Salinity Effects on Sugarcane Germination, Growth, and Root Development

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INTRODUCTION

Saline soil has constituted one of the most important conditions which urgently demand our special attention on the South Coast of Puerto Rico. According to Bonnet (*3*),[2] over 10,000 acres are now affected by saline problems. In 1963–64, canes suffered damage from drought, especially in the areas where the soil contains a high level of salt. Sometimes an entire planting made very little growth; in other fields only certain areas had stunted canes. Needless to say, excessive salinity could have played an important role in preventing normal growth under the drought conditions, hence the need of some criteria to measure specific orders of salt tolerance for sugarcane varieties.

In Taiwan, Shen and Tung (*10*) reported that sugarcane varieties differed greatly in salt tolerance. In investigating the drainage and salinity problem in Iran, Shoji and Sund (*11*) concluded that soil conductivity of 4 millimhos/cm. was the threshold, above which the growth of sugarcane was drastically reduced. A survey of the soil salinity over southwestern Puerto Rico revealed that sugarcane grew poorly in the salty land of the Lajas Valley which contains from 0.53 to 1.19 percent of sodium chloride (*3*).

Owing to the ever-increasing demands for salinity-resistant varieties of sugarcane, it became necessary to test our major varieties of sugarcane for salinity resistance. The objective of the investigation, reported herein, was to determine under greenhouse conditions the reaction of several sugarcane varieties to various levels of soluble sodium chloride, and thus to lead to an improved understanding of the effect of salt on germination growth, and root development in order to develop suitable criteria for determining saline resistance in sugarcane.

MATERIALS AND METHODS

This study was initiated on December 10, 1964, and terminated on February 26, 1965, in the greenhouse of the Soils Department of this Station. Ten sugarcane varieties used were P.R. 980, P.R. 1000, P.R. 1013, P.R. 1016, P.R. 1017, P.R. 1028, P.R. 1048, P.R. 1059, M. 336,

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[2] Italic numbers in parentheses refer to Literature Cited, pp. 209–10.

and Co. 419. Twenty sugarcane cuttings, ten for each variety, were planted in the soil initially nonsaline in a metal flat, provided with drainage, and were irrigated with either a 4,000-p.p.m., or an 8,000-p.p.m. solution of sodium chloride at 2 to 3-day intervals. Tapwater was used as a check.

The treatments used were as follows: Treatment A, irrigated with 1,200 ml. of tapwater each time; treatment B, irrigated with 1,200 ml. of a 4,000-p.p.m. solution of sodium chloride each time; treatment C, irrigated with 1,200 ml. of an 8,000-p.p.m. solution of sodium chloride each time.

A complete randomized design with three replications was employed. Two sugarcane varieties were planted in each metal flat, making a total of 45 flats. Salinity treatments were started at the time of seeding and observations were made on germination and growth thereafter.

The soil used was a Vega Alta clay loam. Soil samples were taken periodically from the various treatments for salt-conductivity determinations. The saturation-extract method (*12*) was used for determining salt conductivity of the soil. During various periods the rate of cane growth was measured, and notes were taken at intervals on injury and appearance of the sugarcane varieties. Roots from each plant were collected and oven-dried separately in an aluminum container at 100° C. for 2 hours.

RESULTS AND DISCUSSION

The differences in percentage germination of sugarcane as affected by the three different levels of soil salinity are given in table 1. Eleven days after seeding, P.R. 1013 showed a significant difference in percentage germination between canes growing in the soil with a salt conductivity of 5 millimhos/cm. and in the soil with a salt conductivity of 0.2 millimhos /cm. The remaining nine varieties tested did not show any significant difference, though P.R. 1000 displayed a significant difference in percentage germination 42 days following seeding at a higher level of soil salinity.

The differences in dry weight of roots of P.R. 1000, P.R. 1017, P.R. 1048, and P.R. 1059, between canes growing in the soil with a salt conductivity of 54 millimhos/cm. and in the soil with a salt conductivity of 1 millimhos/cm. were significant, while the differences in dry weight of root of the other 6 varieties tested were not significant, (table 2).

The salt treatments at the various levels reduced significantly the daily average stem growth in almost all the varieties tested (table 3). The daily average stem growth appeared to be the most effective among the three criteria, percentage of germination, dry weight of root, and daily average stem growth used for evaluating the salt resistance in sugarcane.

A study of the correlation coefficient between the salt conductivity of the soil and the daily average stem growth revealed that the regression

TABLE 1.—*Differences in percentage germination of sugarcane as affected by different levels of soil salinity in the greenhouse*

Treatments	Salt conductivity	Germination of—									
		P.R. 980	P.R. 1000	P.R. 1013	P.R. 1016	P.R. 1017	P.R. 1028	P.R. 1048	P.R. 1059	M. 336	Co. 419
When 11 days old[1]											
	Millimhos/cm	*percent*	*percent*	*percent*	*percent*	*percent*	*percent*	*percent*	*percent*	*percent*	*percent*
A, tapwater	0.2	47	20	40	33	47	37	33	27	37	46
B, 4,000-p.p.m. NaCl	1.5	63	13	40	27	43	47	67	17	23	47
C, 8,000-p.p.m. NaCl	5.4	50	17	20	33	47	53	57	13	13	40
When 42 days old[2]											
A, tapwater	0.4	67	73	63	53	90	53	47	80	73	67
B, 4,000-p.p.m. NaCl	3.9	83	70	67	63	80	83	57	80	77	67
C, 8,000-p.p.m. NaCl	20	67	53	47	67	90	73	70	50	80	60
[1] L.S.D. at 5-percent level		39.4	18.8	16.3	44.7	40	32.6	40	36.5	30.5	34
[2] L.S.D. at 5-percent level		43.2	14.9	20	41.6	25.8	25.8	35.9	38.3	24.9	34

TABLE 2.—*Dry-weight (grams) differences in roots of sugarcane as affected by the different levels of soil-salinity in the greenhouse*

Treatments	Soil conductivity of salt	Dry weights/1									
		P.R. 980	P.R. 1000	P.R. 1013	P.R. 1016	P.R. 1017	P.R. 1028	P.R. 1048	P.R. 1059	M. 336	Co. 419
	Millimhos/cm.	*G.*	*G.*	*G.*	*G.*	*G.*	*G.*	*G.*	*G.*	*G.*	*G.*
A, tapwater	1.00	1.07	1.09	0.44	1.07	0.59	1.16	0.49	0.62	0.82	0.87
B, 4,000-p.p.m. NaCl	5.40	.89	.54	.42	.53	.78	.69	.43	.43	.66	.73
C, 8,000-p.p.m. NaCl	54.0	.57	0	1.05	.25	.09	.43	0	0	.99	.51
[1] L.S.D. at 5-percent level		0.75	0.34	0.77	0.85	0.43	0.98	0.32	0.25	0.69	1.09
[1] L.S.D. at 1-percent level		—	.52	—	—	—	—	—	.38	—	—

TABLE 3.—*Growth differences in sugarcane as affected by different levels of soil salinity in the greenhouse*

Treatments	Salt conductivity	Growth of stem									
		P.R. 980	P.R. 1000	P.R. 1013	P.R. 1016	P.R. 1017	P.R. 1028	P.R. 1948	P.R. 1059	M. 336	Co. 419
5 weeks old[1]											
		In.	*In.*	*In.*	*In.*	*In.*	*In.*	*In.*	*In.*	*In.*	*In.*
A, tapwater	0.4	17.8	10.1	14.2	12.3	14.7	14.4	15.9	14.0	15.7	14.0
B, 4,000-p.p.m. NaCl	3.9	13.6	7.2	11.2	10.8	13.1	13.0	15.6	10.0	14.7	12.0
C, 8,000-p.p.m. NaCl	20	11.7	6.7	10.3	8.4	10.6	12.1	9.7	8.2	9.8	10.7
11 weeks old[2]											
A, tapwater	1.0	23.0	14.5	18.8	19.1	20.1	19.5	21.6	16.7	20.3	18.0
B, 4,000 p.p.m. NaCl	5.4	21.2	10.7	14.3	12.9	17.2	16.0	16.1	13.6	16.9	13.3
C, 8,000 p.p.m. NaCl	54	15.0	0	18.3	8.3	12.0	17.7	0	0	12.8	10.0
[1] L.S.D. at 5-percent level between treatments											
A and B		3.18	2.12	2.39	1.80	1.83	2.77	2.48	2.30	2.56	2.34
A and C		3.32	2.28	2.62	1.75	1.77	2.84	2.38	2.75	2.54	2.44
B and C		3.18	2.28	2.60	1.70	1.83	2.53	2.25	2.75	2.51	2.44
L.S.D. at 1-percent level between treatments											
A and B		4.22	2.82	3.18	2.40	—	—	3.31	3.07	3.40	3.12
A and C		4.41	3.03	3.50	2.37	—	—	3.17	3.66	3.37	3.25
B and C		4.22	3.03	3.46	2.26	—	—	3.00	3.66	3.33	3.25
[2] L.S.D. at 5-percent level between treatments											
A and B		2.47	3.45	3.01	4.30	3.09	4.29	2.96	4.02	3.27	4.13
A and C		3.83	—	5.46	7.74	3.99	4.81	5.67	6.88	4.76	6.65
B and C		3.93	—	5.57	8.07	4.38	5.18	5.81	7.50	5.03	7.36
L.S.D. at 1-percent level between treatments											
A and B		3.31	4.64	4.04	5.83	4.13	—	4.00	5.41	4.38	—
A and C		5.14	—	7.32	10.49	5.33	—	7.66	9.27	6.38	—
B and C		5.27	—	7.48	10.94	5.84	—	7.86	10.10	6.73	—

coefficients (r) were all negative, indicative of decreases of stem growth with increases in salt conductivity of the soil. Table 4 shows the functional relationship worked out and gives the coefficient of correlation. The F-value was highly significant on all the varieties tested as a whole. This implies that stem growth could be used as a criterion for estimating salt resistance of sugarcane. However, the F-values, when correlated individually, were significant only on the varieties P.R. 1000 and P.R. 1048, which means that stem growth can be used as a significant criterion only on those two varieties.

P.R. 1013, which had the lowest correlation coefficient $r = -0.2662$, was disregarded because of the inconsistency of the data in stem growth which

TABLE 4.—*Salt conductivity of soils in relation to growth of 10 sugarcane varieties*

Variety	Functional relationship[1]	Correlation coefficient (r)	F-value[2]
P.R. 980	$Y = 0.3773 - 0.0035X$	−0.6850	3.53
P.R. 1000	$Y = .2219 - .0039X$	−.8731	12.83*
P.R. 1013	$Y = .2903 - .0010X$	−.2662	.300
P.R. 1016	$Y = .2811 - .0033X$	−.7445	4.97
P.R. 1017	$Y = .3331 - .0033X$	−.6931	3.69
P.R. 1028	$Y = .3234 - .0015X$	−.3887	0.71
P.R. 1048	$Y = .3700 - .0067X$	−.8442	9.92*
P.R. 1059	$Y = .1960 - .0029X$	−.5441	1.68
M. 336	$Y = .3417 - .0034X$	−.6659	3.18
Co. 419	$Y = .3067 - .0030X$	−.5837	2.06
All varieties	$Y = .3123 - .0034X$	−.6072	33.8753**

[1] Y = daily average growth of stem to be estimated (inches); X = Salt conductivity (millimhos/cm.).

[2] * = regression is significant; ** = regression is highly significant.

was probably caused by an error. Judging from the effect of salt conductivity of the soil on the daily average stem growth, P.R. 1028 was the most resistant variety to soil salinity with $r = -0.3887$, and P.R. 1000 was the most susceptible one with $r = -0.8731$. The rankings of the sugarcane varieties from the most resistant to the least resistant were as follows: P.R. 1028 > P.R. 1059 > Co. 419 > M.336 > P.R. 980 > P.R. 1017 > P.R. 1016 > P.R. 1048 > P.R. 1000.

Canes appeared normal in the highly susceptible varieties throughout the experiment in the control soil, with a salt conductivity of 1.0 millimhos/cm. But in the salt-treated soil, with a salt conductivity that exceeded 5.4 millimhos/cm., canes were quite similar to those in the control for the first 3 weeks, and then decreased in stem growth as the salt conductivity of the soil increased.

When the salt conductivity of the treated soil reached 20 millimhos/cm. canes showed visible difference in growth and became stunted. The color of the leaves of the severely stunted canes was abnormal and changed from pale green to yellow with intermediate appearance of interrupted yellow, and a general yellowish tinge. Their lower leaves became white, with blackish patches of dead tissues. When the salt conductivity of the soil reached 54 millimhos/cm. most canes of the susceptible varieties died before the experiment was completed.

It has been known for years that saline soil in which plants were grown played an important role in retarding growth and causing injury. According to Ehlig and Bernstein (*4*), strawberry yields were drastically reduced when salt conductivity of the soil was over 2.6 millimhos/cm. Similarly, Hayward and Long (*5*) reported that vegetative growth of tomato plants was reduced at a salt concentration equivalent to, or above 1.5 atm. of osmotic pressure. In sugarcane, no significant effect on stem growth and root development was obtained in this experiment when grown in the soil with a salt conductivity below 5.4 millimhos/cm. In the susceptible varieties of sugarcane salt injuries developed first on sugarcane in soil with a salt conductivity at 5.4 millimhos/cm., which is in line with the findings of Shoji and Sund (*11*) in Iran.

The results obtained in this study generally agreed with the findings of Shen and Tung (*10*) in Taiwan that varieties of sugarcane differed greatly in their salt tolerance. These differences in salt tolerance among varieties should prove successful in developing varieties of sugarcane more tolerant to salinity.

In assessing the suggested tolerance as obtained in this experiment, we must bear in mind that this study differs from other salt-tolerance studies in that the levels of soil salinity increased during the growth of the canes, and an acid soil was used. Since the effect of soil salinity on the yield of both bean tops and pods varied with stage of growth at which salinization took place (*7,8*), and since the importance of stage of growth at time of salinization has also been demonstrated for barley and wheat (*1*), grapevines (*2*), and rice (*6,9*), it is possible that the results obtained in this study may vary somewhat from the field observations where the level of soil salinity remains more or less the same during the entire growth period of the canes. Furthermore, this was only a greenhouse experiment; field tests are needed to confirm the correlations established in these tests.

SUMMARY

A study was made to determine the salt resistance of 10 sugarcane varieties, P.R. 980, P.R. 1000, P.R. 1013, P.R. 1016, P.R. 1017, P.R. 1028, P.R. 1048, P.R. 1059, M. 336 and Co. 419, in the greenhouse, where canes were established in soil initially nonsaline and irrigated with 0, 4,000-,

and 8,000-p.p.m. solutions of sodium chloride at 2- to 3-day intervals. Among the three criteria, percentage of germination, rate of stem growth, and dry weight of root, used for evaluating varietal resistance to soil salinity, the rate of stem growth appeared to be the most significant.

Based on the effect of the salt conductivity on the soil on the daily average stem growth, P.R. 1028 was the most resistant variety to soil salinity and P.R. 1000 was the most susceptible. P.R. 1028 showed no appreciable effect of salt concentration on stem growth, nor did it show any signs of salt damage on root development, when grown in the soil with a salt conductivity as high as 20 millimhos/cm., while P.R. 1000 had salt injuries when grown in the soil with a salt conductivity that exceeded 5.4 millimhos/cm.

RESUMEN

Se hizo un estudio para determinar la resistencia a la sal en el suelo de las variedades de caña de azúcar siguientes: P.R. 980, P.R. 1,000, P.R. 1013, P.R. 1016, P.R. 1017, P.R. 1028, P.R. 1048, P.R. 1059, M. 336 y Co. 419. Estas cañas se sembraron en un invernadero donde el suelo inicialmente no tenía sal, pero que luego fue regado cada 2 a 3 días con agua corriente y con soluciones que contenían cloruro de sodio en las proporciones de 4,000 y 8,000 p.p.m.

Entre los tres criterious que se usaron para evaluar el grado de resistencia de las variedades de caña a la sal, a saber, porcentaje de germinacíon, ritmo del crecimiento del tallo y peso seco de las raíces, el ritmo del crecimiento del tallo fue el más significativo al hacer la evaluacíon.

Basado en el efecto de la conductividad de la sal en el suelo sobre el crecimiento promedio diario del tallo, la variedad P.R. 1028 resultó ser la más resistente a la salinidad y la P.R. 1000 la más susceptible. La P.R. 1028 no demostró que la concentración de sal le afectara apreciablemente el crecimiento del tallo, ni tampoco hubo señales de que sufriera daño alguno en el crecimiento de sus raíces cuando se desarrolló en un suelo con una conductividad tan alta como 20 millimhos/cm., mientras que la P.R. 1000 demostró daños causados por la sal cuando se desarrolló en el suelo cuya conductividad de sal excedía 5.4 millimhos/5 cm.

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