RESPONSES OF TWO SPECIES OF TOMATOES AND THE F_1 GENERATION TO SODIUM SULPHATE IN THE NUTRIENT MEDIUM[1]

C. B. LYON[2]

Introduction

It has been recognized for some time that varieties of a given species of plant differ in their response to various environments. Inbred strains of corn and their F_1 generations have been found to vary in growth responses when available soil moisture was altered **(13),** when grown on rich and poor soil types **(12),** and when various fertilizer treatments were used (3). SMITH (20), using inbred strains and single crosses of corn, found marked differences in growth in relation to the phosphorus and nitrogen content in nutrient solutions. LYNESS (15) used sand cultures and reported results essentially in agreement with those of SMITH. HARVEY (9) found a differential utilization of ammonium and nitrate nitrogen among inbred lines of tomato and corn with their hybrids, and BURKHOLDER and MCVEIGH (2) found that inbred lines of corn and their hybrids differed in their responses to nitrogen supply in sand culture. Definite physiological symptoms of tomato plants in relation to high concentrations of Na_2SO_4 have been reported by EATON (6) and HAYWARD and LONG (11), using a commercial strain of the Marglobe variety.

The experiment here reported was designed to test the effects of high concentrations of sodium sulphate on (a) two species of tomato which are as completely homozygous as it is practicable to obtain, and (b) the heterozygous F_1 generation. Records were made of fruit production, anatomy of the stem, and growth responses.

Material and methods

The tomato, *Lycopersicum esculentum* Mill., variety Johannisfeuer, and *L. pimpinellifolium* (Jusl.) Mill., the Red Currant variety, together with the F, generation, were used. It is an interspecific cross, and the two species differ in many plant characters. The parent strains had been inbred under controlled conditions of pollination for at least five generations, and inasmuch as LINDSTROM (14) has found only 1-3 per cent of natural crossing under field conditions, they were considered essentially homozygous. POWERS (18), POWERS and LYON (19), and LYON (16) have reported the inheritance of some of the quantitative characters.

Seeds of each of the three lines were planted in flats containing sand on May **18,**

[1] Investigation conducted at U.S. Regional Salinity Laboratory, Riverside, California.

[2] Assistant Plant Physiologist, U.S. Plant, Soil, and Nutrition Laboratory, Ithaca, New York.

1940, and germinated in the greenhouse.[3] Individual plants were transplanted on May 3 to 5-gallon glazed crocks filled with quartz sand containing 0.3 per cent of magnetite, which has been found (4) to provide sufficient iron for plant needs. The crocks were placed outdoors in large automatically operated nutrient culture tanks designed and described by EATON (4,5). Eight plants were used in each tank, and the equipment provided 4800 liters of nutrient solution for each tank. This solution was circulated through the crocks for a period of 2 minutes during each hour from 6:00 A.M. to 6:00 P.M., with one additional irrigation at midnight. Each irrigation more than displaced the solution held in the crock. The plants were trained upright, and all axillary growth was pruned off twice weekly.

TABLE 1

COMPOSITION OF NUTRIENT SOLUTIONS

TREATMENT	P.P.M.		MILLIEQUIVALENTS PER LITER									
	B	M	N C	A	MG	NA	K	HCO,	SO,	CL	NO,	H_2PO_4
Tapwater*	0.1		1.8	0.6		1.6	0.2	2.9	0.6	0.6	0.1	
a) Base nutrient.	1.0	0.2	6.2	4.6		1.6	3.4	2.9	4.6	3.0	8.1	0.6
b) Base nutrient+40 m.e. Na_2SO_4	1.0	0.2	6.2	4.6	4	1.6	3.4	2.9	44.6	3.0	8.1	0.6
c) Base nutrient+80 m.e. Na_2SO_4	1.0	0.2	6.2	4.6	8	1.6	3.4	2.9	84.6	3.0	8.1	0.6
d) Base nutrient+120 m.e. Na_2SO_4	1.0	0.2	6.2	4	6 12	1.6	3.4	2.9	124.6	3.0	8.1	0.6

*Analyses of tap water kindly supplied by Dr. A. D. AYERS of the Salinity Laboratory. Ionic concentrations remained practically constant.

The nutrient solution was composed of KNO_3, $MgSO_4$, KH_2PO_4, H_3BO_3, $MnCl_2$, Na_2SO_4, $CaCl_2$, and $Ca(NO_3)_2$. Four solutions were used, consisting of (a) control solution which constituted the base nutrient, (b) base hutrient plus 40 milliequivalents per liter of Na_2SO_4, (c) plus 80 milliequivalents per liter of Na_2SO_4, and (d) plus 120 milliequivalents per liter of Na_2SO_4. Analyzed commercial salts were dissolved in tap water as used at Riverside, California. Salts were added in addition to those present in the water to raise the total concentration of the various ions of the solution to the desired strength (table 1).

To avoid injury of the seedlings immediately after transplanting and to assure the ripening and maturation of twenty fruits per plant, all tanks were initially supplied with base nutrient solution, and Na_2SO_4 was added as required in five equal amounts until the desired concentrations were attained. The additions extended over a 12-day period, and were made on June 27, July 1, 3,6, and 9, 1940, when the plants were 40-52 days old and a few of them were in bloom. Additional water was

[3] The seed was supplied through the courtesy of Dr. LEROY POWERS, Senior Geneticist, U.S. Horticultural Field Station, Cheyenne, Wyoming.

added to the reservoirs twice weekly to replace losses incurred through transpiration and evaporation. The pH of the nutrient solutions was checked daily with a Beckman pH meter and maintained at a pH of 5.5 by additions of HNO_3 when needed. The HNO_3 served the dual purpose of controlling the pH and maintaining nitrogen concentrations between 6 and 8 milliequivalents per liter (7).

After germination, the experiment was conducted outside, where a hygrothermograph placed near the plants recorded temperature and relative humidity. Pyroheliometer readings were obtained from the Citrus Experiment Station at Riverside, California, approximately 3 miles from the location of the experimental plots. The mean daily temperature from June 1 to September 15, 1940, was 74°.0 F., with a mean maximum of 92°.9 and a mean minimum of 55°.1 F. Highest temperatures were noted in July and August, with mean maximums of 96°.7 and 96°.0 F., respectively. During the experiment the mean relative humidity was 68.3 per cent at 8:00 A.M. and 38.0 per cent at 12:00 A.M. The average daily total of solar radiation during this period was 579.4 gram calories per square centimeter of horizontal surface, with the highest values between June 15 and July 15.

The design of the experiment was that of a randomized block (8) with four treatments and twelve tanks. Three tanks were used for each treatment, with eight plants per tank. Eight plants of a strain were grown in each treatment, and the three strains were replicated in each tank. The three tanks, as well as the three strains of tomatoes within each tank, were randomized by the use of TIPPETT'S randomization tables (22). The design provided for eight replications of each strain per treatment, with a total population of ninety-six plants. The data were reduced by means of the analysis of variance, and the t test (21) was used for determining whether particular differences were statistically significant. Odds as great as-or greater than-19.1 against the deviations, being due to the errors of random sampling, were accepted as statistically significant.

Experimentation and results

HEIGHT OF PLANTS

On August 13 the plants were 87 days old and had been growing on complete concentrations of their nutrient solutions for 35 days. At this time differences in plant heights were noted and recorded (table 2). There is a mean difference of 16.8 ± 6.57 cm. demonstrable between parental lines grown on the base nutrient solution, and the F_1 generation was 43.7 ± 6.89 cm. taller than the Johannisfeuer parent. Both of these differences are mathematically significant. The Johannisfeuer parent produced more growth in height of plant than the Red Currant parent, while the F_1 generation grew more rapidly than either parent. Although the magnitude of the differences between the strains, as well as the variability within them, are probably accentuated by pruning away all axillary growth, the relative

plant heights are in agreement with inherent differences demonstrated by POWERS (18).

The application of increasing concentrations of Na_2SO_4 does not affect the relative height of parental lines in comparable treatments or the phenomenon of heterosis shown in the F_1 generation. In a comparison of treatments a and d, significant mean differences of 17.9 $\pm$ 4.34 cm., 26.7 $\pm$ 6.63 cm., and 18.2 $\pm$ 5.87 cm. are demonstrable for Johannisfeuer, the F_1 generation, and Red Currant, respectively. Johannisfeuer plants grown in treatment d were 88.3 per cent as high as those in treatment a, while F_1 plants were 86.4 per cent as high, and Red Currant plants were 86.7 per cent as high on the basis of a similar comparison. For all

TABLE 2*

HEIGHT OF PLANTS IN CENTIMETERS

TREATMENT	STRAIN		
	JOHANNISFEUER	F_1 GENERATION	RED CURRANT
a) Base nutrient.	153.3$\pm$3.42	197.0$\pm$5.98	**136.5f5.61**
b) Base nutrient-t-40 m.e Na_2SO_4	152.0$\pm$2.52	191.6$\pm$2.80	138.Ok3.29
c) Base nutrient-j-80 m.e. Na_2SO_4	142.7k3.65	172.3$\pm$2 71	126.5$\pm$2.44
d) Base nutrient+120 m.e. Na_2SO_4	135.4$\pm$2.67	170.3$\pm$2.86	**118.3k1.73**

*In any comparison, 14 degrees of freedom are available. When $t = 2.145$, P = 0.05 and when $t = 2.977$, P = 0.01.

practical purposes, the total growth depression produced by the addition of 120 milliequivalents of Na_2SO_4 to the base nutrient was the same in all three strains. If the concentrations of Na_2SO_4 had been applied earlier in the life of the plant, the magnitude of the differences might have been increased (11).

DRY WEIGHT OF PLANTS

On August 13, three plants of each strain grown in each nutrient concentration were selected for further experimentation. The selected plants were those which most closely approximated the strain mean for each treatment as regards plant height and date of first bloom. These plants were re-randomized and continued on their respective treatments. The remaining five plants of each strain in each treatment were harvested after all fruits, regardless of stage of development, had been picked. The root systems of each plant were washed successively through a series of mesh screens until separated from all sand particles. The vegetative parts (the fruits are not included) were dried at 80° C. and weighed (table 3).

It is possible to demonstrate in the data, mean differences of 35.2 $\pm$ 6.07 gm.,

95.4 ± 11.20 gm., and 42.8 ± 7.85 gm. for the vines of Johannisfeuer, F_1 generation, and Red Currant, respectively, when treatment a is compared with treatment d. The mean differences are well in excess of twice their standard error and are significant. In all strains the dry weight of the vines was less as the concentration of Na_2SO_4 in the nutrient solution was increased. When plotted against Na_2SO_4 concentrations, the dry weight of the vine closely approximated a linear regression in the case of the parental lines, while a comparatively pronounced reduction in dry weight was obtained for treatment c in the F_1 generation. The dry weight of vines in treatment d was 71, 69, and 56 per cent as great as in treatment a for Johannisfeuer, F_1 generation, and Red Currant strains, respectively. The effect

TABLE 3*

ANALYSIS OF DRY WEIGHT OF PLANTS GIVING STRAIN MEANS IN GRAMS TOGETHER WITH THEIR STANDARD ERRORS

TREATMENT	JOHANNISFEUER		F_1 GENERATION		RED CURRANT	
	VINE	ROOT SYSTEM	VINE	ROOT SYSTEM	VINE	ROOT SYSTEM
a) Base nutrient.	121.0±4.64	19.4±2.12	308.2± 7.67	62.9±3.67	97.8±6.10	18.0±2.61
b) Base nutrient+ 40 m.e. Na_2SO_4.	106.6±4.90	16.5±1.22	276.4± 7.06	57.3±2.01	83.8±2 60	18.7±0.63
c) Base nutrient+ 80 m.e. Na_2SO_4.	101.0±5.77	15.1±0.68	220.2f10.48	45.7±2.64	71.4±3.57	18.0±0.67
d) Base nutrient+ 120 m.e. Na_2SO_4	85.8±3.92	14.9±0.67	212.8± 8.16	42.2±2.73	55.0±4.94	18.7±0.66

*In any comparison, 8 degrees of freedom are available. When t = 2.306, P = 0.05 and when t = 3.355, P = 0.01

of a high concentration of Na_2SO_4 is relatively greater on the Red Currant strain than it is on the other two in this respect.

In a similar comparison of root systems (table 3), a mean difference of 4.5 ± 2.22 gm. and 20.7 ± 4.57 gm. in dry weight is obtained for Johannisfeuer and the F_1 generation, respectively, between treatments a and d. Within these two strains, correlation coefficients computed between the dry weight of the root system and that of the vine were found to be highly significant. (r = 0.73, t = 4.53 for Johannisfeuer; r = 0.80, t = 5.66 for the F_1 generation. Nineteen degrees of freedom are involved in each line.) This means that within the limits of precision obtainable in this experiment, the root system and vine growth of Johannisfeuer and the F_1 generation were affected in the same way and to much the same degree by increases in Na_2SO_4 concentration. In the case of the Red Currant strain, no statistically significant differences in the dry weight of the root system produced were demonstrable. This phenomenon will be discussed later.

The expression of heterosis is clearly demonstrable. The dry weight of the F_1 generation vines is approximately 2.5 times that of the Johannisfeuer strain, which

is the heavier of the parents, while root systems are approximately 3.0 times as heavy in a similar comparison. The relationship is apparently constant in all treatments. This agrees with the observations and data of POWERS (18).

FRUIT PRODUCTION

When the plants were harvested, all fruits-regardless of size or state or maturity-were picked, counted, and weighed (table **4).** At that time a few isolated fruits of the F, generation were completely red. Complete color change had not occurred on any fruit in parental lines.

TABLE 4*

ANALYSIS OF FRUIT PRODUCTION GIVING STRAIN MEANS TOGETHER WITH THEIR STANDARD ERRORS

TREATMENT	JOHANNISFEUER			F_1 GENERATION			RED CURRANT		
	FRESH WEIGHT OF FRUIT (GM.)	NO. OF FRUITS	AVERAGE WEIGHT OF FRUIT (GM.)	FRESH WEIGHT OF FRUIT (GM.)	NO. OF FRUITS	AVERAGE WEIGHT OF FRUIT (GM.)	FRESH WEIGHT OF FRUIT (GM.)	NO. OF FRUITS	AVERAGE WEIGHT OF FRUIT (GM.)
a) Base nutrient	567±58.7	30±3.1	18.9±0.39	286±29.3	136±7.9	2.1±0.16	6 9±2 00	45±12.2	0 16±0.016
b) Base nutrient+40 m.e. Na_2SO_4	542±63.8	34±3.9	17.1±2.93	174±37.2	113±12.9	1.5±0.16	9.9±2.30	65±15.3	0.16±0.013
c) Base nutrient+80 me. Na_2SO_4	529±79.7	36±2 7	14.8±1.49	144±14.9	108± 6.7	1.3±0.09	10.5±1.49	73± g	4 0.14±c.008
d) Base nutrient+120 m.e. Na_2SO_4	342±61.8	33±4.8	10 2±0.88	105±17.9	90±11.8	1.2±0.08	10.2±2.66	81±16 g	o 12±0.012

*In any comparison, 8 degrees of freedom are available. When t = 2.306, P = 0.05 and when t = 3.355, P = 0.01.

The data for Johannisfeuer and the F_1 generation show mean differences in the fresh weight of the fruit produced of 225 ± 85.23 gm. and 181 ± 34.34 gm., respectively, when treatments a and d are compared. The differences are well in excess of twice their standard error and are significant. No statistically significant differences in this respect are demonstrable in the Red Currant strain. By comparing treatments a and d, the fresh weight of fruits produced by the Johannisfeuer are 40 per cent less as a result of the highest concentration of Na_2SO_4 used in the experiment. The fruit production of the F_1 generation was 63 per cent less in the same comparison. At every concentration of Na_2SO_4, greater effects were observed on the F_1 generation. The most pronounced were observed between treatments c and *d* in the Johannisfeuer strain and between treatments a and *b* in the F_1 generation. In other words, there are indications that differences within as well as between strains exist for this character in its response to high Na_2SO_4 concentrations.

The data for the number of fruits produced by the F_1 generation show a mean difference of 46 ± 14.2 when treatments d and a are compared. In this strain the high concentration of Na_2SO_4 had an inhibiting effect on the number of fruits pro-

duced. No statistically significant differences were demonstrable in this respect for parental lines.

By again comparing treatments a and d in respect to the average weight of the individual fruit produced, mean differences of 8.7 $\pm$ 0.96 gm. for Johannisfeuer and 0.9 $\pm$ 0.18 gm. for the F_1 generation are demonstrated. Both differences are highly significant. The data for the Johannisfeuer strain suggest that the effects of increasing Na_2SO_4 concentrations on fruit size are at least additive and possibly cumulative, while the major effect in the F_1 generation occurs between treatments a and *b*, where a significant mean difference of 0.6 $\pm$ 0.23 gm. is demonstrable. In both cases, however, the average weight of the fruit at this stage was less when Na_2SO_4 concentrations were increased. No statistically significant trends are shown in the data for the Red Currant strain. Possible interpretations of these data will be discussed later.

Inherent strain differences in the fresh weight of fruits produced at this time are apparent, as a mean difference of 560.1 $\pm$ 58.73 gm. is demonstrable between parental lines in treatment a. No mathematically significant differences are found in the data between the mean of the F_1 generation and the arithmetic or geometric means computed from the means of parental lines. In treatment a the Johannisfeuer and Red Currant strains do not differ significantly in respect to the number of fruits set at this time in their life cycle, but the F_1 generation set approximately three times as many fruits as the Red Currant, and hybrid vigor is evident. A highly significant mean difference of 18.7 $\pm$ 0.39 gm. in the average weight of the fruit produced is evident between parental lines. The observed mean of the F_1 generation is significantly lower than the arithmetic mean (9.5 $\pm$ 0.20) computed from the means of parental lines.

MATURE FRUIT CHARACTERISTICS

The thirty-six plants (three replications, three strains, and four treatments) which had previously been selected for further experimentation on the basis of their uniformity and close approximation to the strain mean within treatments--in regard to plant height and date of first bloom-were grown until each plant had ripened twenty fruits. Each fruit was picked in the morning of the day that complete color change had occurred. Under these conditions, if the fruits are uninjured no detectable loss in weight occurs in the first 4 hours after harvest. Within this time limit each fruit was weighed in air to the nearest milligram and re-weighed when immersed in distilled water. The weight in air is analogous to the mass (M) and the loss of weight in water is analogous to the volume (V). Fruit density (D) was computed by the equation M/V = D, using twenty fruits per plant and three plants of each strain in each treatment (table 5).

A mean difference in fruit density of 0.032 $\pm$ 0.0018 is indicated in the data for

parental lines in treatment a. The observed mean of the F_1 generation is significantly higher than either the arithmetic or geometric mean computed from parental strains, and partial dominance of the higher fruit density occurring in Red Currant is demonstrable. The relationship between strains is apparently constant in all treatments.

By comparing treatments a and d, mean differences in fruit density of 0.013 $\pm$ 0.0021, 0.013 $\pm$ 0.0024, and 0.017 $\pm$ 0.0012 for Johannisfeuer, F_1 generation, and Red Currant, respectively, were found. All differences are mathematically significant and the addition of 120 milliequivalents per liter of Na_2SO_4 to the base nutrient solution resulted in greater densities of mature fruits in all strains

TABLE 5*

ANALYSIS OF FRUIT DENSITY GIVING STRAIN MEANS TOGETHER WITH THEIR STANDARD ERRORS

TREATMENT	STRAIN		
	JOHANNISFEUER	F_1 GENERATION	RED CURRANT
a) Base nutrient.	0.996±0.0015	1.025±0.0019	1.028±0.0010
b) Base nutrient+40 m.e. Na_2SO_4.	1.003 ±0 .0001	1.026±0.0018	1.038±0.0011
c) Base nutrient+80 m . e . Na_2SO_4.	1.005±0.0023	1.032±0.0028	1.039±0.0007
d) Base nutrient+120 m.e. Na_2SO_4. . . .	1.009±0.0014	1.038±0.0014	1.045±0.0007

* In any comparison, 118 degrees of freedom are available. When = 1.980, P = 0.05 and when = 2.618, P = 0.01.

tested. No differences between strains were noted in the percentage increase in fruit density as a result of treatment d. When treatments a and b are compared, significant mean increases of 0.007 $\pm$0.0015 and 0.010$\pm$0.0015 are demonstrable for the Johannisfeuer and Red Currant strains, while no statistically significant difference is noted in the F_1 generation. In this experiment the fruits of the F_1 generation were affected less by the addition of 40 milliequivalents per liter of Na_2SO_4 to the base nutrient than were the fruits of the parental strains.

The data were examined in regard to the mean weight of each fruit produced by the strains when each fruit is picked immediately after complete color change (table 6). In Johannisfeuer and the F_1 generation, mathematically significant mean differences of 19.0 $\pm$ 4.72 gm. and 1.6 $\pm$ 0.44 gm., respectively, are demonstrable by comparing treatments a and a!. In both strains the weight of each fruit is significantly less in treatment *c* than in a, but the addition of 40 milliequivalents of Na_2SO_4 produced no significant effect. There are no significant trends in the data for the Red Currant strain.

In this experiment, in comparisons made within strains no detectable effect of increasing Na_2SO_4 concentration was obtained for the number of days from planting to the date when twenty fruits per plant were ripened. The increased salt concentration did not significantly affect either the period in days from first fruit ripe to twenty fruits ripe per plant or the period in days from first fruit set to first fruit ripe per plant. When it is recalled that the concentration of the nutrient solutions was increased by additions of Na_2SO_4 at or near the date of first bloom, no effects would be expected, nor were they observed, in number of days from planting to date of first bloom. Within strains, the period from first bloom to first fruit set was unaffected by the treatments. In other words, under the conditions of this

TABLE 6*

ANALYSIS OF AVERAGEFRESH WEIGHT OF MATUREFRUITS GIVING STRAINMEANSTOGETHERWITHTHEIRSTANDARDERRORS

TREATMENT	STRAIN		
	JOHANNISFEUER	F_1 GENERATION	RED CURRANT
a) Base nutrient.	57.6±4.07	4.1±0.35	0.84±0.064
b) Base nutrient+40 me. Na_2SO_4.	52 0±3.58	4.9±0.37	0.75±0.056
c) Base nutrient+% m.e Na_2SO_4.	42.1±3.03	2.8ko.33	0.80±0.042
d) Base nutrient+120m.e. Na_2SO_4.	38.6f2.39	2.5fo.26	0.84±0.031

*In any comparison, 118 degrees of freedom are available. When 1 = 1.980, P = 0.05 and when 1 = 2.618, P = 0.01.

experiment no detectable effects of increased concentrations on the rate of fruit development and maturation were observed.

The plants were harvested immediately after ripening twenty fruits per plant, and the dry weight of vines and root systems in all strains showed the same trends as in table 3. The dry weight of vines in all strains was less as the concentration of Na_2SO_4 was increased. The dry weight of the root systems produced by the Johannisfeuer strain and the F_1 generation was less as the concentration increased, but even at maturity no statistically significant differences in the dry weight of root systems in the Red Currant strain were demonstrable. As would be expected, the dry weight of the vines was greater in this harvest than in the earlier one, and the relative increase in dry weight of the vines was less as the concentrations of Na_2SO_4 increased. No statistically significant increase in the dry weight of root systems was shown in comparing data of both harvests. The magnitude of heterosis demonstrable in the dry weight of F_1 generation plants was less than in the previous harvest.

STEM ANATOMY

When each plant in the experiment was harvested, a section of the stem from the internode nearest the midpoint of the plant axis was fixed with Navashin's solution and air was evacuated from the tissues. The material was dehydrated in an ethyl-tertiary butyl alcohol series and infiltrated with a paraffin-beeswax-rubber mixture. Complete cross sections were cut at 1 5-30 μ and stained with a modified Flemming's triple stain. The material was mounted in balsam.

The stem sections of the plants which were harvested on August 13, as well as those harvested after twenty fruits were produced, had a continuous vascular cylinder, and comparatively few inner pericyclic fibers were thickened (10). The sec-

TABLE 7*

ANALYSIS OF STEM DIAMETERSGIVINGSTRAINMEANS IN MILLIMETERSTOGETHERWITHTHEIRSTANDARD ERRORS

TREATMENT	STRAIN		
	JOHANNISFEUER	F_1 GENERATION	RED CURRANT
a) Base nutrient.	15.0±0.47	14.2±0.53	9 6±0.31
b) Base nutrient+40 m.e. Na_2SO_4	13.3±0.41	13.1±0.34	9.1±0.25
c) Base nutrient+80 m.e. Na_2SO_4.	11.5±0.38	12.4±0.41	8.2±0.23
d) Base nutrient+120 m.e. Na_2SO_4	10.7±0.31	11.2±0.31	8.2f0.22

*In any comparison, 4 degrees of freedom are available. When t = 2.776, P = 0.05 and when t = 4.604, P = 0.01.

tions were magnified 27.5 diameters and the diameter of each stem measured. Four diameters were selected in order to divide the section into eight equal sectors, and the mean of the four measurements was used for each stem. The data in table 7 pertain to those plants harvested immediately after ripening twenty fruits.

Mean differences between treatments a and d of 4.3 ± 0.56 mm., 3.0 ± 0.61 mm., and 1.4 ± 0.38 mm. are demonstrable for the diameter of the Johannisfeuer, F_1 generation, and Red Currant strains, respectively. All differences are of sufficient magnitude to provide "P" values as small as, or smaller than, 0.05 and are statistically significant. In all lines there was less increase in diameter as the concentration of Na_2SO_4 increased. The percentage diameter of the stem as a result of the addition of 120 milliequivalents per liter of Na_2SO_4 to the base nutrient solution was 71.3 per cent for Johannisfeuer, 78.9 per cent for the F_1 generation, and 85.4 per cent for Red Currant. The last strain was affected less in this respect than was the Johannisfeuer, while the magnitude of the effect on the F_1 generation was intermediate.

The data for those plants harvested on August 13, and hence of comparable age rather than comparable maturity, were similar in most respects to those just cited and are not reported. Similarly, a smaller diameter of the stem was demonstrable in all strains as a result of the high Na_2SO_4 concentration. The data differed, however, in that the effect of increased salt concentration on the F_1 generation was greater than it was on parental lines.

At the increased magnification, the tissue systems were measured to the nearest millimeter on eight radii separated from one another by an angle of 45°. The mean of eight radial dimensions for each tissue system was used in the computation of an actual area. The actual area was computed using standard formulas, which were developed for perfect circles. The data in table 8 pertain to those plants harvested after twenty fruits per plant had ripened. The standard errors provide an estimation of variability between plants.

There are no statistically significant differences within a strain in the percentage of area of any of the tissue systems. The smaller diameter of the stem when the concentration of Na_2SO_4 is increased is a direct result of a correspondingly smaller area (and diameter) of each of the constituent tissue systems. For instance, the actual area of the xylem in a cross section of the stem of Johannisfeuer was less as the concentration in the nutrient solution was increased, but no significant differences were obtained in the percentage of the area of the xylem in the cross section of the stem.

In the cross section of the stem, a significant mean difference of **19.7** $\pm$ 3.71 per cent is demonstrable in the percentage of actual area covered by the pith between parental strains. The F_1 generation is intermediate between the parental strains in this respect, and differs significantly from both. The amount of cambial activity differs between parental lines when the formation of secondary xylem and phloem tissues is used as a criterion. A mean difference of **17.7** $\pm$ 3.37 per cent is shown for the amount of secondary xylem formed, and a mean difference of 3.8 $\pm$ 1.09 per cent is demonstrable for the secondary phloem. Both mean differences are statistically significant, and in both respects the F_1 generation is intermediate between parental strains. No significant difference is demonstrable in the percentage of area covered by the cortex. The cross section of the stem of the Johannisfeuer strain has a stele with a comparatively large amount of pith and small amounts of vascular tissue, while the stele of Red Currant has comparatively large amounts of vascular tissue and a small amount of pith. The stele of the F_1 generation is intermediate in all respects. The addition of increased concentrations of Na_2SO_4 to the nutrient solution does not alter inherent differences between genotypes in respect to the anatomy of stem sections.

The stems of the plants harvested when 87 days old showed the same anatomical relationships as those harvested after ripening twenty fruits per plant. The

TABLE 8*

ANALYSIS OF COMPOSITION OF STEM CROSS SECTIONS GIVING STRAIN MEANS IN PERCENTAGE OF ACTUAL AREA TOGETHER WITH THEIR STANDARD ERRORS

Treatment	Percentage area											
	Johannisfeuer				F_1 generation				Red Currant			
	Pith	Xylem	Phloem	Cortex	Pith	Xylem	Phloem	Cortex	Pith	Xylem	Phloem	Cortex
a) Base nutrient	43.5±3.28	27.7±3.19	5.7±0.30	19.3±0.51	34.3±2.09	36.2±1.19	7.4±0.61	20.1±1.31	23.8±1.73	45.4±1.07	9.5±1.05	17.3±1.20
b) Base nutrient+40 m.e. Na_2SO_4	39.2±1.92	32.1±1.95	6.0±0.57	22.2±2.65	32.6±5.56	37.5±4.10	8.1±0.34	19.1±1.33	24.8±3.33	45.5±2.40	9.9±1.98	16.6±0.29
c) Base nutrient+80 m.e. Na_2SO_4	44.0±2.50	29.1±2.14	6.0±0.31	18.6±0.78	32.7±0.50	38.1±0.38	6.1±0.37	18.9±0.79	24.0±1.96	48.5±1.55	8.8±0.61	17.0±0.71
d) Base nutrient+120 m.e. Na_2SO_4	42.5±2.03	31.9±2.08	6.1±0.40	16.9±1.07	29.6±3.00	39.8±2.00	8.1±0.27	20.1±1.91	24.1±2.46	48.0±1.12	9.2±1.43	16.4±0.60

* In any comparison, 4 degrees of freedom are available. When $t = 2.776$, $P = 0.05$ and when $t = 4.604$, $P = 0.01$.

magnitude of the differences was less at this date, but the differences were statistically significant. No effects of treatment were noted in the data.

Discussion

The growth depressions produced as a result of growing plants in nutrient solutions containing high salt concentrations have been pointed out **(1, 17). EATON (6)** and **HAYWARD** and **LONG** (11) have shown differential ionic effects at isosmotic concentrations of the nutrient solution. Unpublished data collected by **EATON** have indicated an interaction between a given salt concentration and such factors of the environment as temperature. It seemed logical that attention should also be given to the hereditary qualities of the test plant in addition to the preceding considerations.

Two criteria were used to measure the relative responses of the plants. First, at a given age, what is the response of the plant to varied environments with respect to any character? This method has been widely used in both physiological and genetic studies. Second, at comparable "physiological maturity," what is the response of the plants to varied environments in respect to any character? It was arbitrarily considered in this paper that plants were at comparable stages of physiological maturity when each had matured and ripened twenty fruits. The latter method has been less extensively used.

Where statistical significance is not demonstrable in an experiment (as is the case in the data for the Red Currant strain) in respect to mean weight of each ripe fruit produced, dry weight of the root system, total fresh weight of immature fruits, etc., it does not mean that differences do not exist. The use of larger populations and more refined methods might demonstrate significant differences in these characteristics. It may be assumed, however, that in this experiment Red Currant was less affected in these characteristics by high concentrations of Na_2SO_4 than were the other two strains.

The results of this experiment have shown that the presence of high concentrations of sodium sulphate in the nutrient solution affects the growth of all three strains. In many respects, the effects produced by the various concentrations on the strains were very similar. For example, the phenomenon of heterosis exhibited by the hybrid with respect to growth in height, dry weight production, number and weight of fruits, and so on, was exhibited to almost the same degree at every salt concentration used. In comparing the effects of increasing the concentration of sodium sulphate in the nutrient solution on the individual strains, it may be noted that Red Currant was affected less than were the other two with respect to such characters as dry weight of root system, fresh weight of all fruits produced, and average weight of mature fruit. For these characters the F_1 hybrid paralleled the Johannisfeuer parent more closely than it did the Red Currant. In all three

strains the density of the ripe fruit produced by plants subjected to increasing concentrations of sodium sulphate increased. Just what effect these changes in density might have upon the nutrient value of the fruit is not known. The effects of presence of sodium sulphate in the solution upon the internal anatomy of the stem of the three strains are very similar. In general there was no indication that the presence of sodium sulphate had a differential effect on any tissue system. In every case, the higher the concentration the smaller was the stem diameter; and in all stems the relative proportions of pith, xylem, phloem, and cortex remained the same, within the limits of error.

Anatomical results are not in entire accord with those of HAYWARD and LONG (11). There are, however, several differences in the methods of experimentation, such as: (1) the time at which the plants were subjected to the various concentrations in Na_2SO_4, (2) ionic concentrations of nutrient solutions used, (3) pH of the solutions, (4) environmental factors, and (5) hereditary qualities of the plant. It is possible that future work may correlate the differences in the results obtained with one or more of these factors.

The occurrence of saline areas is general throughout western states. In addition, comparatively high concentrations of Na_2SO_4 and other salts are prevalent in water supplies used for irrigation purposes. To accompany proper soil management practices and more detailed studies of salt antagonism and toxicity effects, it may be possible and desirable to select and breed plants for tolerance to saline conditions. Such a program should eventually involve not only the production of strains with the characteristic of general tolerance to high salt concentrations but the actual selection and breeding of strains for specific concentrations of two or more ions.

Summary

Tomato plants of the Johannisfeuer strain and the Red Currant strain, together with the F_1 generation, were submitted to four treatments, providing four concentrations of Na_2SO_4 ranging from 4.6 to **124.6** milliequivalents of sulphate ion per liter of nutrient solution.

1. Plant height was less in all strains as the concentration increased. The growth depression resulting from the highest concentration was the same in all strains.

2. The dry weight of vines was less in all strains as the concentration increased.

3. The dry weight of the root system of the Johannisfeuer strain and the F_1 generation was less when the concentration was increased. No statistically significant reduction in this respect was obtained for the Red Currant strain.

4. The total fresh weight of immature fruits produced by plants 87 days old, as well as the average weight per fruit, was less in two strains when salt concentration was increased. No differences were noted in the Red Currant strain.

5. The number of immature fruits produced by each plant of the F_1 generation was less as the concentration increased.

6. The density of ripe fruits increased in all strains with increased concentration.

7. The mean weight of each ripe fruit of the Johannisfeuer strain and the F_1 generation was less with increased concentration.

8. The diameter of the stem of plants harvested after ripening twenty fruits, as well as of plants harvested at an earlier date, was less in all strains with increased concentration.

9. The smaller stem diameter was caused by an inhibited development of each of the component tissue systems.

10. Inherent differences between strains are discussed for each of these characters.

The writer is indebted to Dr. 0. C. MAGISTAD and to the staff of the U.S. Regional Salinity Laboratory for their interest and cooperation during this investigation.

U.S. REGIONAL PLANT, SOIL, AND NUTRITION LABORATORY
ITHACA, NEW YORK

LITERATURE CITED

1. BREAZEALE, J. P., Effect of the concentration of the nutrient solution upon wheat cultures. Science 22: 146-149. 1905.
2. BURKHOLDER, P. R., and MCVEIGH, I., Growth and differentiation of maize in relation to nitrogen supply. Amer. Jour. Bot. 27:414-424. 1940.
3. DE TURK, E. E., HOLBERT, J. R., and HAWK, B. W., Chemical transformations of phosphorus in the growing corn plant, with results on two first generation crosses. Jour. Agr. Res. 46: 121-141. 1933.
4. EATON, F. M., Automatically operated sand-culture equipment. Jour. Agr. Res. 53:433-444, 1936.
5. ——— Plant culture equipment. Plant Physiol. 16:385-392. 1941.
6. ——— The toxicity and accumulation of chloride and sulfate salts in plants. jour. agr. Res. In press.
7. ——— Use of nitric acid in control of pH and nitrate levels in nutrient solution. Plant Physiol. In press.
8. FISHER, R. A., The design of experiments. Oliver and Boyd Co., London. 1937.
9. HARVEY, P. H., Hereditary variation in plant nutrition. Genetics 24:437-461. 1939.
10. HAYWARD, H. E., The structure of economic plants. Macmillan, New York. 1938.
11. HAYWARD, H. E., and LONG, E. M., Anatomical and physiological responses of the tomato to varying concentrations of sodium chloride, sodium sulphate, and nutrient solutions. BOT. GAZ. 102:437-462. 1941.
12. HOFFER, G. N., Some differences in the functioning of selfed lines of corn under varying nutritional conditions. Jour. Amer. Soc. Agron. 18:322-334. 1926.

13. KIESSELBACH, T. A., The comparative water economy of selfed lines of corn and their hybrids. Jour. Amer. Soc. Agron. 18:335-344. 1926.
14. LINDSTROM, E. W., Linked inheritance in tomatoes. Iowa State Coll. Jour. Sci. 1:3-13. 1926.
15. LYNESS, A. S., Varietal differences in the phosphorus feeding capacity of plants. Plant Physiol. 11: 665-688. 1936.
16. LYON, C. B., Studies on the inheritance of the different stages of earliness in an interspecific cross between *Lycopersicum esculentum* Mill. and *L. pimpinellifolium* (Jusl.) Mill. Jour. Agr. Res. In press.
17. MAXIMOW, N. A., The plant in relation to water. New York. 1929.
18. POWERS, L., Studies on the nature of the interactions of the genes differentiating characters in a cross between Lycopersicum *esculentum* and *L. pimpinellifolium*. Jour. Genet. 39: 139-170. 1939.
19. POWERS, L., and LYON, C. B., Studies on the inheritance of stages of development in crosses involving species and varieties of *Lycopersicum*. Jour. Agr. Res. In press.
20. SMITH, S. N., Response of inbred lines and crosses in maize to variations of nitrogen and phosphorus supplied as nutrients. Jour. Amer. Soc. Agron. 26:785-804. 1934.
21. SNEDECOR, G. W., Statistical methods. Collegiate Press, Ames, Iowa. 1938.
22. TIPPETT, L. H. C., Tracts for computers. Random sampling numbers. Cambridge University Press, London. 1927.