THE EFFECT OF FOLIAGE SPRAYS ON WATER LOSS OF PLANTS

Thesis for the Degree of M. S.

Frank Baker Cross

1927

Spraying

THE EFFECT OF FOLIAGE SPRAYS ON WATER LOSS OF PLANTS

Thesis

Submitted to the Faculty of the Michigan State College of Agriculture and Applied Science in partial fulfillment of the requirements for the degree of Master of Science

by
Frank Baker Cross
1927

Approved Aug. 27, 1927.
V. R. Gardner

Table of Contents.

INTRODUCTION

Insects and diseases, some of which are very persistent and destructive, are prevalent wherever plants are grown for either ornamental or economic reasons. The practice of spraying plants with various materials for the control of injurious pests, though of comparatively recent origin and development, is now almost universal.

The kinds and amounts and the best time to make spray applications have been studied by plant pathologists, entomologists, and horticulturists. Little attention, however, has been paid to the effects of the spray materials on the plants themselves, though it has been observed that certain sprays applied under particular conditions may lead to increased or decreased size and color of leaves, extending or shortening the rest period, premature abscission of leaves, russeting of fruits, and other responses. There may be still other less evident effects which are of a physiological nature.

REVIEW OF LITERATURE

As early as 1893 Rumm (1) observed that abscissed shoots of grapes sprayed with Bordeaux mixture remained fresh longer than unsprayed. This he interpreted as meaning that there is a falling off in the rate of water loss from sprayed shoots as compared with the unsprayed

shoots. During the same year the theory that "lessened transpiration" follows spraying was advanced by Müller--Thurgau (2) and by Bayer (3).

Experimental work by Frank and Kruger (4), however, led them to conclude that spraying with Bordeaux mixture caused plants to use more water than is consumed by unsprayed plants. Later Zucker (5) confirmed their results. Schander (6) reports less use of water as a result of spraying with the same material, and Ewarts (7) work seems to support the conclusions of Rumm and Schander.

In a carefully planned experiment Duggar and Cooley (8) collected rather conclusive evidence which tended to show that a surface film of Bordeaux mixture increases the amount of water used by plants.

Martin (9), and later Shreve and Martin (10), published data showing that spraying abscissed leaves and also the foliage of potted plants with Bordeaux mixture had the immediate effect of causing an increased water loss. Duggar and Bonns (11) confirmed these data.

Wells (12) found that the use of Bordeaux mixture as a spray on cherries increased the rate of water loss from the leaves. He ascribed the reduction in size of the fruit, which sometimes follows the use of Bordeaux mixture as a spray on cherry trees, to this increased water loss.

Numerous references may be found to the use of oil sprays on plants, but all of them are concerned with the concentration required for controlling insects without injuring the trees. Nothing is available on the effect of oil sprays on rate of water loss from plants.

OBJECT OF INVESTIGATION

Though experimental data are available to show that certain spray materials increase the rate of water loss from the leaves of plants, there is no clear evidence that any spray materials have the opposite effect. Knowledge of how to reduce water loss by means of sprays might conceivably be of considerable interest.

The purpose of this investigation was to determine whether rate of water loss can be reduced by the application of foliage sprays and, if so, what material or class of materials has this effect. A preliminary investigation started by Bayer (15), but never completed, suggested that whole milk apparently decreases the rate of water loss from the leaves of some plants. This finding furnished the starting point for the present investigation.

METHODS AND MATERIALS

The general plan of the investigation was to conduct a series of spraying tests with whole milk and with its various component parts or groups of compounds

in such a way as to determine their influence on rate of water loss. All told five tests were completed. Whole milk was used first because a previous investigation indicated that it decreased the rate of water loss. Subsequent spray treatments were developed from the knowledge gained by the use of this material and its component parts. The first test was concerned with the use of whole milk; later tests were then made useing fatty or oily substances which were cheaper than butter fat. In the later tests an emulsifying agent was required for the proper mixing of oil with water to make the sprays desired. For the most part soap was employed for this purpose, although Bordeaux mixture also was used. Two types of emulsion may be prepared; in one oil is the dispersed phase and in the other water is the dispersed phase. The former is the one utilized for this experimental work.

The tests were all conducted inside a greenhouse. None of the plants used were in an active growing condition. Medium to large sized Jerusalem cherry plants were used for the first and the third experiments. Cineraria plants, from which the blossoms had been removed, were used for the third. Well branched Hyslop crabapple trees, averaging about three feet in height, were used for the fourth experiment, and for the fifth, one year old seedling apple trees.

The Hyslop crabapple trees were put in eight-inch pots; all other plants were in six-inch pots. These had been made impervious to water by painting the inside of each with melted "parowax" and the outside with two coats of "Duco". The plants were transferred to these prepared pots at the beginning of each experiment. The ball of earth enclosing the roots of the plant was not broken when the transfer was made.

To avoid loss of water from the soil, the top of the pot was sealed with parowax. This was accomplished by painting the top of the soil and the rim of the pot with melted parowax and allowing it to harden. A small circular piece of oil cloth over a slight mound of sand around the base of each plant, or a strip of adhesive tape around its base, were used to prevent the hot parowax from coming into direct contact with the stems.

Before sealing with parowax, a glass tube seven-eighths of an inch in diameter and eight inches in length was inserted in the soil near the base of each plant. This was for the purpose of renewing the water supply from time to time. The upper end of the glass tube was closed with a cork stopper. Thus from the unit consisting of plant, soil and pot, water could escape only through the leaves and the stems of the plant itself and transpiration losses could be determined periodically by weighing.

Care was taken to have as nearly as possible an optimum soil moisture content at the time of sealing the plant. As soon as the plant was sealed in, the unit was weighed. Weights were taken once each day or once in two days, depending on the rate of loss of water from the plant. In most cases it was found best to weigh every day.

After the plants had been sealed in the pots, a period of two or three days was allowed for readjustment before recording any weights. Records were then made of the water losses from individual plants. At each weighing sufficient water was added to bring the unit up to the original weight.

EXPERIMENT 1.

Transpiration Experiments with Jerusalem Cherry Plants Sprayed with Whole Milk or with its Various Constituents.

Fifty-one Jerusalem cherry plants were sealed in pots on January 12, 1926. Pots were numbered, from one to fifty-one inclusive. Each unit (plant, pot and soil) was then weighed daily between 8:00 and 10:00 A.M. and the loss of weight replaced by the addition of water through the glass tube.

Additions of water to each unit were recorded January 24, 25, 26, 27, 28, 29. On the basis of the

total amount of water used for this period the plants were divided into ten groups or series consisting of five plants to each series. The selection of plants for each group was made so that the total loss for each group for the period was approximately the same, thus securing an equal distribution of plants with high and with low losses within each group. Table 1 shows the transpiration records of these plants during this preliminary test period.

TABLE 1

Individual plant losses of water on the basis of which groups having lost the same amount of water were made

Group	Plant number	Loss (in grams) 6 daily weighings	Total
	33	145	
	30	175	
A	47	180	
	25	270	
	6	360	1130
	16	145	
	35	175	
B	37	218	
	13	245	
	3	350	1130
	19	145	
	32	180	
C	40	215	
	11	260	
	43	335	1135
	48	150	
	34	170	
D	31	220	
	8	265	
	20	330	1130
	27	150	
	2	180	
E	1	215	
	50	260	
	14	325	1130
	44	160	
	23	190	
F	4	220	
	17	280	
	28	280	1130
	41	165	
	18	240	
G	38	215	
	10	250	
	51	260	1130

Table 1 con't

Group	Plant number	Loss (in grams) 6 daily weighings	Total
H	42	170	
	29	190	
	30	230	
	49	250	
	26	295	1135
I	46	180	
	22	200	
	15	205	
	24	245	
	12	305	1135
J	21	170	
	7	200	
	5	200	
	45	260	
	9	305	1135

On January 31 the plants of each group in Table 1 were thoroughly sprayed with one of the materials shown in Table 11. Both upper and lower surfaces of the leaves were covered.

TABLE 11

Sprays Applied to Different Groups of Jerusalem Cherry Plants in Experiment 1.

Group A.-Whole milk (3.4 per cent butter fat.)

Group B.-Milk from which butter fat has been removed.

Group C.-A solution made by removing fat and casein from whole milk.

Group D.-A solution made by removing fat, casein, and albumen from whole milk.

Group E.-Cream testing 20 per cent butter fat.

Group F.-Cream testing 38 per cent butter fat.

Group G.-Check.

Group H.-Calcium caseinate in solution and suspension.

Group I.-A solution made by diluting 38 per cent cream with water to give a test of 3.5 per cent fat (same butter fat content as whole milk used in A).

Group J.-A solution made by diluting 38 per cent cream with solution used for spraying C.

After spraying with the materials listed in Table 11, the plants were allowed to dry and then were brought up to their original weights by the addition of water to the soil. Regular daily weighings and additions of water to make up for the loss of weight were made thereafter. This record is shown in Table 111. During the whole of the experiment the plants were subjected to uniform light, temperature, and humidity conditions on a greenhouse bench.

TABLE 111.

Daily losses of water from individual plants after spraying

Plant No.	Original: wt.grams:	Wt.Feb.1: in grams:	Water added: in grams	Wt.Feb.2: in grams:	Water added
1	3460	3435	25	3444	16
2	3720	3692	28	3706	14
3	3525	3466	59	3484	41
4	3720	3705	15	3712	8
5	3520	3487	33	2503	17
6	3695	3644	51	3665	30
7	3625	3600	25	3614	11
8	3620	3574	46	3593	27
9	3370	3332	38	3348	22
10	3330	3288	42	3300	30
11	3495	3447	48	3465	30
12	3680	3650	30	3662	18
13	3630	3600	30	3610	20
14	3830	3795	35	3805	25
15	3395	3375	20	3377	18
16	3345	3323	22	3328	17
17	3630	3608	22	3615	14
18	3480	3450	30	3457	23
19	3450	3428	22	3434	16
20	3450	3397	53	3410	40
21	3540	3518	22	3525	15
22	3780	3756	24	3763	17
23	3380	3373	7	3371	9
24	3780	3756	24	3763	17
25	3600	3566	34	3576	24
26	3680	3635	45	3648	32
27	3560	3550	10	3551	9
28	3650	3623	27	3635	15
29	3830	3802	28	3810	20
30	3815	3785	30	3792	23
31	3620	3590	30	3596	25
32	3380	3345	35	3360	20
33	3575	3555	20	3558	17
34	3340	3312	28	3320	20
35	3100	3075	25	3082	18
36	3815				
37	3470	3442	28	3440	30
38	3280	3250	30	3260	20
39	3340	3325	15	3325	15
40	3390	3352	38	3365	25
41	3395	3371	24	3376	19
42	3290	3272	18	3275	15

TABLE 111 con't

Plant No.	Original Wt.grams	Wt.Feb.1 in grams	Water added in grams	Wt.feb.2 in grams	Water added
43	3540	3485	55	3603	37
44	3480	3467	13	3470	10
45	3665	3630	35	3643	22
46	3425	3400	25	3411	14
47	3540	3512	27	3520	20
48	3760	3747	13	3750	10
49	3310	3281	29	3290	20
50	3450	3433	17	3232	18
51	3335	3300	35	3309	27
52	3280				

Plant No.	Wt.in grams Feb.3	Water added in grams	Wt.Feb.4 in grams	Water added grams	Wt.Feb.5 grams	Water added grams
1	3430	30	3430	30	3422	38
2	3690	30	3694	26	3682	38
3	3454	71	3469	56	3466	80
4	3698	22	3703	17	3695	25
5	3484	36	3494	26	3480	40
6	3640	55	3650	45	3635	60
7	3600	25	3595	20	3595	30
8	3577	43	3583	35	3570	50
9	3330	40	3335	35	3325	45
10	3280	50	3300	30	3266	64
11	3460	45	3455	40	3445	50
12	3637	43	3648	32	3635	45
13	3691	39	3600	30	3588	42
14	3791	39	3800	30	3782	48
15	3355	40	3370	25	3351	44
16	3314	31	3325	20	3310	35
17	3607	23	3610	20	3599	31
18	3441	39	3455	25	3428	52
19	3424	26	3430	20	3415	35
20	3399	51	3400	50	3390	60
21	3514	26	3520	20	3500	32
22	3746	34	3655	25	3739	41
23	3363	17	3367	13	3359	21
24	3741	39	3753	27	3743	37
25	3553	47	3570	30	3554	46
26	3630	50	3640	40	3620	60
27	3542	18	3548	12	3541	19
28	3620	30	3625	25	3622	28
29	3798	32	3800	30	3794	36
30	3773	42	3782	33	3777	38

Table 111 con't

Plant No.	Wt.in Grams Feb.3	Water added in grams	Wt.Feb.4 in grams	Water added grams	Wt.Feb.5 in grams	Water added grams
31	3585	35	3587	33	3585	35
32	3349	31	3357	23	3345	35
33	3550	25	3555	30	3547	28
34	3311	29	3316	24	3305	35
35	3063	37	3076	24	3065	35
36						
37	3430	40	3436	34	3425	45
38	3240	40	3253	27	3240	40
39	3312	28	3324	96	3309	31
40	3354	36	3358	32	3351	39
41	3363	32	3370	25	3355	40
42	3260	30	3327	23	3257	33
43	3485	55	3498	42	3470	70
44	3460	20	3470	10	3458	27
45	3625	40	3530	29	3615	50
46	3390	35	3405	20	3388	37
47	3504	36	3509	31	3505	35
48	3728	32	3736	24	3732	28
49	3260	50	3282	28	3262	48
50	3421	29	3436	14	3418	32
51	3293	42	3299	36	3280	55

Plant No.	Feb.7 Wt. grams	Water added grams	Feb.8 Wt. grams	Water added grams	Feb.9 Wt. grams	Water added grams	Feb.10 Wt. grams	Water added grams
1	3425	35	3410	50	3430	30	3696	30
2	3490	30	3691	29	3690	30	3440	25
3	3430	95	3426	99	3470	55	3700	85
4	3695	25	3696	24	3695	25	3500	20
5	3483	37	3486	34	3490	30	3645	20
6	3633	62	3630	65	3650	45	3600	50
7	3600	25	3597	28	3600	25	3575	25
8	3570	50	3570	50	3586	35	3335	45
9	3323	47	3320	50	3330	40	3280	35
10	3268	62	3263	67	3290	40	3455	50
11	3445	50	3437	58	3460	35	3640	40
12	3640	40	3630	50	3650	30	3590	40
13	3585	45	3085	45	3595	35	3790	40
14	3785	45	3787	43	3800	30	3360	40
15	3352	43	3362	43	3365	30	3315	35
16	3312	33	3310	35	3320	25	3605	30

TABLE 111 con't

Plant No.	Feb.7 Wt. grams	Water added grams	Feb.8 Wt. grams	Water added grams	Feb.9. Wt. grams	Water added grams	Feb.10 Wt. grams	Water added grams
17	3598	32	3605	25	3605	25	3440	25
18	3435	43	3436	45	3450	30	3425	40
19	3420	30	3420	30	3425	25	3405	25
20	3380	70	3385	65	3400	50	3515	45
21	3510	30	3515	25	3510	30	3745	25
22	3740	40	3745	35	3750	30	3365	35
23	3360	20	3357	13	3365	15	3750	15
24	3730	50	3547	33	3750	30	3565	30
25	3550	50	3545	55	3565	35	3630	35
26	3615	65	3632	58	3640	40	3550	50
27	3535	25	3550	10	3540	20	3620	10
28	3610	40	3620	30	3625	25	3795	30
29	3784	46	3790	40	3800	30	3775	35
30	3765	50	3768	47	3785	30	3590	40
31	3576	44	3595	25	3585	35	3350	30
32	3345	35	3350	30	3355	25	3550	30
33	3542	33	3550	25	3660	25	3310	25
34	3305	35	3310	30	2215	25	3065	30
35	3055	45	3063	37	3070	30	3065	35
36								
37	3415	55	3422	48	3435	35	3430	40
38	3232	48	2238	42	3255	25	3240	40
39	3305	35	3308	32	3320	20	3310	30
40	3343	47	3352	38	3385	25	3350	40
41	3355	40	3357	38	3375	20	3360	35
42	3257	33	3276	14	3255	35	3265	35
43	3475	56	3475	65	3505	35	3275	65
44	3455	25	3469	11	3470	10	3450	30
45	3616	49	3625	40	3640	25	3615	50
46	3385	40	3395	30	3405	20	3385	47
47	3495	47	3505	35	3520	20	3500	40
48	3725	35	3732	28	3740	20	3725	35
49	3260	50	3264	46	3285	25	3260	50
50	3412	38	3425	25	3430	20	3410	40
51	3275	60	3276	59	3305	30	3275	60

TABLE 111 con't

Plant No.	Feb. 11 wt. in grams	Water added grams	Feb. 12 wt. in grams	Water added grams
1	3425	35	3485	25
2	3690	30	3700	20
3	3435	90	3670	55
4	3700	20	3700	20
5	3485	35	3500	20
6	3645	55	3665	30
7	3605	20	3600	25
8	3575	45	3600	20
9	3330	40	3340	20
10	3280	50	3290	40
11	3450	45	3465	30
12	3650	40	3650	30
13	3590	40	3600	30
14	3490	36	3800	30
15	3360	36	3375	20
16	3320	25	3330	15
17	3610	20	3605	25
18	3440	40	3455	25
19	3425	25	3430	20
20	3400	50	3405	45
21	3515	20	3515	25
22	3746	35	3750	30
23	3365	15	3365	15
24	3740	40	3460	20
25	3555	46	3570	30
26	3630	50	3636	45
27	3540	20	3550	10
28	3620	30	3630	20
29	3795	36	3805	25
30	3775	40	3790	25
31	3595	25	3595	25
32	3345	35	3370	10
33	3660	25	3555	20
34	3310	30	3320	20
35	3070	30	3075	25
36				
37	3425	45	3445	25
38	3240	40	3250	20
39	3305	35	3340	20
40	3360	30	3365	25
41	3360	35	3375	20
42	3260	30	3275	15
43	3485	55	3500	40
44	3460	20	3470	10
45	3625	40	3640	25
46	3400	25	3405	20
47	3500	40	3520	20
48	3735	25	3740	20
49	3275	35	3285	25
50	3420	30	3430	20

The total loss of water for each plant and for each group during a period of twelve days after spraying is shown in Table IV.

Table IV.

Individual and group losses after spraying

Group	Plant No.	Loss of water (grams) twelve days	Total loss of water (grams) for each group
A	33	263	
	39	277	
	47	351	
	25	347	
	6	548	1786
B	16	228	
	35	341	
	37	425	
	13	396	
	3	786	2236
C	19	274	
	32	309	
	40	375	
	11	471	
	43	584	2013
D	48	270	
	34	306	
	31	342	
	8	456	
	20	597	1953
E	27	163	
	2	280	
	1	344	
	50	283	
	14	400	1470

Table IV con't

Group	Plant No.	Loss of water (grams) twelve days	Total loss of water (grams) for each group
F	44	186	
	23	160	
	4	206	
	17	263	
	28	300	1115
G	41	328	
	18	394	
	38	372	
	10	525	
	51	489	2108
H	42	271	
	29	357	
	30	398	
	49	406	
	26	535	1967
I	46	306	
	22	346	
	15	353	
	24	347	
	12	398	1750
J	21	270	
	7	259	
	5	328	
	45	405	
	9	422	1684

A comparison of the total loss of water from each group shows that there was a wide variation after sprays were applied. Since, after a preliminary transpiration test, these plants were grouped in series, each one of which had lost approximately the same amount of water

(only five grams difference in six days), we may conclude that in:

Group A. Whole milk reduced transpiration 5.2 per cent.

Group B. Milk, with fat removed, increased transpiration 6 per cent.

Group C. The solution made by removing fat and casein from milk reduced transpiration 4 per cent.

Group D. The solution made by removing fat, casein, and albumen from milk reduced transpiration 7.3 per cent.

Group E. Twenty per cent cream reduced transpiration 30.1 per cent.

Group F. Thirty-eight per cent cream reduced transpiration 42.3 per cent.

Group H. Solution and suspension of casein (calcium caseinate) reduced transpiration 6.6 per cent.

Group I. Cream diluted with distilled water to test 3.5 per cent butter fat reduced transpiration 16.9 per cent.

Group J. Cream diluted with a solution derived from milk (milk less fat less casein) reduced transpiration 20.1 per cent.

However, gains or loss up to five or ten per cent may have been due to variability of plants, slight errors in weighing, and other causes. Thus probably no significance is to be attached to the relatively slight differences found

in comparing Groups B, C, D, and H with the check group. On the other hand, where variations run as high as 15 per cent and higher, the spray treatment must have had some real influence. A difference as high as 42 per cent must be regarded as bearing special significance. Reductions in the rate of water loss amounting to 15 per cent and over resulted whenever butterfat was a constituent of the spray material applied. Thus Groups A, E, F, I, and J show significant differences. They also show a certain relationship between the concentration of the butterfat causing greater reductions.

Ten days after the application of sprays the leaves of Groups E and F (20 per cent cream and 38 per cent cream) began to turn yellow; during the next six days many leaves dropped from the plants. Plants of the other groups showed some loss of color and foliage later. This was more prevalent among the groups to which butterfat sprays were applied. On March 1 (one month after the application of sprays) a careful estimate of leaf loss was made. Results were as follows:

	Per cent of leaf loss
Group A	20
Group B	10
Group C	10
Group D	10
Group E	95

	Per cent of leaf loss
Group F	99
Group G	10
Group H	10
Group I	30
Group J	20

Photographs of representative plants six weeks after spraying are shown in Figures 9, 10, 11, 12, 13, 14, pages 49, 50, and 51.

Having secured such a strong indication that the butterfat or "oily" properties of the foregoing sprays were responsible for the reduction of water losses, further experiments were planned to secure additional data and to test different concentrations of vegetable and mineral oils.

EXPERIMENT 11

Transpiration Experiments with Cineraria Plants Sprayed with Whole Milk. "Wesson" Oil Emulsion, and "Sunoco".

Cineraria plants from which the blossoms had been removed were used in the second experiment. The method of procedure previously outlined was followed. The plants were divided into four groups, to which treatments were applied as shown in Table V.

Table V.

Sprays used on Cineraria plants

Group A. Check (foliage sprayed with distilled water).

Group B. Foliage sprayed with whole milk (3.5 per cent butterfat).

Group C. Foliage sprayed with an emulsion of "Wesson" oil (vegetable oil) 3.5 per cent.

Group D. Foliage sprayed with "Sunoco" (mineral oil) diluted to make 3.5 per cent oil.

Each group consisted of six plants. Sprays were applied April 25, and units (plants, pots, etc.) brought up to the original weights by additions of the required amount of water the same day. Weights were then taken and water added April 26, 28, 30; May 3, 5, 7, The amount of water required to bring a unit up to its original weight was recorded at each weighing. After the completion of the spraying test the leaf area of each plant was secured with a planimeter.

Table VI gives individual plant losses, leaf areas, and average daily loss per square centimeter of the plants used in this experiment.

Table VII repeats the average daily loss per square centimeter and gives the mean daily loss for each group of plants to which different sprays were applied.

Table VI.

Average daily loss of water from Cineraria plants after spraying

Plant No.	Grams of water lost in twelve days	Leaf area in sq.centimeters	Av.daily loss in grams per sq.cm.
2	195	310.96	.05225
5	197	365.80	.04487
6	357	380.67	.08019
9	107	103.87	.08584
10	269	503.22	.04454
11	301	444.51	.05643
12	410	552.90	.06179
15	185	263.22	.05857
17	345	312.90	.09187
18	387	309.03	.07739
20	276	296.12	.07767
24	694	654.19	.08840
28	195	310.96	.06494
29	235	326.45	.06998
31	367	625.16	.04892
33	322	524.51	.05115
35	249	569.67	.03642
40	392	483.22	.06760
41	299	282.58	.08817
42	519	503.86	.08583
43	248	405.16	.05101
45	266	380.64	.05823
49	232	549.99	.03333
52	403	455.48	.07372

Table V11

Total and mean daily group losses from Cineraria plants after spraying

	Plant No.	Av.daily loss (grams)per sq. centimeter	Total daily loss per group	Mean daily loss per plant
	17	.09187		
	20	.07767		
Group A	18	.07739		
	40	.06760		
	52	.07327		
	42	.08583	.47363	.07893-.0025
	2	.05225		
	49	.03333		
	11	.05642		
Group B	12	.06179		
	31	.04892		
	6	.08019		
			.33290	.05548-.0039
	5	.04487		
	10	.04454		
	15	.05857		
Group C	28	.04494		
	41	.08817		
	24	.08840		
			.36949	.06158-.0054
		Average daily loss (grams) cu.cm.		
	9	.08584		
	43	.05101		
	29	.05998		
Group D	33	.05115		
	35	.03642		
	45	.95834		
			.34263	.05710-.0041

In this experiment three sprays reduced the rate of water loss. "Wesson" oil emulsion reduced it 22 per cent, "Sunoco" 27.6 per cent, and whole milk 29.7 per cent. Foliage injury was not serious. A slight loss of color was observed in leaves of plants in Groups B, C, and D.

EXPERIMENT 111

Transpiration Experiments with Jerusalem Cherry Plants Sprayed with Linseed, Cottonseed, Corn, and Mineral Oils, Bordeaux Mixture, and Soap.

Having found in Experiment 11 that fatty or oily compounds other than butter fat caused a reduction in the rate of water loss when applied as sprays to the foliage of plants, a rather extensive test of different materials was made in Experiment 111 to determine their efficiency in this respect. Jerusalem cherry plants were prepared and divided into groups as in the previous experiments. Emulsions, with linseed, cottonseed, castor, corn, or mineral oil supplying the oil content and with soap as the emulsifying agent, were sprayed at a concentration of two per cent on the foliage of these plants. An additional two per cent mineral oil spray made by substituting Bordeaux mixture for soap was used on another group of plants. Three checks on the above materials were used; one group was sprayed with soap of the same concentration as found in the oil emulsions, a second group was sprayed with Bordeaux mixture of the same formula as used in making the mineral oil spray, and a third was sprayed with distilled water. These sprays are shown in Table V111.

Table V111.-Sprays applied to Jerusalem cherry plants

Group A. Linseed oil emulsion spray.

Group B. Cottonseed oil emulsion spray.

Group C. Bordeaux mixture 4-4-50.

Group D. Castor oil emulsion spray.

Group E. Corn oil emulsion spray.

Table Vlll con't

Group F. Mineral oil emulsion spray.

Group G. Soap (same dilution as used in emulsion).

Group H. Bordeaux mixture mineral oil.emulsion spray.

Group I. Check. (Sprayed with distilled water).

The plants were sprayed June 5, and brought up to standard (original) weight June 6, and June 7. Water losses were recorded June 8, 9, 10, 12, 14, 15, 16, 17, 18, 19. Individual plant losses and group losses for this period are shown in Table IX.

Table IX.-

Water loss of Jerusalem cherry plants after spraying

	Plant no.	Individual plant losses (grams)	Group loss (grams)	Mean loss (grams)
Group E	11	692		
	36	738		
	38	592		
	23	607		
	15	563	3292	658-18.9
Group F.	4	552		
	49	608		
	41	543		
	3	560		
	19	452	2715	543-15.3
Group I	6	877		
	37	872		
	8	661		
	50	648		
	2	545	3603	721-39.8
Group A	61	765		
	18	751		
	14	645		
	34	459		
	39	763	3383	676-34.1

Table IX con't

	Plant No.	Individual plant losses (grams)	Group loss (grams)	Mean loss (grams)
	7	360		
	17	754		
Group B	42	782		
	52	680		
	32	626	3193	638-45.3
	33	836		
	31	306		
Group C	44	633		
	40	571		
	10	721	3567	713.30.2
	43	897		
	12	718		
Group D	26	637		
	30	604		
	29	639	3395	679-38.8
	9	652		
	24	875		
Group G	25	641		
	13	627		
	45	804	3599	720-30.5
	1	648		
	28	874		
Group H	48	713		
	47	606		
	35	529	3370	654-35.7

The reductions in the amount of water used after the application of emulsion sprays are shown in Table X.

Table X

Reduction in water losses by leaves of the Jerusalem cherry after spraying

	Percentage reduction compared to check
Group A. Linseed oil emulsion spray	6.24
Group B. Cotton oil emulsion spray	11.51
Group C. Bordeaux mixture 4-4-50	1.10
Group D. Castor oil emulsion spray	5.82
Group E. Corn oil emulsion spray	8.74
Group F. Mineral oil emulsion spray	24.69
Group G. Soap (same dilution as used in emulsion)	0.00
Group H. Bordeaux mixture mineral oil emulsion spray	9.29

The figures in Table X show material reduction in water losses as a result of covering the foliage of the plants with oil sprays. They also show that a low concentration of oil is effective, and that five different oils will produce the same general result. A spray consisting of mineral oil emulsified with soap was much more effective than any of the others. The other sprays containing oil caused reduction in water losses, the specific reduction for each differing to some extent. The checks did not differ materially in rate of water losses. Computations for Table X were made by comparing the average rate of water loss from each group to the

the average rate of loss from the group sprayed with distilled water. The plants used in this experiment were kept under observation for a month after the completion of the test and at no time did they show any evidence of foliage injury except a slight loss of green color after the application of oil sprays.

EXPERIMENT IV

Transpiration experiments with Hyslop crabapple trees sprayed with corn, cottonseed, and mineral oils.

A group of Hyslop Crabapple trees, such as are illustrated in Figures 15 and 16, were used in this experiment. They were growing in eight-inch pots that had been waterproofed as previously described and had already formed their terminal buds for the season. Consequently there was little if any change in the leaf area of any individual plant during the course of the experiment. The experiment was begun June 20-22. After a preliminary transpiration test of about two weeks the plants were grouped according to water losses and on July 4 the different groups were treated to spray applications as listed in Table XI. The concentration of oil for each emulsion spray was one per cent.

Table XI

Sprays applied to Hyslop Crabapple trees

Group A. Bordeaux mixture mineral oil emulsion spray.
Group B. Corn oil emulsion spray.
Group C. Mineral oil emulsion spray.
Group D. Check. (Distilled water spray).
Group E. Cottonseed oil emulsion spray.

Records of transpiration losses were made July 6, 7, 8, 9, 10, 12, 13, 14, 15 and 16.

After all data had been collected, alternate leaves from tip to base of each shoot were removed from the trees, and their surface area measured by use of a planimeter. All leaves (those left on trees and those removed) were then measured at points of greatest width and greatest length of leaf blade, to obtain a factor with the aid of which the area of leaves not removed from the tree could be accurately calculated. The total leaf area of each tree was obtained by adding the calculated area of the leaves left on the tree to the measured area of the leaves removed. Data on transpiration losses are presented in Table XII.

Table XII

Leaf area and water losses from Hyslop Crabapple trees sprayed with one per cent oil emulsion

	Plant No.	Grams lost per sq.cm. per day	Total grams lost daily by each group	Mean daily loss of each plant
Group A	19	.09572		
	25	.07374		
	14	.14448		
	5	.10069		
	26	.09897		
			.51360	.10272±.0068
Group B	4	.08335		
	10	.08609		
	3	.09422		
	1	.12509		
	6	.12137		
			.51012	.10202±.0053
Group C	21	.07232		
	9	.07288		
	8	.07891		
	12	.08311		
	13	.08745		
			.39467	.07893±.0017
Group D	11	.12363		
	20	.11791		
	7	.11758		
	24	.08443		
	2	.14826		
			.59181	.11836±.0061
Group E	22	.05764		
	23	.06536		
	15	.08263		
	16	.07023		
	17	.06094		
			.36379	.06736±.0026

Comparing each of these different sprays to the check shows that a Bordeaux mixture-mineral oil emulsion spray reduced the transpiration loss 13 per cent; a corn oil emulsion spray reduced the transpiration loss 14 per cent; a mineral oil emulsion spray reduced it 33 per cent; and a cottonseed emulsion spray reduced it 43 per cent. Thus a rather marked reduction of water loss was secured by the application of oil sprays. The specific reduction for each oil used was variable, cottonseed being the most effective. A mineral oil emulsion with soap was more effective than the same oil emulsified with Bordeaux mixture.

The leaves of some of the trees developed typical "spray burn" injury a few days after they had been sprayed. However, this injury appeared just after the greenhouse had been fumigated with a proprietary nicotine compound. The fact that most of the injured foliage was on plants adjacent to the source of the gas indicated that the gas was the cause of the injury. A slight amount of injury, evidenced by a drying out of the margins of leaves, developed at a later date on the groups sprayed with mineral oil (E) and with cottonseed oil (C). The appearance of this injury was preceded by two days of hot weather. A slight loss of green color was also observed in the leaves of the plants in these two groups.

Experiment V.

Transpiration Experiments with Seedling Apple Trees Sprayed with Mineral Oil, Bordeaux Mixture, and "Volck".

Seedling apple trees one year of age were started in six-inch pots during the winter. They were forced into rapid growth by copious watering during the spring and early summer, then watered sparingly until terminal buds were formed; after this, with adhering ball of earth undisturbed, they were transferred to waterproofed pots and sealed in as previously described. Sealing in was completed July 18. Sixty prepared plants were divided into five groups, and sprays, as indicated in Table XIII, were applied July 27. Each emulsion was diluted with water to give an oil concentration of eight-tenths of one per cent.

Table XIII.-Sprays applied to apple seedlings.

Group A. Bordeaux mixture-mineral oil emulsion.

Group B. Bordeaux mixture 5-5-50.

Group C. Check (distilled water spray).

Group D. "Volck" oil emulsion.

Group E. Mineral oil emulsion.

Records were taken July 29, 30, 31; August 1, 2, 3, 4, 5, 6, 7, 8. The leaves were then stripped from the trees, and leaf areas determined by using a planimeter. Table XIV gives detailed data for each plant used in this experiment.

Group losses are shown in Table XV.

Table XIV

Leaf areas and rates of water losses of seedling apple trees

Plant No.	Leaf area sq. cm.	Loss of water in eleven days (gms)	Gms.loss per sq. cm. in one day
1	229.03	403	.15996
2	280.64	745	.24133
3	361.28	558	.19414
4	574.83	119	.17728
5	286.54	520	.16503
6	358.06	751	.19067
7	472.25	1074	.20675
8	329.67	663	.18625
9	413.54	492	.17410
10	341.93	673	.17893
11	281.28	522	.15996
12	370.32	770	.24133
13	314.83	632	.19414
14	516.12	059	.17728
15	463.22	780	.16503
16	290.32	495	.15500
17	331.61	739	.20259
18	414.83	864	.18934
19	542.57	432	.12264
20	292.90	578	.17939
21	330.96	694	.19063
22	452.90	978	.19631
23	230.96	461	.18109
24	502.57	837	.18901
25	434.83	740	.15471
26	417.41	792	.17231
27	430.32	1032	.21802
28	410.32	863	.19120
29	481.29	854	.16131
30	663.86	1003	.13644
31	456.06	910	.18060
32	370.32	794	.19491
33	409.67	853	.18929
34	363.22	766	.19172
35	266.45	535	.13227
36	651.61	1249	.17425
37	387.74	928	.21758
38	425.16	968	.20698
39	269.67	606	.20427
40	288.40	367	.11062
41	531.61	1141	.19512
42	250.96	593	.21481

Table XIV con't

Plant No.	Leaf area sq. cm.	Loss of water in eleven days (gms)	Gms.loss per sq. cm.in one day
43	369.03	939	.23132
44	575.48	396	.14786
45	610.32	834	.12423
46	407.09	394	.19964
47	591.61	1211	.18690
48	296.77	653	.20003
49	448.38	900	.18247
50	542.57	899	.15063
51	452.90	836	.16781
52	335.48	854	.23142
53	254.83	738	.26327
54	532.90	020	.17400
55	420.64	702	.15710
56	398.70	738	.16824
57	369.67	698	.17165
58	392.90	892	.20639
59	310.96	699	.20435
60	249.67	413	.15938
61	189.03	470	.22603
62	422.57	884	.19018

Table XV

Individual daily water losses and mean daily losses from apple seedlings

	Plant No.	Grams of water lost per sq. cm. per day	Total loss for group (grams)	Mean daily loss of each plant (grams)
Group A	1	.15996		
	6	.19067		
	11	.16871		
	16	.15500		
	21	.19063		
	26	.17231		
	31	.18060		
	36	.17425		
	41	.19512		
	46	.19964		
	51	.16781		
	55	.16827		
			2.12297	.17691±.002
Group B	2	.24133		
	7	.20675		
	12	.18902		
	17	.20259		
	22	.19631		
	27	.21802		
	32	.19491		
	37	.21758		
	42	.21481		
	47	.18609		
	52	.23142		
	57	.17165		
			2.47048	.20587±.004
Group C	3	.19414		
	8	.18265		
	13	.17989		
	18	.18934		
	23	.18109		
	28	.19120		
	33	.18929		
	38	.20698		
	43	.23132		
	48	.20003		
	53	.26327		
	58	.20639		
			2.41559	.2013±.004

Table XV con't

	Plant No.	Grams of water lost per sq. cm. per day	Total loss for group (grams)	Mean daily loss of each plant (grams)
	4	.16593		
	9	.17893		
	14	.15327		
	19	.17939		
	24	.15471		
	29	.13644		
Group D	34	.13272		
	39	.11062		
	44	.12423		
	49	.15062		
	54	.17400		
	59	.20435		
			2.11554	.17629$\pm$.004
	5	.16503		
	10	.17893		
	15	.15327		
	20	.17939		
	25	.15471		
	30	.13644		
Group E	35	.13272		
	40	.11062		
	45	.12423		
	50	.15062		
	55	.15171		
	60	.15038		
			1.78805	.149$\pm$.003

Substantial reductions in losses of water followed the application of oil sprays. A mineral oil spray emulsified with Bordeaux mixture reduced the transpiration rate 11 per cent, and the same oil emulsified with soap reduced it 26 per cent; "Volck" reduced it 12 per cent. The plants in Group B, to which Bordeaux mixture was applied, showed a slight increase in amount of water used as compared with the check. No foliage injury or loss of color developed.

Reviewing the data for the five experiments we find that in general, regardless of the kind of plant, organic and mineral oil sprays have a tendency to lessen water loss. There is much difference between the various oils used; sprays made up from mineral oil and from cottonseed oil give the greatest reductions. Their influence is more or less proportional to the concentration of the sprays, a concentration of approximately one per cent causing the greatest reduction without injuring the foliage.

Examination of Stomata

The data that have been offered show that there is a reduction in water losses from plants following the use of oil sprays. They do not furnish any information as to how such reductions in water loss are brought about. With this object in mind a brief study was made

of the daily periodic opening and closing of the stomata of the leaves of the apple seedlings used in Experiment V. Following Lloyd's (16) procedure samples of epidermis were taken from the under sides of leaves from sprayed and from unsprayed trees. These samples were secured by stripping off with tweezers a portion of the epidermis, which was immediately plunged into absolute alcohol. By this procedure it is possible to preserve epidermal sections without any change in the opening of the stomata. These sections were stained, mounted and photographed. A study of many stained sections indicated that an oil spray caused a delay in the opening and also in the closing of the stomata of the leaves. This may have had some effect on the amount of water lost because evaporation would be less during the evening when the stomata in leaves of unsprayed plants were partly open, than it would be during the pre-noon period when those in leaves of sprayed plants were fully open. Further studies are necessary to verify this point. Figures 1, 2, 3, 4, 5, 6, 7, and 8 give some indication of the nature of the evidence on which these statements are based.

SUMMARY

1. Oil sprays applied to the foliage of apple, cineraria, and Jerusalem Cherry plants caused a reduction in the rate of water loss. Sprays containing high concentrations of oil caused greater reductions in rate of water loss than sprays containing low concentrations of oil.
2. Some oils gave greater reductions than others. Sprays made up from mineral oils and from cotton-seed oil gave the greatest reductions.
3. Injury to foliage was not apparent when sprays of low oil concentration were used; it was serious when sprays of high oil concentration were used. Injury was evidenced by the drying and browning of the margins of leaves. Another form of possible injury was evidenced by a lighter color of the leaves on sprayed plants. This was apparent in Experiments 1, 2, 3, and 4, but did not develop in Experiment 5.
4. Oil sprays containing one per cent or less of oil caused marked reductions in the rate of water loss and at the same time produced no visible evidences of injury to the foliage.

Acknowledgement

The work described herein was started at the suggestion of Professor V.R.Gardner, of the Department of Horticulture, Michigan State College. The writer wishes to express to him, and to Doctor John W.Crist and Professor W.C.Dutton of the same Department, his thanks for the helpful suggestions and kindly criticism offered during this investigation.

Citation of Literature

1. Rumm, C. Ueber die Wirkung der Kupferpraparate bei Bekampfung der sogenannten Blattfallkrankheit der Weinrebe. Ber. d.deut. bot. Ges.11: 79-93. 1893.

2. Müller-Thurgau, H.Jahresb. der schweizischen Versuchsstation und Schule f. Obst-, Wein-und Gartenbau in Wadensweil. 1892-93: 58-59.

3. Bayer, L. Beitrag sur pflanzenphysiologischen Bedeutung des Kupfers in der Bordeauzbruhe. Inaug-Dissert. Konigsberg, 1902.

4. Frank, A.B., and Kruger, Fr. Ueber den direkten Einfluss der Kupfervitriolkalkbruhe auf die Kartofelpflanze. Arb. d. deut. landw. Ges. 1894; 1-46.

5. Zucker, A. Beitrag zur direkton Beeinflussung der Pflanzen durch die Kupfervitriol-Kalkebruhe. Inaug-Dissert. Stuttgart. 1896.

6. Schnader, R. Ueber die physiologische Wirkung der Kupfervitriolkalkbruhe. Landw. Jahrb. 33: 517-584. 1904.

7. Ewert, R. Der wechselseitige Einfluss des Lichtes und der Kupferkalkbruhen auf den Stoffwechsel der pjlanzen. Landw. Jahrb. 34: 233-311. 1905.

8. Duggar, B.M., and Cooley, J.S. Effect of Surface Films and Dusts on the Rate of Transpiration. Ann. Mo. Bot.Gard.1: 1-22: 351-356. 1914.

9. Martin, W.H. Influence of Bordeaux Mixture on the Rate of Transpiration from Abscissed Leaved and from Potted Plants. Jour. Agr. Res. VII 529-584. 1916.

10. Shive, J.W., and Martin, W.H. The Effect of Surface Films of Bordeaux on the Foliage Transpiring Power in Tomato Plants. Plant World 20: 67-97. 1917.

11. Duggar, B.M., and Bonns, W.W. The Effect of Bordeaux Mixture on the Rate of Transpiration. Ann. Mo. Bot. Gard. 5: 153-176. 1918.

12. Wells, H.M. Unpublished Thesis in Michigan State College Library.

13. Smith, J.B., N.J. Agr. Exp. Sta. Rpt. 1904, page 646.

14. Ackerman, A.J. Preliminary Report on Control of San Jose Scale with Lubricating Oil Emulsion. U.S.D.A. Circular 263, 1923.

15. Boyer, C.A. Data collected while registered as Graduate Student at Michigan State College. Unpublished.

16. Lloyd, Francis E. The Physiology of Stomata. Carn. Inst. Pub. No.82, 1908.

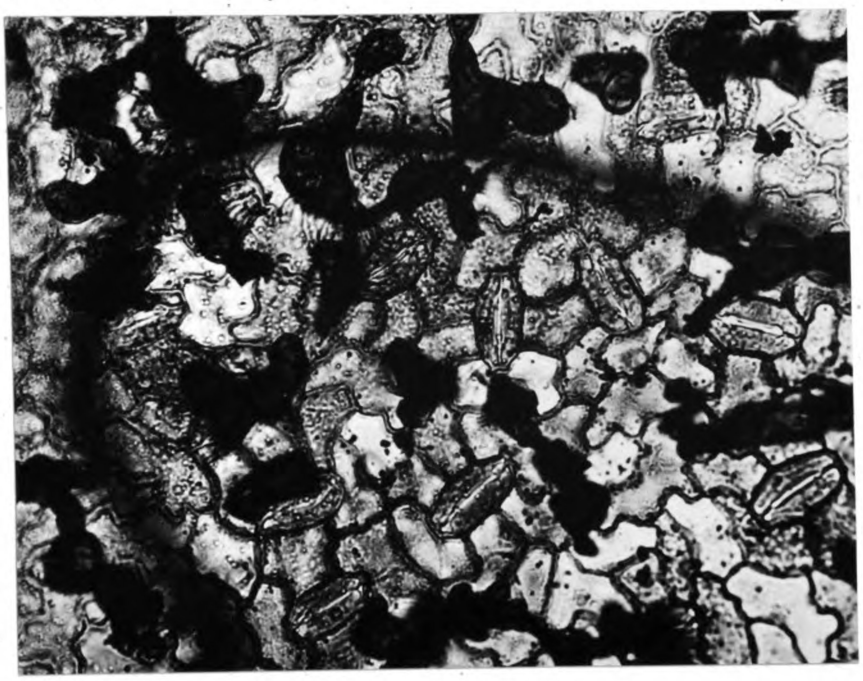

Figure I. Section of Epidermis From the Lower Side of an Apple Leaf Sprayed Two Weeks Previously with an .8 Per Cent Oil Emulsion, Showing Opening of Stomata at 6 A.M. Compare with Figure II.

Figure II. Section of Epidermis from the Lower Side of an Apple Leaf Which Had Not Been Sprayed, Showing Opening of Stomata at 6 A. M. Compare with Figure I.

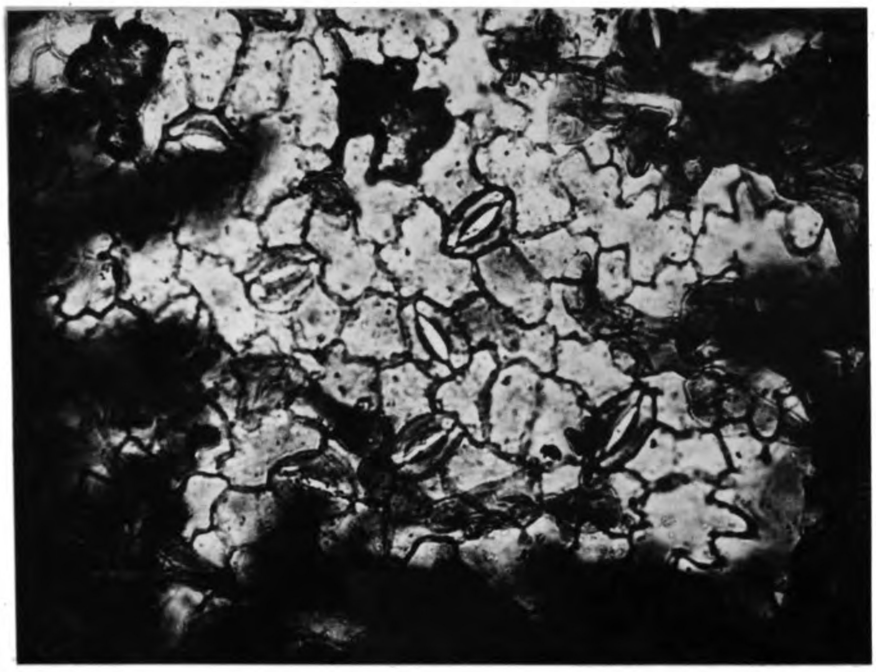

Figure III. Section of Epidermis From the Lower Side of an Apple Leaf Sprayed Two Weeks Previously with an .8 Per Cent Oil Emulsion, Showing Opening of Stomata at 12 M. Compare with Figure IV.

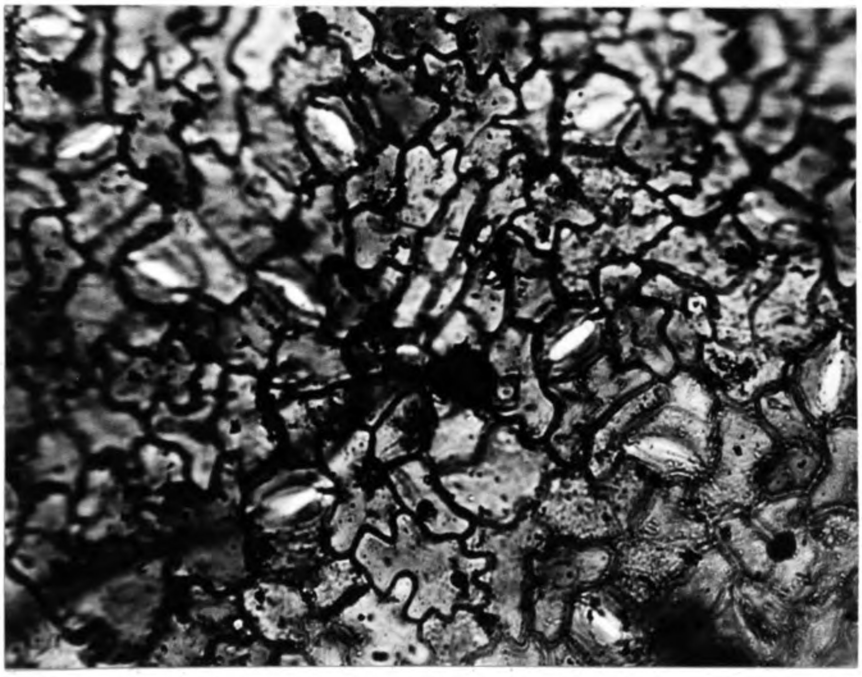

Figure IV. Section of Epidermis From the Lower Side of an Apple Leaf Which Had Not Been Sprayed, Showing Opening of Stomata at 12 M. Compare with Figure III.

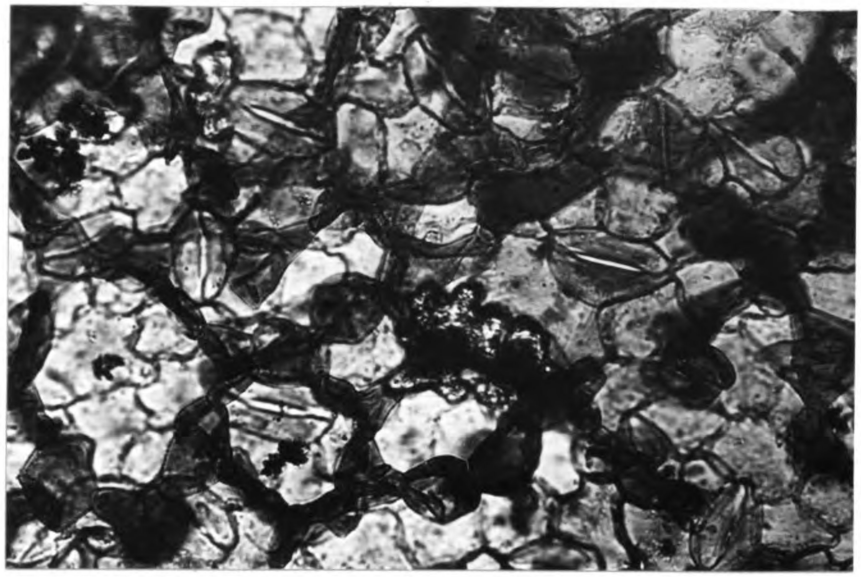

Figure V. Section of Epidermis From the Lower Side of an Apple Leaf Sprayed Two Weeks Previously with an .8 Per Cent Oil Emulsion, Showing Opening of Stomata at 2 P.M. Compare with Figure VI.

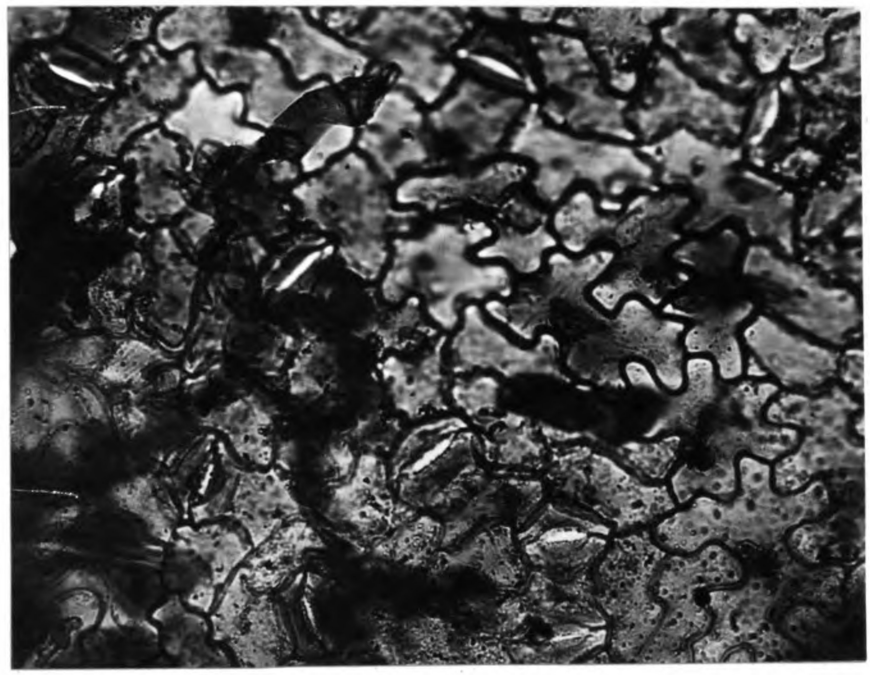

Figure VI. Section of Epidermis From the Lower Side of an Apple Leaf Which Had Not Been Sprayed, Showing Opening of Stomata at 2 P.M. Compare with Figure V.

Figure VII. Section of Epidermis From the Lower Side of an Apple Leaf Sprayed Two Weeks Previously with an .8 Per Cent Oil Emulsion, Showing Opening of Stomata at 8 P.M. Compare with Figure VIII.

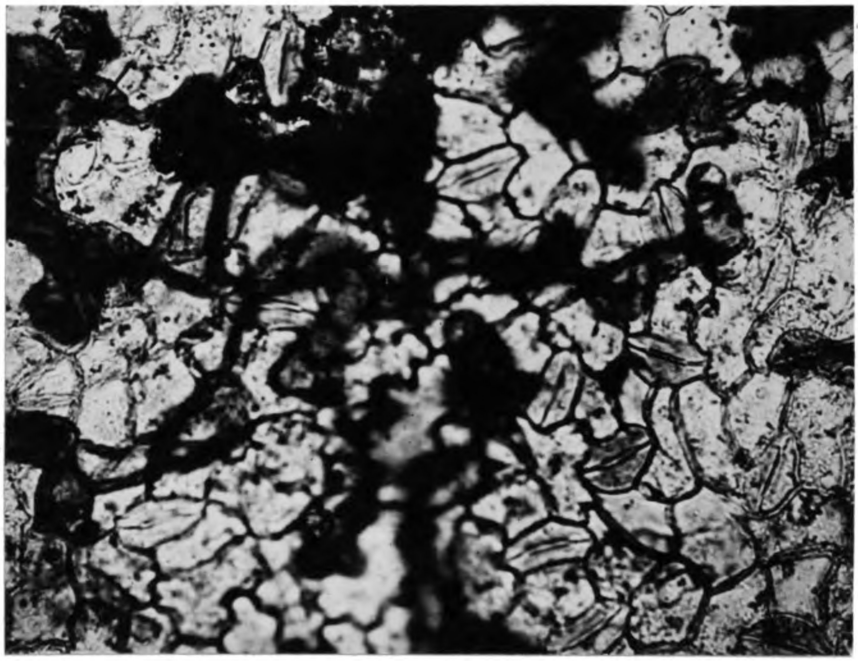

Figure VIII. Section of Epidermis From the Lower Side of an Apple Leaf Which Had Not Been Sprayed, Showing Opening of Stomata at 8 P.M. Compare with Figure VII.

Figure IX. Jerusalem Cherry Plant One Month After Applying a 20% Cream Spray.

Figure X. Jerusalem Cherry Plant One Month After Applying a 38% Cream Spray.

Figure XI. Jerusalem Cherry Plant One Month After Applying a 3.5% Butter Fat Spray Made by Diluting 38% Cream with Water.

Figure XII. Jerusalem Cherry Plant One Month After Applying Whole Milk Spray (3.5% Butter Fat).

Figure XIII. Jerusalem Cherry Plant One Month After Applying a Spray Consisting of a Solution Made by Extracting Fat and Casein From Whole Milk.

Figure XIV. Check. No Spray Applied.

Figure XV. Apple Tree Used in Experiment IV.

Figure XVI. Apple Tree Used in Experiment IV.