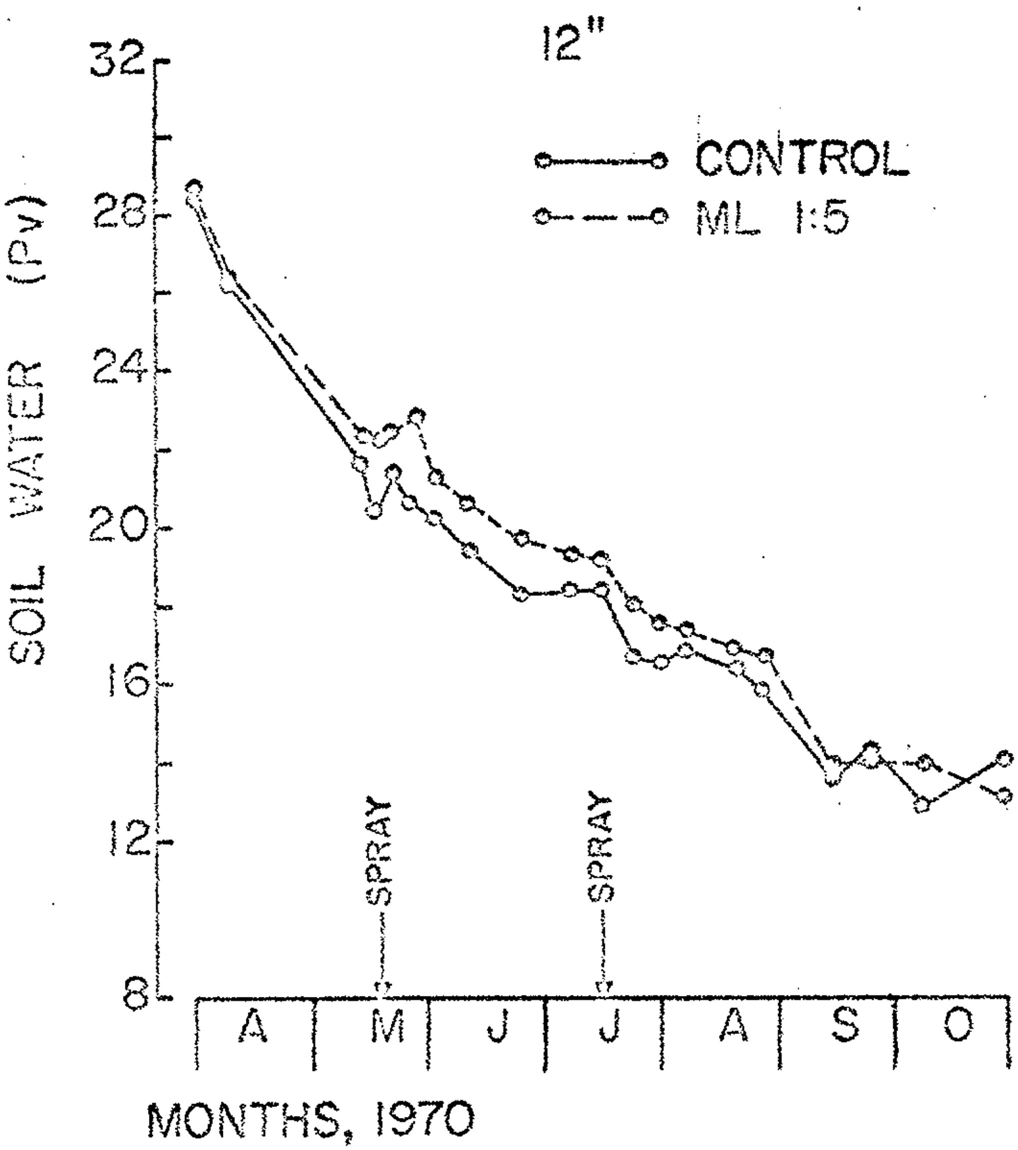


Figure 4A:

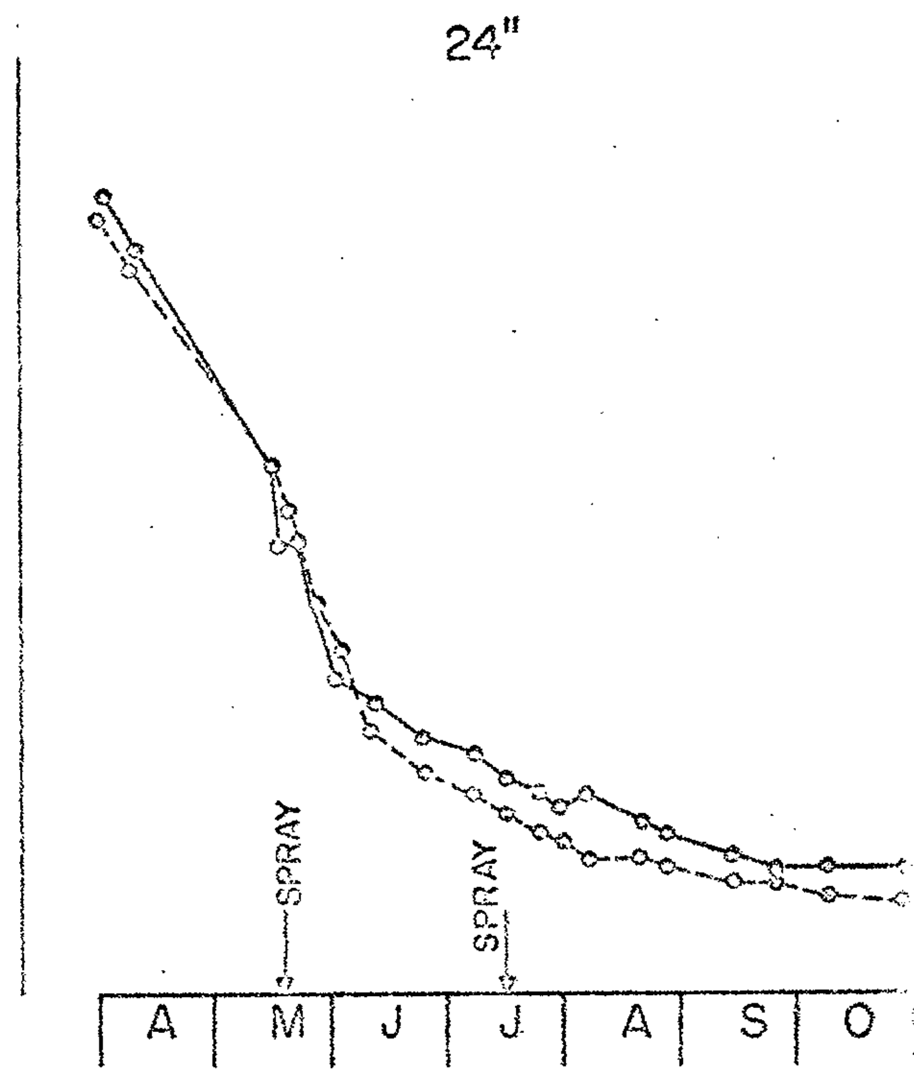


Figure 4B:

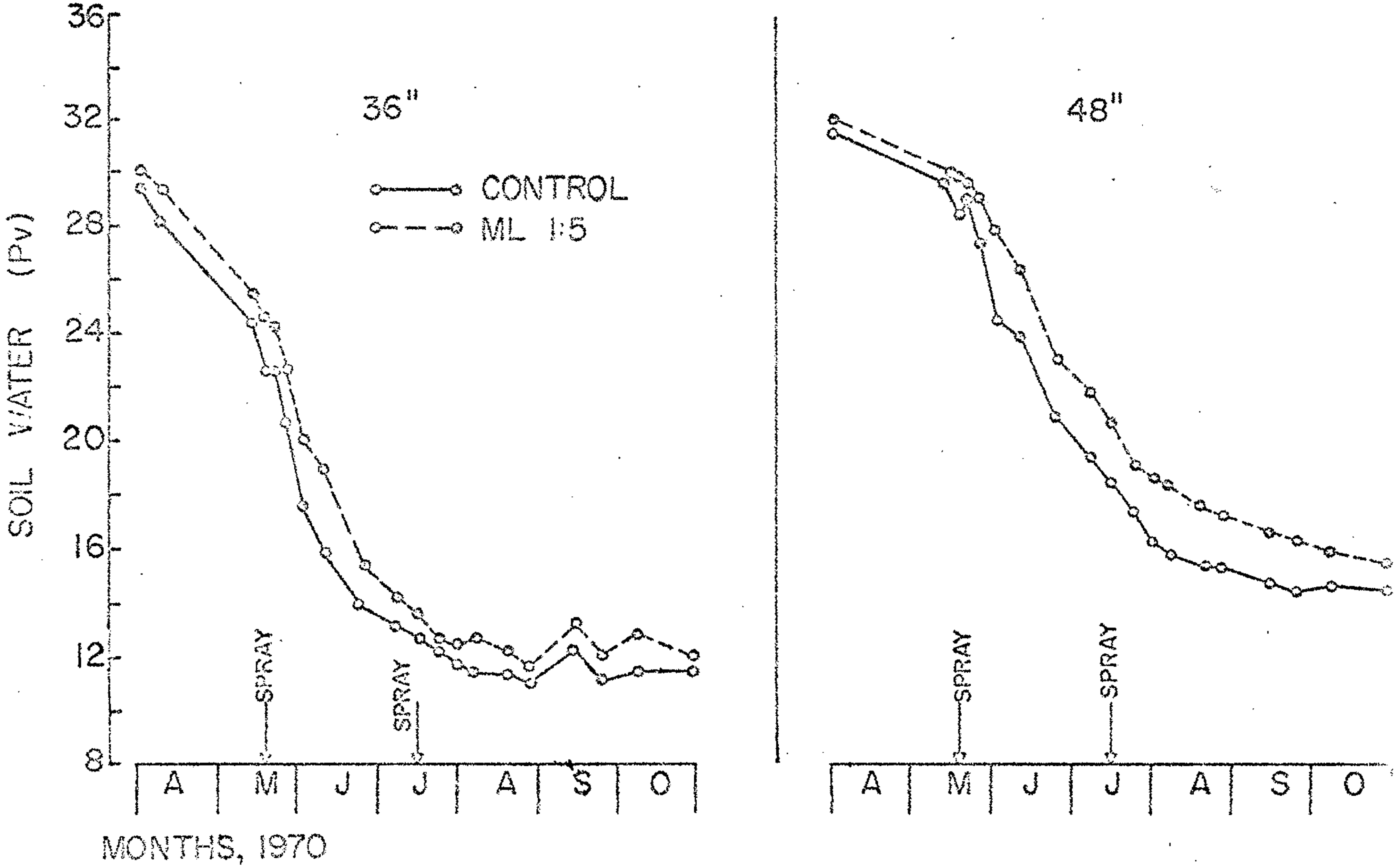
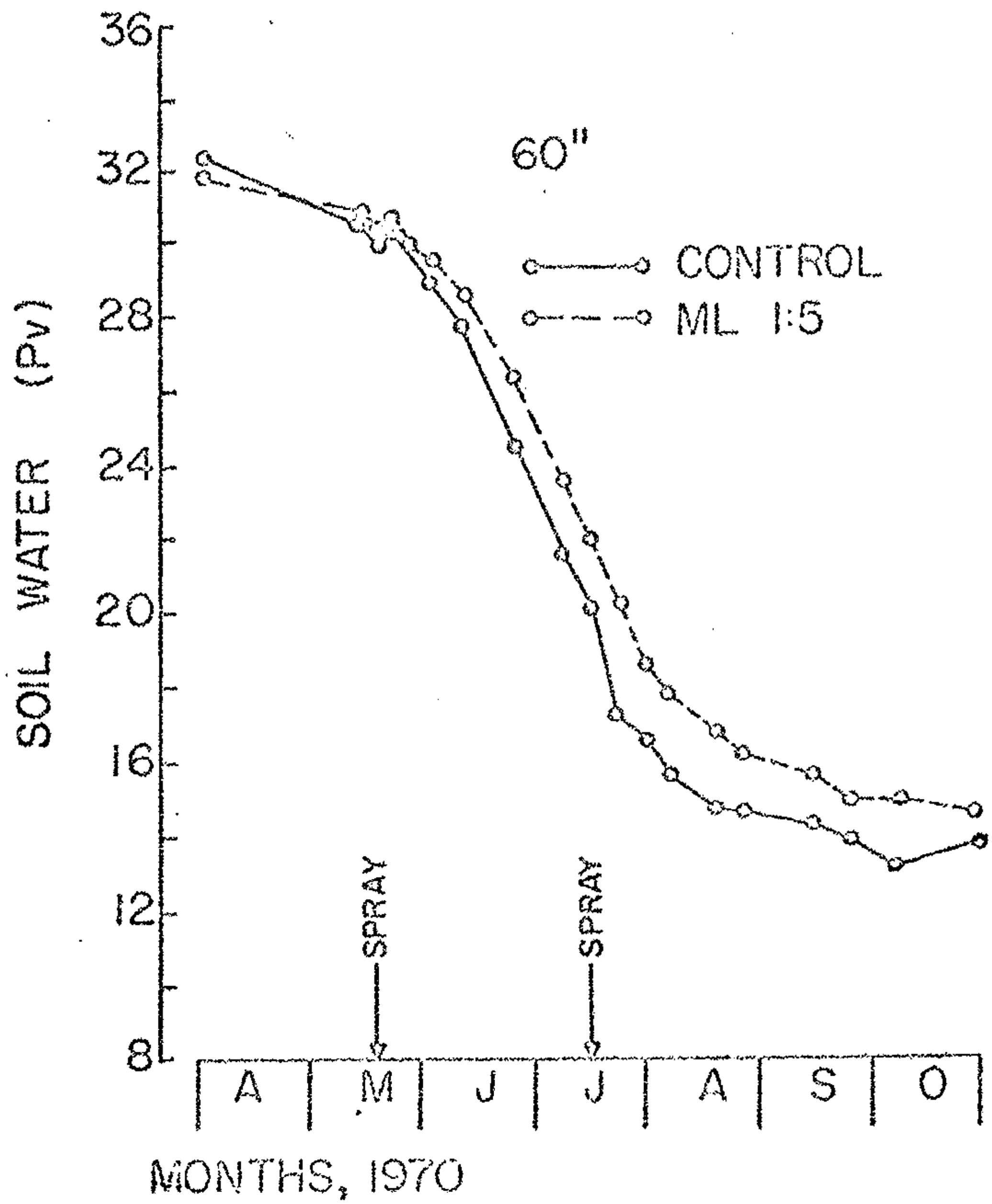


Figure 4C:

Figure 4D:



60"
CONTROL
ML 1:5
SOIL WATER (Pv)
36
32
28
24
20
16
12
8
SPRAY
SPRAY
A
M
J
J
A
S
O
MONTHS, 1970

Figure 4E:

were no longer reduced by the antitranspirant and, therefore, the second Mobileaf spray was not effective. However, because of the savings of water during the latter part of May and in June, the final soil-water contents were higher in the antitranspirant-treated plots.

The soil-water depletions (in terms of P_v) for the two spray periods are given in Table 3. The effectiveness of the Mobileaf in reducing depletion is apparent only at the 48- and 60-inch depths in the first period. Thus, the average depletion in P_v over the 60-inch soil depth was slightly reduced by Mobileaf only in the first spray period, but the total depletion for the summer (5/21 to 10/28) was slightly increased by the antitranspirant, i.e., about 7.0 inches for control and 7.3 inches for Mobileaf. By comparison, the total depletion between 5/21 and 10/28/70 from the 60-inch profile, by a companion set of irrigated oleanders was twice as great, i.e., about 14 inches.

Table 3

Effect of Mobileaf (1:5) on soil-water depletion by un-irrigated oleanders during two spray periods in 1970. (Spraying dates were 5/18 and 7/15.)

	Soil-Water Depletion (P_v)			
	1st spray period (5/21 to 7/15)		2nd spray period (7/15 to 10/28)	
Soil Depth (inches)	Control	Mobileaf	Control	Mobileaf
12	3.0	3.3	4.4	6.0
24	6.1	7.0	2.4	2.3
36	9.8	10.7	1.3	1.6
48	10.5	9.0	4.2	5.1
60	10.2	8.5	6.3	7.5
Average depletion in 60" profile: (P_v)	7.9	7.7	3.7	4.5
(inches)	4.74	4.62	2.22	2.70

Total average depletion in 60" profile from 5/21-10/28	Control	Mobileaf
(P_v)	11.6	12.2
(inches)	6.96	7.32

By September, there was a distinct difference in appearance between the irrigated and unirrigated plants, for the former were greener, denser in foliage (an asset for screening headlight glare on highways), and generally had a more pleasing appearance. The differences between irrigated and unirrigated oleanders under most highway conditions, where rooting depths and water availability are often limited, would be much more obvious. Therefore, irrigation of highway oleanders is desirable inspite of their xerophytic features. Furthermore, since retardation of transpiration is useful for conserving soil water only when the water is readily available for plant use, i.e., under irrigated conditions (c.f. Tables 2 and 3), antitranspirant sprays will be valuable for reducing irrigation frequency by preventing unnecessarily rapid depletion of soil moisture.

Since antitranspirants are known to reduce photosynthesis, it was thought that this would result in reduced growth of the oleander shoots. This is a desirable effect, since excessive growth is usually not wanted on highway plantings. Measurements were, therefore, made in 1970 on oleanders in one-gallon containers in a greenhouse to determine the effects of CS-6432 (2%), and of the growth retardant Alar (3,000 ppm) incorporated in the CS-6432 emulsion, on shoot growth. After a uniformity trial, five shoots, distributed over three pots, were selected for each treatment for growth measurements. Before spraying, the rates of internode growth were the same for all treatments (Figure 5). After spraying, the internodes of those plants which were treated with CS-6432 grew more rapidly than controls. The incorporation of Alar, however, reduced the rate of internode growth. The CS-6432 also increased the growth of leaves (Figure 6), but as expected, Alar did not suppress leaf growth. The reason for the increase in shoot growth, in spite of reductions in photosynthesis as a result of CS-6432 treatment, was that the antitranspirant increased plant-water potential and thereby enabled more rapid elongation. Thus spraying an antitranspirant, such as CS-6432, with an incorporated growth retardant should decrease the irrigation requirements as well as excessive growth of highway plantings. The effect of Alar alone was not assessed in this experiment. The large increases in internode growth of antitranspirant-treated plants over control plants may also be due to partial soil-moisture stress developing in the control, but not so much in the CS-6432 pots, in the course of the day. This stress may not have developed in larger containers, in which case growth responses to CS-6432 may not be as large.

The effects of an antitranspirant and growth retardant on shoot growth were also tested in the field on irrigated oleanders at the Davis experimental farm. The treatments were 1) control (water + 0.1% X-77 surfactant); 2) Alar (5000 ppm + 0.1% X-77); 3) Mobileaf (1:5); 4) Mobileaf (1:5) + Alar (5000 ppm). One liter of solution was sprayed on each plant. There were three replicate plants for each treatment, and five shoots were tagged and measured on each plant for internode and leaf elongation. Measurements were made on the uppermost internode and leaf which were initially about 0.5 cm and 5.0 cm in length, respectively. Increases in length over given time periods were then determined with a ruler.

In Figure 7, the variation in internode growth (relative to shoots which were designated as controls) prior to treatment was about $\pm$ 10% between 5/22 and 5/29. In the three dry periods just after spraying on 5/29, there were marked reductions in internode growth in those treatments which included Alar, whereas the Mobileaf had no effect. However, in the following eight days,

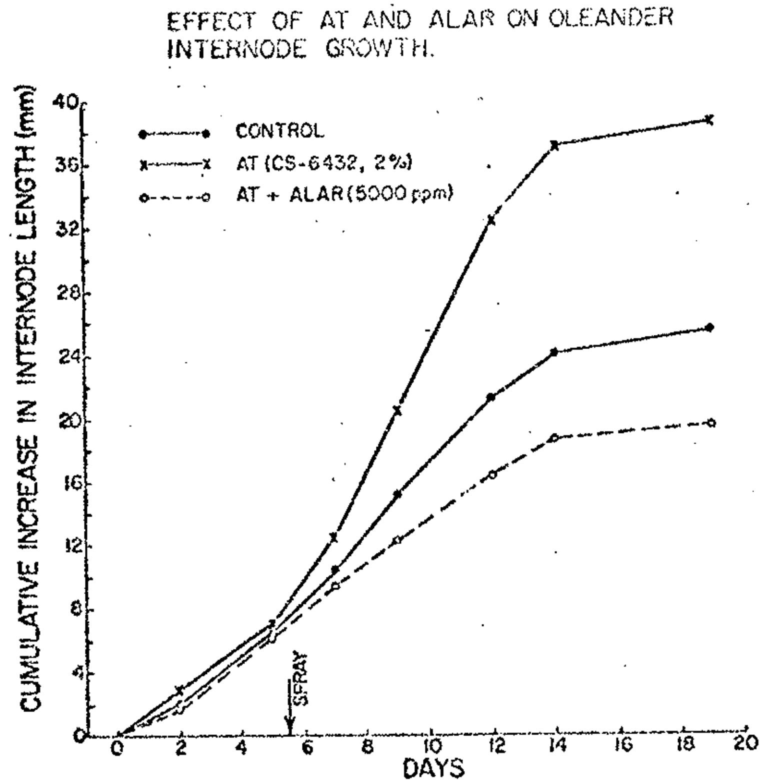


Figure 5. Effects of CS-6432 and Alar on internode growth of Oleander shoots.

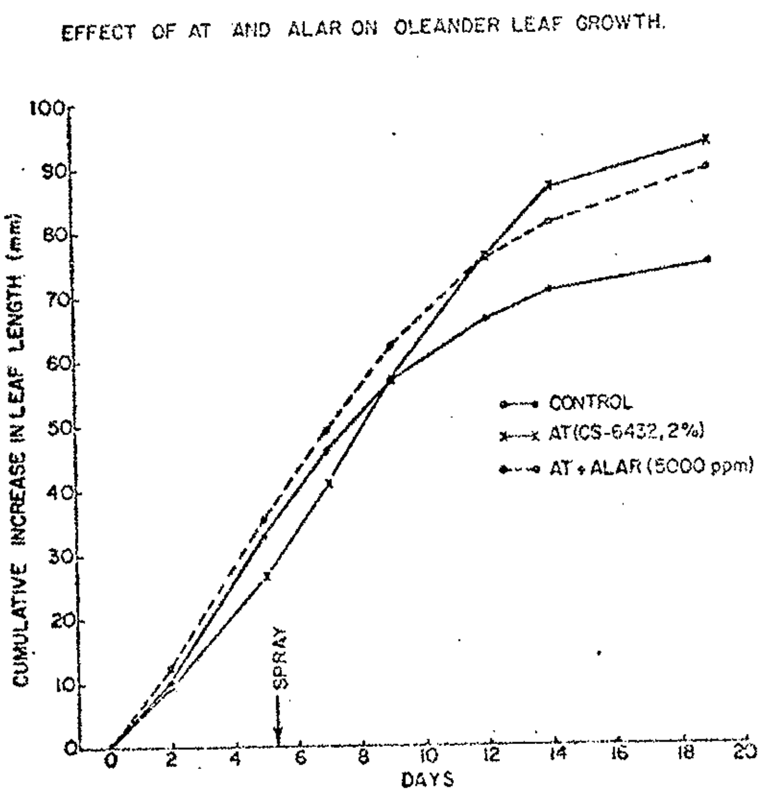


Figure 6. Effects of CS-6432 and Alar on leaf growth of Oleanders.

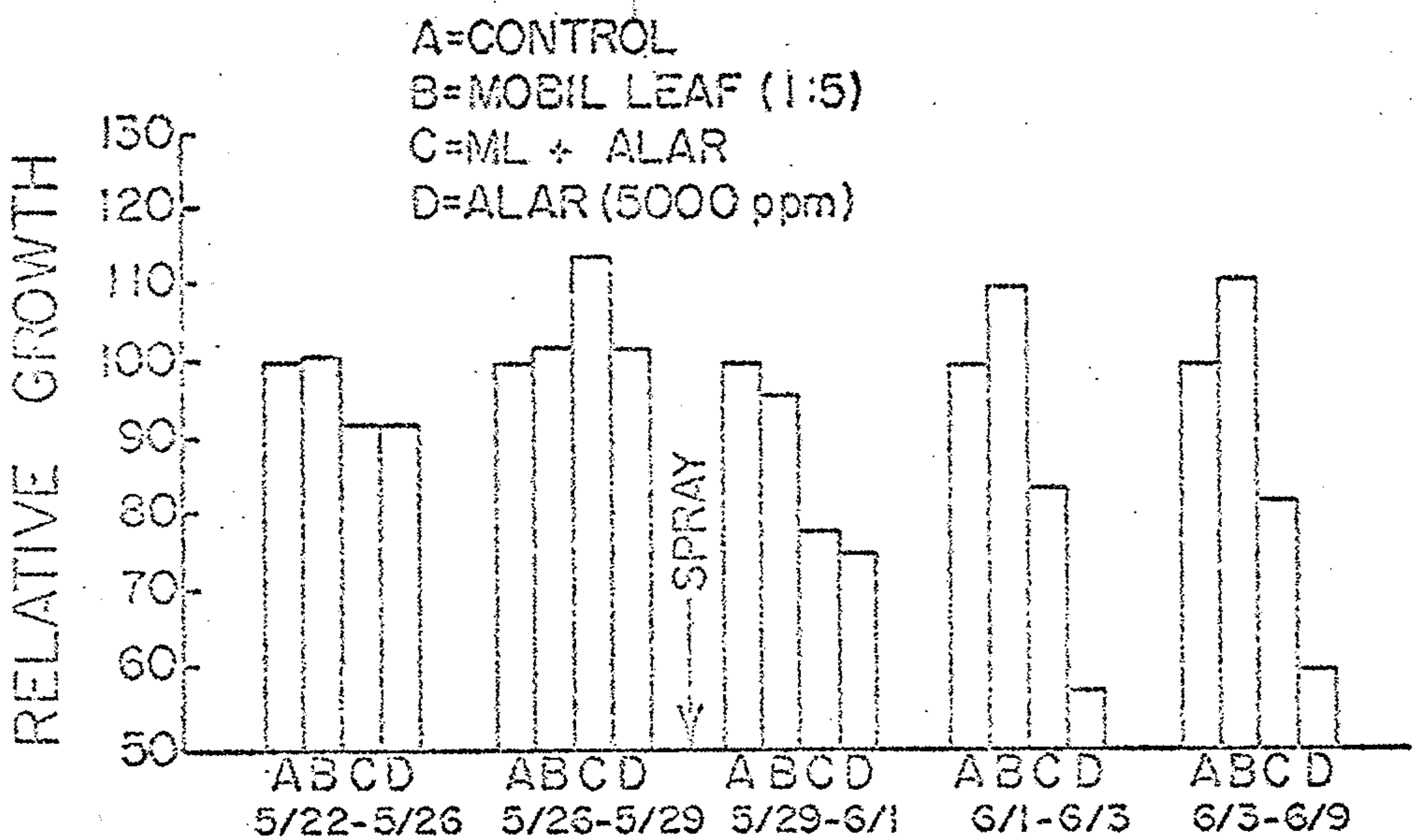


Figure 7: Effects of Mobileaf and Alar on internode growth of Oleander shoots.

Mobileaf alone increased growth slightly and Alar alone decreased internode growth by about 40%. The Mobileaf-Alar mixture decreased growth to a lesser extent (nearly 20%), i.e., the effect was intermediate between the increase by the antitranspirant and the decrease by the growth retardant. This may have been due to 1) compensating effects, or 2) chemical or physical interaction between the Alar and Mobileaf solutions.

In Figure 8, pretreatment variations in leaf elongation were small between 5/22 and 5/26, but relatively larger between 5/26 and 5/29. However, after spraying, a definite pattern emerged so that by 6/3 to 6/9 leaf elongation was greatest for antitranspirant-treated plants, and least for growth retardant-treated plants, though the effect of Alar on leaves was not as severe as on internodes.

A new series of shoot measurements was started on June 1 on the same plants, using the new internodes and leaves just above the ones measured for the data in Figures 7 and 8. In the periods 6/3 to 6/9 and 6/9 to 6/15, there were distinct reductions in internode growth by all treatments, these being about 20% by Mobileaf, 35 to 45% by Alar, and 50 to 60% by the Mobileaf-Alar mixture. Thus, in this case, the Mobileaf actually depressed growth, and gave the greatest growth reduction when combined with Alar, growth being reduced more by the combination than by Alar alone. The depression in internode growth between 6/1 and 6/15, but not between 5/29 and 6/9, resulting from the antitranspirant spray on 5/29, may have been due to a delayed reaction of the young internodes to reduced photosynthesis. In other words, soon after spraying Mobileaf (i.e., around 6/1), the increase in plant-water potential had an overriding effect and growth of the young internodes (about 3 cm in length) was enhanced, but several days later (i.e., around 6/9), the reduced rates of photosynthesis had an overriding effect, and growth of the young internodes (also about 3 cm in length) was decreased.

The June 1 to 15 measurements on the new leaves indicated that elongation was reduced (by about 25%) only if Alar was present in the spray. Mobileaf alone did not reduce leaf length, possibly because photosynthates for growth were produced in these new leaves which had no antitranspirant on them, i.e., unlike the internodes, they did not depend on translocation of photosynthates.

The measurements described above dealt with the effects of Mobileaf and Alar on growth of individual internodes and leaves. The effects of these treatments on total shoot growth, i.e., the integrated length of all the internodes above the point where measurements were initiated on 5/22 are shown in Table 4. By August 10, shoot elongation was unaffected by Mobileaf but was reduced 15% by the Mobileaf-Alar mixture and 30% by Alar alone.

Table 4

Effects of Mobileaf (1:5), Alar (5000 ppm) and their mixture, sprayed on 5/29/70, on the growth of oleander shoots between 5/22 and 8/10/70.

	Growth (cm) (5/22-8/10)	%
Control	40.72	100
Mobileaf	40.89	100
Mobileaf + Alar	34.55	85
Alar	28.85	71

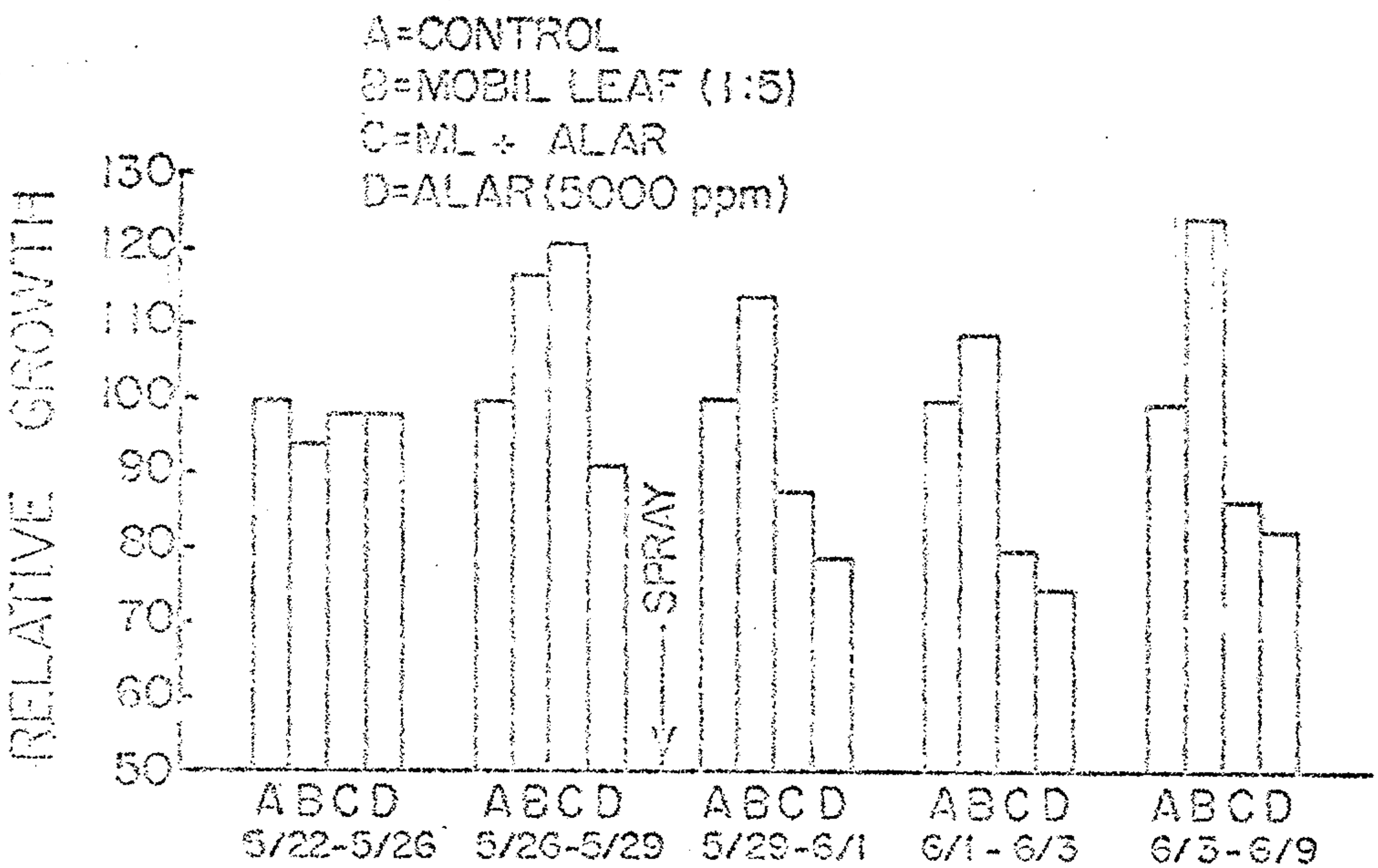


Figure 8: Effects of Mobileaf and Alar on leaf growth of Oleanders.

Reduction of irrigation requirement of turf grass

Turf grass is used in a variety of situations including home lawns, play fields, golf courses, and orchard sod, and in most cases requires frequent irrigation. Reduction of transpiration and therefore irrigation frequency, may be useful for conserving water and prolonging irrigation intervals, particularly for home gardens when owners are away on vacation.

Perrenial ryegrass was grown in 30-foot square plots and was mowed regularly to form complete swards. Gypsum blocks were installed to measure changes in soil-matric suction at depths of 15 and 30 cm, where most of the roots were located. The plots were sprayed with 1) water + 0.1% X-77 (control); 2) PMA (100 ppm) + 0.1% X-77; and 3) PMA (150 ppm) + 0.1% X-77; or 4) CS-6432 (3%).

On the day of spraying, soil-matric suctions were about 0.1 atm in all the plots at the 15-cm depth. Table 5 shows that the greatest suctions developed in the control plots, and that most of the moisture loss was from the top 15 cm of soil. At this depth, CS-6432 conserved the most moisture in the first week, but by the end of the second week, PMA (150 ppm) appeared to be the most efficient (lowest soil-matric suction). Also, at the 30-cm depth higher suctions developed in the control than in the treated plots, PMA (150 ppm) being the most effective at the end of the two-week observation period.

Table 5

Effects of antitranspirants, sprayed on perennial ryegrass, on soil-matric suctions (atm) at two soil depths.

Days after spraying	6		13	
Soil depth (cm)	15	30	15	30
Control	1.07	0.21	8.70	1.01
PMA (100 ppm)	0.95	0.10	6.38	0.82
PMA (150 ppm)	0.82	0.13	6.23	0.63
CS-6432 (3%)	0.78	0.18	6.87	0.77

The grass was not mowed during this observation period. The effectiveness of an antitranspirant would be expected to decrease as new growth appeared on the grass, and respraying after mowing would be necessary if maximum effectiveness were to be maintained. However, addition of a suitable growth retardant in the antitranspirant spray may not only reduce the rate of appearance of new unsprayed leaf surface, but may also reduce mowing frequency.

PLANT-WATER STATUS AND GROWTH

Survival of Transplants

When a seedling is uprooted and then replanted, there is always some damage to the roots and 'transplant shock' results. The reason for this is that water loss from the leaves often exceeds uptake by the root system which has been damaged. Application of an antitranspirant to the foliage of seedlings should therefore increase the survival of transplants, as well as enable quicker establishment. Apart from increasing survival percentage, the treatment should result in a more uniform stand since the number of replants is decreased. Only one experiment was carried out to demonstrate the effectiveness of an antitranspirant for increasing transplant survival.

Seedlings of pinto beans were divided into large, medium, and small size groups. Seedlings from each group were uprooted, and the tops were dipped in CS-6432 (2%) for five seconds, and allowed to drain with their tops pointed down on an inclined plane to avoid contact of the antitranspirant with the roots. At the same time, five seedlings from each size group were also uprooted and laid alongside the treated seedlings for the duration of the drying time to serve as controls. When the CS-6432 on the treated seedlings had completely dried, all of the seedlings were transplanted in a tray of wet vermiculite. There were three pairs of rows of five plants each, corresponding to the large, medium, and small size groups. Each pair in each group comprised a control and an antitranspirant-treated row. After transplanting in the greenhouse, the tray was placed in the sun (about 10,000 foot candles of light and 85°F temperature). After half an hour, the control seedlings in the large size group began showing signs of wilt. Two hours after transplanting, these seedlings were severely wilted, and many of the untreated seedlings in the medium-sized group showed signs of wilt. None of the antitranspirant-treated seedlings showed any signs of wilt in the large and medium-sized groups. In the small-sized group, there was very little wilt, even in the untreated seedlings. It, therefore, appears that an antitranspirant would be more useful in increasing survival of bigger plants where the ratio of leaf surface to root is relatively large. If transplanted seedlings in a field vary in size, the uniformity of seedling establishment would be greatly improved by antitranspirant treatment.

Growth and yield of snap beans (in cooperation with Dr. W. L. Simms, Vegetable Crops Extension Service, UCD).

A field experiment with the Tendercrop variety of snap beans was conducted in July to September 1968 to note the effects of CS-6432 (3%) and PMA (110 ppm) sprays, applied 38 days after sowing. A second CS-6432 spray was given 11 days later. Each treatment plot consisted of a 20-foot length of row, replicated four times. The PMA was phytotoxic, so no measurements on leaf expansion were made for this treatment.

CS-6432 decreased the rate of leaf expansion by about 25% for small leaflets and 50% for medium-sized leaflets (Table 6). Presumably, the CS-6432 did not reduce leaflet expansion as much in the small as in the medium-sized leaflets because the rate of development of new untreated leaf surface was faster for the former. Both CS-6432 and PMA reduced the final height, yield, and number of beans per plant (Table 7).

Table 6

Effect of CS-6432 (3%) on leaf area expansion of snap beans.

	Leaf area (cm^2)			
	August 23	August 30	Gain	% of Control
Small Leaflets				
Control	5.4	58.5	53.1	100
CS-6432	5.3	45.8	40.5	76
Medium Leaflets				
Control	24.1	89.8	65.7	100
CS-6432	27.6	60.2	32.6	50

Table 7

Effects of CS-6432 (3%) and PMA (110 ppm) on final height, yield, and number of beans per plant.

	Height (cm/plant)	Yield (g/plant)	Number (beans/plant)
Control	73	141	37
CS-6432	65	101	31
PMA	57	66	24

Some interesting observations on the effects of the antitranspirants on rates of pod maturity were noticed because harvests were made on two separate dates, September 19 and 23. In Table 8, it can be seen that yields were greater on the second harvest date than on the first--by 28% for CS-6432, 87% for PMA, but only 6% for control. This therefore suggests that part of the yield reduction by the antitranspirants can be attributed to a delay in maturity resulting from the antitranspirant treatment. (The final yield values in Table 7 are the averages of the yields of the two harvest dates.) The green beans were also graded into various size groups at both harvest dates, and it was interesting that only a relatively small proportion of the antitranspirant yield (about 20%) fell in the over-mature grade size at the first harvest, whereas about 40% of the yield from control plots was in the over-mature category at the first harvest.

Table 8

Effects of CS-6432 (3%) and PMA (110 ppm) on yield of green snap beans on two harvest dates.

	Yield (g/plant)		
	September 19 (A)	September 23 (B)	% yield increase of (B) over (A)
Control	134	148	6
CS-6432	89	114	28
PMA	46	86	87

Observations were also made on resistance to water vapor diffusion from the snap bean leaves, and on changes in soil matric suction (measured by gypsum blocks). The antitranspirants increased diffusive resistances of the leaves and therefore decreased rates of soil-moisture depletion. However, all irrigations were scheduled to ensure that severe soil-water deficits did not occur, and all treatments were irrigated on the same date regardless of differential rates of water extraction. It is, therefore, possible that the reduction in vegetative growth and yield caused by antitranspirant treatment would not have been so severe if the untreated plots had not been irrigated as frequently. The growth reductions by the antitranspirants were undoubtedly due to their effects on reducing photosynthesis, and for PMA, to phytotoxicity. (This would suggest that a lower concentration should have been used.) The growth reductions in this experiment with an annual field crop are in contrast to increases in growth observed by us on established perennial crops such as oleanders and fruit trees. A probable reason for this is that growth in annual crops is more heavily dependent upon photosynthetic production, whereas that in the perennial crops, where large reserves of photosynthates already exist in storage tissues, is more heavily dependent upon maintaining high plant-water potentials. It should, however, be kept in mind that continuous use of an antitranspirant year after year on a perennial crop such as a fruit tree, while giving seasonal increases in growth, may result in long term growth decreases which might show up as diminished rates of trunk expansion from year to year. The long-term effects on growth require further investigation.

Orchard studies

Almond trees:

By decreasing transpiration losses with an antitranspirant, water uptake by the roots is more easily able to keep pace with its loss through the leaves, and this results in an improved water status of the plant. One method of assessing this effect is by the use of dendrometers which measure radial expansion and contraction of tree trunks. Since daytime shrinkage of tree trunks is caused by excessive transpiration, it is postulated than an antitranspirant, by reducing water loss from the leaves, would reduce shrinkage of the tree trunks.

Verner-type dendrometers were installed on 30 Nonpareil almond trees selected out of five rows in an orchard, with six trees instrumented per row. Trunk shrinkage and growth patterns were obtained for six weeks before treatment, and post-treatment data were adjusted to compensate for the inherent variations. Diurnal patterns of trunk radial changes were also obtained as a basis for comparison of tree response before and after treatment.

Changes in soil matric suction were measured by gypsum blocks installed about two to three feet from the trees at 1-, 2- and 3-foot depths. For each treatment and depth there were five replicates. The antitranspirant materials were applied with a Solo Mist Blower with special attention given to coverage of the underside of leaves where stomata are exclusively located. About 3 1/2 liters of diluted spray were applied per tree. In the first experiment, there were five replicates of the following treatments: 1) distilled water + X-77; 2) CS-6432*(2%); 3) Allied**(2%); 4) PMA***(34 ppm); 5) CHM****(15 ppm), and 6) unsprayed.

In spite of considerable variation in daytime trunk shrinkage among the trees, it was obvious that on the day of spraying (July 22), the greatest shrinkage occurred on the unsprayed trees because their foliage had not been wetted. For three days after spraying, the largest reduction of shrinkage was achieved by CS-6432, but thereafter, the effect disappeared. The other treatments appeared to have little, if any, effect on reducing trunk shrinkage.

Radial expansion of the tree trunks depends on 1) overnight rehydration of daytime shrinkage, and 2) accumulation of photosynthates, i.e., growth. Growth of the tree trunks was reduced by the film-forming sprays, particularly CS-6432, by up to 30%. The reduction in radial expansion did not occur until three days after spraying, this presumably being the time required for the reduction in photosynthesis and translocation of metabolites to become evident. Growth continued to be reduced for about two weeks. The other treatments did not significantly reduce growth, and CHM appeared to increase it, though no explanation can be given for this.

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* Chevron Chemical Co., Richmond, Calif. - experimental film antitranspirant

** Allied Chemical Co., New York - experimental film antitranspirant

*** Phenylmercuric Acetate - stomata-closing antitranspirant

**** Cycloheximide - protein inhibitor fungicide

Relative water content (RWC) of the almond leaves was measured one day after spraying. In the morning, all of the treatments showed higher RWCs than controls (Table 9). In the evening (a little before sunset) when RWCs are generally low because of continuous transpiration during the day, only the film antitranspirant increased RWC, whereas PMA and CHM reduced it. A possible explanation for the evening data is that PMA and CHM retarded stomatal closure (see Part I for effects of PMA), which had probably already started in the leaves of control trees, thereby delaying restoration of their water balance and RWC. On the other hand, CS-6432 and Allied had reduced water loss from the leaves throughout the day, and therefore produced higher relative water contents.

Table 9

Effects of various sprays on relative water contents (RWC) of almond leaves, measured one day after spraying.

	Relative water content (%)	
	AM (0830)	PM (1900)
Control	85.4	82.7
PMA (34 ppm)	86.9	81.7
CHM (15 ppm)	87.6	81.6
Allied (2%)	87.3	83.8
CS-6432 (2%)	87.7	84.1

The first orchard experiment on almond trees described above showed that 1) at the low dilution used, PMA and CHM were not effective antitranspirants; 2) only the film-forming sprays, and particularly CS-6432, produced the effects expected of an effective antitranspirant, i.e., improved the water status of the tree (reduced trunk shrinkage and increased RWC) and decreased growth dependent on photosynthate accumulation (reduced trunk expansion). Therefore, in the second experiment on almond trees, only antitranspirants of the film-forming type were used.

The second experiment was carried out in the same almond orchard. Pre-treatment dendrometer readings were made from August 17 to 21, 1967, to establish growth and shrinkage patterns for the tree trunks. On August 31, the following treatments were sprayed at three liters per tree: 1) control (unsprayed); 2) Wilt-Pruf (1:4); a polyvinyl chloride complex produced by Nursery Specialty Products, Inc., N.Y.; 3) single spray of CS-6432 (2%); 4) double spray of CS-6432 (2%), i.e., a second spray being given as soon as the first had dried. On the day before spraying, the daytime shrinkage patterns of the trees were very similar, but on the day after spraying, the patterns showed that all the antitranspirant treatments were effective, the two-spray applications of CS-6432 giving the greatest reduction (about 50%) in shrinkage (Figure 9). This was

Figure 9:

EFFECTS OF ANTITRANSPIRANTS ON DAYTIME SHRINKAGE PATTERNS OF ALMOND TREE TRUNKS

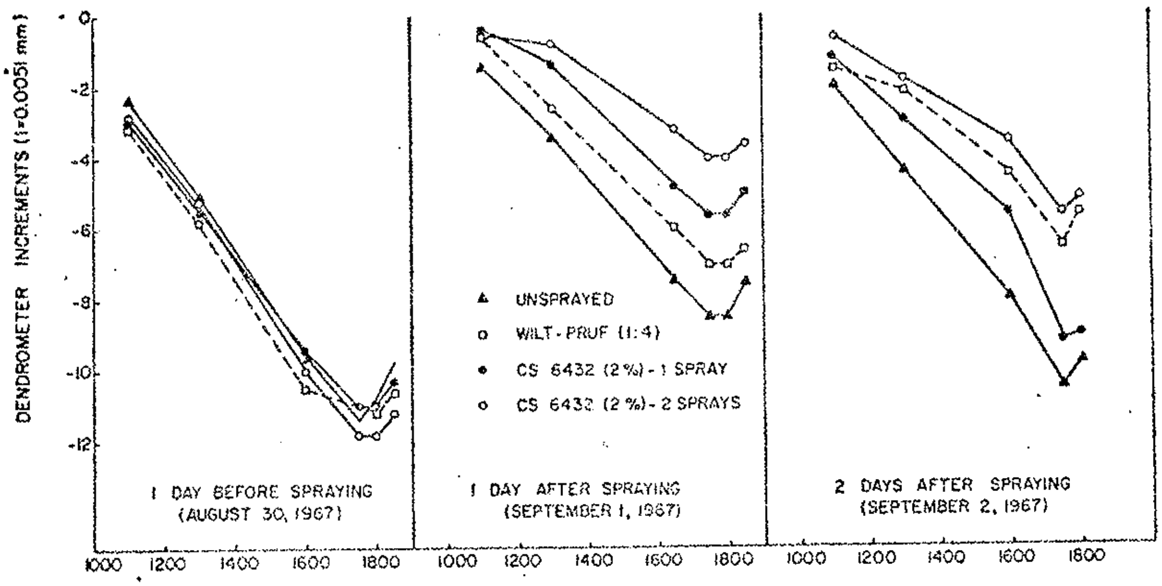
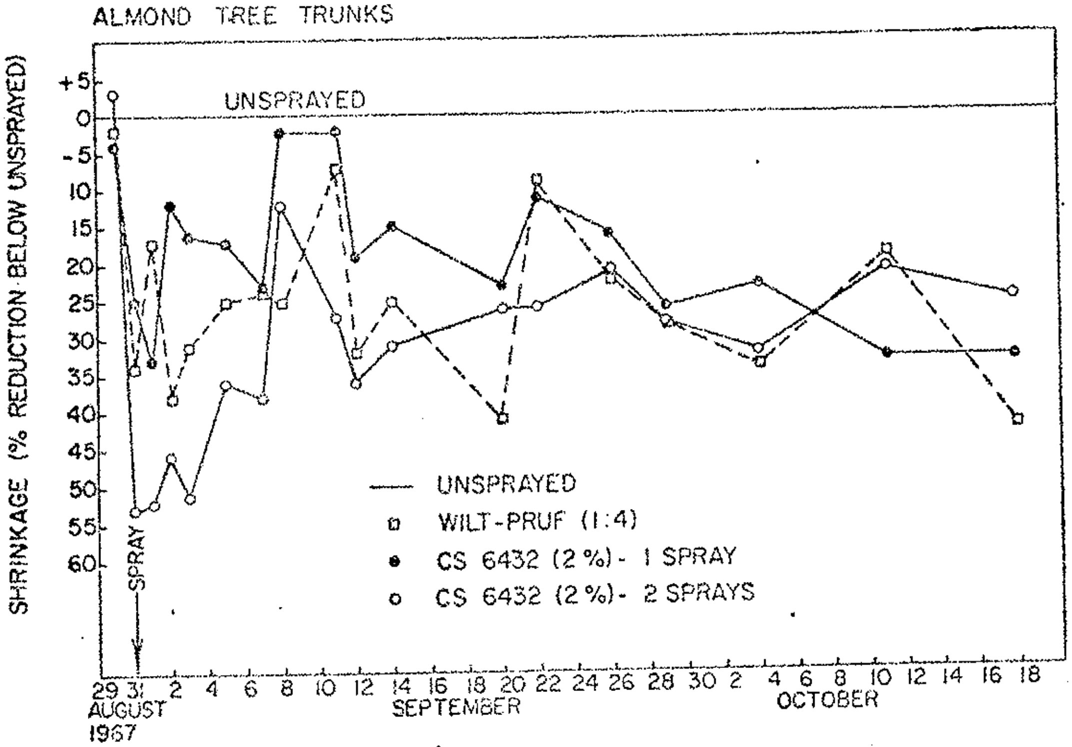


Figure 10:

EFFECTS OF ANTITRANSPIRANTS ON THE MAXIMUM DAILY SHRINKAGE OF ALMOND TREE TRUNKS



probably due to a greater amount of coverage and to the thicker films resulting from the double spray. By the second day after spraying, Wilt-Pruf was consistently more effective than the single spray of CS-6432, but the double CS-6432 spray continued to give the greatest shrinkage reductions. The long-term effects of these sprays on maximum daytime shrinkage (which occurred at about 1700-1730 hours in September) are expressed in Figure 10 as percentage reductions below control. Initial reduction in shrinkage was over 50% by the double spray of CS-6432 and about 35% by the single spray and Wilt-Pruf. The treatments continued to reduce shrinkage for as long as 1 1/2 months. This was encouraging, but somewhat surprising in view of the previous results on almond trunk shrinkage. The absence of new foliar growth at this late stage of the season might be a plausible explanation for this more persistent effect.

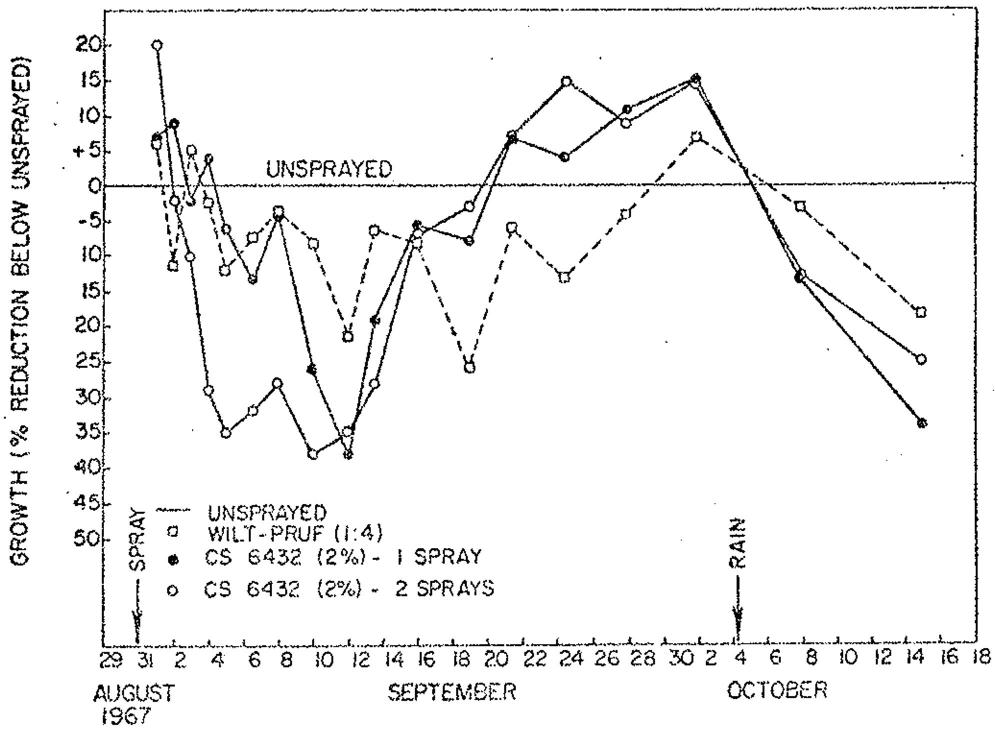
The percentage increases or decreases in radial trunk growth, relative to control, are shown in Figure 11. The antitranspirants produced slight increases in growth during the first two days after spraying, probably because of an improved plant-water balance. Thereafter, trunk growth was retarded as a result of suppressed photosynthesis and the consequent reduced accumulation of photosynthates. The double spray of CS-6432 reduced growth by 30 to 35% between the 4th and 10th days after spraying; the other treatments also decreased growth, but to a lesser degree. However, by late September, the daily trunk expansion of antitranspirant-treated trees exceeded that of controls, probably because depletion of soil moisture was reducing growth rates, particularly for the controls. The average soil-matric suction in the 1 to 3 foot profile increased from about 2 atm on August 31 (day of spraying) to about 5 atm on September 22 and about 6 atm on October 18. The cumulative changes in soil-matric suction (averaged for measurements at 1-, 2- and 3-foot depths) after spraying on August 31 are shown in Figure 12. The amount of increase in matric suction was always greater for control than for the antitranspirant treatments. By the end of September, this effect was noted only in the deeper soil layers since most of the moisture in the upper foot had already been depleted.

The presentation of growth data in Figure 11, as percentage increases or decreases around the controls, is useful for assessing relative effects at any one time, but can be a little misleading when comparing effects at different times. Thus, on September 6, the actual magnitudes of growth per day (in dendrometer units) were about 17 for control and about 11 1/2 for CS-6432 (double spray), i.e., a reduction of 5 1/2 units; on September 24 corresponding values were about 11 and 13 units, i.e., an increase of only 2 units; and on October 15 they were about 7 1/2 and 5 1/2 units, i.e., a decrease of 2 units. Thus in absolute units, the growth reduction in early September, soon after antitranspirant application, were greater than the growth increases which occurred in late September and early October, and the total radial growth of the trunk, from August 31 to October 18, was reduced by 60 units (about 0.3 mm) by the CS-6432 (double spray). The single spray of CS-6432 reduced total radial growth by 40 units, and Wilt-Pruf reduced it by 70 units. Thus, although Wilt-Pruf initially did not reduce growth as much as CS-6432, its growth suppressing effect persisted (unlike CS-6432) through the latter part of September.

Relative water contents (relative turgidities) of leaves from treated trees, sampled in the late afternoon when shrinkage was maximum, were always from 4 to 7% (actual RWC units) greater than those of the untreated trees, indicating that lower plant moisture stress resulted from the antitranspirant treatments (Figure 13). It is noteworthy that this effect on relative

Figure 11:

EFFECTS OF ANTITRANSPIRANTS ON DAILY RADIAL GROWTH RATES OF ALMOND TREES



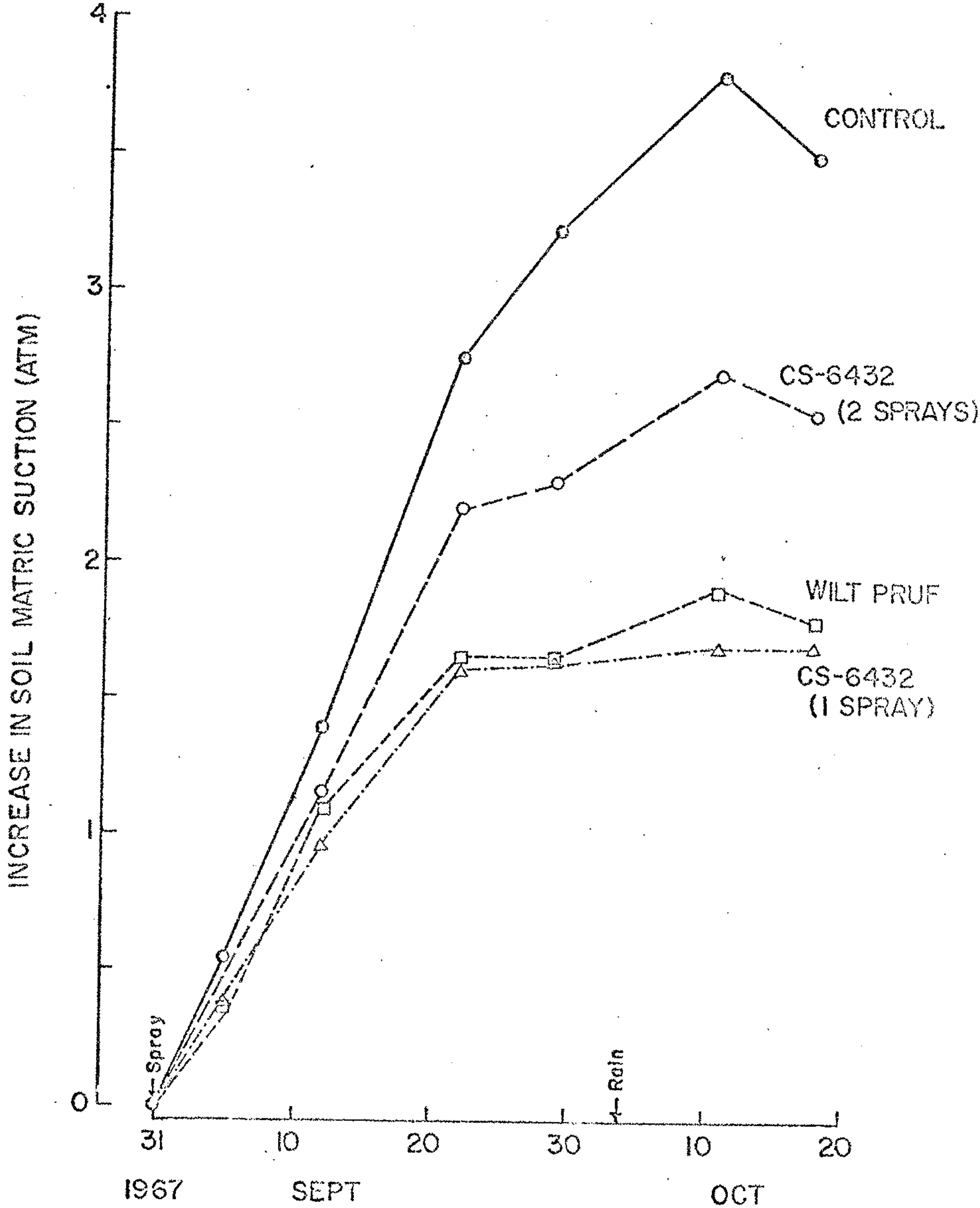


Figure 12: Effects of antitranspirants on cumulative changes in soil matric suctions (averaged for a 3-foot profile) after spraying Almond trees on August 31.

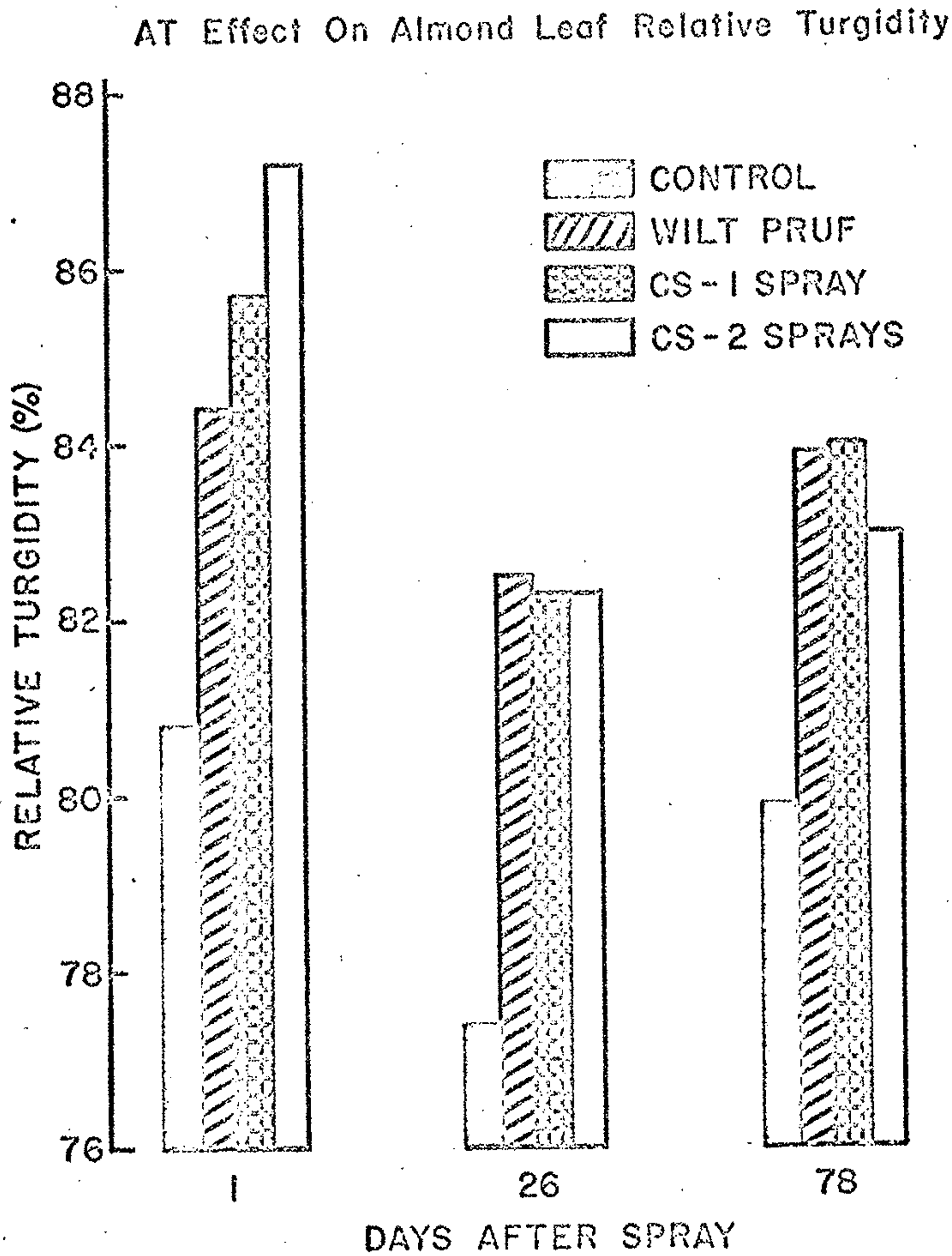


Figure 13: Effects of antitranspirants on relative turgidities of Almond leaves.

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The percentage increases or decreases in radial trunk growth, relative to control, are shown in Figure 11. The antitranspirants produced slight increases in growth during the first two days after spraying, probably because of an improved plant-water balance. Thereafter, trunk growth was retarded as a result of suppressed photosynthesis and the consequent reduced accumulation of photosynthates. The double spray of CS-6432 reduced growth by 30 to 35% between the 4th and 10th days after spraying; the other treatments also decreased growth, but to a lesser degree. However, by late September, the daily trunk expansion of antitranspirant-treated trees exceeded that of controls, probably because depletion of soil moisture was reducing growth rates, particularly for the controls. The average soil-matric suction in the 1 to 3 foot profile increased from about 2 atm on August 31 (day of spraying) to about 5 atm on September 22 and about 6 atm on October 18. The cumulative changes in soil-matric suction (averaged for measurements at 1-, 2- and 3-foot depths) after spraying on August 31 are shown in Figure 12. The amount of increase in matric suction was always greater for control than for the antitranspirant treatments. By the end of September, this effect was noted only in the deeper soil layers since most of the moisture in the upper foot had already been depleted.

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Relative water contents (relative turgidities) of leaves from treated trees, sampled in the late afternoon when shrinkage was maximum, were always from 4 to 7% (actual RWC units) greater than those of the untreated trees, indicating that lower plant moisture stress resulted from the antitranspirant treatments (Figure 13). It is noteworthy that this effect on relative turgidity continued for 2 1/2 months after spraying, thereby lending support to the long-term effects on shrinkage.

These experiments with almond trees gave us sufficient experimental evidence to believe that certain antitranspirant sprays reduce transpiration and thus improve the water status of the tree. It was postulated that, inspite of reductions in photosynthesis and trunk growth, this may result in increased fruit growth, if the trees were sprayed during the latter stages of the maturation period of the fruit, when increase in fruit size is more dependent on maintenance of plant turgidity than on photosynthesis. Increase in fruit size not only results in greater tonnage, but also puts more fruit in higher size grades. This is particularly important if a large percentage of the fruit tend to be around the minimum acceptable size for canning or marketing.

Peaches: (in cooperation with Dr. K. Uriu, Pomology Dept., UCD).

Halford peaches - 1969

In August 1969, an experiment with Halford peaches, consisting of the following treatments, was conducted in a commercial orchard near Yuba City, California. Twelve trees were divided into two groups of six, one group being a wet and the other a dry treatment. Each group of six was divided into two subgroups, i.e., control (water + 0.1% X-77) and CS-6432 (1%). The trees in the wet group were irrigated on August 3, 12, 17 and 24. Those in the dry group were irrigated only on August 3 and 12. Tensiometers at 24" and 36" measured soil-matric suction. Before the start of the experiment, all trees were treated uniformly. Dendrometers were used to measure trunk growth and contraction. The rate hygrometer and pressure bomb measured leaf resistance and pressure potential, respectively. Resistance readings were made on one or two spots on an attached leaf. The leaf was then detached and put in the pressure bomb. Vernier calipers were used to measure diameters of 15 fruit on each tree. The diameters were later converted to volumes, assuming the fruit to be a sphere. Since each fruit was tagged, it was possible to measure the same fruit periodically to establish its growth curve, including pre- and post-treatment measurements. At the start of the experiment on August 1, the fruit were still green and were about 50 mm in diameter. Fruit were harvested on August 29. Soluble solid content in the juice expressed from the fruit was determined refractometrically. The trees sprayed on August 16 and again on August 27 at the rate of 10 to 15 gallons per tree at 400 lb/in^2 pressure, using a commercial orchard sprayer.

No attempt was made to determine differential rates of soil-moisture depletion between sprayed and unsprayed trees. However, the differences in soil-matric suction between plots which received the 8/17 and 8/24 irrigations, and those which were not irrigated after 8/12 is shown in Figure 14. Matric suctions were maintained at .10 to .15 atm at 2 to 3 foot depths for irrigated trees, but rose to .50 to .75 for unirrigated trees.

Maximum daytime trunk shrinkage before and after spraying, are shown in Figure 15. After the sprays on August 16 and 27, shrinkage was decreased, but this effect was small and temporary for the irrigated trees since the magnitude of shrinkage was not large. On the other hand, in the trees which did not receive the August 17 and 27 irrigations, trunk shrinkage was large, and the effects of CS-6432 in decreasing this shrinkage was very noticeable after each

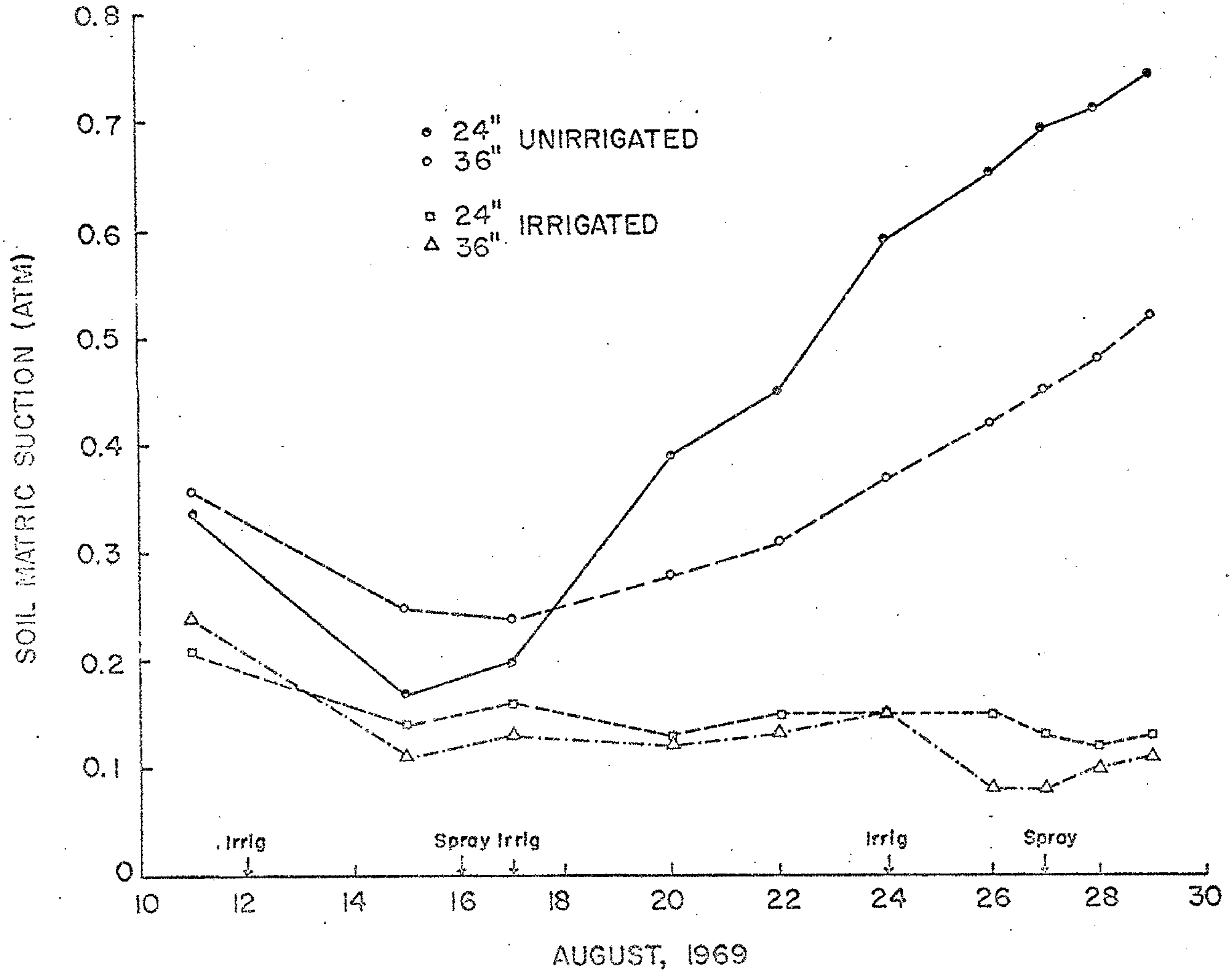


Figure 14: Soil matric suctions, measured by tensiometers, for unirrigated and irrigated Halford Peach trees.

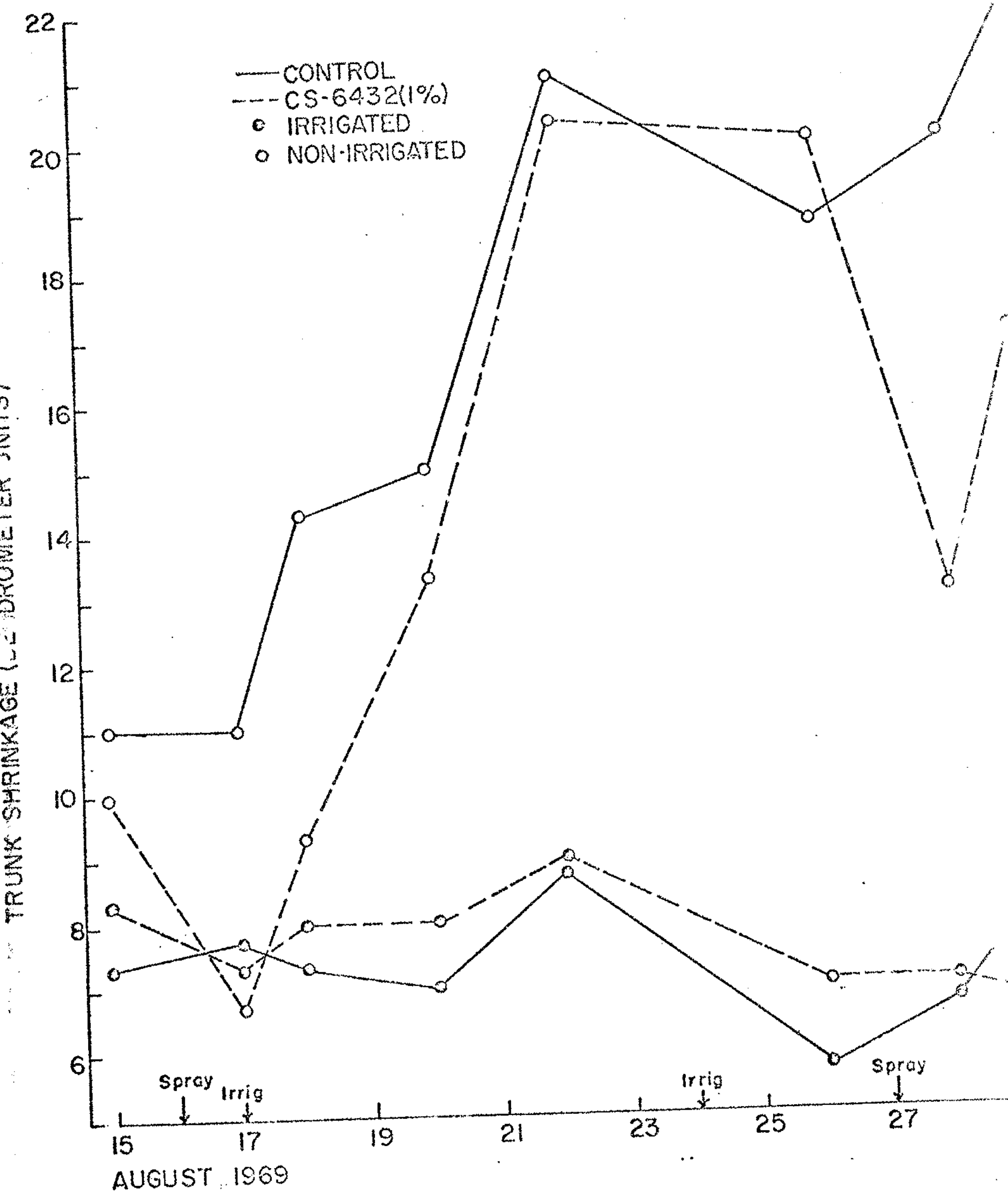


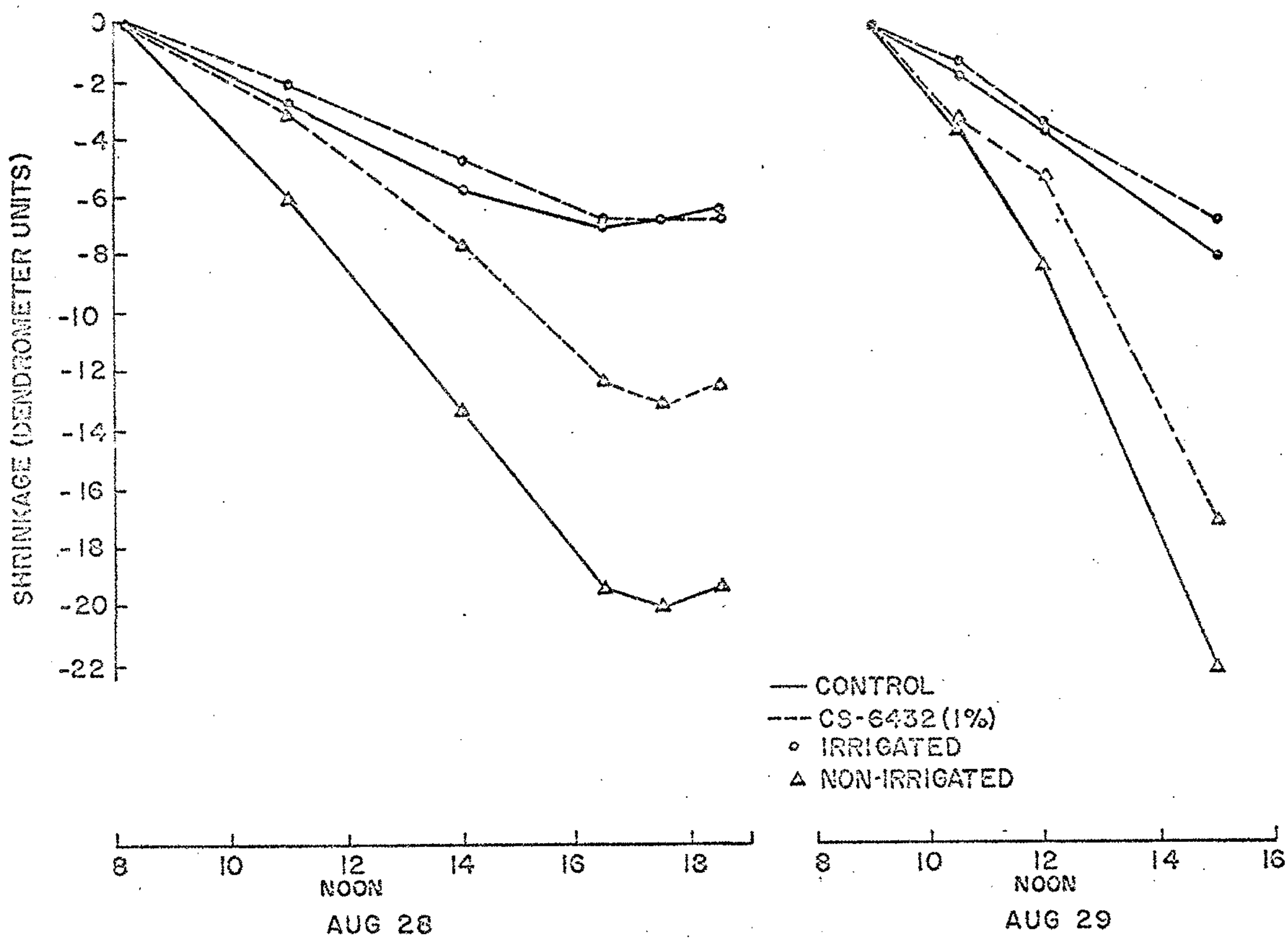
Figure 15: Effects of CS-6432 antitranspirant and late irrigations on maximum daily trunk shrinkage of Halford Peach trees.

spray. In Figure 16, the patterns of trunk shrinkage during the day, on August 28 and part of August 29 indicated greater rates of shrinkage for unsprayed unirrigated trees than for the other treatments.

Radial trunk growth of the peach trees at this time of year was small, making it difficult to accurately assess the effects of the antitranspirant on this aspect of growth. Radial growth may have been larger if younger trees were used. However, trunk growth reductions were noticeable on the unirrigated trees after 8/17. These reductions were often in the form of negative growth. Thus, after the spray on 8/27, the radial trunk growths from 8/28 to 8/29 for control and treated irrigated trees were 0.7 and -0.7 dendrometer units, respectively, whereas corresponding values for the unirrigated trees were -1.3 and -1.0.

The effects of the antitranspirant spray and irrigation on 1) resistance to water vapor diffusion from the leaf lower surface, and 2) pressure potential of the same leaf are shown in Table 10. In general, the antitranspirant increased resistance and pressure potential (less negative values) for both the irrigated and unirrigated trees. It was a little surprising that there was very little difference in resistance and potential between the leaves from irrigated and unirrigated control trees until 8/29 when the afternoon resistance rose to 0.27 min cm^{-1} and potential to -20 atm for unirrigated trees. Treatment effects on resistance and potential of leaves in the course of the day on 8/29 (one day after the second CS-6432 spray) are shown in Figure 17. During most of the day, leaf resistances were highest for antitranspirant-treated unirrigated trees. However, by evening, partial stomatal closure occurred in the control leaves (particularly for unirrigated trees) though it was still light, but not in the sprayed leaves. Thus, the reduction of plant stress earlier in the day, resulting from antitranspirant treatment, prevented early stomatal closure. Pressure potentials were always greater than -15 atm for leaves of irrigated sprayed trees, whereas the controls dropped to less than -20 atm by noon. By mid afternoon, only the sprayed irrigated trees were able to maintain relatively high water potentials. By evening, water potentials of control leaves increased to about -12 atm, presumably as a result of their early stomatal closure.

The rates of growth of fruit on the various trees prior to spraying was fairly similar. Figure 18 shows the percent increase in volume for the various treatments after spraying on August 16 (about two weeks before harvest) and again about two days before harvest. The increase in volume was smallest for the untreated dry trees, and largest for the CS-6432 treated trees. In the dry plots, it was interesting to note the response of the treated trees to the first spray, but after August 22 the dry soil drastically reduced the rate of volume increase. The final dips in the curves were due to partial shrinkage of the fruit by hot, dry weather. Figure 18 does not show absolute sizes of the fruit. However, based on volumes, the amount of growth between the first spray and harvest in the wet plots was 44% more for the antitranspirant-treated fruit than for the controls. The actual increase in final volume of the fruit, attributable to the antitranspirant, was 8.5%. An estimate of the returns resulting from, say, a 7% increase in final volume (v weight) of peach fruits is given below.



<u>Figure 16:</u> Effects of CS-6432 antitranspirant and late irrigations on daytime trunk shrinkage patterns of Halford Peach trees.

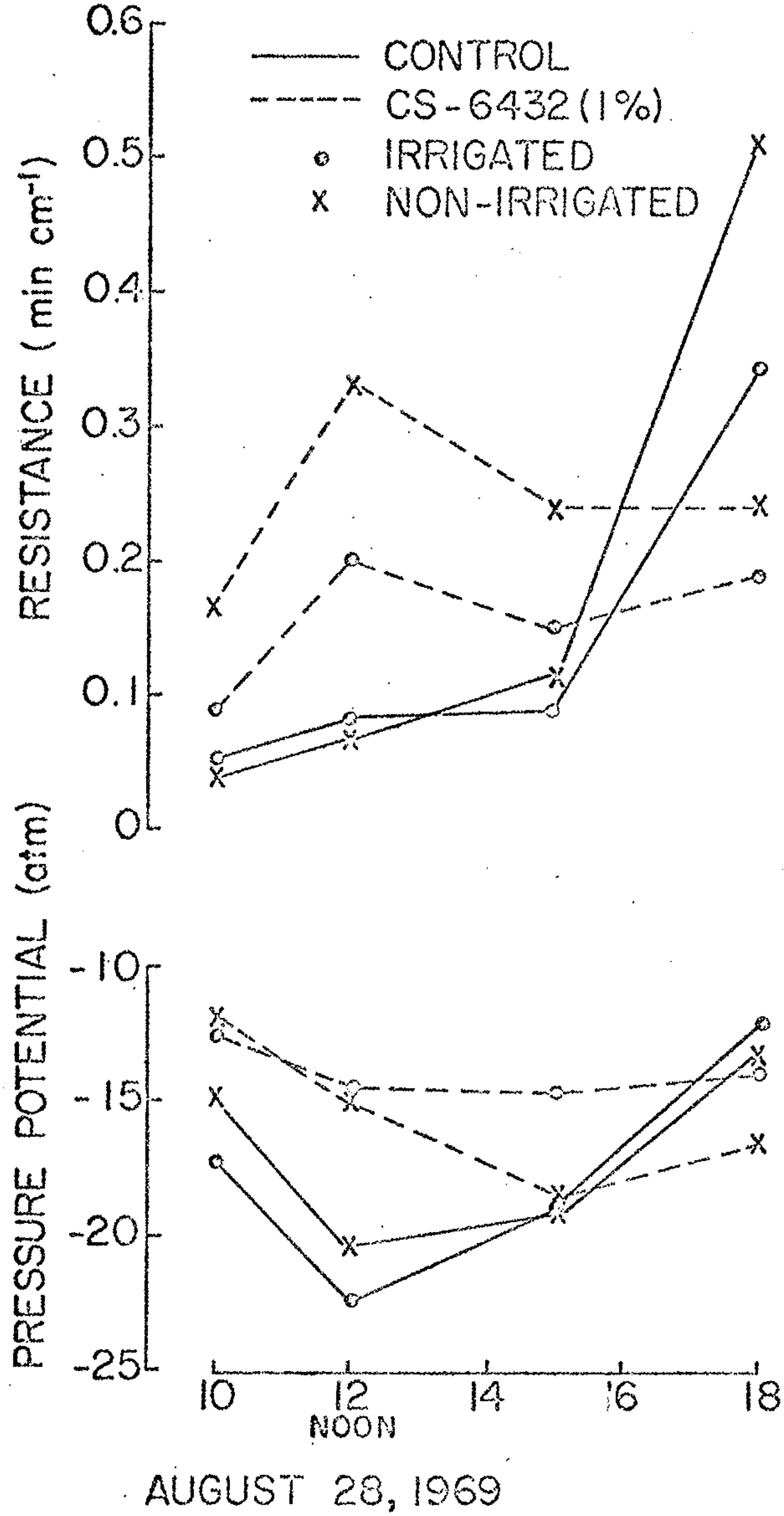


Figure 17: Effects of CS-6432 antitranspirant (sprayed on August 27) and irrigation on diffusive resistance and pressure potential of Halford Peach leaves.

EFFECTS OF ANTITRANSPIRANTS AND IRRIGATION ON HALFORD PEACH GROWTH.

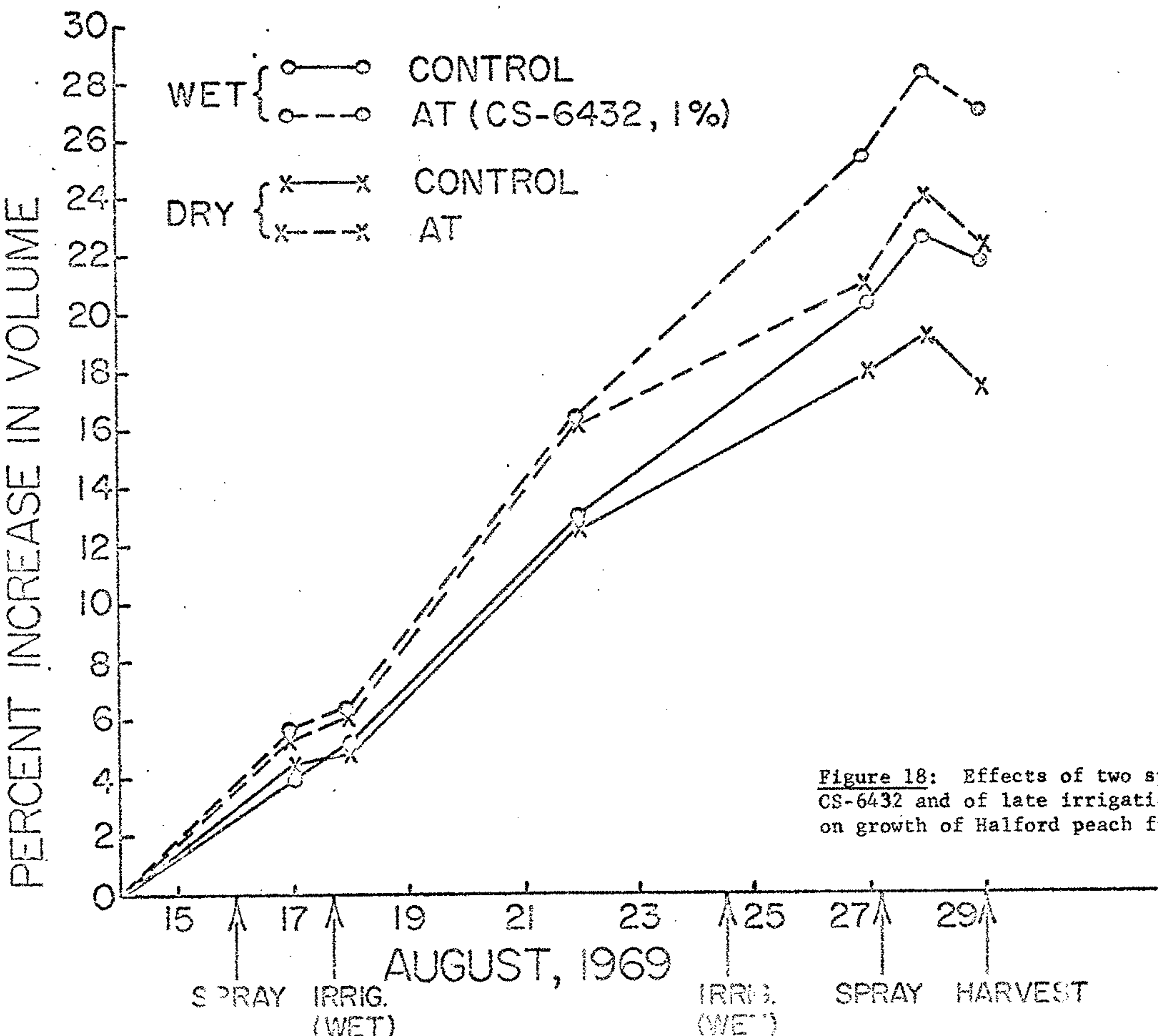


Figure 18: Effects of two sprays of CS-6432 and of late irrigations (Wet) on growth of Halford peach fruit.

Yield	15 tons/acre

Extra yield due to antitranspirant = .07 x 15 = about 1 ton/acre
At $60/ton, gross extra returns = 1 x 60 = about $60/acre

Using a mist blower to apply 2 gal. of diluted (1%) CS-6432 spray per tree, the amount of CS-6432 concentrate used was 0.04 gal./tree.
CS-6432 concentrate = .04 gal/tree x 100 trees/ac. = 4 gal./acre.
(since CS-6432 is an experimental material, its cost has not as yet been determined.)
Spraying cost (excluding material) = about $10/acre.
Therefore, net extra returns per acre due to the CS-6432 spray = $60/acre minus $10/acre, minus cost of 4 gal. CS-6432.

The possibility of incorporating the antitranspirant with a normally applied insecticide or fungicide spray prior to harvest should be kept in mind; this would eliminate the spraying cost. The antitranspirant has been used only on canning peach varieties. Since the skin is removed (by immersion in hot lye) before canning, the problem of removing the film from the fruit does not arise. When a sample of antitranspirant-treated fruit was put through the lye process, there was no noticeable affect on the taste of the skinned fruit.

Caliper measurements of the fruit on a hot day (August 29, when maximum air temperature was 96°F) showed that CS-6432 reduced shrinkage of the peach fruit, as measured between 9 a.m. and 2 p.m. (Figure 19). Fruit from the unsprayed unirrigated trees showed the greatest shrinkage, and those from the antitranspirant-sprayed irrigated trees the least. It is also interesting to note that the fruit from the antitranspirant-sprayed unirrigated trees did not shrink as much as the irrigated control trees.

The fruit soluble solids content from 8/11 to 8/29 varied between 9 and 11%, indicating that the accumulation of solids was largely complete by the time the spray was applied. However, there appeared to be about a 10% reduction in soluble solids resulting from the CS-6432 spray (Table 11). It is believed that this was probably a dilution effect resulting from higher water contents (manifested as increased pressure potentials in the leaves) in the fruit from antitranspirant-treated trees. However, the effects of photosynthetic reductions, caused by antitranspirants, on accumulation of photosynthates in fruits and elsewhere in the tree requires investigation.

Vivian Peaches - 1970

In July 1970, another experiment on peaches near Yuba City was carried out. In this case, an early variety, Vivian, was used and only one spray of CS-6432 (1 1/2%) was applied one week before harvest. The treatments were similar to the experiment on Halfords in that there were wet and dry plots, with unsprayed and sprayed treed in each. However, in this case, the differential irrigation began only one week before harvest, i.e., all of the trees were irrigated on July 6, but only the wet plot trees were irrigated on July 18;

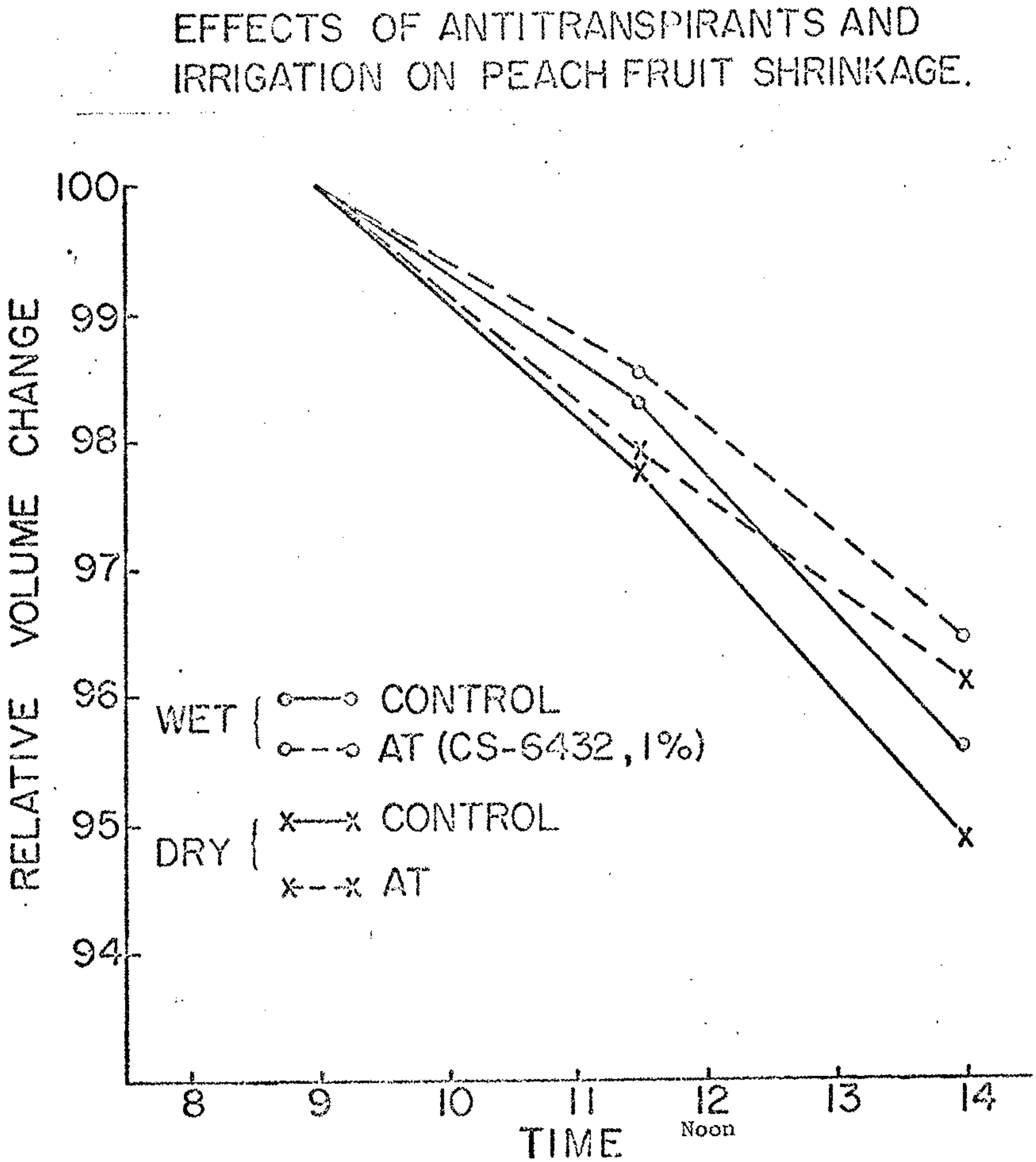


Figure 19: Effects of CS-6432 and late irrigations (Wet) on daytime shrinkage of Halford peach fruit.

Table 10

Effects of CS-6432 (1%), sprayed on 8/16 and 8/27, and irrigation applied on 8/17 and 8/24, on diffusive resistance to water vapor (R, in min cm^{-1}) and pressure potential (P, in atm) of Halford peach leaves.

	Irrigated				Nonirrigated			
	Control		CS		Control		CS	
	R	P	R	P	R	P	R	P
8/17 (1100-1300)	.08	-15.2	.11	-10.4	.10	-15.3	.17	-11.9
8/24 (0940-1050)	.06	-----	.08	-----	.06	-----	.08	-----
8/28 (0935-1100)	.05	-17.3	.09	-12.4	.04	-15.0	.17	-12.1
(1130-1215)	.08	-22.4	.20	-14.8	.07	-20.3	.33	-15.1
(1430-1540)	.09	-19.0	.15	-14.8	.11	-19.0	.24	-18.7
(1740-1830)	.34	-12.2	.19	-13.8	.51	-13.6	.24	-16.7
8/29 (1000-1100)	.03	-18.2	.08	-14.6	.08	-17.2	.10	-12.2
(1330-1430)	.09	-16.4	.11	-15.4	.27	-19.6	.18	-19.7

Table 11

Effects of CS-6432 (1%) on soluble solids (%) of fruit from irrigated and unirrigated trees.

	Irrigated		Unirrigated	
	Control	CS-6432	Control	CS-6432
8/15 (pre-spray)	10.47	10.53	9.97	9.97
8/29 (after spraying on 8/16 and 8/27)	10.47	9.43	9.97	8.93
Reduction	0	1.10	0	1.04
Percentage reduction	0	10.4	0	10.4

harvest was on July 23. At harvest, average soil-moisture percentages (dry weight basis) sampled at 2-foot intervals to six feet were about 11% in the unirrigated and 16% in the irrigated plots.

Dendrometer measurements showed that, like the Halford peach trees in 1969, the antitranspirant was more effective in reducing daytime trunk shrinkage of the unirrigated than irrigated trees. Trunk shrinkage of trees which did not receive an irrigation on 7/18 was about two to three times greater than that of the irrigated trees. There was very little radial growth of the tree trunks making it difficult to assess the effect of the CS-6432 on trunk expansion. However, trunk growth was greatly decreased by witholding the last irrigation (Figure 20).

In Figure 21, the cumulative increases in fruit volume for the various treatments are plotted. The response to the final irrigation is clearly visible as an increase in the growth curves of the wet plot trees, compared with the flattening of the growth curves of the wet plot trees, compared with the flattening of the curves of the dry plot trees after July 20. The response to CS-6432 after the spray on July 16 is also clearly visible, the larges response being for irrigated trees. It is also interesting to note that the final volumes of fruit from the unirrigated antitranspirant-treated trees were approximately the same as those from the irrigated control trees. In other words, the antitranspirant appears to have substituted for the final irrigation. The significance of this finding is that an antitranspirant may be used to at least maintain fruit growth rates during the final days before harvest, and eliminate the need for a final irrigation. This would not only reduce the cost for water and labor, but would also allow the grower to disc in his irrigation contours and have his field ready for mechanical harvesters (which are becoming necessary because of increasing labor costs) without being hampered by wet soil at the critical harvest dates. Although the CS-6432 gave a 40% increase in volume growth between the date of spraying and harvest in both the wet and the dry plots, the actual increase in final fruit volume was only about 3 1/2%, compared with 8 1/2% for the Halfords in the previous year. Nevertheless, the increase in fruit size was clearly demonstrated, as was also the decrease in fruit shrinkage during the day, as measured between 9:30 a.m. and 5:30 p.m. on July 22 (Figure 22). The greatest fruit shrinkage occurred on the unirrigated trees, and the least on the irrigated trees. In each of these groups, fruit from the antitranspirant-treated trees shrank the least, and there was very little difference between the amount of shrinkage of CS-6432-treated fruit in the dry plots and control fruit in the wet plots.

Halford peaches - 1970

Another experiment with Halford peaches was initiated in late July 1970. The purpose was to note the effects of Mobileaf, a wax antitranspirant from the Mobil Oil Co., on fruit sizing. Diameter measurements with vernier callipers were made on 20 fruit per tree on five replicate trees of each treatment. The treatments were an early spray (E) on 8/3, a late spray (L) on 8/14, and an early + late spray (E + L). Harvest was on 8/21. A toxicity trial indicated that concentrations of 1:5 (1 part Mobileaf in 5 parts water), 1:6 and 1:7 caused some leaf yellowing, but 1:9 did not. Laboratory measurements of transpiration and photosynthesis of sugar beet leaves showed that the 1:9 concentration was effective as an antitranspirant. Mobileaf (1:9) emulsions

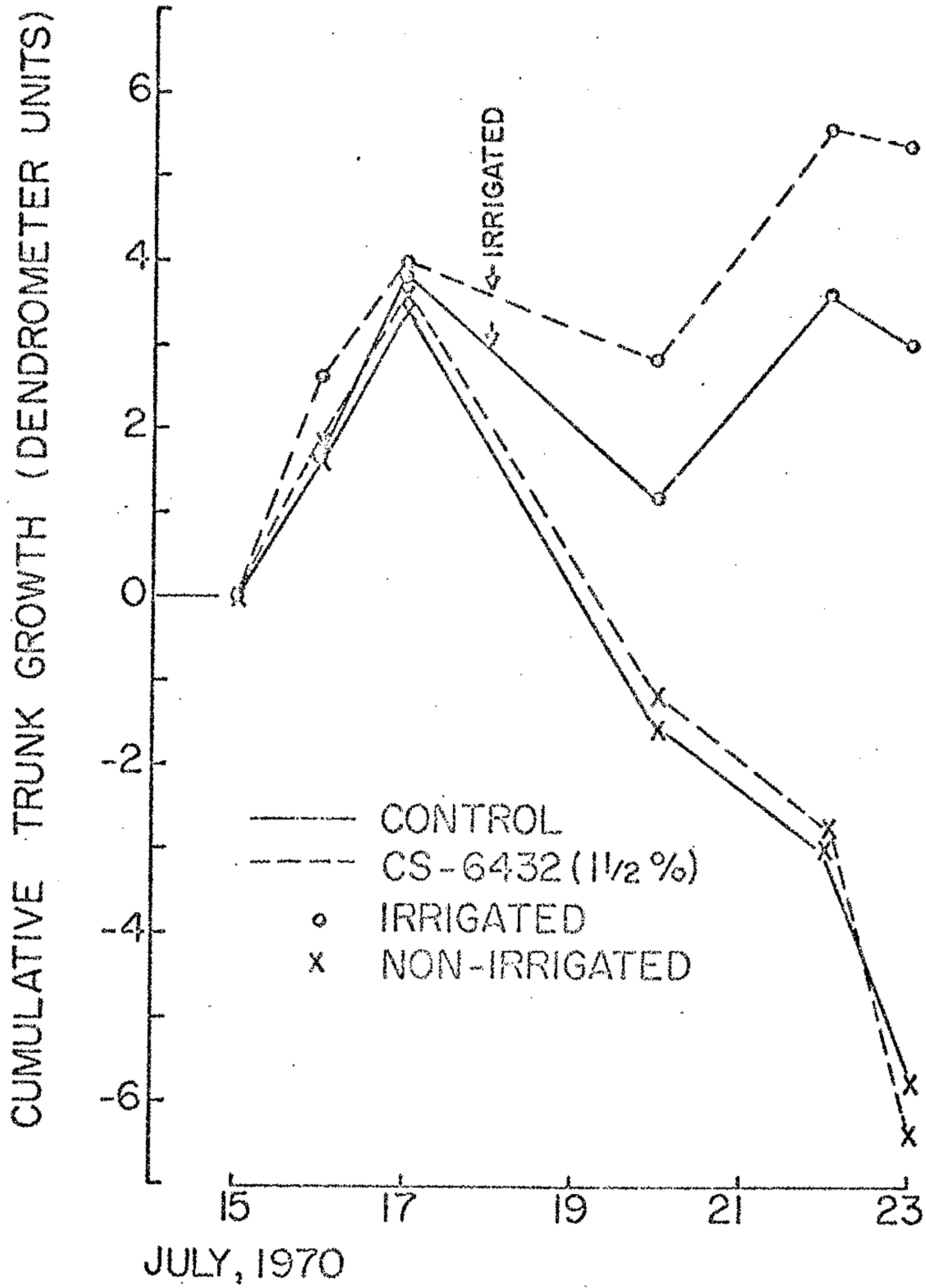
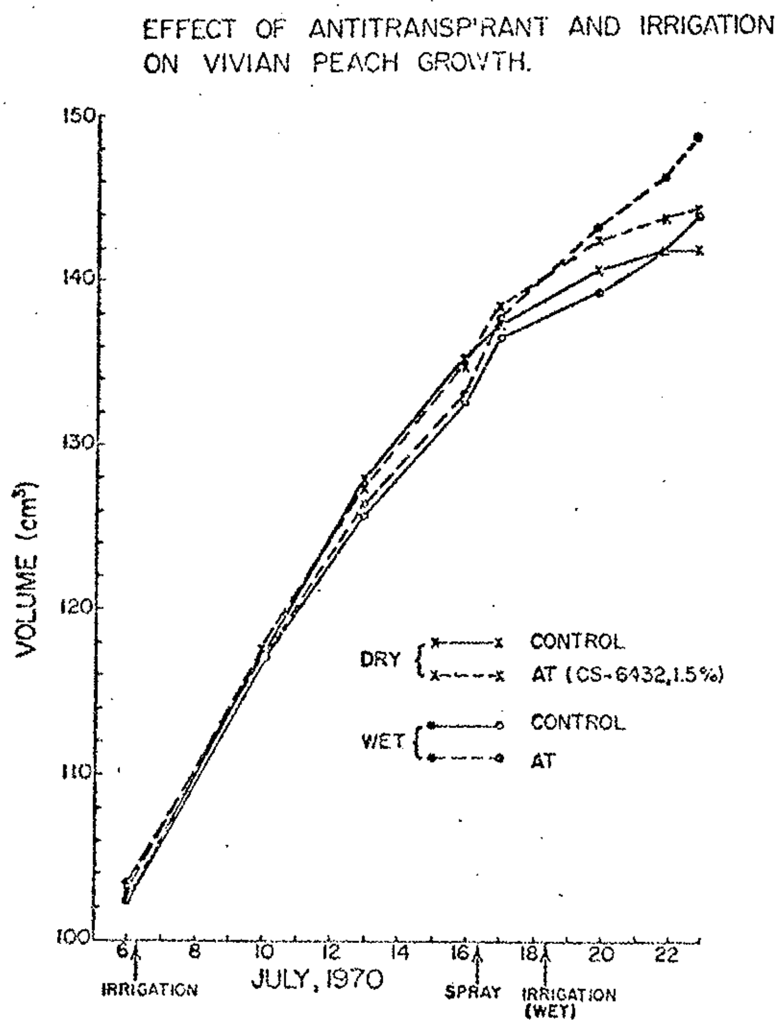


Figure 20: Effects of CS-6432 antitranspirant and irrigation on radial trunk growth of Vivian Peach trees.



<u>Figure 21</u>: Effects of CS-6432 and a late irrigation (Wet) on growth of Vivian peach fruit.

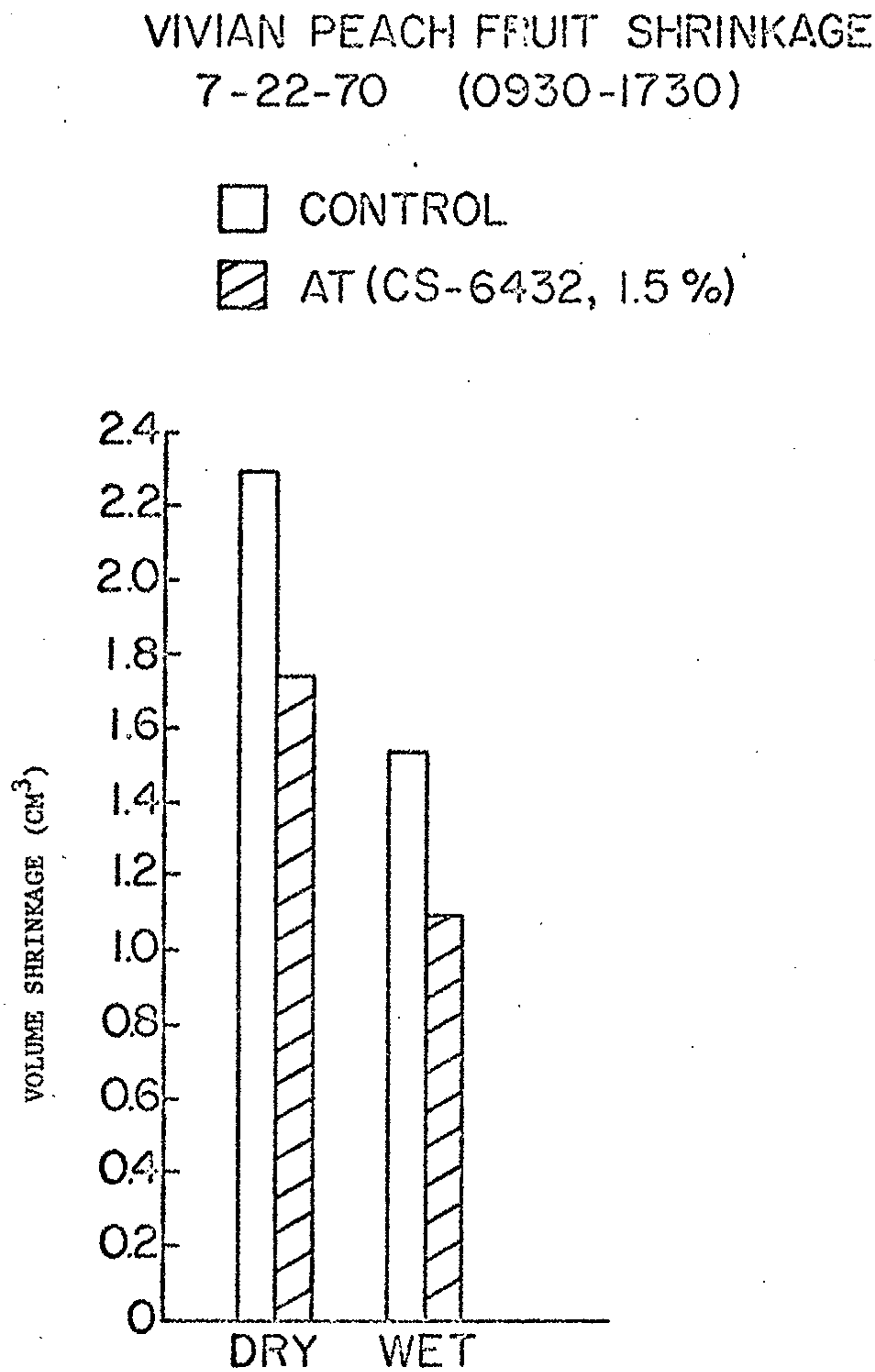


Figure 22: Effect of CS-6432 and a late irrigation (Wet) on daytime shrinkage of Vivian peach fruit.

were therefore applied by a mist blower at 7 liters per tree. Observations of leaf samples collected on 8/18, under a scanning electron microscope indicated that the Mobileaf film coverage on the upper and lower surfaces of the leaves was satisfactory. However, it is unlikely that there was complete film coverage on the stomatal bearing surfaces of all leaves of a sprayed tree. Dendrometers were attached to the trees to pick up radial changes in trunk size, but the large inherent variability from tree to tree prevented detection of significant treatment effects on trunk radial changes. The orchard was irrigated on 7/29, 8/7 and 8/15.

Measurements of resistance to water vapor diffusion from the lower surfaces of the leaves of control and antitranspirant (E) trees were made on the afternoon of 8/5, two days after spraying. These measurements were usually made on leaves on the shady side of each tree, after which the leaves were put in a pressure bomb for determination of pressure potential. A few measurements were also made on leaves on the sunny side of the tree. Resistance and pressure potential were increased by Mobileaf spray (Table 12). These parameters were lower for leaves in the sun.

Table 12

Effect of Mobileaf (1:9) on resistance to water vapor diffusion and pressure potential of Halford peach leaves. Trees were sprayed on 8/3/70 and measurements were made on 8/5.

	Resistance (min cm^{-1})	Potential (atm)
Shade		
Control	.07	-14.6
Mobileaf (E)	.19	-12.3
Sun		
Control	.03	-20.7
Mobileaf (E)	.08	-19.1

Resistance and pressure potential of leaves in the shade were measured again on 8/21 in the early and late afternoon to assess the effects of the E, L, and E+L sprays. Mobileaf increased resistance and potential, the E+L treatment being the most effective (Table 13).

Table 13

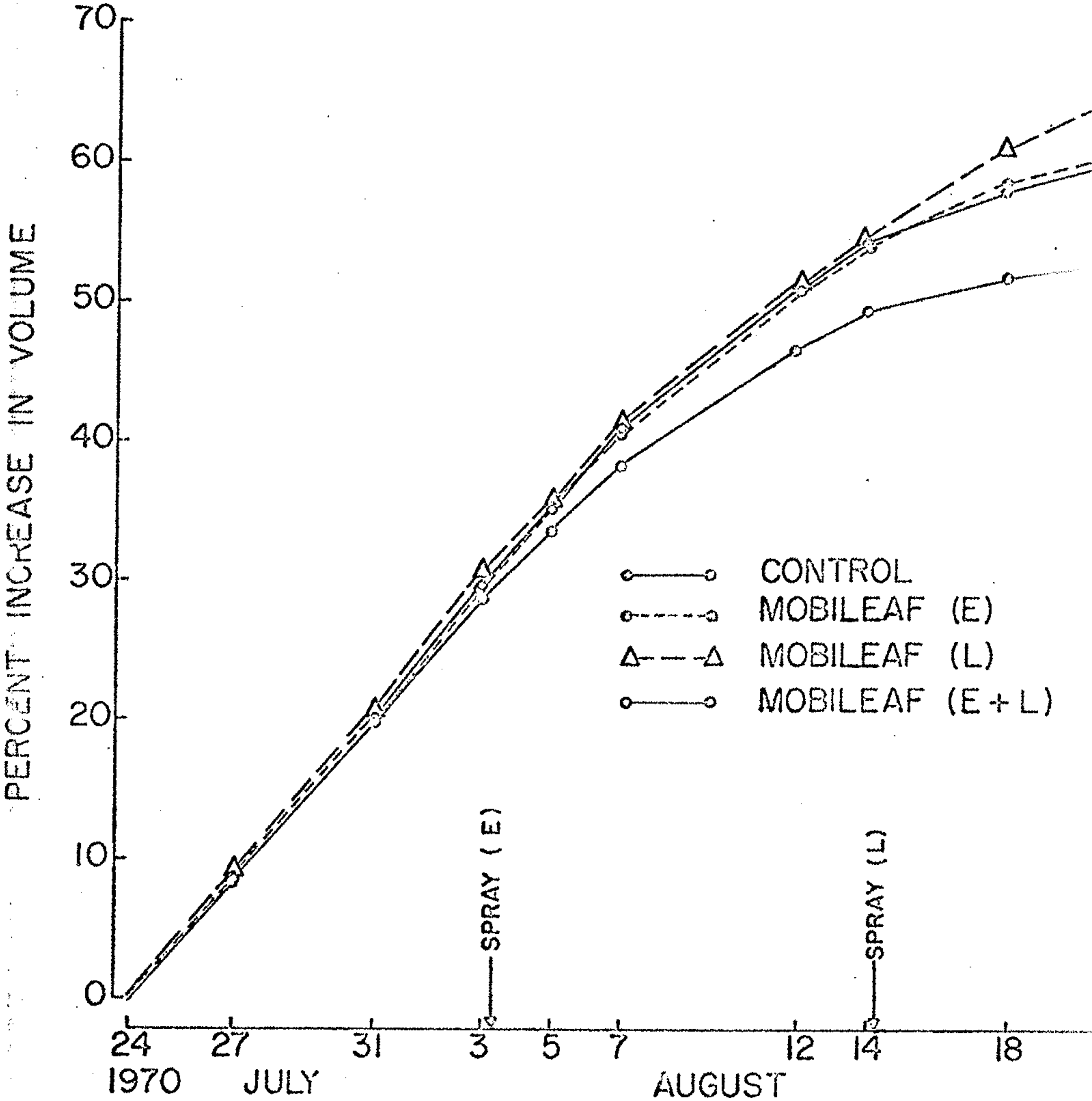
Effects of early (E) and late (L) and E+L sprays on Mobileaf (1:9) on resistance to water vapor diffusion and pressure potential of Halford peach leaves. Trees were sprayed on 8/3/70 (E) and 8/14 (L), and measurements made on 8/21.

	1330 - 1430		1520 - 1620	
	Resistance ($min\ cm^{-1}$)	Potential (atm)	Resistance ($min\ cm^{-1}$)	Potential (atm)
Control	.04	-20.2	.08	-15.9
Mobileaf (E)	.11	-14.9	.20	-13.6
Mobileaf (L)	.09	-14.2	.23	-11.1
Mobileaf (E+L)	.83	- 9.9	.42	-10.1

The effects of the antitranspirants on fruit growth, expressed as percentage increase in volume growth since measurements were initiated on 7/24, are shown in Figure 23. The rates of growth of fruit from the control, E and E+L trees prior to the spray on 8/3 were approximately the same. Thereafter fruit from the sprayed trees (treatments E and E+L) grew at an enhanced rate. However, the additional spray on 8/14 did not give a further boost to growth in the E+L treatment. Fruit from the L treatment had an inherently higher growth rate than controls prior to being sprayed on 8/14. Nevertheless, the rate of fruit growth after spraying these trees was greatly enhanced. The relatively greater flattening of the growth curve of control than of treated fruit during the final week is quite evident in Figure 23.

The actual fruit volumes and volume changes during pre- and post-treatment periods are shown in Table 14. Adjustments of post-treatment fruit growth rates of sprayed trees were made on the basis of their pre-treatment variations from control growth rates. From 8/3 to 8/21 the E spray gave 6.07 cm^3 more volume enlargement per fruit than controls, whereas the E+L spray produced only 5.45 cm^3 extra volume in the same period, suggesting that the second spray had no additional benefit in increasing fruit size. In other words, the 2.29 cm^3 increase from 8/14 to 8/21 should be attributed to the E, rather than to the L of the E+L spray. In fact, the growth increase from 8/14 to 8/21 for the E treatment (nor shown in Table 14) was 3.21 cm^3, indicating that the 8/3/70 spray continued to be effective during the final week before harvest. From 8/14 to 8/21 the L spray produced 5.32 cm^3 more volume per fruit than control.

The data in Table 14 are adjusted increases in fruit growth during post-treatment periods. However, the actual increases in final fruit volume attributable to the sprays were determined after subtracting from the final volumes of fruit from sprayed trees, the amount by which they exceeded the volumes of control fruit just before treatment. Thus, the Mobileaf sprays increased final fruit volumes by 4 to 5% (Table 15). Although this increase was not as large as that observed in 1969 on Halford peaches, it demonstrated once again the potential of antitranspirants for sizing of fruit.



<u>Figure 23</u>: Effects of early (E), late (L), and early + late (E + L) sprays of Mobileaf (1:9) antitranspirant on percent increase in volume of Halford Peach fruits.

Table 14

Effects of Mobileaf (1:9) sprays on volume (cm^3) increases of Halford peach fruit after adjusting for inherent growth rate differences before treatment.

	PRE-TREATMENT				POST-TREATMENT				
	Volume (cm^3)		Increase (cm^3)	Adjustment Factor (con/treat.)	Volume (cm^3)		Increase (cm^3)	Adjusted Increase (cm^3)	Difference (cm^3)
	7/24	8/3			8/3	8/21			
Control	95.93	123.68	27.75		123.68	146.57	22.89	22.89	
Mobileaf (E)	97.70	126.53	28.83	0.96	126.53	156.70	30.17	28.96	6.07
	7/24	8/14			8/14	8/21			
Control	95.93	143.20	47.27		143.20	146.57	3.37	3.37	
Mobileaf (L)	96.43	148.83	52.40	0.90	148.83	158.48	9.65	8.69	5.32
	7/24	8/3			8/3	8/14			
Control	95.93	123.68	27.75		123.68	143.20	19.52	19.52	
Mobileaf (E+L)	97.54	126.41	28.87	0.96	126.41	150.03	23.62	22.68	(3.16)
					8/14	8/21			
Control					143.20	146.57	3.37	3.37	
Mobileaf (E+L)					150.03	155.93	5.90	5.66	(2.29)
					8/3	8/21			
Control					123.68	146.57	22.89	22.89	
Mobileaf (E+L)					126.41	155.93	29.52	28.34	5.45

Table 15

Effects of early (E) and late (L) and E+L sprays on Mobileaf (1:9) on final fruit volumes of Halford peaches after adjusting for pretreatment size differences.

	Adjusted final volume/fruit on 8/21 (cm^3)	Increase over control (%)
Control	146.57	0
Mobileaf (E)	153.85	5.0
Mobileaf (L)	152.85	4.3
Mobileaf (E+L)	153.20	4.5

Olives: (in cooperation with Dr. K. Uriu, Pomology Dept., UCD).

Manzanillo olives - 1969

Olive growers have observed that rainfall occurring during, or immediately prior to harvest increases olive size and dollar returns. This precipitation is, therefore, aptly called "million dollar rain." The increase in fruit size is attributed entirely to the rain, and not to increased soil moisture. Therefore, the fruit either absorbs rainwater, or the high ambient humidity during the days of rainfall drastically reduces the rate of water loss. If the latter occurs, an antitranspirant would also be expected to increase fruit size. Since there was no guarantee of rain occurring during our experimental period, some of the trees were sprayed during the daylight hours for 1 1/2 days with distilled water to simulate rain. The water spraying was continuous so that most of the foliage and fruit on the trees was always wet during the day.

The following treatments were used in an experiment on Manzanillo olive trees: 1) control (no spray); 2) water control (water plus X-77 surfactant); 3) artificial rain (continuous distilled water spraying); 4) CS-6432 sprayed on October 6 (23 days before harvest); 5) CS-6432 sprayed on October 13 (16 days before harvest); 6) CS-6432 sprayed on October 6 and 13. The CS-6432 was applied as 1 1/2% solution by a Bean orchard sprayer at a pressure of about 400 pounds per square inch, using approximately 10 to 15 gallons per tree, depending on the size of the tree. The October 6 and October 13 sprays were referred to as the early (E) and late (L) sprays, respectively. All of the trees in the six treatments mentioned above were irrigated on September 24. However, this irrigation was withheld from another group of trees, half of which were used as water controls and the other half sprayed with CS-6432 (1 1/2%) on October 6 and 13 (E + L). Each tree was replicated three times, giving a total of 24 trees in the experiment, including the dry plot. Growth of fruit, measured by Vernier calipers, was made on 20 fruit per tree, i.e., 60 fruit per treatment.

Soil moisture changes were determined gravimetrically by soil sampling at one-foot intervals to a depth of four feet (Table 16). Samples were taken periodically at two locations each in the irrigated and unirrigated plots. No attempt was made to assess the effects of antitranspirants on soil moisture depletion.

Table 16

Soil moisture contents (%, dry weight basis) in the irrigated (I) and unirrigated (U) sections of the Manzanillo Olive orchard. (The irrigated plot was watered on September 24, 1969. Rain occurred on October 14-16.)

	Soil Moisture (%)				Ave.
Depth (In.):	0-12	12-24	24-36	36-48	0-48
10/2 I	12.4	19.0	21.6	19.1	18.0
U	5.5	12.2	15.1	13.3	11.5
10/6 I	14.5	20.0	17.0	14.1	16.4
U	5.4	11.3	16.5	15.0	12.1
10/14 I	11.8	16.8	15.9	16.9	15.3
U	9.3	12.4	14.6	14.5	12.7
10/20 I	17.4	20.2	11.1	18.1	16.7
U	12.3	13.5	16.9	16.7	14.8
10/27 I	15.1	16.6	16.9	18.6	16.8
U	11.4	12.7	15.6	15.3	13.7

Because of the irregular shapes of the trunks, dendrometers had to be installed on one limb per tree. Thus, radial changes were more a function of the activity of the leaves and fruit on that limb, than of the tree as a whole. Resistance to water vapor diffusion from the leaves was measured by a rate hygrometer, and pressure potentials of leaves and fruit by a pressure bomb.

Radial growth of the limbs was either small or negative at this time of the year, and any positive growth was probably due more to hydration than to accumulation of photosynthates. The effect of hydration on growth was evident after two days of cloudy weather and rain (October 14-15) when the limbs of all the trees swelled (Table 17). Further evidence of the effects of hydration (resulting from antitranspirant treatment) on radial growth can be seen in Table 17: 1) on October 6-7 for those trees sprayed with CS-6432 on October 6, and 2) on October 13-14 for those trees sprayed with CS-6432 on October 13. The large negative growth values on October 28-29 were caused by warm, dry winds which tended to desiccate the trees during the night of October 28.

(Measurements with the rate hygrometer showed that the stomata on olive leaves do not close completely at night.) However, the relatively larger growth reductions for the CS-6432 treated trees on October 28-29 is difficult to reconcile with the expected role of an antitranspirant. The cumulative growth from October 1-28 (excluding the larger shrinkages on the final day) was greatest for the CS-6432 treated trees in the unirrigated plot and least for the unirrigated controls.

Table 17

Radial growth of limbs of Manzanillo olive trees as affected by antitranspirant (AT) sprays on 10/6 (E) and 10/13 (L), and by rain and irrigation.

	Not Irrigated		Irrigated on September 24					
1969	Control (H_2O)	AT (E+L)	Unsprayed	Control (H_2O)	Rain (L)	AT (E)	AT (L)	AT (E+L)
Oct. 1-2	-4.3	-2.7	-3.3	-2.7	-3.0	-3.0	-3.3	-2.7
2-3	-2.0	-1.7	-1.3	-1.0	1.7	0.7	6.7	0.3
3-6	3.7	1.3	3.3	2.0	0.7	3.7	-2.3	1.3
Spray (E) 10/6								
Oct. 6-7	-2.0	9.7	-0.3	0	0	9.3	-0.7	3.7
7-9	-1.7	6.7	0	1.3	2.0	4.0	0.3	2.0
9-10	2.0	0	2.3	3.0	2.3	0.7	2.0	1.7
10-13	-3.3	-2.5	-2.0	-3.5	-1.3	-2.3	-1.0	-1.3
Spray (L) 10/13								
Oct. 13-14	2.3	4.3	0	0.3	3.3	0.7	3.3	2.0
Rain - Oct. 14-15								
Oct. 14-16	15.0	19.0	13.0	14.3	17.7	15.0	16.7	15.7
16-17	-5.7	-2.0	-5.3	-5.7	-6.3	-6.7	-4.7	-3.7
17-20	-1.7	-4.0	-2.0	-3.3	-5.0	-4.7	-2.3	-1.0
20-23	0	-2.3	-2.3	-2.0	-1.3	-4.7	-6.3	-5.7
23-27	0	-1.3	2.0	1.3	2.3	2.7	0.3	0.3
27-28	-5	-2.3	-1.0	-2.3	-2.0	-0.3	-1.3	-1.0
28-29	-6.3	-17.0	-11.7	-9.0	-9.7	-15.7	-12.7	-13.0
Cumulative growth								
(Oct. 1-28)	-2.7	22.2	3.1	1.7	11.1	15.1	7.4	11.6

In the irrigated plot, the least cumulative growth was for control limbs, and the greatest for the early CS-6432 spray. If an antitranspirant had been applied earlier in the year when photosynthates were being channelled into the trunk and limbs, some reductions in radial growth would probably have occurred.

Treatment effects on daytime shrinkage of the limbs were also measured by the dendrometers. The reductions in shrinkage, resulting from curtailed transpiration after spraying CS-6432, are shown in Figure 24 for irrigated trees. Before the early spray on October 6, the maximum variation in limb shrinkage among the trees was $\pm$ 10%. After spraying, shrinkage was reduced by as much as 70%. Shrinkage of limbs on the late spray (L) trees was similar to that of control limbs prior to the October 13 spray, but was reduced by about 50% after the L spray. In the E+L treatment, shrinkage remained relatively small after the second spray, whereas the E spray alone appeared to lose some of its effectiveness with time. Limb shrinkage, relative to that of control unirrigated trees is shown in Figure 25. Prior to the October 6 spray, all the unirrigated trees showed similar limb shrinkage, but thereafter shrinkage of the treated trees wa reduced by 40%. Limbs of the control irrigated trees did not shrink as much as those of the control unirrigated trees. Figure 25 shows that shrinkage of CS-6432 sprayed trees in the irrigated plots was reduced by as much as 85%, relative to that of control unirrigated trees, thereby emphasizing the benefit of adequate soil and plant water potentials for reducing daytime water depletion in the tree.

Whereas Figures 24 and 25 show maximum daily shrinkage of the limbs, Figure 26 shows the shrinkage pattern on a single day (October 29). Shrinkage of the control limbs began by 0800 , and of the sprayed limbs, after 0900 By noon, shrinkage for the control unirrigated trees was about 1.5 times greater than that for control irrigated trees, and three times greater than for the antitranspirant-treated trees. Maximum shrinkage occurred around 1530 (PST), with the control irrigated trees shrinking the most (33 dendrometer units or 0.168 mm), and the CS-6432 irrigated trees the least (20 units or 0.102 mm). Maximum shrinkage in the treated unirrigated trees was the same as that of control irrigated trees (24 units or 0.122 mm), suggesting that the antitranspirant offset the deficiency of soil moisture. Recovery of the water balance of the limbs began after 1730.

Continuous diurnal observations on radial changes of tree limbs and size changes of olive fruit were made from 0800 on October 28 to 1800 on October 29. A hygrothermograph in the orchard also gave continuous records of temperature and relative humidity. Fruit diameters were measured with callipers on 30 fruit (15 fruit per tree on two trees) per treatment. Only the Control and CS-6432 (E+L) trees in the irrigated plot were measured. The data are shown in Figure 27 as contraction or expansion of fruit and limbs, using 0800 (PST) on October 28 as a starting reference. During daylight hours, when the temperature was around 70°F (21°C), and relative humidity about 23-30%, shrinkage of both limbs and fruit occurred. However, the reduction of daytime shrinkage by the antitranspirant was more pronounced for the fruit than for the limbs. (The reduction of limb shrinkage by CS-6432 on October 29 can be seen more clearly in Figure 26 in which the morning reference point is common for control and treated trees.) In the evening when temperature was dropping and humidity rising, rehydration of the tree began. The recovery of the fruit began about one hour later than that of the limbs. One of the most interesting observations in Figure 27 was the occurrence of a warm, dry north wind during the night which

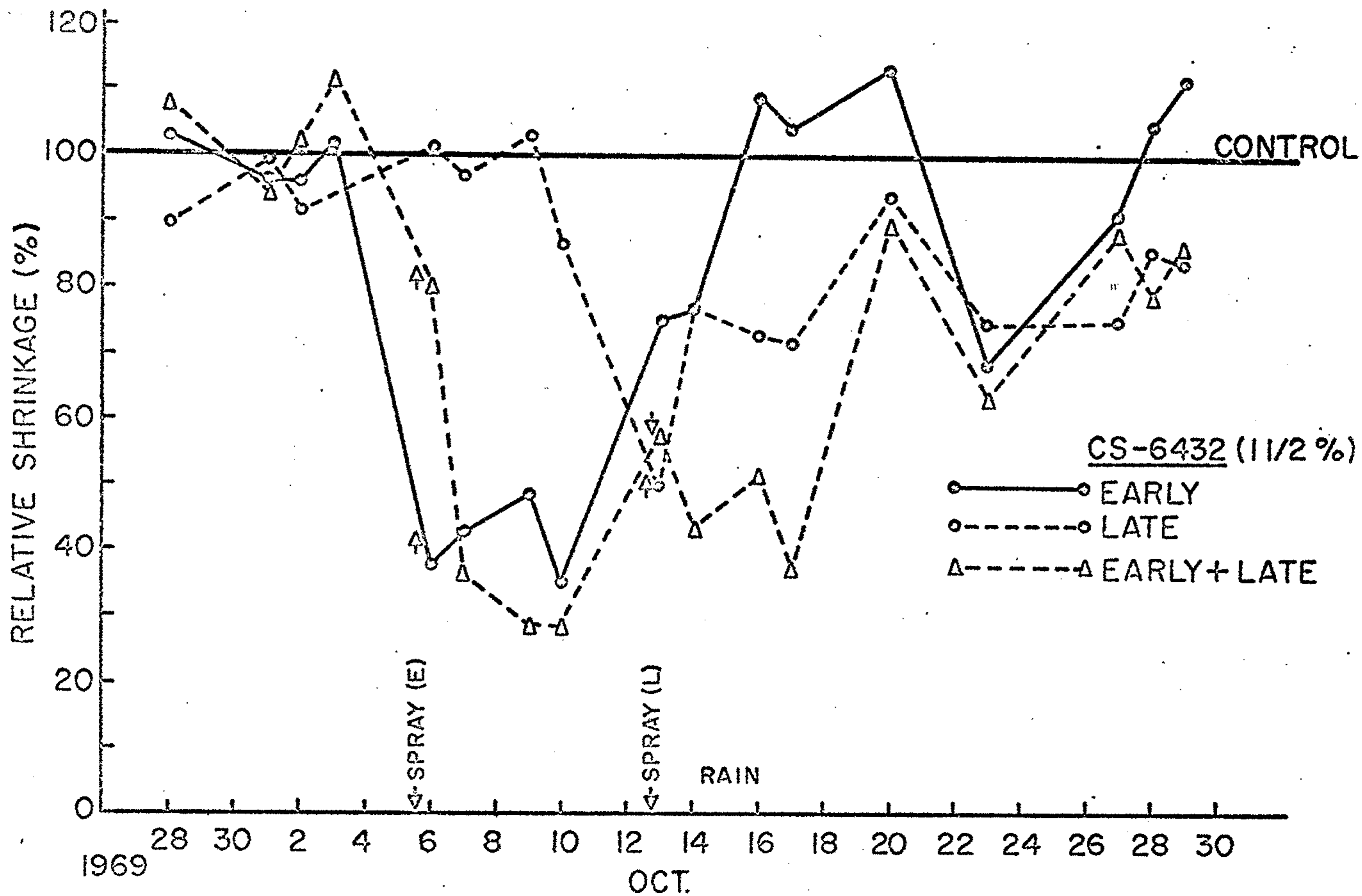


Figure 24: Effects of early and late sprays of CS-6432 ($1\frac{1}{2}\%$) antitranspirant on maximum daily shrinkage of Manzanillo olive limbs. (Arrows on the curves indicate sprays.)

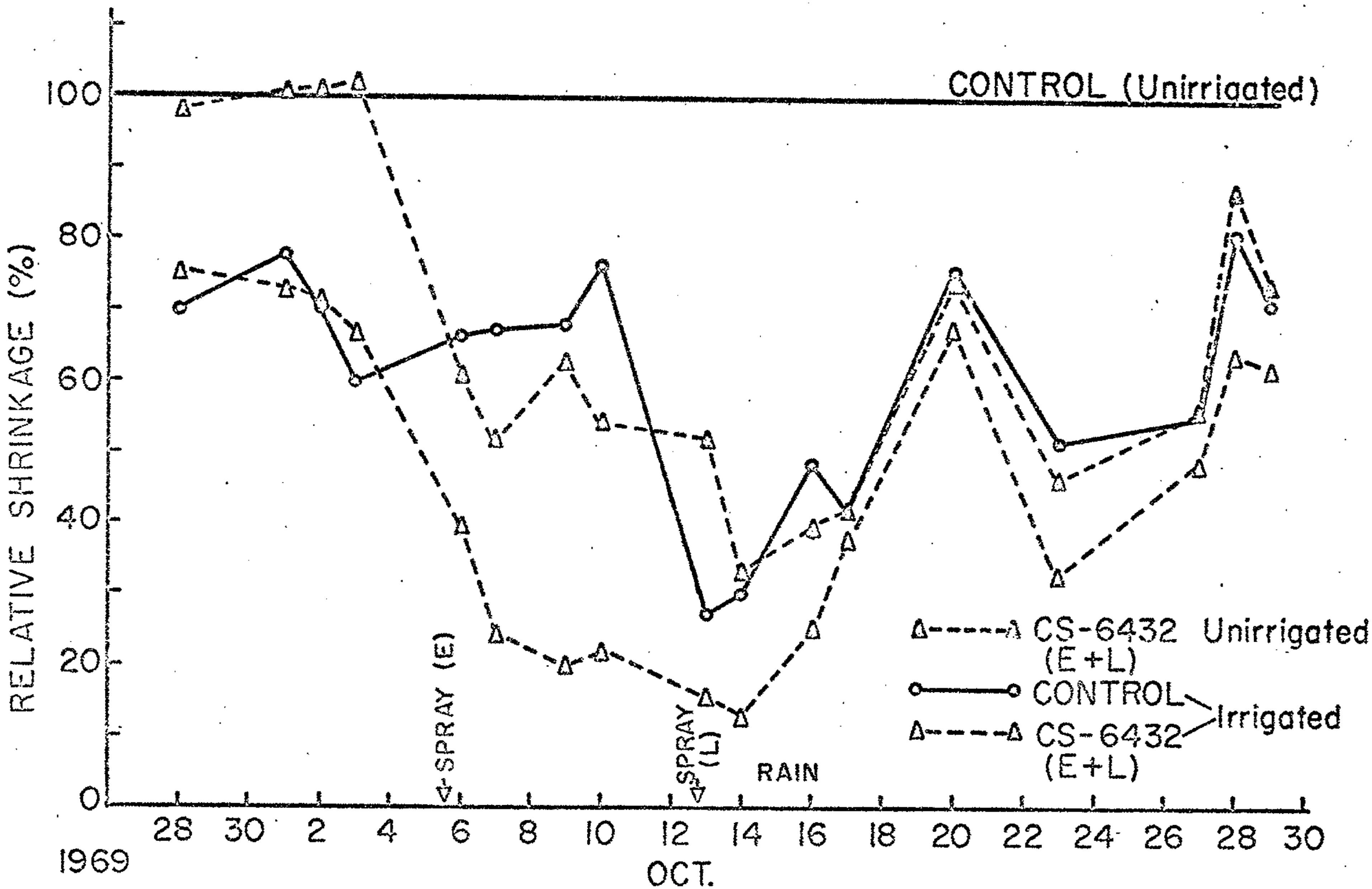


Figure 25: Effects of irrigation and early (E) + late (L) sprays of CS-6432 ($1\frac{1}{2}\%$), antitranspirant on maximum daily shrinkage of Manzanillo olive limbs.

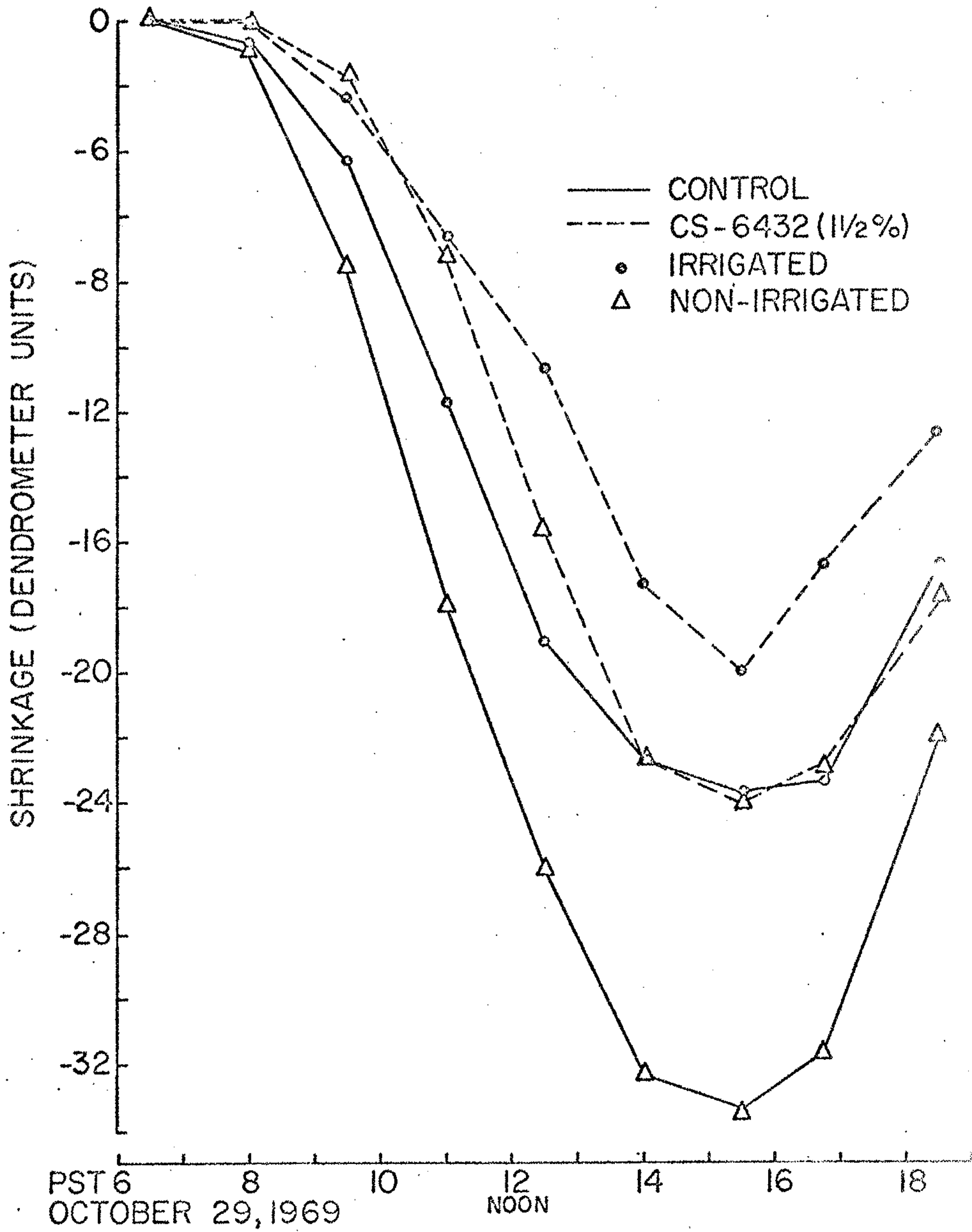
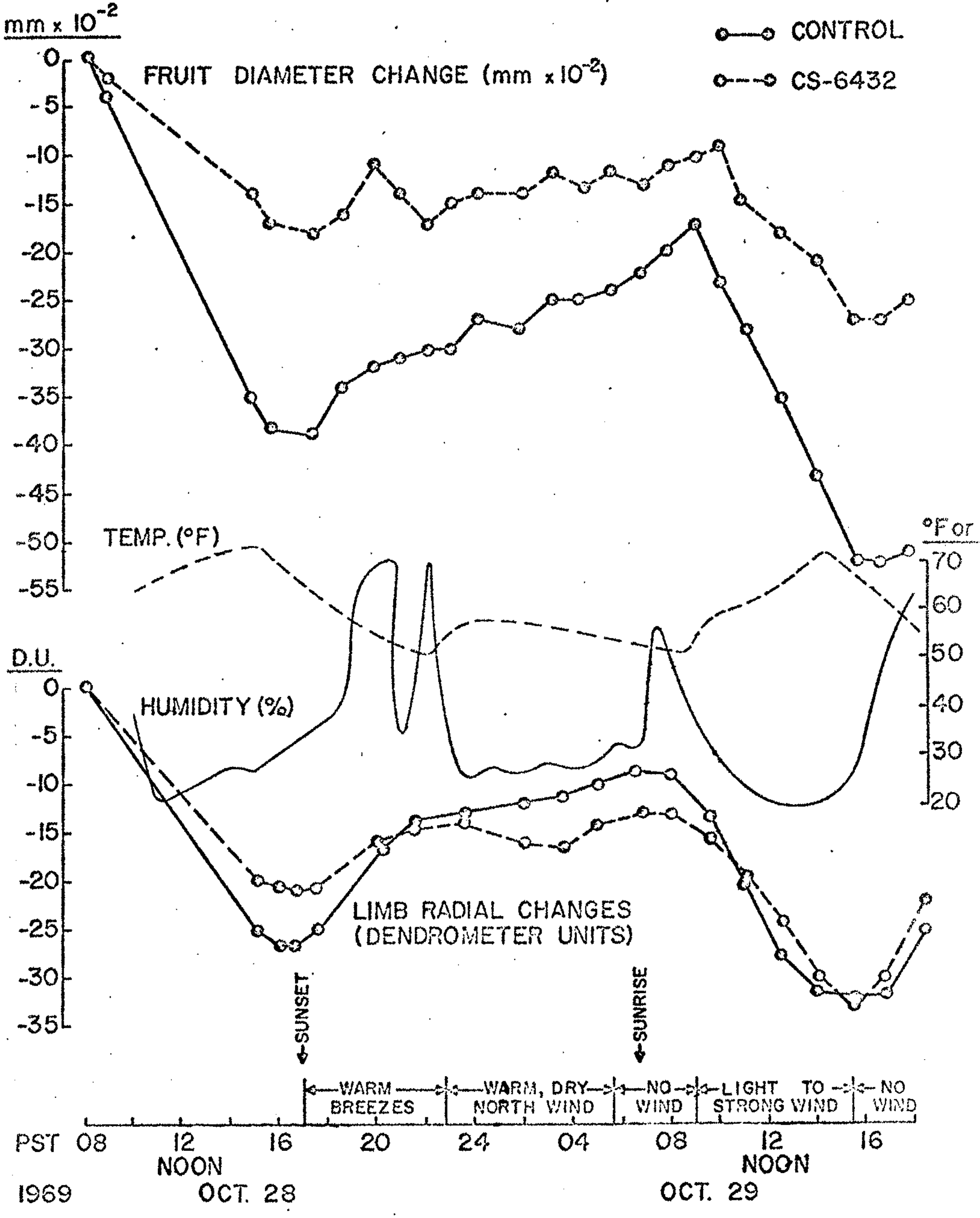


Figure 26: Effects of irrigation and CS-6432 (1½%) antitranspirant on daytime shrinkage patterns of Manzanillo olive limbs.

Figure 27: Effects of CS-6432 ($1\frac{1}{2}\%$) on diurnal contraction and expansion of fruit and limbs of Manzanillo olives. (Fluctuations in ambient temperature and humidity for the two observation days are also shown.)



mm x 10⁻²
CONTROL
CS-6432
FRUIT DIAMETER CHANGE (mm x 10⁻²)
0
-5
-10
-15
-20
-25
-30
-35
-40
-45
-50
-55
TEMP. (°F)
°F or
70
60
50
40
30
20
D.U.
HUMIDITY (%)
LIMB RADIAL CHANGES
(DENDROMETER UNITS)
SUNSET
SUNRISE
WARM BREEZES
WARM, DRY NORTH WIND
NO WIND
LIGHT TO STRONG WIND
NO WIND
PST 08 12 16 20 24 04 08 12 16
NOON
NOON
1969
OCT. 28
OCT. 29

Figure 27:

raised the temperature from 50°F to 58°F at midnight and lowered ambient humidity from 70% to 25%. This curtailed rehydration, so that neither the fruit or limbs expanded to their original size at the starting reference (0800 on 10/28). The incomplete overnight rehydration was due to: 1) relatively slow water uptake by the roots, since the trees had not been irrigated for six weeks, and 2) night transpiration, which was enhanced by the low humidities.

An interesting observation in Figure 27 is the relatively smaller overnight recovery of treated than control fruit and limbs. Thus, the overnight fruit expansion, between 1720 on 10/28 and 0900 on 10/29 was 0.22 mm for control, but only 0.08 mm for CS-6432. The corresponding overnight limb expansions for control and CS-6432 were, respectively, 17 and 8 dendrometer units (0.087 and 0.041 mm). The explanation for this may be found in one, or a combination of, the following reasons: 1) during the preceeding daylight hours the controls experienced greater deficits, which gave a large water potential gradient from source to sink; 2) reduced photosynthate accumulation in the antitranspirant treatment; and 3) relatively more open stomata, and therefore greater night water loss, from the CS-6432 leaves - (the antitranspirant increases leaf turgidity, causing wider stomatal apertures and greater water loss from those portions of leaves not covered by the film). It will also be noticed in Figure 27 that during the night: 1) the limbs and fruit of treated trees were more responsive to changes in humidity than were those of controls; and 2) this response lagged about a half hour behind the commencement of the humidity changes. The reversals in rehydration of treated, but not control, trees are particularly noticeable: 1) at 2100 hours when only the treated fruit shrank in response to the temporary humidity drop at 2030 hours; and 2) after midnight when only treated limbs shrank in response to the humidity drop a little before midnight. The increased humidity between 0600 and 0900 on 10/29 enhanced the rate of fruit rehydration. Thereafter, humidity dropped and daytime shrinkage occurred.

The explanation for the nighttime responses to low humidity described above are based on the premise that the stomata of olive leaves do not close fully at night, or that cuticular water losses from leaves and fruit are large at night. Using the rate hygrometer, it was found that water vapor diffusion from the upper nonstomata bearing surfaces of olive leaves was nil, or at least so small that it could not be detected by the instrument's humidity sensor. The loss of water from the tree at night was, therefore, stomatal rather than cuticular. This was confirmed by making measurements on the lower (stomata bearing) surfaces of leaves at night. A shield was used to ensure that no light from the flashlight, used for reading the instrument, fell on the leaves. Normally, plant stomata close at night, and the humidity sensor of the rate hygrometer shows no response, i.e., resistance = infinity. During the day, the rate at which the sensor is humidified by water vapor leaving the leaf, clocked over a given meter range (transit time), may be about 6 sec., corresponding to a resistance of 0.05 min cm^{-1} at a day temperature of 31°C. At night, the transit time may be 30 sec., and resistance 0.06 min cm^{-1} at a night temperature of 10°C. Thus, the day and night transit times differ by a factor of 5, but resistance is increased by only 0.01 min cm^{-1}. The strong dependence of the resistance diffusion calibration on temperature is clearly evident, and this casts some doubt on the validity of comparisons of absolute resistance values measured at widely differing temperatures. Nevertheless, a 30 sec. transit time in the dark is ample evidence that olive stomata remain partially open at night. (The range of night transit times recorded for the olive leaves was 16 to 18 seconds, the average being 29 seconds). Some night and day values of leaf diffusive resistances are given in Table 18. Keeping in mind the comments above, night resistances were not much greater than day resistances, and were sometimes even lower. Moonlight was not responsible for opening of stomata at night.

Table 18

Night and day resistances to diffusion of water vapor from the lower surface of olive leaves. (Each value is the average of measurements on three leaves.)

Condition	Date	Time (PST)	Resistance (min cm^{-1})
Twilight	10/29	1715	0.027
Dark	10/29	1745	0.063
Dark	10/29	1800	0.090
Dark	10/29	1900	0.070
Dark (Moonlight)	10/30	2320	0.040
Dark (No Moonlight)	10/30	2330	0.040
Light (Sun)	10/31	1000	0.027
Light (Shade)	10/31	1015	0.060
Light (Sun)	10/31	1300	0.050
Light (Shade)	10/31	1315	0.070

Treatment effects on resistance to water vapor diffusion and pressure potentials of leaves on various dates are shown in Table 19. (Time did not permit measurements for all treatments on each date.) Experimental variation was minimized by: 1) making alternate measurements on control and treated trees to avoid confounding time effects with treatment effects on resistance and potential; and 2) selecting leaves from the same side of each tree, usually the shady side. On October 9 (3 days after the early spray), resistance was doubled by the CS-6432 in the irrigated plot. On October 10 in the irrigated plots, there was virtually no difference in resistance and potential between control unsprayed trees, and control trees sprayed with water + surfactant on October 6. Resistance and pressure potential were increased by the antitranspirant for both the irrigated and unirrigated trees. It is interesting that the pressure potential of CS-6432 treated leaves of unirrigated trees (-16.3 atm) was slightly higher than that of control irrigated trees (-17.9 atm). On October 16 (3 days after the late spray), resistances were higher for CS-6432 treated leaves (0.09 to 0.27 min cm^{-1}) than for controls or those given artificial rain 6.03 to 0.04 min cm^{-1}). On October 17 and 24, the increase in resistance and pressure potential resulting from the early and

Table 19

Effects of CS-6432 ($1\frac{1}{2}\%$) and irrigation on resistance to water vapor diffusion, R, (min cm^{-1}) and pressure potential, P, (atm.) of leaves of Manzanillo olives. The early (E) and late (L) sprays were given on 10/6 and 10/13, respectively. Each figure is based on measurements on at least 5 leaves.

	10/9		10/10		10/16		10/17		10/24		10/29		11/12	
	R	P	R	P	R	P	R	P	R	P	R	P	R	P
Unirrigated														
Control	--	--	.06	-21.0	.03	--	.01	-20.7	.03	-21.9	.06	-23.9	.06	-20.5
CS (E+L)	--	--	.21	-16.3	.27	--	.12	-10.1	.06	-13.6	.13	-18.8	.08	-17.8
Irrigated														
Unsprayed	--	--	.03	-18.7	--	--	--	--	--	--	--	--	--	--
Control	.07	--	.04	-17.9	.04	--	.03	-16.5	.02	-17.6	.06	-19.4	.06	-17.1
Rain (L)	--	--	--	--	.03	--	--	--	--	--	--	--	--	--
CS (E)	--	--	--	--	.10	--	.05	-10.9	.04	-13.1	.04	-19.5	.05	-15.2
CS (L)	--	--	--	--	.09	--	.06	-11.6	.03	-14.8	.04	-19.2	.04	-17.7
CS (E+L)	.14	--	.16	-10.6	.14	--	.08	-12.1	.05	-13.7	.10	-17.6	.07	-14.7

the late antitranspirant sprays were more pronounced for the unirrigated than for the irrigated trees. By October 29 (harvest date), only the E+L sprayed trees appeared to manifest continued increases in resistance and pressure potential. Post-harvest measurements on November 12, indicated that leaf pressure potentials were still slightly higher for CS-6432 treated trees. The potential of leaves from unirrigated sprayed trees was about 3 atm. greater than that of unirrigated controls, but was about the same as that of irrigated controls.

Pressure potential measurements were also made on olive fruits on various dates. Table 20 shows the effects of the early spray (10/6) on leaves and fruit, as determined by the pressure bomb on 10/10. The CS-6432 was more effective in preventing low pressure potentials in the leaves than in the fruit. The antitranspirant effect was more pronounced for the irrigated trees. In Table 21, the potentials of fruit on the trees on, and after the harvest date (10/29) are presented. With the exception of measurements on 10/30, all fruit were sampled from the shady side of the tree. At the end of October, CS-6432 raised fruit pressure potentials by 4 to 5 atm. for the unirrigated trees, and to a lesser extent for the irrigated trees, where untreated fruit had relatively higher potentials (about -20 atm. cf -26 atm. for unirrigated controls). However, on 11/12, (nearly one month after the late spray) fruit potentials of the control irrigated trees had dropped to -28.6 atm.) whereas those of the sprayed irrigated trees were about 5 atm. higher.

Table 20

Effects of CS-6432 (1 1/2%) and irrigation on pressure potentials of leaves and fruit of Manzanillo olives, as found by the pressure bomb on October 10, 1969.

	Pressure potentials (atm)					
	Leaves			Fruit		
	Time	Control	CS-6432	Time	Control	CS-6432
Unirrigated	1530	-21.5	-11.3	1600	-21.7	-20.7
	1605	-19.9	-11.4	1700	-22.6	-19.6
Irrigated	1550	-20.6	-9.1	1630	-19.8	-15.3
	1620	-17.1	-8.0	1645	-18.8	-14.0

Table 21

Effects of CS-6432 (1 1/2%) and irrigation on pressure potentials (atm) of Manzanillo olive fruits at, and after, the normal harvest date (10/29). The early (E) and late (L) sprays were given on 10/6 and 10/13, respectively. Each value is based on measurements of five leaves.

Date	10/29		10/30		10/31	11/12
Time	(1600-1645)	(0930-1030)	(1215-1300)	(1300-1315)	(1445-1530)	(1600)
Unirrigated						
Control	-27.2	----	-26.7	-25.2	-26.5	----
CS(E+L)	-22.0	----	-22.0	-20.0	-21.9	----
Irrigated						
Control	-24.4	-20.3	-20.3	----	-21.6	-28.6
CS(E)	-22.0	-17.6	----	----	----	----
CS(L)	----	-18.8	----	----	----	----
CS(E+L)	-19.7	-17.8	-20.0	----	-20.1	-23.5

Daytime changes in fruit diameter were measured periodically for all treatments by making calliper readings on all tagged fruit in the morning (0900-1000) and evening (1600-1700)--Figure 28. On 9/29, before spraying the antitranspirant, fruit shrinkage was relatively large on all trees, with a tendency for greater shrinkage in the unirrigated plot. On the day of the early spray (10/6), and on the following days, diameter changes were either positive or only slightly negative for fruit on CS-6432 sprayed trees. It will be noticed that fruit from the control trees which were sprayed with water + surfactant (treatments A and D in the unirrigated and irrigated plots, respectively) did not behave very differently from the fruit of completely unsprayed control trees (treatment C). On the day of the late spray (10/13), shrinkage was generally low. However, fruit from all trees sprayed with antitranspirant on this day (treatments B, G and H) increased in size. The simulated rain (continual wetting with distilled water) produced the greatest fruit swelling. On the subsequent measuring days fruit of the "rain" trees behaved essentially the same as controls. The CS-6432 continued to reduce daytime shrinkage up to harvest (10/29), and there was a tendency for two sprays (10/6 and 10/13) to be more effective than one spray in this respect. By 10/29 there appeared to be no difference between fruit shrinkage of the irrigated and unirrigated trees, and the antitranspirant was equally effective in both cases. The reduction, and in some instances prevention, of daytime fruit shrinkage as a result of antitranspirant treatment indicates improvement in the water status of the tree and suggests the potential for increasing fruit growth.

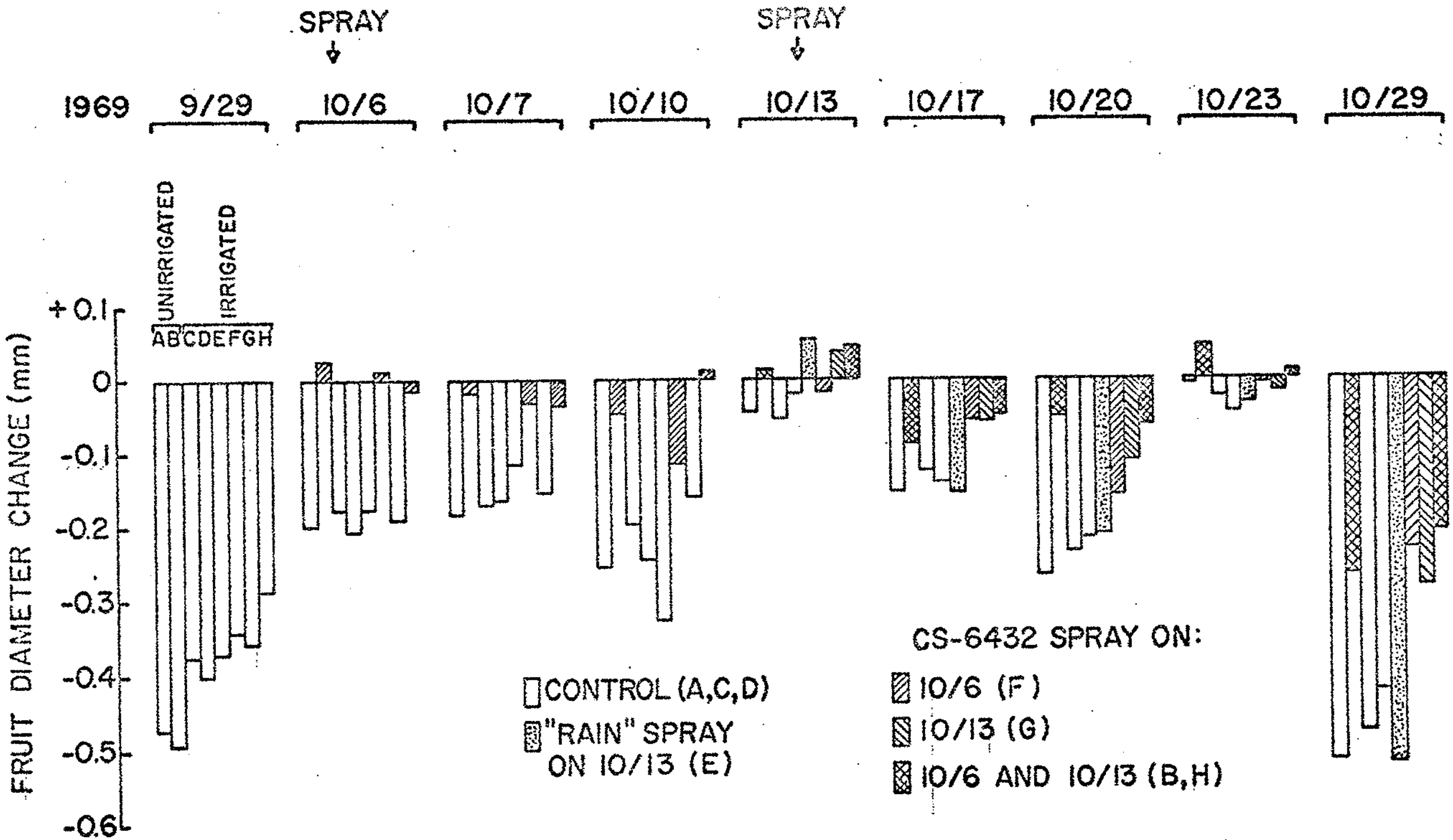


Figure 28: Effects of CS-6432 ($1\frac{1}{2}\%$) antitranspirant sprays, simulated rain, and irrigation on maximum daytime shrinkage of Manzanillo olive fruits.

The sizing of the olive fruits was followed from September 24, when their volumes ranged from 3.1 to 3.4 cm^3, until Sept. 29, when the range was 3.7 to 4.6 cm^3, depending on treatment (Figure 29). The initial size differences were due to chance, and treatment effects are therefore assessed by growth rates, i.e., the slopes of the curves. Thus, the absence of a Sept. 24 irrigation reduced the growth rates (c.f. slopes of lower two curves with upper 6 curves in Fig. 29). Prior to 10/6, the slopes of the curves within the two irrigation treatments were fairly similar, but after the sprays on 10/6 and 10/13, the antitranspirant effects are manifested as increased growth rates. In the irrigated plot, the approximately identical shapes of the two controls (unsprayed and water + surfactant) shows that the antitranspirant effect was produced by the CS-6432 film and not by mere wetting of the foliage.

The various treatment effects can be seen more clearly, when expressed as percent volume increase from the date of the early (10/6) spray (Fig. 30, A-C). The effects of the E, L and E+L sprays on fruit growth of irrigated trees is shown in Figure 30A. Between Oct. 6 and 13, the E and E+L fruit increased in volume by about 11% compared to a 5% increase for the water-sprayed control and L treatments. However, from Oct. 13 to 29, the L spray on 10/13 greatly enhanced fruit expansion, relative to control. Much of the rapid increase in fruit size occurred immediately after spraying. Thus, on 10/13, the additional L spray on the E+L treatment increased growth relative to the E treatment. In fact, the absence of any foliar wetting on 10/13 of the early antitranspirant treatment appeared to slightly decrease growth rate relative to the water sprayed control, between 10/13 and 10/14.

In Figure 30B, the effects on fruit growth of the antitranspirant (L) and simulated rain sprays, both applied on 10/13, are compared to the unsprayed control in the irrigated plot. Prior to 10/13, fruit growth rates on these trees were very similar. From 10/13 to 10/14 both the simulated rain and the CS-6432 increased growth rates, thus substantiating the claims about "million dollar rain" mentioned earlier. Natural rain between Oct. 14 and 16 enhanced fruit growth and provided further evidence of fruit swelling due to precipitation and cloudy humid weather. However, with the passing of the rain and the re-emergence of the sun after 10/16, those trees which were not sprayed with antitranspirant, lost most of the absorbed rain water (probably via the leaf stomata) and the fruit resumed growth at the rates which were observed prior to the rain. Nevertheless, the slight boost in growth rate from 10/13 to 10/14, resulting from the simulated rain, did enhance final fruit size somewhat. On the other hand, fruit on the antitranspirant treated trees, did not lose the benefit of the rain by decreasing in size, but continued expansion at an enhanced rate. Thus, olive fruit swelling due to rain is a real, but largely temporary response. Thus, the "million dollar rain" is beneficial only if it occurs at harvest, whereas the persistence of retarded transpiration (and the resulting increase in plant water potential) due to an effective antitranspirant applied 2 to 3 weeks before harvest, provides a more reliable means of increasing fruit size.

In Figure 30C, the effects on fruit growth of early + late applications of CS-6432 are compared for the irrigated and unirrigated trees. Growth rates of irrigated fruit were slightly greater than those of unirrigated fruit after 10/6. As already pointed out, much of the response to the 9/24 irrigation occurred before 10/6. The response to CS-6432 sprayed on 10/6 is very clear in both the irrigated and unirrigated trees. The final reductions in growth

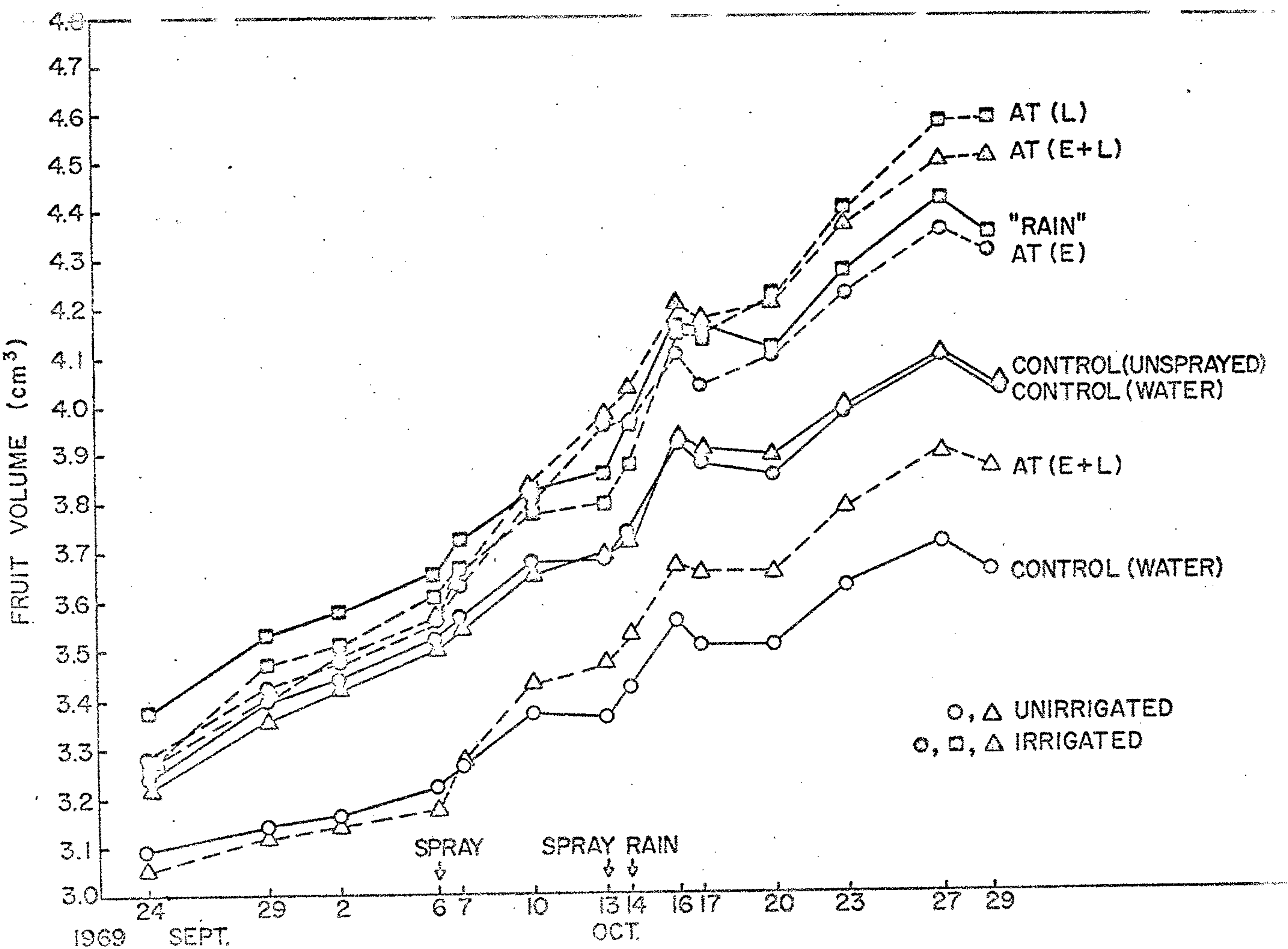
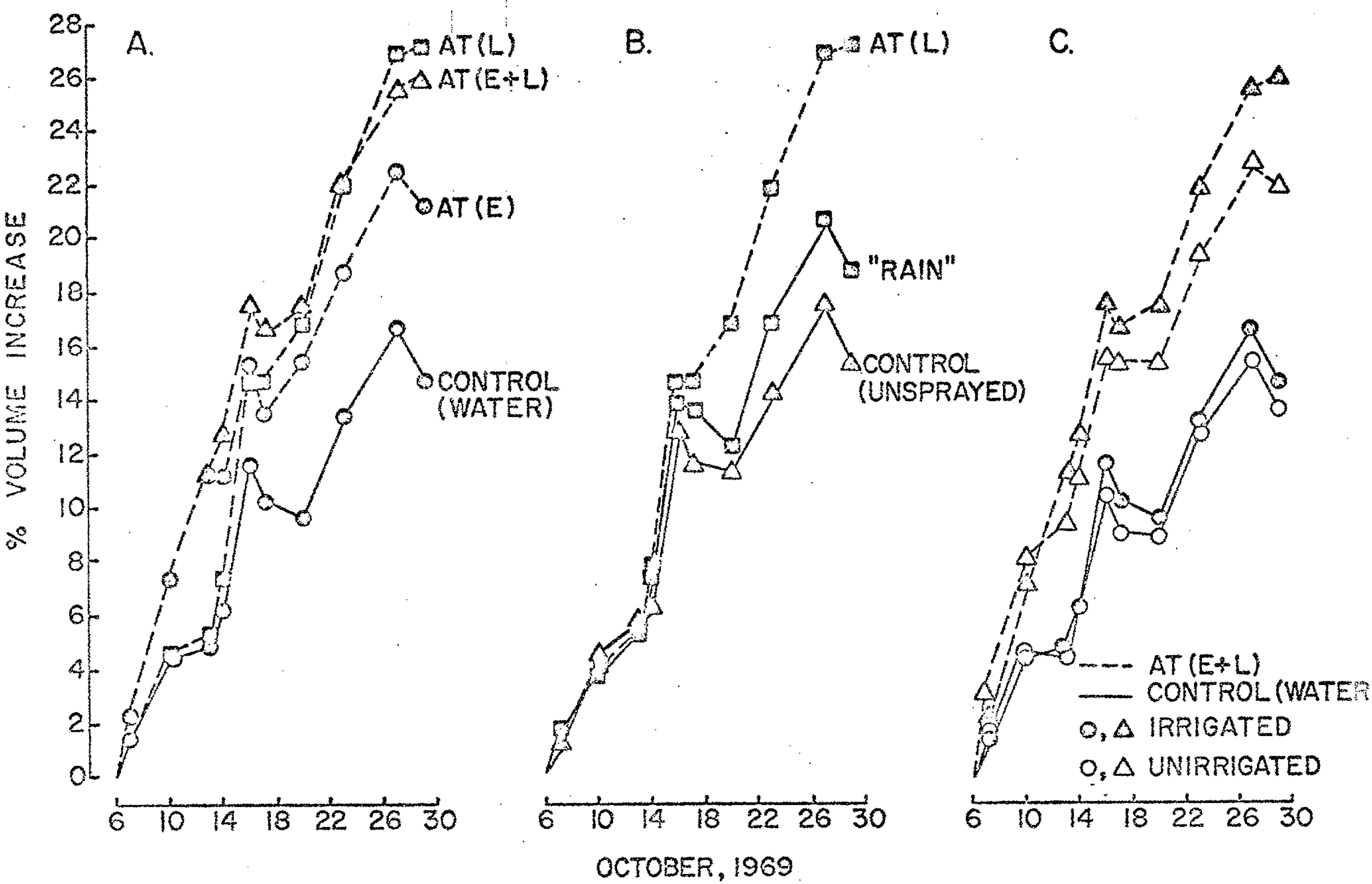


Figure 29: Effects of irrigation, simulated rain, and early (E) and late (L) sprays of CS-6432 ($1\frac{1}{2}$%)



<u>Figure 30</u>: Effects on fruit volume growth of simulated rain and of early (E), late (L) and early + late sprays of CS-6432 ($1\frac{1}{2}\%$) antitranspirant (AT).

A. Effects of E and L AT sprays on irrigated trees.
B. Effects of L AT and simulated rain on irrigated trees.
C. Effects of E+L AT for irrigated and unirrigated trees.

were due to the low night humidity reported in Figure 27. Note that these growth reductions occurred for all treatments except the L and E+L sprays on irrigated trees. Finally, between 10/6 and 10/29 the smallest increase in fruit volume (13.7%) occurred in the unirrigated control trees, and the largest increase (27.2%) in the irrigated trees sprayed with CS-6432 on 10/13.

Although the amount of fruit growth between spraying and harvest was enhanced several fold by the antitranspirant, the most meaningful assessment of treatment effect is the actual increase in final fruit volume. Differences in initial fruit volumes on 9/24 (see Figure 29) were used to adjust the final fruit volumes to compensate for inherent pre-treatment size differences (Table 22).

Table 22

Treatment effects on final fruit volumes of Manzanillo olives. Comparisons are relative to unsprayed controls in the irrigated plot. Final volumes were adjusted for initial size differences from the control. (AT = antitranspirant (CS-6432); E = early spray; and L = late spray)

	Initial (9/24/69)		Final (10/29/69)			
	Actual Vol. (cm^3)	Difference from control (cm^3)	Actual Vol. (cm^3)	Adjusted Volume (cm^3)	%	% Effect
Irrigated						
Control (Unsprayed)	3.22	0	4.04	4.04	100	0
Control (Water)	3.24	+ 0.02	4.04	4.02	99.5	- 0.5
"Rain"	3.37	+ 0.15	4.35	4.20	103.9	+ 3.9
AT (E)	3.27	+ 0.05	4.32	4.27	105.7	+ 5.7
AT (L)	3.26	+ 0.04	4.59	4.55	112.6	+ 12.6
AT (E+L)	3.26	+ 0.04	4.51	4.47	110.6	+ 10.6
Unirrigated						
Control (Water)	3.09	- 0.13	3.66	3.79	93.8	-6.2
AT (E+L)	3.05	- 0.17	3.87	4.04	100.0	0

In the irrigated plot, increase in final volume of fruit was about 11 to 13% due to the L and E+L CS-6432 sprays, whereas the early spray alone was only half as effective (6% increase in final volume). The temporary boost from the simulated "rain" increased final volume by 4%, but the water + surfactant control showed no effect. In the unirrigated plot, the absence of the 9/24 irrigation reduced final fruit size by 6%, but the antitranspirant (E+L) compensated for this, so that no reduction in final size occurred. In other words, the antitranspirant substituted for the irrigation on 9/24. The increase in final fruit size due to the E+L antitranspirant spray (not shown in Table 22), was 7% for the unirrigated, compared with 11% for the irrigated trees.

An estimate of the returns resulting from, say, a 10% increase in final volume and weight of olive fruits is given below:

Yield	4 tons/acre
Extra yield due to CS-6432	0.4 ton/acre

At \$300/ton, gross extra returns = 0.4 x 300 = \$120/acre

Olives are priced on various size grades (large, extra-large, jumbo, etc.) with a \$20 average price differential between grades, and assuming that the antitranspirant puts more fruit in a higher grade size equivalent to, say, a conservative increase of 1/2 a grade, we would have an increase of 1/2 x \$20 = \$10/ton. Thus, with a 4 ton yield, we would get 4 x \$10 = \$40 extra/acre.

Therefore total gross gain = \$120 + \$40 = \$160/acre.

In this experiment, about 12 gallons of CS-6432 spray was applied per tree. At a concentration of 1 1/2% (active ingredient), this is equivalent to 0.36 gallons of CS-6432 concentrate/tree, and with 60 trees/acre, 21.6 gallons concentrate/acre. However, with more efficient spraying techniques, such as the use of a mist blower, it may be possible to achieve the same effects with only 4 gallons of spray/tree, (only 1/3 as much antitranspirant/acre), i.e., only 7.2 gallons of CS-6432 concentrate/acre. Since CS-6432 is an experimental material, its cost has not as yet been determined. Normal spraying costs (excluding material applied) are about \$10/acre.

Therefore net extra returns per acre due to the CS-6432 spray

= \$160/acre minus \$10/acre minus cost of 7.2 gal. CS-6432 concentrate.

The moisture content of the fruit from the various treatments sampled on the afternoon of the harvest date, indicated that the CS-6432 conserved more moisture within the fruit (Figure 31). A texture rating test, based on the resistance offered by a 35 g sample of olive fruit flesh, showed that fruit from CS-6432 trees had slightly lower resistance pressures.

The rates of moisture loss from harvested fruit from control and CS-6432 treated trees, determined by weight loss between November 3 and 13, are shown in Figure 32. The rate of water loss from the sprayed fruit (from trees which had been treated with CS-6432 three weeks earlier) was about 50% less than that from control fruit, and as a result the latter were completely shriveled by November 10, whereas the treated fruit remained smooth and plump. However, In the irrigated plot, increase in final volume of fruit was about 11 to 13% due to the L and E+L CS-6432 sprays, whereas the early spray alone was only half as effective (6% increase in final volume). The temporary boost from the simulated "rain" increased final volume by 4%, but the water + surfactant control showed no effect. In the unirrigated plot, the absence of the 9/24 irrigation reduced final fruit size by 6%, but the antitranspirant (E+L) compensated for this, so that no reduction in final size occurred. In other words, the antitranspirant substituted for the irrigation on 9/24. The increase in final fruit size due to the E+L antitranspirant spray (not shown in Table 22), was 7% for the unirrigated, compared with 11% for the irrigated trees.

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Olives are priced on various size grades (large, extra-large, jumbo, etc.) with a \$20 average price differential between grades, and assuming that the antitranspirant puts more fruit in a higher grade size equivalent to, say, a conservative increase of 1/2 a grade, we would have an increase of 1/2 x \$20 = \$10/ton. Thus, with a 4 ton yield, we would get 4 x \$10 = \$40 extra/acre.

Therefore total gross gain = \$120 + \$40 = \$160/acre.

In this experiment, about 12 gallons of CS-6432 spray was applied per tree. At a concentration of 1 1/2% (active ingredient), this is equivalent to 0.36 gallons of CS-6432 concentrate/tree, and with 60 trees/acre, 21.6 gallons concentrate/acre. However, with more efficient spraying techniques, such as the use of a mist blower, it may be possible to achieve the same effects with only 4 gallons of spray/tree, (only 1/3 as much antitranspirant/acre), i.e., only 7.2 gallons of CS-6432 concentrate/acre. Since CS-6432 is an experimental material, its cost has not as yet been determined. Normal spraying costs (excluding material applied) are about \$10/acre.

Therefore net extra returns per acre due to the CS-6432 spray

= \$160/acre minus \$10/acre minus cost of 7.2 gal. CS-6432 concentrate.

The moisture content of the fruit from the various treatments sampled on the afternoon of the harvest date, indicated that the CS-6432 conserved more moisture within the fruit (Figure 31). A texture rating test, based on the resistance offered by a 35 g sample of olive fruit flesh, showed that fruit from CS-6432 trees had slightly lower resistance pressures.

The rates of moisture loss from harvested fruit from control and CS-6432 treated trees, determined by weight loss between November 3 and 13, are shown in Figure 32. The rate of water loss from the sprayed fruit (from trees which had been treated with CS-6432 three weeks earlier) was about 50% less than that from control fruit, and as a result the latter were completely shriveled by November 10, whereas the treated fruit remained smooth and plump. However,

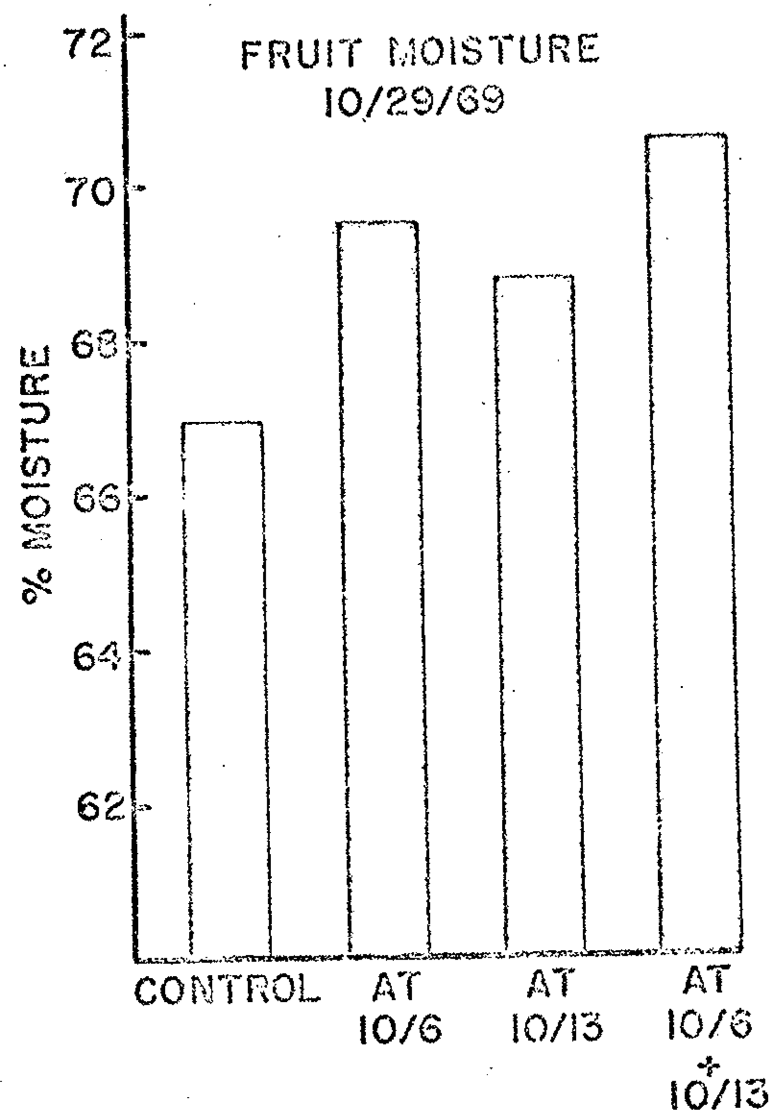


Figure 31:
Effects of early (10/6) and late (10/13) sprays of CS-6432 ($1\frac{1}{2}$%) on moisture content of Manzanillo olive fruit at harvest.

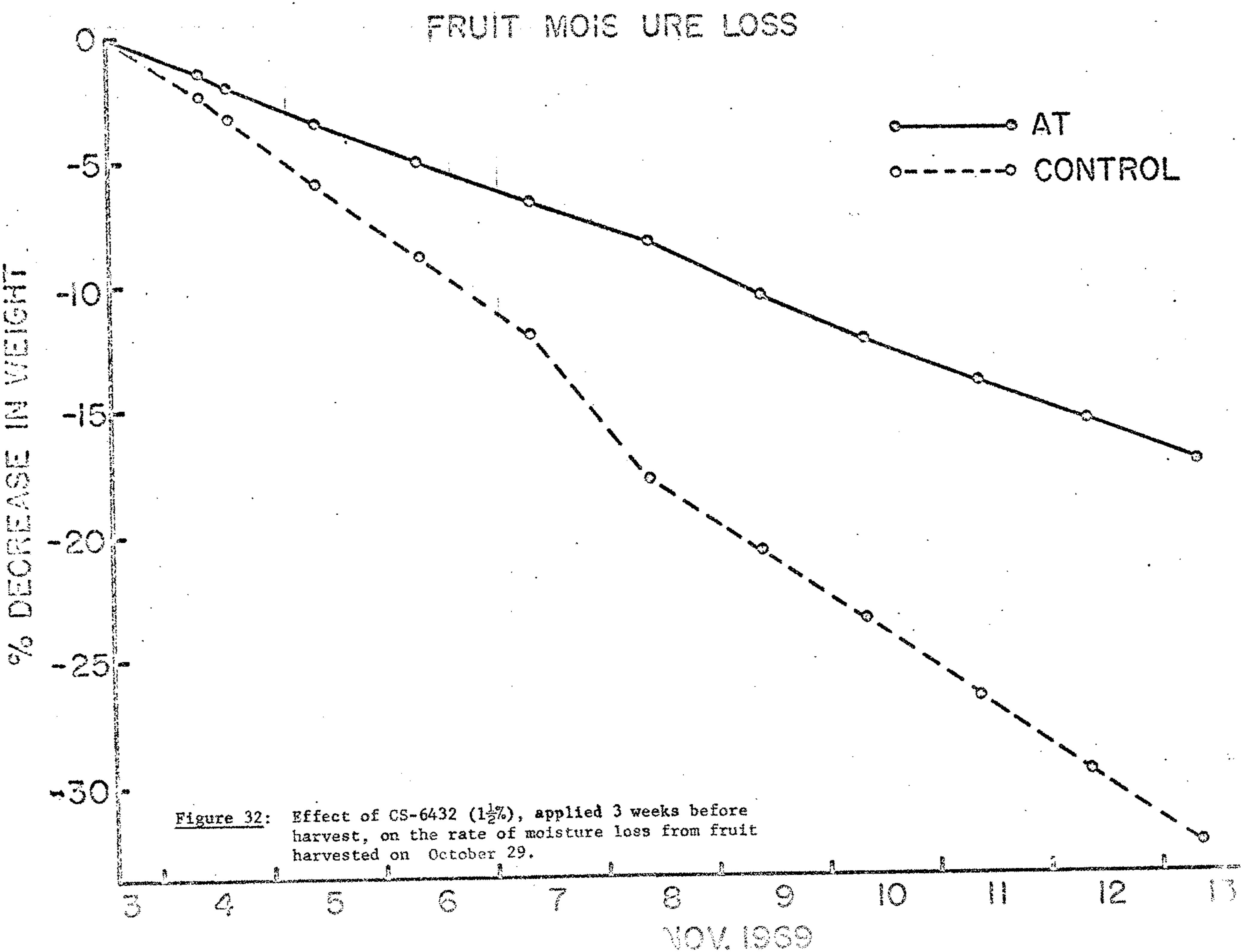


Figure 32: Effect of CS-6432 ($1\frac{1}{2}\%$), applied 3 weeks before harvest, on the rate of moisture loss from fruit harvested on October 29.

post-harvest shrivel of olive fruit is not normally a problem, since the time from harvest to processing is usually short, and only fruit on the upper surfaces of the crates are subject to severe drying. Upon arrival at the processing plant the fruit are put in brine to hold them until they can be processed. The reduction in post-harvest water loss from the fruit, as a result of previous antitranspirant treatment of the trees, is therefore only a demonstration of the efficiency of CS-6432 as a water vapor barrier. Also, the increases in pressure potential and fruit growth by antitranspirant treatment were probably more a function of retarded water loss from the leaves than from the fruit.

Since the harvested olive fruits still had CS-6432 film on their surfaces, experiments were run to see whether the normal lye and water washing process, to which they are subjected before marketing, would remove the film. Preliminary small-scale trials indicated that the film could be removed, but when a larger scale investigation was tried by the Department of Food Science, at Davis where the black ripe olive process was used, a certain amount of the film still adhered to the fruit at the end of the processing. Although most of the film was removed (enhanced by agitation from the aeration process) many fruit still had a circle of film adhering to their lower ends, where the antitranspirant had obviously accumulated and dried in a drop at the time of application. However, the partial removal of the film from most of the fruit is a promising sign that at least some modification of the process (possibly a detergent wash) will totally remove the CS-6432 film. Furthermore, if the ingredients of CS-6432 have EPA clearance, the use of this material for increasing fruit size appears very promising.

OTHER INVESTIGATIONS

Fruit cracking (in cooperation with Dr. K. Uriu, Pomology Dept., UCD).

Prunes:

Side cracking of prunes appears to be related to fluctuating temperatures, the moisture status of the growing fruit, and soluble solid levels. Since antitranspirants may affect at least the latter two factors, CS-6432 (1%) was sprayed on prune trees to note its effects. A spray of the growth retardant, Alar, (2000 ppm), was also included as a treatment. Sprays were made on June 19 on one set of trees and on July 7 on another set. Comparisons were made with control trees (sprayed with water + 0.1% X-77 surfactant).

Increases in resistance to water vapor diffusion and pressure potential of leaves resulted from treatment with CS-6432, but not with Alar (Table 23). The CS-6432 also reduced daytime trunk shrinkage and day to day trunk growth.

Table 23

Effects of a film-antitranspirant (CS-6432) and Alar on diffusive resistance and water potential of prune leaves.

	Resistance ($min\ cm^{-1}$)	Pressure Potential (atm)
Control	.03	- 9.5
Alar (2000 ppm)	.04	-10.7
CS-6432 (1%)	.15	- 6.7

It was noted that after spraying the antitranspirant, soluble solids in the fruit were decreased. Since soluble solid measurements were measured by a refractometer, this was probably a dilution effect resulting from increased plant water potential. It was also noted that the moisture content of fruit from CS-6432 treated trees was greater than that of controls. During a critical 10 to 14 day period, when fruit soluble solids begin to increase, any additional water may increase turgidity and cause the prune to rupture. Therefore, if an antitranspirant is to be used as a means of isolating the causes of side cracking, the timing of its application and its effects should be such that it falls within this critical period. Unfortunately, since there was very little cracking of the fruit that year, and since the critical period for cracking was not properly predicted, the chief outcomes from this experiment were that CS-6432: 1) temporarily reduced soluble solids in the fruit, and 2) increased water potential. With these observations in mind, an antitranspirant may be useful in future studies as a research tool for further isolating the causes of side cracking. It is also possible that cracking may be increased by the uptake of dew by the fruit. In this case, an antitranspirant and film on the fruit may prevent this uptake and thereby reduce cracking.

Cherries:

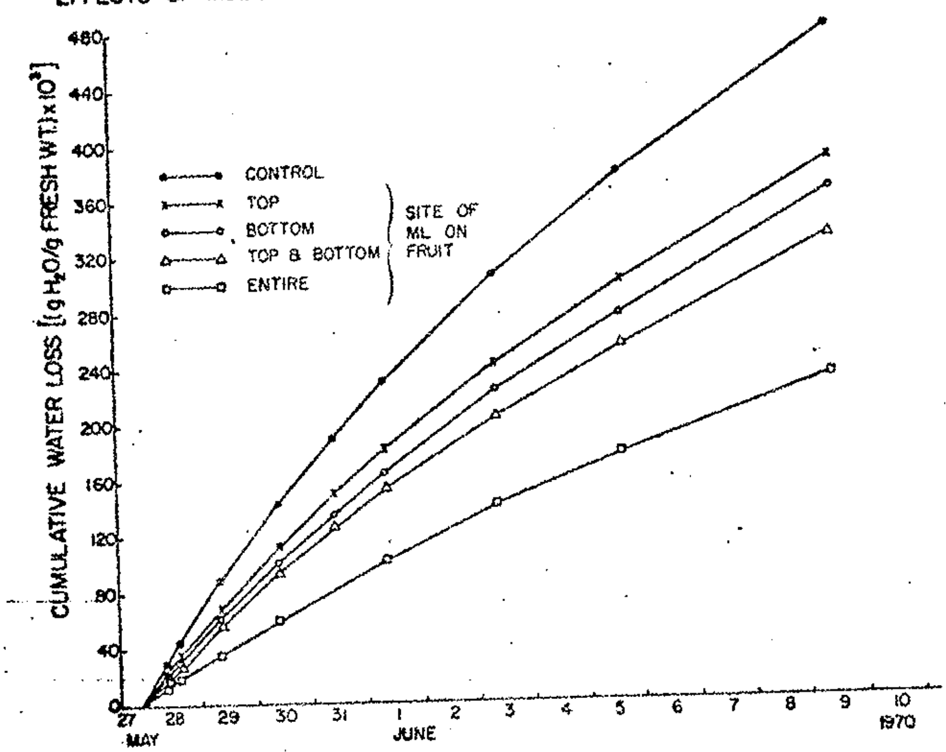
Rainfall just before harvest often occurs in many cherry growing areas, such as Oregon, Washington and sometimes in California. This results in cracking of the cherry due to direct water absorption by the fruit. Since the cherry crop is valued at about $5,000/acre, and since 50% of the fruit is often damaged by cracking, this amounts to a $2,500/acre loss. Experiments were therefore conducted with film antitranspirants to see whether a film on the fruit would reduce the uptake of external water and thereby reduce cracking.

In preliminary laboratory tests in May-June 1970 Mobileaf (1:5) was used to determine from which parts of the cherry fruit most of the water is: 1) lost, and 2) absorbed. The water loss experiment was done over a 2-week period in the laboratory at ambient temperatures of about 65 to 75°F and relative humidities of 40 to 50%. Water loss was determined as cumulative weight changes from pairs of cherry fruits hanging from a wire. There were four replicates of the following treatments: control (fruit dipped in water); Mobileaf (1:5) on the top, bottom, top + bottom, or over the entire fruit surface. The basis for the various partial film coverings on the fruit was the belief that cherry cracking may be due to water uptake primarily from: 1) the top of the fruit where the stem is attached and where a drop of rain water can accumulate in the 'cup', and/or 2) from the bottom (apical end) of the fruit where drops of rain may hang and be absorbed. It was hoped that curtailment of water loss from various parts of the fruit by an antitranspirant would provide an indication as to which parts of the fruit offer the least resistance to the passage of water. In Figure 33, rates of water loss were greatest from controls, least from fruit which were entirely treated (dipped) with Mobileaf, and intermediate from the various partially treated fruits. Thus, curtailment of the rate of water passage appears to be more closely related to the amount of skin surface covered, than to any specific region of the fruit covered by the antitranspirant. (Since the amount of water lost from a fruit dipped in the Mobileaf was reduced by over 50%, the potential for using such materials to prevent post-harvest desiccation of cherries is promising.)

The next step was to make a direct measure of water uptake by the cherry fruit, and to note the effects of an antitranspirant film in curtailing this uptake. The fruits were treated with Mobileaf (1:5), as before, and four replicates were used, but in this case each replicate of each treatment comprised eight fruits. After the antitranspirant had dried, the batches of eight fruit were weighed and then completely immersed in beakers of distilled water. At suitable time intervals the fruits were removed from the water, blotted, and again weighed in batches of eight to determine weight increases, i.e., water uptake. The uptake rates were expressed as grams water per gram of initial fresh weight of fruit (Figure 34). Water intake was not curtailed by treatment at the top of the fruit, and only slightly curtailed by treatment of the bottom. However, treating the entire fruit with Mobileaf greatly curtailed the amount of water taken into the fruit. Thus after 12 hours, water uptake was reduced by about 50%. Water uptake was severely retarded by the entire Mobileaf coating only after an initial rapid uptake, which was probably due to hydration of the wax film itself during the first hour. This initial hydration, plus whatever water was entering the fruit at a retarded rate, was of the order of about 10 milligrams per fruit. Assuming a 50% retardation in water intake to the fruit, the actual quantity of water retained by the film itself, or trapped under the film, would be about 5 milligrams per fruit.

Figure 33:

EFFECTS OF MOBIL LEAF (1:5) ON WATER LOSS FROM HARVESTED CHERRIES



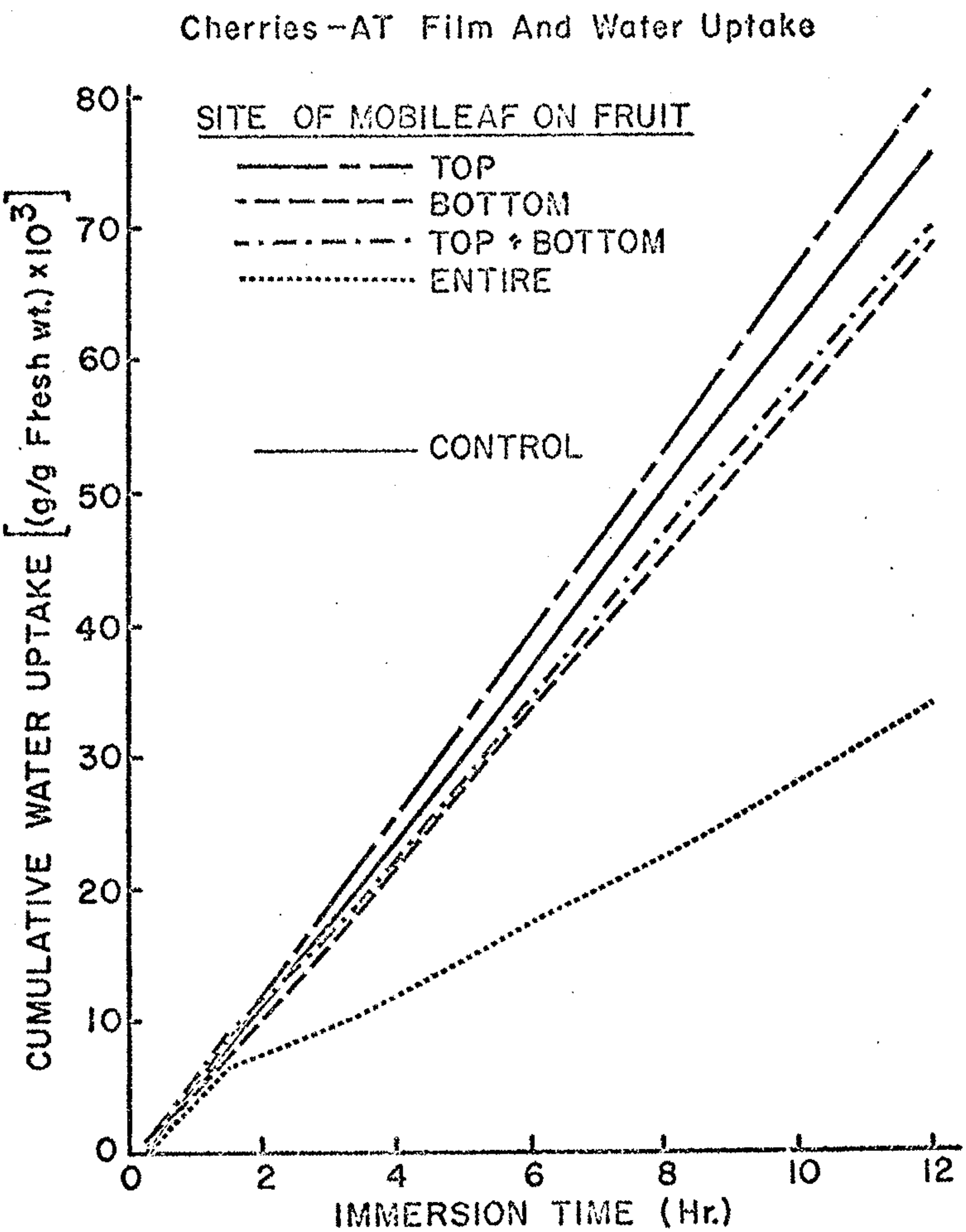


Figure 34: Effects of Mobileaf (1:5), applied to different parts of cherry fruits immersed in distilled water, on water uptake by the fruit.

Observations were also made on the water immersed cherries to determine initiation of fruit cracking. However, it should be kept in mind that the number of fruit involved in this experiment was too small to obtain a reliable estimate of cracking percentage, and that complete immersion of the fruit in water is a somewhat unrealistic means of inducing cracking. Nevertheless, the first cracks were observed on control fruit within 3 hours of immersion, whereas fruit entirely coated with Mobileaf showed cracking after about eight hours of immersion. All of the fruits showed some cracks at the end of 12 hours. The predominant type of crack was on the bottom of the fruit, but many of the fruit also had top and side cracks as well.

The experiment just described involved complete or partial antitranspirant treatment of the fruit surface, and complete immersion of all fruits in distilled water. In the next experiment, described below, the effects on water uptake of partial immersion in distilled water of fruit entirely treated with Mobileaf (1:4) were investigated. Three immersion treatments were used: 1) fruit completely immersed, 2) only the apical ends of the fruit immersed, and 3) drops of water placed in the cups of the cherries at the point where the stem joins the fruit. In each of these immersion situations a pair of untreated fruit and a pair of Mobileaf-treated fruit was used. Each treatment pair was replicated four times. As water was being continuously absorbed by the fruit, it had to be replaced with fresh distilled water, particularly in the top immersion situation where only a drop of water could be placed at a time. The accumulative water uptake, expressed as mg water uptake/cherry, is shown in Figure 35. In each of the three immersion systems the greatest water intake was by fruit not treated with antitranspirant. Water intake in the complete immersion system was about three times greater than in the two partial immersion systems. However, the Mobileaf-treated fruit in the complete immersion system absorbed water at about the same rate as the untreated fruit in the partial immersion system. The lowest rates of absorption were from the antitranspirant treated fruit in the partial immersion system, there being very little difference between bottom and top immersion. Thus, once again it appears that water intake occurs through the entire fruit surface, and that coating the surface with an antitranspirant such as Mobileaf does curtail the rate of water intake.

Before conducting the field experiment on cherry cracking a phytotoxicity trial involving CS-6432 at 1, 2, and 4%, and Mobileaf at 1:6, 1:3, and 1:2 concentrations was carried out. The CS-6432 produced a ring on the bottom of the fruit, and very slight browning on some of the fruit at the 2 and 4% concentrations. There was no significant damage to the leaves. The Mobileaf resulted in slight browning of the leaf margins and some of the veins at all concentrations, but there was no damage visible on the fruit. On the basis of this phytotoxicity trial the following treatments were selected for spraying on fruits of selected limbs on cherry trees in the orchard: 1) control (distilled water plus 0.1% X-77 surfactant); 2) CS-6432 (1%); 3) Mobileaf (1:5); 4) Mobileaf (1:3).

Three Bing cherry trees were selected in the orchard and each treatment was sprayed on two limbs of each tree. Approximately one liter of spray solution was applied only to the fruit of the six limbs of each treatment. No attempt was made to spray the leaves, although some of the leaves around the clusters of fruit were inevitably wetted by the antitranspirant. Two days later, i.e., on May 27, 1970, simulated rain was applied to the three trees by spraying them at half-hour intervals with distilled water at the rate of about 6 gallons per tree per spray. The simulated rain was sprayed from 0830 to 1945 ,

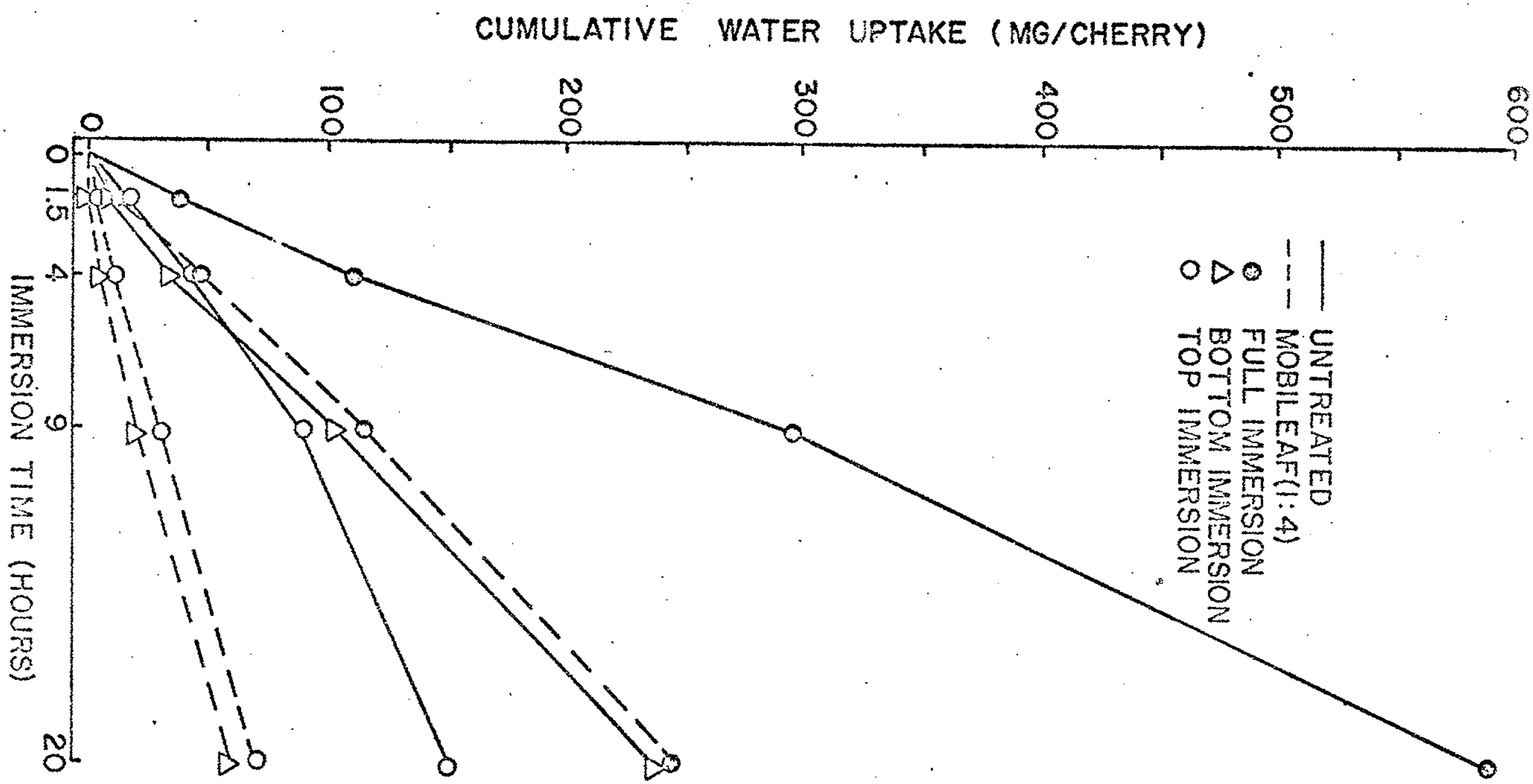


Figure 35: Effects on water uptake by cherry fruit of Mobileaf (1:4) on the entire fruit, and of complete and partial immersion of the fruit in distilled water.

on the first day, 0800 to 1700 on the second day, and from 0545 to 1045 on the third day. The frequent sprays ensured that the foliage and fruits remained wet throughout the three days of simulated rain. The first fruit cracking was observed on the second day of simulated rain, but it was difficult to make an accurate count of cracked fruit while they were still on the tree. Therefore, on the third day (May 29) one treatment limb was harvested on each of the first two trees. (Fruit on the third tree were less mature than on the first two and harvest of this tree was delayed until June 4.) On June 4 the remaining treatment limbs on the first two trees and all of the limbs on the third tree were harvested.

The following categories of cracking were used in making the cracking counts: 1) top cracks (usually in concentric circles along the shoulder of the fruit); 2) bottom cracks (the most severe type, occurring at the apical end of the cherry); 3) top and bottom cracks (occurring simultaneously on the same fruit); 4) suture cracks; and 5) no cracks. Since the suture cracks were often only small, and also occurred on fruit from trees which were not subjected to the simulated rain, the suture cracks were grouped with the no-cracks. Also, to simplify the final analysis any fruit which had a top, bottom, or both types of cracks were placed in a broad category labelled cracked, and were expressed as a percentage of the total number of fruit harvested from the treatment limbs. Thus a cracking percentage of 30 indicates that out of 100 fruit counted, 30 of them had top and/or bottom cracks and 70 had no cracks or only suture cracks.

The data for the first harvest (just after 2 1/2 days of simulated rain), based on two limbs per treatment, are given in Table 24A. The total number of cherries per treatment varied from 109 to 157. It appeared that only the two Mobileaf concentrations significantly reduced the amount of cracking. The 1% concentration of CS-6432 was not effective, but if higher concentrations had been used they might have reduced cracking. The final analysis was based on data from all the treatment limbs and included both harvest dates (Table 24B). Once again Mobileaf reduced the percent of cracked fruit, whereas the CS-6432 (1%) did not. The percentage of cracked fruit in all treatments was greater in Table 24B, than in 24A, suggested that a significant amount of cracking occurred between May 29 and June 4. This was possibly due to an increased susceptibility to cracking as maturity advanced. This observation was substantiated by comparing the percentage cracked fruit between two limbs of the same treatment on the third tree on June 4th. Thus, of the two control limbs the one with the more mature fruit had a cracking percentage of 75, compared with 54 on the control limb with less mature fruit. Similarily, in the CS-6432 treatment the limb with more mature fruit had 70% cracked, compared with 64% cracked on the less mature limb.

Table 24

Effects of antitranspirant film on cracking of cherry fruits. (A) Just after simulated rain, and (B) for the total experiment.

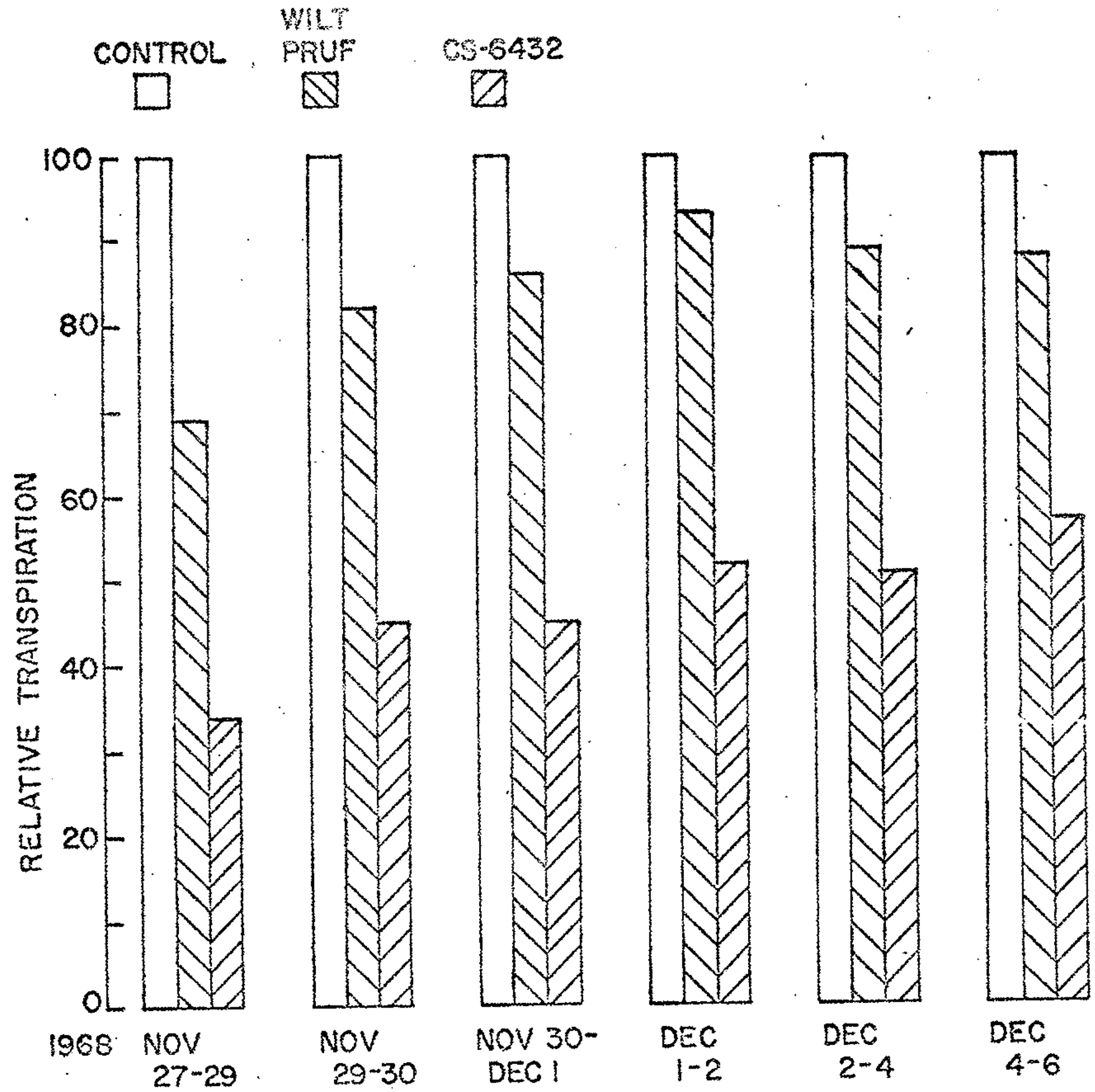
	A. 1st harvest 5/29/70			B. Complete harvest 5/29 & 6/4		
	No. of fruit		%	No. of fruit		%
	Cracked	Total	Cracked	Cracked	Total	Cracked
Control	50	119	42	264	458	58
CS-6432 (1%)	42	109	38	241	429	56
Mobileaf (1:5)	41	157	26	181	502	36
Mobileaf (1:3)	32	110	29	175	403	43

Natural rain occurred on June 8 and 9, and qualitative observations in the cherry orchard indicated that bottom and top cracks occurred on the fruit as a result of the rainfall. On June 12, an article in the Sacramento Bee indicated that "the cherry crop is in danger of splitting, due to the untimely rains which hit the Sacramento Valley this week." The article went on to say that "....the cherry crop nearly harvested, will be affected by splitting if hot weather is intense enough. Cherry crop damage is also feared in El Dorado and Sutter Counties." Thus, natural rainfall during the cherry harvest season is a danger not only in the Northern states but also in California. Furthermore, there is an indication that increased cherry yields can be obtained by the use of over head sprinklers. If this system of irrigation is adopted, the change of cherry cracking are greatly increased, and the need for a means for preventing cracking, such as by the use of antitranspirant films, cannot be overemphasized.

Christmas trees

Desiccation and needle drop from cut Christmas trees is a perennial problem, which might conceivably be alleviated by antitranspirants. Young Douglas Fir trees, cut in the Sierras north of Auburn, California, were treated with CS-6432 (3%), and were kept in a greenhouse where observations were made on transpiration, needle drop and needle desiccation. In one experiment, 12-inch Douglas Fir twigs were placed with their stems in jars of water and transpiration rates were measured by weight differences. Four replicates of the following treatments were used: 1) control (water + X-77 surfactant); 2) CS-6432 (3%); and 3) Wilt Pruf, a polyvinyl chloride in an aerosol dispenser. Transpiration rates from treated twigs in each replicate were adjusted by a factor which was based on the fresh weight of the twigs, relative to the fresh weight of the control twig in that replicate. This procedure compensated for differences in transpiring surface among the twigs.

During the first week (November 29 to December 6), CS-6432 and Wilt Pruf reduced transpiration by 40 to 70% and 10 to 30%, respectively (Figure 36). However, after cutting the ends of the stems and changing the water in the jars,



<u>Figure 36</u>: Effects of antitranspirants on transpiration from Douglas Fir twigs.

transpiration rates from the treated twigs were not consistently suppressed during the following two weeks. Thereafter transpiration was again reduced, by about 30%. Since the ends of the stems were not cut under water, it is likely that there was air blockage in the xylem, and that the confused results during the second and third weeks were due to differential water uptake, rather than to differences in water loss.

In the first experiment with 3 to 4 foot Douglas Fir trees, the bases of the trees were not kept in water. The treatments were: unsprayed trees (control); CS-6432 (3%) sprayed before cutting the trees; CS-6432 (3%) sprayed 24 hours after cutting the trees. Three replicate trees of each treatment were set up in the greenhouse in pots of dry gravel. During the first two weeks CS-6432 reduced transpiration, relative to unsprayed trees. However, during the next three weeks the rates of water loss from treated trees exceeded those from the controls. Since there was a definite relationship between tree size and transpiration (larger trees transpiring more water), the transpiration rates were divided by the initial fresh weights of the trees to compensate for differences in transpiring surfaces. These ratios are presented in Table 25 for the total five-week period (November 26 to December 30), as well as for the first two-weeks (November 26 to December 11) and the last three weeks (December 11 to December 30). During the first two weeks, the control trees showed the largest ratios (greatest water loss per unit of tree weight) and the post-cut spray trees, the smallest. However, during the following three weeks this relationship was reversed. This occurred because the trees still had sufficient water within them during the first period to lose 8 to 9 grams per day, but thereafter desiccation set in and water loss rates were greatly reduced (2 to 3 grams per day). Thus, for the total observation period of five weeks there was no net gain in water conservation by the CS-6432 treatment (0.510 ratio for CS-6432 post-cut spray, compared with 0.504 ratio for control). The pre-cut spray resulted in a saving of water from the plant, in spite of showing little effectiveness initially.

Table 25

Effects of pre-cut and post-cut sprays of CS-6432 (3%) on ratios of total transpiration (g/tree) to initial tree freshweights (g/tree) for given time periods.

	Nov. 26-Dec. 11	Dec. 11-Dec. 30	Nov. 26-Dec. 30
Control	0.368	0.136	0.504
CS-6432 (Pre-cut)	0.364	0.123	0.487
CS-6432 (Post-cut)	0.320	0.190	0.510

In the second experiment with Douglas Fir, half of the trees had their bases in water, and the other half did not. Each of these groups had control and CS-6432 (3%)-sprayed trees. The antitranspirant did not reduce transpiration in either the wet or the dry group of trees, and in fact appeared to increase the rate of water loss. The most striking differences were between the watered and the unwatered trees. Thus, after about two weeks, the transpiration (g/tree/day) was 22 for the watered and only 7 for the unwatered trees. Furthermore, those trees which had their bases in water were green and healthy looking at the end of this period, whereas the needles of the unwatered trees were visibly brown. It would therefore appear that greater benefit would be obtained by ensuring that cut Christmas trees are adequately watered, than by applying an antitranspirant. Severe needle drop did not occur from any of the Douglas Fir trees, so no assessment could be made on the effects of CS-6432 on needle drop. During the course of this experiment, periodic sampling of needles was made to determine their moisture percentage (dry weight basis). The CS-6432 had no significant effect on moisture content of the needles. However, whereas the needles from all of the trees had the same initial moisture content on January 17, by the end of the experiment on January 31, the moisture content of needles from the watered trees were about 90%, compared with only 10% from the unwatered trees.

It was thought that the inconsistent, and often complete lack of, effect of CS-6432 was possibly due to poor film coverage on the naturally waxy needles. Twigs of Douglas Fir were therefore sprayed with CS-6432 or CS-7784 (the wax component of CS-6432). After the spray had dried the twigs were placed in a 2% solution of sodium hydroxide for 24 hours and were then transferred to distilled water for another 24 hours. This treatment made the antitranspirant visible, by separating the films from the needles. Film coverage was fairly complete with both CS-6432 and CS-7784. Part of the explanation for the lack of effectiveness may lie in the experimental procedure, since our facilities did not allow enough uniform space for sufficient replication of these trees. Part of the problem was probably due to xylem blockage and rotting of the stems which were in water. It is possible that an antitranspirant spray may be most useful for those trees which are harvested early in the season, i.e., in late summer in areas which do not receive summer rain or irrigation. A summer application of antitranspirant may ensure harvest of turgid, rather than water deficient trees, and thereby increase their post-harvest life.

Blossom drop (In cooperation with Dr. W. L. Simms, Vegetable Crops Extension Service, UCD)

It has been observed under field conditions that blossom drop from snap beans can be quite high, with the result that fruit set is greatly reduced. The reason for blossom drop is unknown, but it may be dependent upon the water status of the plant, especially under conditions of high radiation and desiccating winds. Inflorescence counts were therefore made in untreated and CS-6432 (3%) treated plots of two popular snap bean varieties (Cornelli 14 and G.V. -50). The experiment was carried out in early July 1968 when maximum air temperatures were 90 to 95°F, and minimum relative humidities about 50%. Observations were made both in moderately dry soil (soil water potential in the root zone varied from about -0.4 to -0.8 atmospheres) and just after an irrigation (soil water potential approximately -0.1 to -0.3 atmospheres). The CS-7432 had virtually no effect in reducing blossom drop under the conditions prevailing. (The most interesting outcome of this experiment was that blossom drop was significantly more severe for G.V. -50 than for Cornelli 14.)

Tip burn (in cooperation with Dr. V. E. Rubatzky, Vegetable Crops Extension Service, UCD).

Tip burn in lettuce usually occurs when weather conducive for high transpiration rates follows a cool spell. A preliminary experiment with lettuce in the field was carried out with CS-6432 sprayed on each lettuce head. The treatment did not reduce the incidence of tip burn under the warm weather conditions prevailing at Davis at the time. This would suggest that the physiological cause of this disorder should be investigated more deeply; an antitranspirant may prove to be a useful research tool in such investigations.

Bedding plants (in cooperation with Dr. W. P. Hackett, Dept. of Environmental Horticulture, UCD).

Wholesale nurserymen have indicated that an extension of shipping time by as little as 24 hours would substantially enlarge the market area available to bedding plant growers. Preliminary tests were conducted with Mobileaf on commercial packs of economically important bedding plants: marigold, petunia, zinnia and tomato. In experiments simulating trucking conditions (low light and temperature), antitranspirant treated plants showed excellent storage quality, but their ability to respond to normal light and temperature following storage was severely impaired. Application techniques must be worked out to achieve more complete coverage consistently before meaningful experiments can be conducted on transplant survival of the bedding plants.

Vase life of roses (in cooperation with Dr. H. C. Kohl, Dept. of Environmental Horticulture, UCD).

In California alone, cut roses constitute a $60,000,000/year crop. Experiments were done to determine the usefulness of CS-6432 for extending the vase life of florists' cut roses. These differ from garden cut roses in that they are given commercial chilling and holding temperatures until sold to the public. A commercial floral preservative, Floralife, was added to the water in all of the experiments. It was latter reported to partially close stomates in and of itself.

In a preliminary experiment with excised rose leaves dipped in CS-6432 (3%), the foliage was laid out on paper towels in the lab between hourly weighings. After seven hours, one of the control leaves was nearly dried to the point of crumbling. The eight hour total water losses were 0.7/g for control and 0.27g for CS-6432.

A subsequent experiment using 'Forever Yours' cut red roses, replicated in two environments, showed no readily observable difference in the opening pattern of the ones treated with CS-6432 (3%) and those treated treated with distilled water. However, after five days, some foliar toxicity was evident on the CS-6432 treated leaves.

Using bouquets of nine stems, each with two leaves, water consumption was recorded for five and a half days. The stems were treated by plunging them bud first into a vat of 1% CS-6432. The control plants were similarly dipped in distilled water plus 0.1% X-77. One set was defoliated. All bouquets opened equally, but there were differences in water loss (Table 26).

Table 26

Effects of CS-6432 and defoliation on water loss (ml) from rose bouquets.

	Periodic water losses (ml/bouquet)					
April	14-15	15-16	16-17	17-20	Total	
Time	1645-1530	1530-1620	1620-1600	1600-0900	(5 1/2 days)	%
Treatment						
Control	77.0	80.8	71.0	136.2	365.0	100
CS-6432 (1%)	31.0	60.5	68.1	145.2	304.8	83.5
Defoliated	45.0	39.5	44.1	85.4	214.0	58.6

When applied as an aerosol spray, CS-6432 (1%) was effective in reducing water loss from the foliage, again without a marked increase in the keeping quality of the flower (Table 27).

Table 27

Cumulative water loss (ml) from six stems per treatment for seven days following application.

Control	560.7
Decapitated	432.2
Defoliated	254.8
CS-6432 (1%) (spray)	503.1

When CS-6432 (1%) was applied as a dip to stems which had been left out of water until the flower neck began to be limp, the treated stems covered well when again put in water. One of the control stems collapsed completely and the other did not open successfully.

Trials with another antitranspirant, Mobileaf, indicated that the favorable water balance produced by antitranspirant treatment tended to accelerate the early stages of flower opening except when the flower buds were dipped, thus 'gluing' the petals closed. When Mobileaf was applied to wilted cut roses the petals stayed on longer than on the controls although they used more water, possibly indicating a more complete recovery from the stress.

Experiments are planned in which the antitranspirants will be tested in the absence of floral preservatives, thus more closely simulating home use. Also tests will be run at the grower to wholesaler point of production, during which time the cut stems are occasionally completely out of water.

SUMMARY OF APPLIED INVESTIGATIONS WITH ANTITRANSPIRANTS

Antitranspirants retarded the rates of water use by oleanders grown along California's highways, and therefore have a potential for reducing the frequency of their irrigation as well as the associated costs and hazards. Antitranspirants also showed a potential for reducing the watering requirements of turf grass.

Apart from water conservation, antitranspirants also proved useful in improving plant performance by increasing plant water potential. Thus, 1) survival of transplanted seedlings was increased; 2) water potentials in fruit trees were raised, leading to higher growth rates of fruit, final volumes of peaches being increased by 8% and of olives by 13%; 3) shoot growth of oleanders was increased, but this could be partly offset by incorporating a growth retardant (Alar) in the spray. On the other hand, antitranspirants decreased vegetative growth and yield of an annual field crop (snap beans), but also had the effect of delaying the maturity of the crop. Miscellaneous investigations included attempts to reduce blossom drop of beans, increase the life of cut Christmas trees, reduce lettuce tip burn, reduce the cracking of prune and cherry fruit, and increase the shipping life of bedding plants and the vase life of roses.

FUTURE INVESTIGATIONS

The potential uses for antitranspirants which still require investigation are many and varied. They include 1) conservation of water by decreasing transpiration from watershed and riparian vegetation, thereby increasing streamflow; 2) decrease of plant water stress at moisture sensitive stages of crop growth; 3) extension of the range of environmental adaptability by reducing plant desiccation; 4) substitution for irrigation to reduce root rot and also to enable farm machinery (e.g., harvesters) to enter the field; 5) retard post-harvest drying of fruits and vegetables; 6) decrease plant damage caused by pests, fungi and smog and salt spray by forming a prophylactic film.

Current experiments with antitranspirants at the University of California, Davis include: 1) continued investigations on basic aspects such as improvement of antitranspirant materials, optimum concentrations, application methods, foliar coverage and duration of effects; 2) uses in ornamental horticulture (e.g., continued cooperation with the California Highway Landscaping Department, and further experiments on extension of vase life of cut flowers); 3) increased survival of both young and mature transplants (we are currently cooperating with a large farming concern near Bakersfield in increasing survival and performance of several thousand 8-year-old transplanted citrus trees); 4) decrease russetting of pears; 5) decrease cherry fruit cracking caused by rainfall and/or over-tree sprinklers; and 6) continue efforts to maximize fruit size.

PUBLICATIONS

(Based on research presented in this Completion Report)

Davenport, D. C., R. M. Hagan and P. E. Martin. 1969. Antitranspirants research and its possible application in hydrology. Water Resources Research 5(3);735-743.

Davenport, D. C., R. M. Hagan and P. E. Martin. 1969. Antitranspirants...uses and effects on plant life. California Agriculture 23(5):14-16. (The authors have also prepared a list of "Some Commercially Available Antitranspirants" including trade names, main ingredients and manufacturers. The list is available on request from the Editor, California Agriculture, UC Berkeley, California 94720).

Davenport, D. C., M. A. Fisher and R. M. Hagan. 1971. Retarded stomatal closure by phenylmercuric acetate. Physiologia Plantarum 24:330-336.

Papers in Preparation

Davenport, D. C., R. M. Hagan and P. E. Martin. Effects of antitranspirants on growth and yield. Crop Science.

Davenport, D. C., P. E. Martin and R. M. Hagan. Effects of antitranspirants on water use by oleanders. Journal of Horticultural Science.

Fisher, M. A. and T. L. Lyon. Cathodoluminescence: detection of wax films by scanning electron microscopy. American Journal of Botany.

Davenport, D. C., M. A. Fisher and R. M. Hagan. Effects and uses of antitranspirants in horticulture.

In addition to the above, we expect to prepare papers for publication on the following subjects dealing with antitranspirant research arising out of this project:

Antitranspirant application and foliar coverage
Antitranspirant-environment interactions
Effects of stomata-closing and film-forming antitranspirants on stomatal apertures
Effects of antitranspirants on plant water potential and fruit growth
Specialized uses for antitranspirants

Reports

Davenport, D. C. and R. M. Hagan. 1966-1967. Potential usefulness of transpiration retardants. Annual Progress Report to Water Resources Center. 5 pp.

Davenport, D. C. and R. M. Hagan. 1966-1967. Research with antitranspirants. California Contributing Project Report, Western Regional Research Project (W-67), Water-Soil-Plant Relations. 5 pp.

Reports (continued)

Davenport, D. C. and R. M. Hagan. 1967-1968. Potential usefulness of antitranspirants for increasing water use efficiency of plants. (W-174; OWRR No. B-054-CAL.) Annual Report to Water Resources Center. 5 pp.

Davenport, D. C. and R. M. Hagan. 1967-1968. Research with antitranspirants. California Contributing Project Report, Western Regional Research Project (W-67), Water-Soil-Plant Relations. 6 pp.

Davenport, D. C., P. E. Martin and R. M. Hagan. 1968. Antitranspirants - A Brief Description. Antitranspirant Information Bulletin No. 1, May 1968. Department of Water Science and Engineering, University of California, Davis.

Davenport, D. C. and R. M. Hagan. 1968-1969. Research with antitranspirants. California Contributing Project Report, Western Regional Research Project (W-67), Water-Soil-Plant Relations. 9 pp.

Davenport, D. C. and R. M. Hagan. 1968-1969. Potential usefulness of antitranspirants for increasing water use efficiency of plants. (W-174; OWRR No. B-054-CAL.) Annual Report to Water Resources Center. 7 pp.

Davenport, D. C. and R. M. Hagan. 1969-1970. Potential usefulness of antitranspirants for increasing water use efficiency of plants. (W-174; OWRR No. B-054-CAL.) Annual Report to Water Resources Center. 16 pp.

Davenport, D. C. and R. M. Hagan. 1970. Antitranspirants and their effects. Antitranspirant Information Bulletin No. 2, May 1970. Department of Water Science and Engineering, University of California, Davis.

Davenport, D. C. and R. M. Hagan. 1970. Use of the experimental antitranspirant 'CS-6432'. Report to the Chevron Chemical Company, Ortho Division.

Davenport, D. C. and R. M. Hagan. 1970. Use of the Antitranspirant 'Mobileaf.' Report to the Mobil Oil Corporation. September. 12 pp.

Davenport, D. C. and R. M. Hagan. 1970. Assessment of 'Wilt Pruf' as an antitranspirant. Report to Nursery Specialty Products, Inc. (Prepared October 1968; revised, 1970).

Davenport, D. C. and R. M. Hagan. 1970. Stomatal Resistance from Rates of Transpiration. In Section III, "Measurement of Stomatal Opening" for Techniques of Plant-Soil-Water Research, W-67 Regional Publication (submitted).

Papers Presented at Conferences

Hagan, R. M. and D. C. Davenport. 1968. "Water waster No. 1--the green plant." Farm Advisor Conference. University of California, Agricultural Extension Service. Davis, California. February 26-28.

Davenport, D. C., P. E. Martin and R. M. Hagan. 1968. "Antitranspirants for horticultural crops." 65th Annual Meeting American Society for Horticultural Science. Davis, California. August 18-21.

Papers Presented at Conferences (continued)

Davenport, D. C., P. E. Martin and R. M. Hagan. 1968. "Antitranspirants research and its possible application in hydrology." 7th National Fall Meeting, American Geophysical Union. San Francisco, California. December 2-5.

Davenport, D. C. 1969. "Antitranspirants and possible uses on fruit crops." Pomology Farm Advisor Training Conference. Davis, California, November 4-6.

Davenport, D. C., P. E. Martin, M. A. Fisher and R. M. Hagan. 1970. "Evaluating the effectiveness of antitranspirants." 51st Annual Meeting, American Association for the Advancement of Science; American Society for Horticultural Sciences (Western Region). Berkeley, California. June 21-25.

Fisher, M. A., D. C. Davenport and R. M. Hagan. 1971. "Scanning electron microscope studies of antitranspirant films." For the Annual Meeting of the American Society of Plant Physiol., Pacific Grove, California. August 22-26.

Davenport, D. C., M. A. Fisher and R. M. Hagan. 1971. "Some paradoxical effects of antitranspirants." For the Annual Meeting of the American Society of Plant Physiol., Pacific Grove, California. August 22-26.