EFFECT OF NUTRIENT RATIO AND CONCENTRATION ON GROWTH AND COMPOSITION OF TOMATO PLANTS AND ON THE OCCURRENCE OF BLOSSOM-END ROT OF THE FRUIT[1]

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Introduction

Much work has been done on physiological balance where from two to six major elements have been varied, with the osmotic concentration nearly constant. In this experiment only one major element was varied in the ratio, but no attention was paid to the osmotic concentration. This would be more nearly like the application of fertilizer under field conditions. Blossom-end rot has recently been reviewed by Robbins (**2**) with many references given on the subject. In most cases a disturbance of the normal water relations has been assigned as a cause of the physiological disease. This experiment was set up to study the effect of balance of nutrient elements on the growth of tomato plants grown in sand culture using the subirrigation method.

Materials and methods

Individual plants of Marglobe tomatoes were grown in plant bands in a large moisture-proof box, being fed nutrient solution twice a day by the subirrigation method (**3**), the sand being the same as that used in the regular experiment. When the plants were between two and three inches high, they were transferred to two-gallon glazed crocks with a hole in the side at the bottom. A number three rubber stopper with an eight-millimeter glass tube reaching to the center of the bottom of the crock was fastened securely in the hole. Over the end of the eight-millimeter tube was placed a sixteen-millimeter glass tube about ninety millimeters long, the ends of which were covered with glass wool. This allowed very quick filling and draining of the crocks.

The crocks were then filled to within 1½ inches of the top with no. 20 white diamond silica sand, which had previously been sieved through a Clipper seed cleaner and then washed. The smallest sand grains passed over a 20-mesh sieve while the largest were about 14-mesh. This sand, having no particles less than 20-mesh, drained very quickly.

The two-gallon crocks were then placed on a rack and connected by ¼-inch rubber tubing to one-gallon crocks on a movable support.

The movable supports were connected by a chain to a shaft which was driven by a ¼-horse-power, back-geared, electrically reversible motor. The height to which the one-gallon crocks were raised and lowered, and the reversing of the motor were controlled by a double pole, double throw switch in series with a single pole, double throw electric time clock.

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The plants were watered automatically four times a day, thus insuring very uniform feeding and aeration conditions. Distilled water was added daily to bring the water supply for each plant up to the 3½-liter mark.

Stock solutions were made up by dissolving one gram of chemically pure salt to ten or twenty milliliters of distilled water; this was then measured out with a pipette or graduate cylinder and poured into approximately thirteen liters of distilled water. After adding all the nutrients, the solution was then made up to fourteen liters.

The ratios and concentrations varied about a base solution called regular, hereafter known as R, which contained the following parts per million of the elements: nitrogen, 600; phosphorus, 100; potassium, 400; calcium, 500; magnesium, 200; and sulphur, 200.

In the concentration series the above six nutrient elements were used at ¼, ½, 2, and 4 times the R concentration; thus ¼ R would contain, in parts per million, 150 nitrogen, 25 phosphorus, 100 potassium, 125 calcium, 50 magnesium, and 50 sulphur. In the ratio series only one of the elements was varied at a time. They were varied at the rate of ¼, ½, 2, and 4 times for each element; thus ¼ N contained 150 p.p.m.; ½ N, 300 p.p.m.; 2 N, 1200 p.p.m.; and 4 N, 2400 p.p.m. of nitrogen. The phosphorus, potassium, calcium, magnesium, sulphur, and minor elements were at the R rates.

It will be noted that the concentration series designated as ¼ R, ½ R, R, 2 R, and 4 R has the same amount of nitrogen as the ¼ N, ½ N, R, 2 N, and 4 N; the same amount of potassium as the ¼ K, ½ K, R, 2 K, 4 K; the same amount of calcium as the ¼ Ca, ½ Ca, R, 2 Ca, 4 Ca; the same amount of magnesium as the ¼ Mg, ½ Mg, R, 2 Mg, 4 Mg; and the same amount of sulphur as the ¼ S, ½ S, R, 2 S, 4 S. In 22 of the 33 treatments it was possible to get the desired concentrations and ratios by merely changing the proportions of the salts used as sources of the nutrient elements. In the remaining 11 treatments, it was necessary to use chlorides[2] to balance the relatively high cation concentration. The solution 2 as given by HOAGLAND and ARNON (1) was used as a check. Four plants, each in an individual two-gallon crock, were used for each treatment in 1939 and 1940. They were planted outdoors after the last frost, the second week in June, and were harvested about the middle of September. The solutions were changed once a week. In 1939, a second ¼ R was changed twice a week; also, a series on phosphorus was run at ¼ P, ½ P, R, 2 P, and 4 P, which produced very uniform plants with little or no blossom-end rot.

In 1940, a second calcium series was used in place of the phosphorus series designated as ¼ Ca/2, ½ Ca/2, ½ R, 2 Ca/2, and 4 Ca/2. In this series, the concentration of all of the six major nutrient elements was exactly one-half of that used in the regular calcium series. In fact, the regular calcium series was made up except for the minor elements, then split in half, minor elements added, then made up to 14 liters.

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[2] The parts per million of chlorine in the 11 treatments were ¼ N, 885; ½ N, 514; 2 K, 117; 4 K, 843; 2 Ca, 884; 4 Ca, 2654; 2 Ca/2, 442; 4 Ca/2, 1327; 2 Mg, 338; 4 Mg, 1504; and ¼ S, 88.

Results

GROWTH OF PLANTS

The tomato plants in all of the replicates grew uniformly well. With the exception of the plants grown with 4 R and 4 N, the plants grew to an average height of between three and four feet. The $\frac{1}{4}$ R and 4 Ca were the only treatments which grew plants shorter than those grown with the check treatments (table I). All of the plants showed considerable rolling of the lower leaves. These rolled leaves, however, remained alive and green on all the plants with the exception of those grown on 4 N. The lower leaves on the plants grown with 4 N died and fell off the plant.

The green weight of the vines in general averaged 600 to 700 grams. The lighter plants were produced with treatments 4 N, 4 R, 4 Ca, and $\frac{1}{4}$ R. The heavier plants were produced with treatments $\frac{1}{2}$ N, $\frac{1}{4}$ Ca, $\frac{1}{4}$ S, $\frac{1}{2}$ R, 2 K, and $\frac{1}{4}$ Mg.

NUMBER AND WEIGHT OF FRUITS

The average number of fruits one inch in diameter and larger ranged, in general, from 10 to 14 per plant. The first hands on plants grown with $\frac{1}{4}$ R, $\frac{1}{4}$ N, and HOAGLAND nutrient solution produced considerably larger fruits than did plants grown with other treatments. These same treatments, however, produced small fruits on the second and third hands. The $\frac{1}{4}$ Ca produced more hands and averaged more fruit than did any other treatment. In 1939, all of the fruits on this treatment were very small but, in 1940, a few fruits which escaped blossom-end rot were good sized.

The average weight of fruits per plant varied from about 1000 to 1400 grams. Treatments $\frac{1}{2}$ R, $\frac{1}{2}$ N, and $\frac{1}{4}$ S produced over 1500 grams per plant. The 4 N treatment averaged 236 grams, whereas the 4 R treatment averaged 468 grams; in both treatments, there was exactly the same amount of nitrogen.

CHEMICAL COMPOSITION[3]

The vines, fruits, and roots of the tomato plants produced in this experiment during the 1939 season were analyzed in an attempt to ascertain the relation between chemical composition of tomato plants and the occurrence of blossom-end rot, and also to study the effect of nutrient ratio and concentration on the chemical composition of the plants.

The tomato plants produced with different treatments showed considerable variation in composition. In some cases, rather definite trends are evident, which appear to be related to the variations in the nutrient solutions.

The ash content of the tomato plants (table II) tended to increase with an increase in potassium, calcium, or total concentration of nutrient solutions. The ash content tended to decrease with increasing nitrogen and sulphur in the nutrient solutions.

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[3] These chemical analyses were made under the supervision of DR. CHARLES A. BRAUTLECHT, Professor of Chemistry and Chemical Engineering and Collaborating Chemist in Agricultural Experiment Station, University of Maine, Orono, Maine.

TABLE I

THE HEIGHT IN FEET, GREEN WEIGHT OF PLANT, NUMBER OF FRUIT, WEIGHT OF FRUIT, AND PERCENTAGE END ROT OF TOMATOES WHEN GROWN UNDER SUB-IRRIGATION WITH VARYING NUTRIENT SOLUTION

TREATMENT	HEIGHT			GREEN WEIGHT OF PLANT			NUMBER OF FRUIT			WEIGHT OF FRUIT			PERCENTAGE BLOSSOM-END ROT		
	1939	1940	Av.	1939	1940	Av.	1939	1940	Av.	1939	1940	Av.	1939	1940	Av.
	ft.	*ft.*	*ft.*	*gm.*	*gm.*	*gm.*				*gm.*	*gm.*	*gm.*	%	%	%
¼ R	2.90	3.08	2.99	439	468	454	9.00	10.50	9.75	1214	1346	1280	0.00	0.00	0.00
½ R	3.48	3.80	3.64	703	791	747	9.75	12.00	10.88	1556	1477	1516	0.00	0.00	0.00
R	3.50	3.73	3.62	644	662	653	12.75	16.50	14.62	1337	1481	1409	5.88*	1.52*	3.42
2 R	3.40	2.97	3.18	642	529	586	11.00	10.33	10.66	858	909	884	13.64†	6.45*	10.67
4 R	2.60	2.62	2.61	330	280	305	11.75	8.75	10.25	508	428	468	40.43†	25.71§	34.15
¼ N	3.50	3.25	3.38	650	598	624	11.50	10.25	10.88	1303	1485	1394	0.00	2.44*	1.15
½ N	3.68	3.52	3.60	794	749	772	13.00	14.25	13.62	1534	1558	1546	0.00	0.00	0.00
R	3.50	3.73	3.62	644	662	653	12.75	16.50	14.62	1337	1481	1409	5.88*	1.52*	3.42
2 N	3.52	3.50	3.51	609	574	592	12.25	12.50	12.38	793	974	884	32.65†	24.00‡	28.28
4 N	2.85	2.52	2.68	168	211	190	7.50	12.25	9.88	142	332	236	83.33†	51.02†	63.29
¼ K	3.38	3.50	3.44	579	548	564	7.75	11.50	9.62	956	1453	1204	0.00	0.00	0.00
½ K	3.15	3.50	3.32	643	636	640	10.75	11.75	11.25	1292	1572	1432	0.00	4.26*	2.22
R	3.50	3.73	3.62	644	662	653	12.75	16.50	14.62	1337	1481	1409	5.88*	1.52*	3.42
2 K	3.78	3.92	3.85	750	735	742	13.75	13.75	13.75	1429	1267	1348	1.82*	3.64*	2.73
4 K	3.62	3.66	3.64	717	740	728	14.50	13.00	13.75	946	790	868	37.93†	30.77‡	34.55
¼ Ca	3.98	3.90	3.94	850	648	749	15.00	16.25	15.62	770	1297	1034	66.33†	47.69†	55.20
½ Ca	3.82	3.85	3.67	733	681	707	11.75	15.00	13.38	1204	1350	1277	29.79‡	13.33§	20.56
R	3.50	3.73	3.62	644	662	653	12.75	16.50	14.62	1337	1481	1409	5.88*	1.52*	3.42
2 Ca	3.22	3.80	3.51	654	540	597	11.25	13.33	12.29	1314	1268	1291	0.00	5.00*	2.35
4 Ca	3.25	3.22	3.24	546	446	496	9.75	9.75	9.75	671	735	702	38.46†	5.13*	21.79
R/2/¼ Ca	....	3.53	....	....	597	....	....	15.50	....	....	1132	....	....	53.23†	....
R/2/½ Ca	....	3.63	....	....	690	....	....	10.33	....	....	1503	....	....	9.68‡	....
½ R	....	3.80	....	....	791	....	....	12.00	....	....	1477	....	....	0.00	....
R/2/2 Ca	....	3.66	....	....	712	....	....	11.75	....	....	1488	....	....	0.00	....
R/2/4 Ca	....	2.93	....	....	620	....	....	11.00	....	....	1445	....	....	6.06*	....
¼ Mg	3.70	3.75	3.72	698	762	730	12.75	14.50	13.25	1274	1286	1280	0.00	0.00	0.00
½ Mg	3.35	3.70	3.52	636	778	707	11.50	12.33	11.91	1278	1383	1330	2.17*	0.00	1.20
R	3.50	3.73	3.62	644	662	653	12.75	16.50	14.62	1337	1481	1409	5.88*	1.52*	3.42
2 Mg	3.15	3.47	3.31	630	664	647	12.00	13.67	12.84	1256	1608	1432	10.42‡	0.00	5.62
4 Mg	3.48	3.27	3.38	686	560	623	13.00	14.50	13.75	693	849	771	59.62†	36.21‡	47.27
¼ S	3.48	3.75	3.61	740	756	748	11.25	13.25	12.25	1558	1494	1526	0.00	0.00	0.00
½ S	3.62	3.73	3.68	705	647	676	11.50	13.67	12.58	1243	1478	1360	2.17*	9.75*	5.75
R	3.50	3.73	3.62	644	662	653	12.75	16.50	14.62	1337	1481	1409	5.88*	1.52*	3.42
2 S	3.38	3.72	3.55	636	637	636	10.25	15.25	12.75	1080	1455	1268	0.00	18.03*	10.78
4 S	4.10	3.42	3.76	759	548	654	15.00	13.00	14.00	507	754	630	75.00†	40.38†	58.93
HOAGLAND	3.22	3.32	3.27	700	659	680	9.75	12.25	11.00	1539	1406	1472	0.00	0.00	0.00

* Blossom-end rot on 1 plant.

§ Blossom-end rot on 2 plants.

‡ Blossom-end rot on 3 plants.

† Blossom-end rot on 4 plants.

TABLE II

CHEMICAL COMPOSITION OF VINES, FRUITS, AND ROOTS OF TOMATO PLANTS GROWN WITH VARYING NURTIENT SOLUTION. RESULTS GIVEN AS PERCENTAGE DRY WEIGHT

TREATMENT	ASH			NITROGEN			PHOSPHORUS			POTASSIUM			CALCIUM			MAGNESIUM			SULPHUR		
	VINES	FRUIT	ROOTS	VINES	FRUIT	ROOTS	VINES	FRUIT	ROOTS	VINES	FRUIT	ROOTS	VINES	FRUIT	ROOTS	VINES	FRUIT	ROOTS	VINES	FRUIT	ROOTS
	%	%	%	%	%	%	%	%	%	%	%	%	%	%	%	%	%	%	%	%	%
$\frac{1}{4}$ R	13.70	7.40	9.16	2.42	2.70	3.29	0.51	0.59	0.58	1.32	2.70	0.90	2.92	0.21	1.18	1.23	0.22	1.33	0.73	0.14	0.33
$\frac{1}{2}$ R	15.56	10.47	8.78	2.85	3.43	3.83	0.70	0.81	0.67	1.52	4.25	1.26	3.27	0.26	1.17	1.42	0.31	1.09	0.93	0.19	0.25
R	18.60	10.72	15.98	3.38	3.40	4.00	1.01	0.81	1.58	3.03	4.35	4.54	3.56	0.22	1.39	1.12	0.28	0.81	1.46	0.22	0.49
2 R	18.35	11.04	19.75	3.92	3.70	4.56	0.96	0.72	2.05	3.49	4.85	6.37	2.98	0.19	1.12	1.18	0.28	0.59	1.37	0.19	0.67
4 R	19.86	8.89	26.03	3.89	3.55	4.70	0.74	0.54	1.94	4.28	3.49	7.70	3.04	0.18	2.74	1.29	0.25	0.70	1.12	0.12	1.68
$\frac{1}{4}$ N	19.09	9.49	17.13	2.66	3.02	3.03	0.98	0.63	1.59	2.93	4.31	3.96	3.49	0.22	1.31	1.32	0.25	1.10	1.17	0.16	0.29
$\frac{1}{2}$ N	17.75	9.68	16.13	2.78	3.02	3.47	0.85	0.66	1.54	2.68	4.38	4.01	3.56	0.24	1.63	1.27	0.26	1.08	1.21	0.15	0.44
R	18.60	10.72	15.98	3.38	3.40	4.00	1.01	0.81	1.58	3.03	4.35	4.54	3.56	0.22	1.39	1.12	0.28	0.81	1.46	0.22	0.49
2 N	14.49	8.60	14.29	5.46	4.32	5.56	1.02	0.83	1.59	2.95	3.88	4.40	2.02	0.14	0.80	0.59	0.21	0.38	1.08	0.17	0.46
4 N	12.20	8.57	10.94	8.64	6.72	6.01	1.00	1.02	1.33	1.99	3.71	1.88	1.55	0.18	1.05	0.50	0.23	0.41	0.71	0.17	0.56
$\frac{1}{4}$ P	18.98	9.91	13.87	3.46	3.40	4.24	0.32	0.52	0.37	3.54	4.19	3.94	3.52	0.20	1.17	1.31	0.28	0.99	1.47	0.21	0.56
$\frac{1}{2}$ P	18.42	10.18	14.40	3.38	3.29	4.28	0.66	0.66	0.86	3.12	4.42	4.20	3.40	0.20	1.10	1.04	0.27	0.87	1.28	0.21	0.56
R	18.60	10.72	15.98	3.38	3.40	4.00	1.01	0.81	1.58	3.03	4.35	4.54	3.56	0.22	1.39	1.12	0.28	0.81	1.46	0.22	0.49
2 P	19.24	9.80	14.71	3.69	3.30	4.17	1.18	0.73	1.99	3.17	4.22	3.95	3.59	0.21	0.90	1.05	0.25	0.67	1.39	0.22	0.39
4 P	14.98	9.88	13.87	3.62	3.59	4.18	1.09	0.83	2.15	2.93	3.67	3.14	2.38	0.19	0.95	0.71	0.24	0.41	1.00	0.21	0.25
$\frac{1}{4}$ K	15.61	5.97	8.35	4.60	3.19	4.90	1.23	0.61	1.30	0.65	2.45	0.74	3.58	0.21	0.89	1.08	0.15	0.99	0.80	0.16	0.14
$\frac{1}{2}$ K	16.52	8.87	11.07	3.79	3.51	4.28	1.06	0.79	1.66	1.84	3.66	1.24	3.52	0.21	0.94	1.01	0.23	1.00	1.10	0.19	0.23
R	18.60	10.72	15.98	3.38	3.40	4.00	1.01	0.81	1.58	3.03	4.35	4.54	3.56	0.22	1.39	1.12	0.28	0.81	1.46	0.22	0.49
2 K	18.52	10.66	25.18	3.02	2.97	3.66	0.80	0.68	2.60	3.83	4.83	5.98	3.05	0.22	4.08	1.23	0.29	0.69	1.16	0.18	0.67
4 K	11.16	10.27	28.45	2.96	2.96	3.56	0.49	0.51	2.43	6.53	4.67	8.12	1.95	0.13	3.87	1.05	0.24	0.54	0.71	0.12	0.96
$\frac{1}{4}$ Ca	16.57	9.83	13.06	4.58	3.86	5.05	1.24	0.79	1.61	3.77	4.23	4.14	1.32	0.14	0.56	1.22	0.26	0.40	1.22	0.22	0.34
$\frac{1}{2}$ Ca	15.67	9.78	13.23	4.18	3.66	4.67	1.05	0.69	1.41	3.46	4.31	4.12	1.94	0.16	0.64	0.96	0.26	0.45	1.13	0.22	0.37
R	18.60	10.72	15.98	3.38	3.40	4.00	1.01	0.81	1.58	3.03	4.35	4.54	3.56	0.22	1.39	1.12	0.28	0.81	1.46	0.22	0.49
2 Ca	21.23	7.75	23.70	2.85	2.68	3.30	0.76	0.48	2.65	2.95	2.86	4.20	5.10	0.23	4.73	1.68	0.18	1.46	1.17	0.14	0.54
4 Ca	23.80	9.00	28.41	3.00	3.16	3.02	0.79	0.61	3.28	2.61	3.47	4.39	6.39	0.19	6.17	0.87	0.20	1.79	0.89	0.11	0.51
$\frac{1}{4}$ Mg	17.28	10.50	13.90	4.21	3.89	4.72	1.12	0.86	1.51	3.61	5.12	4.07	2.96	0.24	0.97	0.42	0.25	0.90	1.36	0.23	0.42
$\frac{1}{2}$ Mg	18.90	11.51	15.49	4.05	3.85	4.52	1.13	0.81	1.73	3.34	5.18	4.45	3.65	0.23	1.01	1.60	0.27	0.87	1.34	0.21	0.46
R	18.60	10.72	15.98	3.38	3.40	4.00	1.01	0.81	1.58	3.03	4.35	4.54	3.56	0.22	1.39	1.12	0.28	0.81	1.46	0.22	0.49
2 Mg	17.94	9.48	22.57	2.83	2.99	3.44	0.83	0.58	2.71	2.39	4.34	3.54	3.32	0.18	3.81	1.71	0.27	0.67	1.16	0.15	0.57
4 Mg	18.58	7.64	17.80	3.47	2.81	3.71	0.95	0.50	1.70	2.64	3.15	4.93	2.75	0.12	0.78	1.36	0.20	0.41	0.80	0.11	0.50
$\frac{1}{4}$ S	18.26	11.32	20.13	3.03	3.53	4.36	0.87	0.72	2.35	2.70	4.55	3.66	4.12	0.32	3.67	1.33	0.33	1.13	0.75	0.17	0.31
$\frac{1}{2}$ S	16.43	10.76	16.68	3.22	3.45	4.18	0.86	0.75	1.50	2.63	4.76	3.95	3.26	0.24	1.21	1.02	0.28	0.89	0.92	0.24	0.45
R	18.60	10.72	15.98	3.38	3.40	4.00	1.01	0.81	1.58	3.03	4.35	4.54	3.56	0.22	1.39	1.12	0.28	0.81	1.46	0.22	0.49
2 S	18.29	8.32	15.32	4.18	3.30	4.76	1.06	0.67	1.62	2.75	3.19	3.60	3.27	0.16	1.17	0.90	0.22	0.58	1.55	0.20	0.77
4 S	12.07	7.40	13.61	4.91	3.51	4.83	0.95	0.67	1.29	2.88	3.05	3.25	1.05	0.13	1.29	0.50	0.19	0.27	1.03	0.32	1.08
HOAGLAND	16.90	11.67	10.22	2.67	3.64	3.29	0.40	0.71	0.50	2.39	5.16	2.06	3.43	0.24	1.26	1.06	0.32	0.87	1.01	0.20	0.32

As the concentration of the nutrient solution was increased, the nitrogen in the vines, fruit and roots, the phosphorus of the roots, the potassium of the vines, fruit, and roots, and the sulphur of the roots increased and the magnesium of the roots decreased.

When nitrogen was increased in the nutrient solution the nitrogen content of the vines, fruit, and roots was increased. It was very evident that high nitrogen delayed maturity and phosphorus in the roots increased. Calcium in the vines and magnesium in the vines and roots decreased as the nitrogen was increased.

With an increase in phosphorus in the solution the phosphorus content of the vines, fruits, and roots increased; the magnesium and sulphur of the roots decreased.

When potassium in the solution was increased, the nitrogen in the vines, fruits, and roots decreased. Phosphorus in the vines decreased while it increased in the roots. Potassium in the vines, fruit, and roots increased. Calcium in the vines decreased while calcium in the roots increased. Magnesium in the roots decreased, while sulphur in the roots increased.

With an increase in calcium in the nutrient solution, nitrogen in the vines, fruit, and roots decreased, potassium in vines decreased. Calcium in the vines and roots increased, and magnesium in the roots increased.

When sulphur was increased, the nitrogen in the vines increased; in general, calcium and magnesium decreased and sulphur in the roots increased.

OCCURRENCE OF BLOSSOM-END ROT

The occurrence of blossom-end rot in the concentration series was similar to the results of ROBBINS (**2**), except that the percentages in this experiment were much lower. It must be remembered that the plants in this experiment were grown in the open in a climate with a rather high humidity and relatively cool days. Hot, bright days appear to hasten blossom-end rot, and also kill the plant when grown in unbalanced solutions, as was observed in a preliminary experiment in 1938.

Plants grown on the 2 N treatment which had the same amount of nitrogen as the plants grown with 2 R had more than twice as much blossom-end rot, and the 4 N plants with the same amount of nitrogen as 4 R plants had nearly twice as much blossom-end rot as 4 R plants. The 4 K plants with the same amount of potassium as 4 R plants had about the same amount of blossom-end rot. In this case, chlorine may be the cause of the blossom-end rot. The 4 Mg plants with the same amount of magnesium as the 4 R plants had considerably more blossom-end rot than the latter, and perhaps here also chlorine may be the cause of the blossom-end rot. The 2 S plants with the same amount of sulphur as 2 R plants had about the same amount of blossom-end rot, whereas the 4 S plants with the same amount of sulphur as 4 R had nearly twice as much blossom-end rot.

In no instance could the blossom-end rot be attributed to the osmotic values (table III) of the solutions, for in all cases the R series plants had a higher osmotic value than the nitrogen, potassium, magnesium, or sulphur series plants; yet, in all cases they had less blossom-end rot.

In the calcium series, 55.20 per cent. of the fruits on the ¼ Ca plants and 20.56 per cent. of fruits on the ½ Ca plants showed blossom-end rot, while ¼ R plants and ½ R plants with the same amount of calcium as in the calcium series produced no blossom-end rot. The blossom-end rot on the 4 Ca plants may have been produced by the chlorine in the solution. The ¼ Ca plants were the tallest of all the plants. They were next to the heaviest, and averaged a larger number of fruits than any other treatment. These plants appeared to use about as much water as those on any other treatment.

TABLE III

THE PERCENTAGE OF CALCIUM IN THE VINES, ROOTS, AND FRUIT; THE OSMOTIC VALUE OF THE SOLUTIONS; AND THE PERCENTAGE OF THE FRUITS WITH BLOSSOM-END ROT ARRANGED WITH PERCENTAGE CALCIUM IN THE FRUIT IN DECREASING ORDER

TREATMENT	PERCENTAGE CALCIUM			PERCENTAGE BLOSSOM-END ROT			
	VINES	ROOTS	FRUIT	1939	1940	AV.	OSMOTIC VALUE
	%	%	%	%	%	%	*atm.*
¼ S	4.12	3.67	0.32	0.00	0.00	0.00	1.28
½ R	3.27	1.17	0.26	0.00	0.00	0.00	0.66
½ N	3.56	1.63	0.24	0.00	0.00	0.00	1.13
¼ Mg	2.96	0.97	0.24	0.00	0.00	0.00	1.28
H	3.43	1.26	0.24	0.00	0.00	0.00	0.54
½ S	3.26	1.21	0.24	2.17*	9.75*	5.75	1.39
2 Ca	5.10	4.73	0.23	0.00	5.00*	2.35	2.09
½ Mg	3.65	1.01	0.23	2.17*	0.00	1.20	1.30
R	3.56	1.39	0.22	5.88*	1.52*	3.42	1.20
¼ N	3.49	1.31	0.22	0.00	2.44*	1.15	1.02
2 K	3.04	4.08	0.22	1.82*	3.64*	2.73	1.36
¼ R	2.92	1.18	0.21	0.00	0.00	0.00	0.52
¼ K	3.58	0.89	0.21	0.00	0.00	0.00	1.18
½ K	3.52	0.94	0.21	0.00	4.26*	2.22	1.31
2 R	2.98	1.12	0.19	13.64†	6.45*	10.67	2.03
4 Ca	6.39	6.17	0.19	38.46†	5.13*	21.79	3.25
4 R	3.04	2.74	0.18	40.43†	25.71§	34.15	4.09
4 N	1.55	1.05	0.18	83.33†	51.02†	63.29	3.16
2 Mg	3.32	3.81	0.18	10.42‡	0.00	5.62	1.76
½ Ca	1.94	0.64	0.16	29.79‡	13.33§	20.56	1.24
2 S	3.27	1.17	0.16	0.00	18.03*	10.78	1.41
2 N	2.02	0.80	0.14	32.65†	24.00‡	28.28	1.65
¼ Ca	1.32	0.56	0.14	66.33†	47.69†	55.20	1.18
4 K	1.95	3.87	0.13	37.93†	30.77‡	34.55	2.56
4 S	1.05	1.29	0.13	75.00†	40.38†	58.93	1.47
4 Mg	2.75	0.78	0.12	59.62†	36.21‡	47.27	3.49

* Blossom-end rot on 1 plant.
§ Blossom-end rot on 2 plants.
‡ Blossom-end rot on 3 plants.
† Blossom-end rot on 4 plants.

In 1940, in order to check the theory of osmotic relationship, in relation to the occurrence of blossom-end rot, the calcium series was repeated at ½ of the above concentration except for the minor elements which were used at the same rates. The occurrence of blossom-end rot in the two series was very similar; in fact, the ¼ Ca/2 plants with osmotic value of 0.55 atmospheres produced fruit with 53.23 per cent. blossom-end rot, while the ¼ Ca plants with an osmotic value of 1.18 atmospheres produced fruits with 47.69 per cent. blossom-end rot.

It would appear that the balance between the elements is more important as a cause of blossom-end rot than the actual concentration of the elements or the osmotic concentration of the solution. It also appears that this unbalanced condition causes blossom-end rot by preventing the utilization of the necessary amount of calcium for normal fruit formation, for whenever the calcium content of the fruit (table III) in this experiment was lower than 0.20 per cent., there was generally blossom-end rot on some of the fruits.

Summary

Marglobe tomato plants were grown outdoors with subirrigation method, using widely different nutrient ratios.

Response to treatments was measured by height and weight of plant, number and weight of fruit, and the occurrence of blossom-end rot.

The vines, fruits, and roots were analyzed to ascertain the relationship between nutrient solutions used and chemical composition of plants, and also to study the relationship between composition of plant and incidence to blossom-end rot.

In general, as a nutrient element is increased in the nutrient solution that element tends to increase in the vines, roots, and fruit of the tomato plant.

When certain elements are increased in the nutrient solution, they have a tendency to decrease the content of certain other elements in the plant; for example, increasing potassium in the nutrient solution tends to decrease the nitrogen content of tomato plants.

Variation in nutrient solution appears to have much less effect on the composition of fruits than it has on the composition of either vines or roots of the tomato plant.

Blossom-end rot was produced at relatively low osmotic values.

Blossom-end rot was produced by high nitrogen, high sulphur, high magnesium, high potassium, high chlorine, and low calcium.

Analysis of the fruits indicated that those plants which produced fruits with less than 0.20 per cent. calcium content generally produced fruits with blossom-end rot.

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