EFFECT OF CERTAIN FUNGICIDES AND ENVIRONMENTAL FACTORS ON THE RATE OF TRANSPIRATION OF TOMATO PLANTS [1]

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INTRODUCTION

The effect on rate of transpiration of the application of certain fungicides to the foliage of plants has attracted considerable attention during the past 25 years. Recently, however, this interest has become more intense because of the effect of a number of these fungicides, especially those containing zinc sulfate or copper phosphate, on the growth and metabolic responses of the plant. In many of the experiments reported, the plants used were young, the foliage was tender, and the apparent increase in rate of transpiration was due to injury by the fungicide and subsequent desiccation and cuticular loss, as suggested by Horsfall and Harrison (*17*).[2] At the present time it appears that when certain fungicides are applied to young, tender plants there is a definite measurable increase in the rate of transpiration, but when applied to old, mature plants the rate of transpiration changes little. Very few data have appeared in the literature that show the effects of these fungicides on the rate of transpiration of large, bearing plants, when grown under widely different environmental conditions.

Since fungicides are also applied to large, bearing plants when grown under field conditions in commercial practice, the rate of transpiration and the metabolic responses of the plants under these conditions are of considerable importance. Therefore, any additional quantitative data secured under conditions approaching those of normal crop plant growth, where the effects of several environmental factors affecting the rate of transpiration are measured concurrently with the effects of certain fungicides, would appear to be desirable in evaluating and interpreting many factors involved in this problem.

In this paper, data are presented showing the independent effects and interactions of fungicides and environmental factors on the rate of transpiration of maturing tomato plants (*Lycopersicon esculentum* Mill.)

REVIEW OF LITERATURE

The literature relating to the effect of fungicides on the rate of transpiration of plants is extensive and varied. The following workers have all reported an increase in the rate of transpiration due to the application of fungicides either on detached leaves or, in many experiments, on young potted plants: Bain (*1*), Bonde (*3*, *4*), Butler (*5*), Duggar and Cooley (*9*, *10*), Duggar and Bonns (*8*),

[1] Received for publication August 30, 1940.

[2] Italic numbers in parentheses refer to Literature Cited, p. 733.

Dutton and Wells (*11*), Frank and Krüger (*15, 16*), Krausche and Gilbert (*18*), Martin (*21*), Martin and Clark (*22*), Runnels and Wilson (*25*), Shive and Martin (*27*), Wilson and Runnels (*30, 31, 32*), and Zucker (*33*).[3] A number of other investigators have failed to find very marked effects of fungicides on the rate of transpiration when, in most instances, normal or field types of plants were used. Among these are Bayer (*2*),[4] Childers (*6*), Clinton (*7*), Ewert (*12*), Horsfall and Harrison (*17*), Lutman (*19, 20*), Miller (*23*), Rumm (*24*), Schander (*26*), and Sturgis (*29*).

MATERIALS AND METHODS

ENVIRONMENTAL CONDITIONS

The tomato plants used in the three experiments reported herein were grown in a fertile greenhouse soil at the Arlington Experiment Farm, Arlington, Va., during 1933 and 1934. The controlled factors were temperature, soil moisture, and the proportions of mineral nutrients. The fungicidal sprays studied were copper phosphate-bentonite-lime mixture, zinc sulfate-lime, and bordeaux mixture.

The experimental method used has been described in detail in previous papers (*13, 14*). The tomato plants were grown at a number of different soil-moisture levels, which will be indicated later. Each of the experimental series was set up by first determining the original amount of water in the soil and then adding sufficient water to bring the water content up to the required percentage. After the seedlings had been transplanted to the crocks the soil moisture was maintained at approximately the desired level by frequent additions (four to six times daily) of measured amounts of water, the required amounts being determined by weighing the cultures on solution balances of 40-kg. capacity.

The plants used were similar to staked and pruned plants grown under field conditions. They were fruiting, large, and had heavy thick foliage. Figure 1 shows the very marked effect of temperature on the growth and habit of the tomato plants used in these experiments; all other conditions were uniform, with soil moisture at 86 percent of water-retaining capacity and with 12–6–12 fertilizer. Figure 2 shows the effect of soil moisture on plant growth and habit when other conditions were uniform.

Three crops of tomatoes were used in the experiments, and the experimental methods differed considerably in the three tests. For convenience in presenting the data, the three experiments will be designated as the copper phosphate, zinc-lime, and bordeaux mixture experiments, and the details will be given under these headings.

All plants in the three experiments were healthy and the fungicides were applied solely to determine their effect on the rate of transpiration.

COPPER PHOSPHATE EXPERIMENT

The copper phosphate experiment was conducted from March 3 to May 24, 1933, and the duration of the water-expenditure record was 82 days. The prespray period extended from March 3 to April 17, or 45 days, and was for the purpose of determining the relative tran-

[3] Cited by Miller (*23*, p. *522*).
[4] Cited by Miller (*23*, p. *507*).

spiration ratios of the paired plants before spraying. The spray period lasted from April 17 to May 24, or 37 days, during which time the effect of copper phosphate on the rate of transpiration was observed.

FIGURE 1.—Tomato plants showing influence of different temperatures on growth. Cultures grown at (*A*) 65°, (*B*) 70°, and (*C*) 74° F. All were grown at 86 percent of soil-water-retaining capacity and with 12–6–12 fertilizer.

This crop of tomatoes was grown in two different temperature units of the greenhouse (units 2 and 3), but because of rising outside temperatures the differences between the units decreased with time. During the prespray period the mean temperature of unit 2 was 65.1° F. and that of unit 3 was 68.5°, a difference of 3.4°. During the spray period the mean temperature of unit 2 was 71.4° and that of unit 3 was 72.9°, a difference of only 1.5°. These data indicate a 6.3° mean-temperature difference between the prespray and the spray period for unit 2, and a 4.4° mean-temperature difference for unit 3.

In this experiment, a check and six fertilizer mixtures of the following formulas were used: 0–0–12, 0–6–6, 0–12–0, 6–0–6, 6–6–0, and

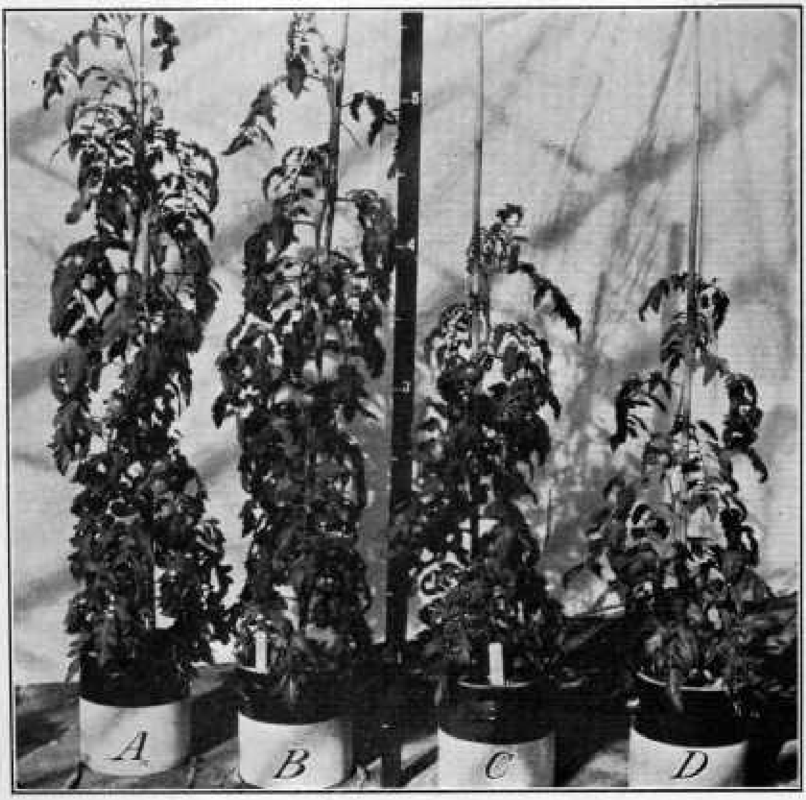

FIGURE 2.—Tomato plants showing influence of soil moisture on growth. Cultures grown at (*A*) 65, (*B*) 56, (*C*) 47, and (*D*) 39 percent of soil-water-retaining capacity. All were grown at 76° F. and with 12–2–2 fertilizer. Plants from a series grown in 1932.

12–0–0, the values in each formula representing nitrogen, phosphorus, and potassium, respectively; the check received no additional fertilizer. Five different soil-moisture levels were established and maintained at approximately 86, 77, 69, 60, and 51 percent of the water-retaining capacity of the soil. (See table 1.)

Single plants were grown in 3-gallon glazed crocks. Two crocks of each fertilizer treatment and of the check (receiving no additional fertilizer) were placed in each of the five soil-moisture series in each of the two different temperature units of the greenhouse. One plant of each pair was sprayed and the other was not, giving a treated (T) and a control (C) plant at each of the 70 points of observation, a total of 140 plants under approximately controlled environmental conditions.

This crop was sprayed with three applications at 10-day intervals during the 37 days of the spray period. The spray mixture consisted of 2 pounds of copper phosphate, 4 pounds of hydrated lime, and 2 pounds of bentonite, mixed and suspended in 50 gallons of water. Approximately 400 cc. of this mixture was applied to each treated plant at each of the three applications. In spraying, the plants were tipped at an angle to avoid application of the spray to the soil. Since the plants were always in the greenhouse, no spray residue was removed by rainfall.

ZINC-LIME EXPERIMENT

The zinc sulfate-lime experiment was conducted on a fall crop of tomatoes from November 23, 1933, to January 22, 1934, a period of 60 days. In this experiment, no prespray period was established since the cultures were of uniform size, permitting pairing at the beginning, one being sprayed and the other not sprayed.

Three fertilizer mixtures of the following formulas were used: 12–6–12, 12–0–12, and 6–12–6. Three soil-moisture levels were established: 86, 77, and 69 percent of the water-retaining capacity of the soil. The plants were grown under three different temperature conditions, and because of favorable outside temperature, inside temperature control was fairly constant. The mean temperatures for units 1, 2, and 3 were 76°, 71°, and 65° F., respectively.

Four crocks (single-plant cultures) of each fertilizer treatment were placed at each of the three soil-moisture levels in each of the three different temperature units of the greenhouse. Two of each of these were sprayed and two were not sprayed, giving two replications at each of the 54 points of observation and a total of 108 plants under well-controlled environmental conditions.

The tomato plants in this experiment were sprayed with a mixture of 4 pounds of zinc sulfate and 4 pounds of hydrated lime in 50 gallons of water. Three applications of this fungicide were made, each at the rate of 400 cc. per treated plant. The first application was made November 23, the date of the first water-expenditure record, and the succeeding applications 2 and 4 weeks later.

BORDEAUX MIXTURE EXPERIMENT

The bordeaux mixture experiment was also made upon a fall crop, the water-expenditure record beginning September 18 and ending December 1, 1934, extending over 74 days. The prespray period lasted 43 days, September 18 to October 31, 1934. The spray period was 31 days, from October 31 to December 1, 1934.

This experiment was different from the other two, as temperature was the only variable in the environment. The mean temperatures for units 1, 2, and 3, were 74°, 70°, and 66° F., respectively. A soil moisture of 72 percent of water-retaining capacity and a 6–12–6 fertilizer were used for the experiment. Three replications at each of the six points of observation gave for study a total of 18 plants.

This crop of tomatoes was sprayed with a 4–4–50 bordeaux mixture, 400 cc. to each treated plant. Three applications were made at 10-day intervals during the spray period.

TREATMENT OF DATA

The statistical procedure used by Duggar and Cooley (*9*, *10*) and adopted by Miller (*23*) and others for measuring the effect of fungicides upon the rate of transpiration of plants was followed in the computation and interpretation of the data presented in this work. This method was designed to remove the influence of all factors except those due to spray, i. e., the ratio between the transpiration from the treated and the control plant (T : C). In addition to the calculation of the transpiration ratios, the results of other statistical treatment of the data are also given, namely, the ratio of units of water transpired to the units of dry material produced above ground (water requirement); the water expended during the prespray, spray, and the entire experimental period. It is important to observe that the Duggar-Cooley and the analysis of variance computations appear to give consistent results; consequently either method is a valid basis for the interpretation of data.

Duggar and Cooley (*9*, *10*) divided their plants into two groups, designating those to be sprayed "T" (treated) and the control plants "C." These plants were paired and the transpiration ratio T′: C′ was determined before spraying. After the standardization period, the treated plants, T, were sprayed, and the ratio of the units of transpiration T : C was again determined for each pair of plants. If the ratio T : C had increased after spraying, the transpiration rate increase was presumed to be due to the application of the fungicide. If the ratio T : C had decreased, if the transpiration rate was less, or if it had not changed there was no apparent effect of the spraying on the transpiration rate. The third ratio T : C, which is a relative measure of the effect of spraying for the spray period, is then calculated by considering the ratio before spraying as 1.00.

In many of the experiments reported by other workers the amount of water transpired daily by the plants used was small, and the prespray and spray periods were of very short duration. Data obtained under such conditions are difficult to interpret and are not applicable to larger, older plants. To overcome these difficulties bearing plants were used (figs. 1 and 2) that transpired a large volume of water during daily periods, and the prespray and spray periods were extended over several weeks.

The amounts of water transpired over the entire period of observation by all the plants used in these experiments are of interest. During the prespray period of 45 days in the copper phosphate experiment, the average plant transpired a total of 18.3 liters of water; during the spray period of 37 days, 37.5 liters; and for the two periods, a total of 55.8 liters. These amounts are the means for 140 plants (treated and control groups), and if marked stimulation of transpiration had occurred, as has been frequently reported, the large amounts of water recorded would obviously be adequate to determine the different responses.

The tomato plants used in the other two experiments reported herein likewise transpired large amounts of water.

EFFECT OF FUNGICIDES ON TRANSPIRATION RATE OF TOMATO PLANTS

COPPER PHOSPHATE EXPERIMENT

The effect of copper phosphate on the rate of transpiration of tomato plants is illustrated in table 1, which shows the ratios of treated to control (T : C) plants during the prespray period, the spray period, the difference between periods, and the corrected ratio for the spray period. These data are listed under appropriate subheads for each level of soil moisture and each fertilizer under which the spray test was conducted. The application of Snedecor's (*28*) adaptation of the analysis of variance to the ratios (test to control) showed no significant effect of temperature, fertilizer, or soil moisture. However, the difference between the observed treatment mean (1.064) and a hypothetical control mean (1.000) shows the effect of copper phosphate-bentonite-lime spray to be a highly significant factor in increasing water expenditure by odds of more than 99 : 1 (table 2).

To test further the effects of copper phosphate spray on the rate of transpiration of tomato plants, data on the water transpired during the 37 days of the spray period and on the water requirement (total units of water transpired per unit of dry weight of aerial parts of plants) were analyzed by the variance method (table 2). In table 2 the significant effects of copper phosphate spray (test and control groups) on transpiration, and the highly significant effects of temperature, soil moisture, and fertilizer are clearly evident. The following interactions were significant: Temperature × moisture, temperature × fertilizer, and moisture × fertilizer. It is important also to note that there were no significant first-order interactions involving spray treatment, which indicates that the effect of copper phosphate on the rate of transpiration of tomato plants was not influenced significantly by the environments under these experimental conditions.

For the spray period the mean weight of water transpired by the sprayed plants was 38.4 liters and by the unsprayed, 36.7 liters; the mean dry weights were 77.4 gm. and 80.8 gm., respectively. The mean water requirements for the plants under the various conditions were as follows:

	Cc.
Sprayed	749
Unsprayed	703
Greenhouse unit 2 [1]	702
Greenhouse unit 3 [1]	750
At soil moisture percentage:	
86	826
77	735
69	702
60	710
51	658
With fertilizer mixture:	
No fertilizer	781
0–0–12	766
0–6–6	744
0–12–0	784
6–0–6	692
6–6–0	696
12–0–0	620

[1] For temperature of greenhouse unit, see p. 724.

TABLE 1.—*Transpiration ratios of control tomato plants and plants sprayed with copper phosphate when grown under different soil moisture and soil nutrient conditions in two different temperature units*

[For temperature of greenhouse unit, see p. 724.]

GREENHOUSE UNIT 2

Fertilizer formula	Transpiration ratios [1] of plants grown in soil of indicated moisture (percentage of saturation)																			
	86				77				69				60				51			
	T':C' before spray	T:C after spray	Relative increase [2]	Ratio increase [3]	T':C' before spray	T:C after spray	Relative increase [2]	Ratio increase [3]	T':C' before spray	T:C after spray	Relative increase [2]	Ratio increase [3]	T':C' before spray	T:C after spray	Relative increase [2]	Ratio increase [3]	T':C' before spray	T:C after spray	Relative increase [2]	Ratio increase [3]
Check	0.899	0.922	1.026	0.023	1.022	1.235	1.208	0.213	0.959	1.008	1.051	0.049	1.026	0.940	0.916	-0.086	0.901	1.033	1.147	0.132
0-0-12	.939	1.143	1.217	.204	[4] .998	[4] 1.016	[4] 1.018	[4] .018	.984	1.031	1.048	.047	1.040	1.026	.987	-.014	1.027	.948	.923	-.079
0-6-6	1.044	1.013	.970	-.031	.951	1.067	1.122	.116	1.014	1.192	1.176	.178	.973	1.033	1.062	.060	1.105	1.062	.961	-.043
0-12-0	.972	.963	.991	-.009	1.052	1.063	1.010	.011	1.031	1.114	1.081	.083	.918	.986	1.074	.068	1.017	1.081	1.063	.064
6-0-6	.781	.954	1.222	.173	[4] .974	[4] .992	[4] 1.018	[4] .018	.982	.981	.999	-.001	.761	1.129	1.484	.368	1.006	1.181	1.174	.175
6-6-0	1.118	1.134	1.014	.016	1.029	1.097	1.066	.068	.991	1.131	1.141	.140	1.060	1.071	1.010	.011	1.020	1.146	1.124	.126
12-0-0	.907	.985	1.086	.078	.934	.977	1.046	.043	.924	1.000	1.082	.076	[4] 1.010	[4] 1.082	[4] 1.071	[4] .072	.966	.930	.963	-.036

GREENHOUSE UNIT 3

Fertilizer formula	86: T':C' before spray	86: T:C after spray	86: Relative increase [2]	86: Ratio increase [3]	77: T':C' before spray	77: T:C after spray	77: Relative increase [2]	77: Ratio increase [3]	69: T':C' before spray	69: T:C after spray	69: Relative increase [2]	69: Ratio increase [3]	60: T':C' before spray	60: T:C after spray	60: Relative increase [2]	60: Ratio increase [3]	51: T':C' before spray	51: T:C after spray	51: Relative increase [2]	51: Ratio increase [3]
Check	0.938	0.887	0.946	-0.051	1.019	0.756	0.742	-0.263	1.081	1.270	1.175	0.189	1.103	1.108	1.005	0.005	1.062	1.053	0.992	-0.009
0-0-12	1.178	1.100	.934	-.078	.891	1.019	1.144	.128	1.086	1.079	.994	-.007	.996	1.031	1.035	.035	.930	1.092	1.174	.162
0-6-6	1.006	.870	.865	-.136	1.004	1.058	1.054	.054	1.043	1.014	.972	-.029	.974	1.079	1.108	.105	.871	1.051	1.207	.180
0-12-0	1.191	1.347	1.131	.156	1.091	1.103	1.011	.012	.980	1.018	1.039	.038	1.001	1.105	1.104	.104	[4] .980	[4] 1.082	[4] 1.104	[4] .102
6-0-6	.874	1.065	1.219	.191	.969	1.120	1.156	.151	.973	1.016	1.044	.043	.981	1.163	1.186	.182	1.058	1.043	.986	-.015
6-6-0	.865	.988	1.142	.123	1.091	1.086	.995	-.005	1.014	1.036	1.022	.022	1.005	1.041	1.036	.036	.894	1.091	1.220	.197
12-0-0	1.150	1.133	.985	-.017	.966	.915	.947	-.051	.990	1.038	1.048	.048	1.015	.993	.978	-.022	.900	1.139	1.266	.239

[1] A difference of 0.340 between 2 ratios is considered significant by odds of 99 : 1.
[2] T : C :: T' : C' equals relative transpiration rate.
[3] Absolute increased transpiration ratios due to spray; minus signs indicate decrease.
[4] Control plants sprayed once by error.

TABLE 2.—*Analysis of variance of data showing the effect of copper phosphate spray on the transpiration ratio (T : C and T′ : C′, table 1), total water transpired during spray period, water requirement, and dry weight of tomato plants*

Source of variance	Degrees of freedom	Mean square for—			
		Transpiration ratios	Total water transpired	Water requirement	Dry weight of plants
Total	139	0.008,304	136.52	13,737	552.29
Between spray treatments	1	[1] .123,018	[2] 108.98	[1] 74,199	[2] 389.44
Between temperatures	1	.009,578	[1] 1,145.37	[1] 76,332	[1] 773.62
Between moistures	4	.001,896	[1] 591.20	[1] 108,129	[1] 1,490.43
Between fertilizers	6	.009,459	[1] 2,027.77	[1] 72,035	[1] 8,430.13
Total interactions	127	.007,459	25.13	7,041	150.09
Spray treatments × temperatures	1	.001,872	.01	4,144	107.54
Spray treatments × moistures	4	.002,500	1.29	2,861	9.30
Spray treatments × fertilizers	6	.006,084	5.74	1,238	42.44
Temperatures × moistures	4	.008,154	[1] 23.63	11,910	25.40
Temperatures × fertilizers	6	.014,362	[2] 15.18	[2] 15,915	[2] 179.98
Moistures × fertilizers	24	.008,588	[1] 106.31	8,795	[1] 486.38
Remainder interactions (error)	82	.007,000	5.04	6,797	70.83

[1] Significant by odds of more than 99 : 1.
[2] Significant by odds of more than 19 : 1 but less than 99 : 1.

The application of the copper phosphate spray to tomato plants also had a highly significant effect on the water requirement of the plants as is indicated in table 2. It is of particular interest to note that the effects of copper phosphate, temperature, and fertilizer upon water requirement were of similar magnitude, all being highly significant. Soil moisture also had a highly significant effect. The only significant interaction observed was temperature × fertilizer. Since there was no significant interaction involving spray, it appears that in these studies the effect of spray on water requirement was entirely independent of these environmental factors.

Table 2 also gives a variance analysis of data showing the effects of copper phosphate spray and the environmental factors on the dry weight of the tomato plants. There were significant differences in the dry weights of the sprayed and of the control groups, and highly significant differences due to temperature, moisture, and fertilizer. Rather large interactions were observed for temperatures × fertilizers, and moistures × fertilizers, but there were no significant interactions involving spray treatments.

ZINC-LIME EXPERIMENT

The zinc sulfate-lime experiment differed from the other two experiments reported in this paper. There was no prespray period. The 108 plants were paired at the beginning of the experiment; 54 were sprayed with zinc-lime mixture and the remainder were used as controls. Furthermore, the plants in temperature units 1 to 3 (76°, 71°, and 65° F.) were harvested at different dates (22 days between the 76° and 65° F. lots). These differences in cutting dates interfere with close comparisons of temperature effects as measured by dry weights and total water expended divided by dry weights. However, the data permit the determination of the major effects of the several factors on transpiration during the 60-day period from November 23, 1933, to January 22, 1934.

The mean for the total water transpired was 33.5 liters for the sprayed plants and 33.9 liters for the unsprayed. The analysis of variance of the data on total water transpired during this period

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(table 3) indicates that the application of zinc-lime spray had no effect. However, the differences due to temperature were very large; the effects of soil moisture and fertilizer were highly significant; and there were highly significant interactions for temperature × soil moisture, temperature × fertilizer, and soil moisture × fertilizer. There were no significant interactions involving spray treatment.

TABLE 3.—*Analysis of variance of data, based on the total water transpired, showing the effects of zinc-lime spray and environmental factors on the transpiration of 54 spray and 54 control plants during the period Nov. 23, 1933, to Jan. 22, 1934 (60 days)*

Source of variance	Degrees of freedom	Mean square for total water transpired
Total	107	164.88
Between spray treatments (treated and control)	1	4.24
Between temperatures	2	[1] 7,541.96
Between moistures	2	[1] 725.00
Between fertilizers	2	[1] 52.01
Temperatures × moistures	4	[1] 109.42
Temperatures × fertilizers	4	[1] 20.11
Moistures × fertilizers	4	[1] 25.53
Spray treatments × temperatures	2	2.17
Spray treatments × moistures	2	8.26
Spray treatments × fertilizers	2	2.25
Remainder interactions (error)	82	4.32

[1] Significant by odds of more than 99 :1.

To show further the effects of zinc-lime spray mixture on the rate of transpiration of tomato plants, analysis of variance is given in table 4 for data on "water requirement" (ratio of total units (cubic centimeters) of water transpired to total units (grams) gain in dry weight of aerial part of plant). This table contains data relating to the high-temperature (76° F.) greenhouse unit only. The results showing the effects of spray in the other two units were in agreement with those in unit 1. Data from all three temperature units were not combined in a single analysis of variance because of the differences in stage of development accompanying different harvest dates. The mean water requirement for the sprayed plants was 581 cc. per gram of increase in dry weight, and for the control 612 cc., an insignificant difference. The effect of soil moisture on water requirement also was not significant in this experiment, but fertilizer had a very marked effect which was highly significant. If zinc-lime spray had influenced the rate of transpiration (see table 4), this effect probably would have been reflected in the water requirement data.

TABLE 4.—*Analysis of variance of data on water requirement showing the effects of zinc-lime mixture in the high-temperature unit (76° F.)*

Source of variance	Degrees of freedom	Mean square
Total	35	4,667
Between spray treatments (test and control)	1	8,311
Between moistures	2	6,793
Between fertilizers	2	[1] 32,866
Total interactions	30	2,524
Spray treatments × moistures	2	3,591
Spray treatments × fertilizers	2	1,610
Moistures × fertilizers	4	3,464
Remainder interactions	22	2,338

[1] Significant by odds of more than 99 : 1.

BORDEAUX MIXTURE EXPERIMENT

The results of the bordeaux mixture experiment are presented in table 5. They show the effects of the treatment on the transpiration ratio of tomato plants under the experimental conditions described. A variance analysis of T : C before and after spraying is given in table 6. The mean T : C for the first (prespray) period was 1.029; for the second (spray) period 1.010; and the mean for the ratio between the two periods, 0.982. A hypothetical mean of 1.000 would indicate no change; although the value 0.982 might suggest a depression of the transpiration rate following spraying, the difference is not significant (table 6).

Additional data show further that bordeaux mixture does not affect the rate of transpiration of mature tomato plants appreciably. The mean water transpired per plant during the spray period by the treated plants was 27.4 liters and by the control plants 27.3 liters. The mean dry weight of the treated plants was 82.4 gm. and that of the controls 82.1 gm., the total water expended was 50.0 and 49.4 liters, respectively, and the mean water requirement 614 cc. and 610 cc., respectively.

TABLE 5.—*Effect of bordeaux mixture on the transpiration ratio of 9 pairs of sprayed and control plants, Sept. 18 to Dec. 1, 1934 (74 days)*

Temperature (°F.)	Transpiration ratio			
	T′: C′ before spray	T: C after spray	Relative increase [1]	Ratio increase [2]
74	1.043	1.002	0.961	−0.041
	1.022	.961	.940	−.061
	.945	.982	1.039	.037
70	.954	1.061	1.112	.107
	.963	.958	.995	−.005
	1.086	.917	.844	−.169
66	1.164	1.127	.968	−.037
	1.008	1.025	1.017	.017
	1.079	1.059	.981	−.020

[1] T : C :: T′: C′ equals relative transpiration rate.
[2] Absolute increased transpiration ratios due to spray; minus signs indicate decrease.

TABLE 6.—*Analysis of variance of data showing the effect of bordeaux spray on total water transpired, dry weight, water requirement, and transpiration ratio (T: C and T′: C′, table 5) of plants*

Source of variance	Degrees of freedom	Mean square for—			
		Total water transpired	Dry weight of plants	Water requirement	Transpiration ratio
Total	17	37.78	68.92	12,140	0.004521
Between spray treatments	1	1.65	.35	61	.001643
Between temperatures	2	[1] 296.63	[2] 221.55	[1] 87,627	[2] .014746
Spray treatments × temperatures	2	6.84	24.69	3,697	.000038
Remainder (error)	12	2.80	56.56	1,973	.003803

[1] Significant by odds of more than 99 : 1.
[2] Significant by odds of more than 19 : 1.

In table 6 data are given showing the lack of significance of the effect of bordeaux mixture on the total water transpired, dry weight of the plants, and water requirement. However, temperature differences had a highly significant effect on total water transpired and the water requirement, and a significant effect on the dry weight of the plants. It is of particular interest to note that there were no significant interactions of spray × temperature.

Table 7 gives an analysis of variance of the data for the water transpired during the spray period and also during the prespray period. In each test period there was no significant difference in the quantity of water transpired between the two groups of plants (spray and control). Temperature, however, had a highly significant effect. These data on rate of transpiration further indicate that bordeaux mixture had no effect regardless of the method used in attempting to measure effect.

TABLE 7.—*Analysis of variance of data for total water transpired for the prespray and spray periods, showing the effect of bordeaux spray and temperature*

Source of variance	Degrees of freedom	Mean square for water transpired—	
		Prespray period	Spray period
Total	17	4.81	17.28
Between spray treatments	1	1.16	.04
Between temperatures	2	[1] 32.09	[1] 135.73
Spray treatments × temperatures	2	1.22	2.28
Remainder (error)	12	1.17	1.48

[1] Significant by odds of more than 99 : 1.

DISCUSSION

The tomato plants used in all three experiments reported in this paper were healthy and free from all traces of parasitic or virus diseases. The three fungicides used were applied solely to determine their effects on rate of transpiration of the respective cultures. All the plants used were large and fruitful, with heavy thick leaves, and they showed a fairly large loss of water over daily periods.

Miller (*23*) and Childers (*6*) were apparently the first two investigators to attempt to determine the effect of bordeaux mixture on the rate of transpiration of mature tomato plants that were grown under conditions favorable to a high rate of transpiration. Both workers reported that bordeaux mixture either had no effect on or actually caused a reduction in the rate of transpiration. They did not attempt to determine the interaction between the effects of spray and other environmental variables (concurrently) on the rate of transpiration of their plants. The present studies confirm and extend the applicability of those results.

In tables 1 and 2 data are given that indicate definitely that copper phosphate-bentonite-lime mixture, when applied as a fungicide, caused a highly significant increase in the rate of transpiration of mature plants. This definite increase in rate of water expenditure occurred regardless of how the increase was calculated. It is of special interest that there was no significant interaction between effect of spray and the other environmental variants. The response to spraying was consistent regardless of the cultural conditions. The data on total water transpired and water requirement basis also indicated a definite increase in water utilization after the application of copper phosphate-bentonite spray. It has not been determined whether copper phosphate or bentonite or both substances were responsible for the results observed.

Very little is known about the effects of bentonite. This fact should be kept in mind before too definite conclusions are attempted with reference to the effect of copper phosphate on transpiration. The zinc-lime and bordeaux mixtures did not contain bentonite.

SUMMARY

In this report data are presented that show the effect of copper phosphate-bentonite-lime, zinc-lime, and bordeaux mixture on the rate of transpiration of large, fruiting tomato plants (*Lycopersicon esculentum* Mill.). Extensive data are also presented which show the lack of interaction of these fungicides under widely different environmental conditions on the rate of transpiration of tomato plants, and indicate that environment does not influence the effect of the spray mixtures on the transpiration.

Copper phosphate-bentonite-lime, applied as a fungicide, caused a significant increase in the rate of transpiration of mature tomato plants.

Zinc-lime and bordeaux mixture had no significant effect on the rate of transpiration under the experimental conditions reported.

Added increments of soil nitrogen, reduced soil moisture, and reduced air temperature all caused a marked reduction in rate of transpiration.

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