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Effects of Soil Salinity Status on Pineapple
I. Growth Parameters

H. Wambiji and S. A. El-Swaify

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FOREWORD

Departmental Paper 22, Hawaii Agricultural Experiment Station, Contribution 612, Hawaii Institute of Geophysics, is based on a thesis submitted by the senior author in partial fulfillment of the requirements for the M.S. degree, University of Hawaii.

ABSTRACT

Pineapple slips and transplants 8 and 12 months old were grown in a greenhouse on Wahiawa silty clay soil, which had been brought to salinity levels corresponding to electrical conductivities of 2, 4, 6, and 8 mmhos/cm in saturated soil solution. It was found that both the salt level and duration of treatment had profound effects on leaf enlargement, weight, elongation, and water potentials. Losses of fresh and dry weights at the end of 6 months of growth indicated that pineapple may be classified as a high tolerance crop and that its tolerance to salinity increases with age.

EFFECTS OF SOIL SALINITY STATUS ON PINEAPPLE
I. GROWTH PARAMETERS

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INTRODUCTION

Pineapple [*Ananas comosus* (L.) Merr] is a major crop in Hawaii's agriculture. It is known to be drought-resistant (*2*) as it grows successfully under little precipitation or irrigation, by comparison consuming only about a third of the water used by bermudagrass grown under similar environments. Its resistance to water stress may also indicate high tolerance to salinity in soils or in irrigation water. This assumption is supported by the work of Sideris and Young (*7*) in solution cultures and by later observations of Sideris (*6*) on the effects of sea spray. As is true for many tropical crops (*8*), however, little published information is available on the response of pineapple to salt content in soils or irrigation water. This study was conducted to evaluate the effect of different soil salinity levels on the growth performance of pineapple plants at several stages of development.

MATERIALS AND METHODS

The surface plow layer (Ap horizon) of Wahiawa silty clay, a Tropeptic Eutrustox widely used for pineapple production and previously classified as a Low Humic Latosol, was used as a planting medium in greenhouse pots. As reported for other Oxisols (*3*), this soil is made up primarily of kaolin and oxide minerals, has excellent structure, and lends itself well as a growth medium under imposed sodic conditions. Other characteristics of this soil are shown in Table 1.

Table 1. Some characteristics of Ap horizon of Wahiawa silty clay

Characteristic	Value
Depth, cm	0-30
Water retention, gravimetric %	
1/3 bar	52
15 bar	25
Organic carbon, %	1.6
pH, 1:1	
in water	5.8
in *N* KCL	5.0
Cation exchange capacity, me/100 g	18
Exchangeable cations, me/100 g	
Ca	5.6
Mg	2.6
K	0.92
Na	0.31
Acidity	8.3

Plants were potted from slips (in 1-gallon pots) and from 8- and 12-month-old transplants (in 5-gallon pots). Optimum water, pesticide, and nutritional requirements consisting of foliar sprays appropriate for supplying the plants with N, P, K, Mg, B, Mn, S, Zn, Cu, Fe, and Mo, were maintained. Salinity treatments were begun one month after planting. NaCl was used to provide a level of electrical conductivity ($E.C._{25}$) that corresponded to the levels of control, 2 (low), 4 (medium), 6 (medium-high), or 8 (high) mmhos/cm. Salt concentrations were gradually increased at the rate of 2 mmhos/24-hour interval until the final desired level was achieved, so that sudden shock by salt concentration gradients was avoided. Soil samples were collected 5 days after salinization and later at biweekly intervals to verify the exact salt concentration level at prevailing water content throughout the duration of the experiment. Results showed that the controls experienced a mean conductivity range from 1.2 mmhos/cm at planting to 5.1 mmhos/cm at harvest; the low treatments, 2.9 to 7.1 mmhos/cm; the medium, 4.8 to 10.2 mmhos/cm; the medium-high, 6.8 to 15 mmhos/cm; and the high, 9.4 to 20 mmhos/cm. Table 2 shows detailed electrical conductivity trends for slip plantings throughout the experiment.

The experiment design consisted of a 1 by 3 by 5 factorial laid out in a rotating randomized block with three replicates for each age group. Using tensiometer readings of 0.7 bars as a guide to irrigation, tap water was required almost daily, but in varying amounts depending on pot size. The experiment was continued for six months. All leaf measurements were conducted on the d-leaves. Leaf enlargement, weight, elongation, and leaf water potential, using the dye method (*4*), were monitored at the regular intervals of approximately two weeks. Plant heights of slip plantings were also monitored. Fresh- and dry-matter weights for plants and subsequent suckers were determined at the end of the growth period. Nutrient absorption was also monitored, but results on that phase of the study are reported separately (*10*).

Table 2. Effect of salt application on electrical conductivity of soil solution for slip plantings

	E.C.25 x 103 mmhos				
Month	Control	Low	Medium	Medium-high	High
1	1.18	3.72	6.13	8.18	9.78
2	1.59	3.89	6.56	8.21	10.62
3	2.20	4.56	6.64	8.64	11.16
4	2.76	5.58	7.99	11.25	12.55
4 1/2	2.71	5.21	7.65	10.40	11.55
5	3.88	6.06	7.86	12.01	14.35
5 1/2	3.20	4.96	7.26	11.44	13.96
6	4.33	6.80	8.80	13.90	16.64
Harvest	4.60	6.50	10.70	15.40	18.30

RESULTS AND DISCUSSION

As shown in Table 3, the extent to which leaves were enlarged during the growth period was significantly affected by salt level as well as by duration of treatment. Calculations of F values by analysis of variance

Table 3. Effect of salinity treatment on leaf enlargement

Planting	Month	Control leaf enlargement, cm	Enlargement, % of control			
			Low	Medium	Medium-high	High
Slips	1	2.3	92	90	115	103
	2	2.4	97	96	115	105
	3	2.5	96	98	110	105
	4	2.6	94	95	106	100
	5	2.7	90	89	99	89
	6	2.8	84	82	91	81
8-month-old transplants	1	6.4	102	104	102	98
	2	6.4	100	97	95	86
	3	5.9	108	100	91	81
	4	5.5	105	92	82	73
	5	5.3	101	88	75	73
	6	6.4	75	65	58	59
12-month-old transplants	1	7.6	108	119	116	123
	2	6.5	117	135	125	128
	3	6.5	99	108	95	113
	4	6.1	78	97	82	104
	5	6.4	60	72	63	66
	6	5.7	55	77	66	67

showed the salt effects to be significant at the 1% level for the slips and at the 5% level for the 8- and 12-month-old transplants. Effect of duration, on the other hand, was significant at the 5% level for the slips and at the 1% level for the transplants. After 3 months, it was noted that, in all cases, treatment caused reduction of leaf enlargement, particularly in the 8-month-old transplants. This finding is not surprising since pineapple is presumed to have attained its maximum growth rate at the 8-month stage. Linear regression analysis for enlargement showed better correlation against salinity levels than against duration. Values of r2 for salinity level ranged from 0.61 to 0.77 for slips, 0.51 to 0.74 for 8-month-old transplants, and from 0.63 to 0.76 for 12-month-old transplants; values of r2 for duration of treatment ranged from 0.70 to 0.49 for slips, 0.72 to 0.44 for 8-month-old transplants, and from 0.67 to 0.49 for 12-month-old transplants. In all cases, there was a continuous decrease over the growth period, especially in the last two months.

Table 4. Effect of salinity treatment on d-leaf weight

Planting	Month	Control leaf weight, cm	Weight, % of control			
			Low	Medium	Medium-high	High
Slips	1	6.7	110	100	58	75
	2	8.1	98	106	58	73
	3	9.3	90	96	65	56
	4	10.0	74	71	50	43
	5	10.0	79	65	46	37
	6	11.2	71	50	35	28
8-month-old transplants	1	27.7	148	118	133	118
	2	34.4	94	84	83	81
	3	38.0	115	87	84	73
	4	40.8	106	69	76	65
	5	34.6	115	73	75	69
	6	27.6	107	88	73	74
12-month-old transplants	1	70.5	103	114	111	108
	2	89.2	104	105	104	105
	3	99.0	89	101	99	93
	4	91.0	101	96	81	107
	5	72.5	88	102	107	102
	6	70.5	103	108	95	95

Table 4 shows d-leaf weights to be clearly affected by salinity treatments. The F values from analysis of variance show that salinity effects were significant at the 1% level for all stages of growth. As shown in data on controls, the weights increased consistently with time only for the slips. On the other hand, for both transplant groups weights declined consistently after the fourth month of growth. Again, as for enlargement, linear-regression analysis for leaf weights showed better correlation against salinity levels than against duration. Values of r2 for salinity level ranged from 0.63 to 0.85 for slips, 0.71 to 0.76 for 8-month-old transplants, and from 0.63 to 0.79 for 12-month-old transplants. For duration, corresponding values ranged from 0.50 to 0.32, 0.67 to 0.49, and 0.71 to 0.69 for the three age groups, respectively, and generally the lower values were obtained for the later months of treatment.

Plant height (for slips) and d-leaf elongation (for both age groups of transplants) were also evaluated. Table 5 shows that slips made little progress during the growth period. F-values from analysis of variance show that reported salinity effects were significant at the 1% level and that the effects of length of treatment (duration) were also significant, but only at the 5% level. Both effects were significant at the 1% level for d-leaf elongation of 8-month-old transplants. In contrast, neither salt level nor

Table 5. Effect of salinity treatment on plant height (slips) or leaf elongation (transplants)

Planting	Month	Control length, cm	Length, % of control			
			Low	Medium	Medium-high	High
Slips	1	26.0	105	100	96	91
	2	29.0	109	118	104	94
	3	32.6	111	122	100	94
	4	37.7	93	94	95	87
	5	40.1	90	86	81	76
	6	42.6	83	76	71	67
8-month-old transplants	1	56.6	98	105	108	103
	2	62.3	104	113	111	103
	3	74.5	108	104	93	78
	4	81.6	114	96	85	71
	5	74.5	108	99	88	72
	6	71.1	108	99	88	72
12-month-old transplants	1	43.5	109	121	124	113
	2	58.0	108	114	145	107
	3	70.3	79	95	111	83
	4	60.6	93	94	97	81
	5	48.6	107	100	101	101
	6	47.0	102	103	97	95

duration had significant effects on this parameter for the 12-month-old transplants. Linear regression analysis for plant height or d-leaf elongation showed slightly better correlation against salt level than against duration of treatment, in confirmation with the previously mentioned parameters. Values of r2 for salinity level ranged from 0.76 to 0.87 for slip height, from 0.67 to 0.78 for 8-month-old leaf elongation, and from 0.75 to 0.87 for 12-month-old leaf elongation. Corresponding values for duration were 0.53 to 0.62, 0.46 to 0.73, and 0.61 to 0.71, respectively.

Leaf-water potential (LWP), monitored throughout the growth period, is shown in Table 6. A linear increase in LWP appears to occur as a result of increases in salinity level, which reflects the osmotic adjustment made by the plant to counteract changes of osmotic potential in the soil solution. Similar observations were previously made on other crops (*1*, *4*, *5*) and reflects increased mineral absorption by the plants. This was confirmed by direct measurements reported separately (*10*). Analysis of variance for data in Table 6 showed that changes in LWP due to salinity levels were significant at the 1% level for all age groups. Time effects were less significant, particularly for 12-month-old transplants in the last three months of their treatment. Regression analysis showed r2 values for LWP changes with salinity level and treatment duration to be the best among all parameters studied, generally falling above 0.80 and reaching as high as 0.91.

Table 6. Effect of salinity treatment on leaf-water potentials (LWP)

Planting	Month	Control LWP (- Atm)	LWP, % of control Low	Medium	Medium-High	High
Slips	1	6.7	115	145	160	182
	2	8.5	127	139	144	172
	3	10.2	120	135	160	171
	4	10.1	133	159	176	198
	5	10.1	154	166	195	223
	6	13.0	125	139	171	199
8-month-old transplants	1	11.4	99	121	118	142
	2	13.0	115	125	142	151
	3	14.8	115	124	149	155
	4	12.2	133	150	175	194
	5	11.8	122	153	179	199
	6	13.0	118	134	152	165
12-month-old transplants	1	13.1	105	131	108	130
	2	13.6	122	118	142	147
	3	13.8	121	130	150	167
	4	13.4	141	143	149	159
	5	12.2	149	159	171	187
	6	13.4	132	146	157	150

Finally, the effect of salinity on mean plant weights at the end of the growth period is shown in Table 7. Both fresh and dry weights decreased with increasing soil-salinity levels. The majority of the decrease was encountered at and above the medium-high level. Dry weights appear to have sustained greater loss than fresh weights. It was also noted that the response of the 12-month-old transplants to treatment was rather erratic,

Table 7. Effect of salinity on plant weights

Salt treatment	Fresh weight Slips	Fresh weight 8-mo.-old transplants	Fresh weight 12-mo.-old transplants	Dry weight Slips	Dry weight 8-mo.-old transplants	Dry weight 12-mo.-old transplants
Control	180 g	6865 g	7441 g	28 g	460 g	1130 g
	% of Control					
Low	96	104	113	101	129	97
Medium	92	105	130	89	116	113
Medium-high	86	97	114	88	95	84
High	80	98	126	75	90	108

perhaps because of the tendency to produce more fruit and suckers, which were included in totaling green- and dry-matter production. Scattered observations of fruit sizes on 12-months-old transplants showed a considerable reduction from 1530 g in control to 495 g, 637 g, and 761 g in the low-, medium-, and high-salt treatments, respectively. These data must be considered only as indicative since fruit production was insufficient to render the data subject to statistical analysis. Similar trends were noted for sucker dry weights, which decreased from a mean of 26 g for control to 19 g, 16 g, and 10 g for the low, medium, and high treatments, respectively.

CONCLUSIONS

The criterion developed by the U.S. Salinity Laboratory Staff (*9*) is that the salinity level at which a reduction of 50% occurs in yield may be used to set the salt tolerance of a given crop. Using fresh and dry weights as a measure of pineapple performance, slips, even though less tolerant than the other two age groups, may be classified as "high" in tolerance class since reduction in their dry-weight production never exceeded 25% of the control. This class includes such tolerant plants as barley, cotton, asparagus, and bermudagrass. Transplants, older than slips, appear to be even more tolerant, indicating that pineapple is a salt-tolerant crop. Field evaluation of these greenhouse results would be advisable, however, before formal limits are set for the salt tolerance of this crop.

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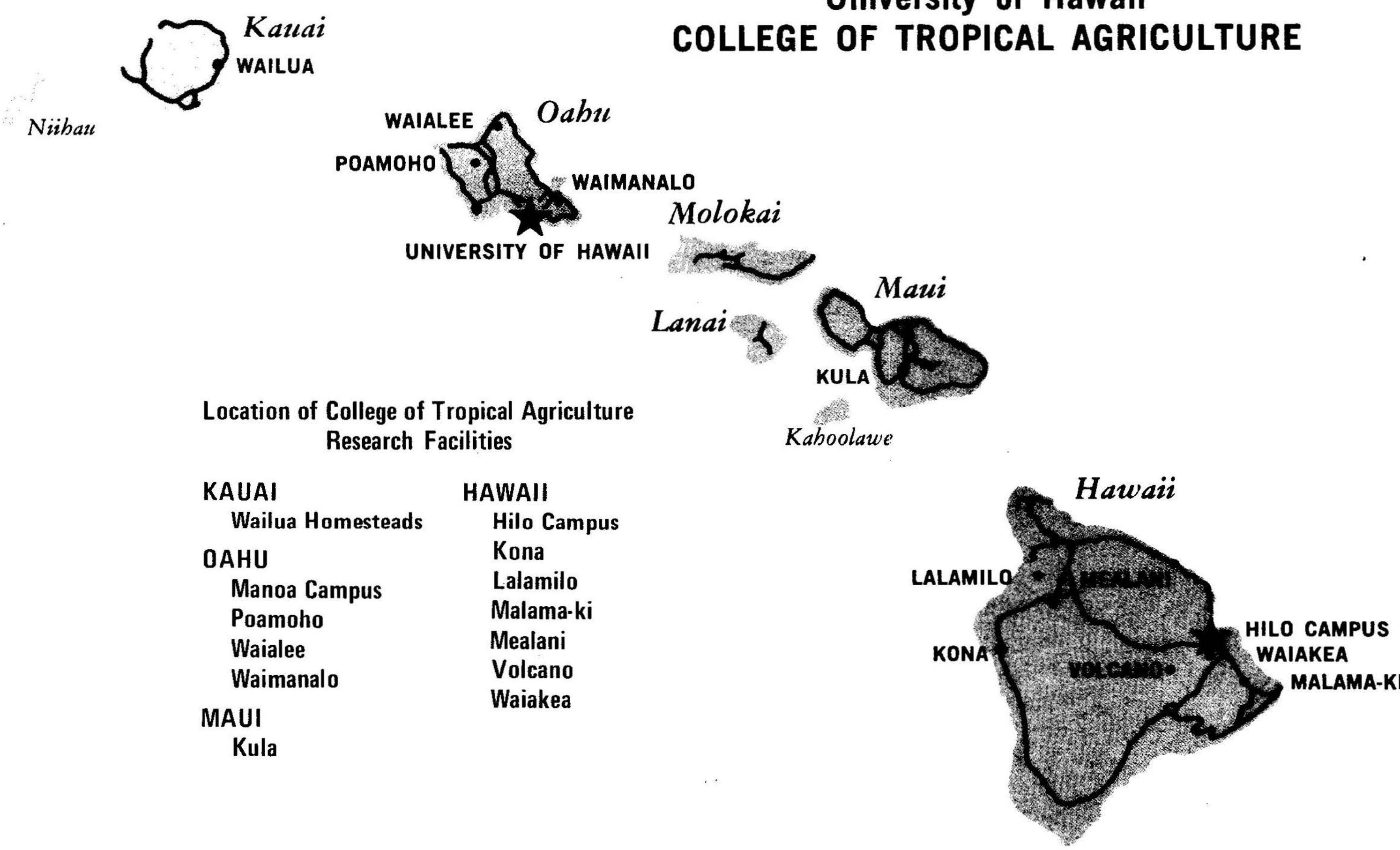

Location of College of Tropical Agriculture Research Facilities

KAUAI
- Wailua Homesteads

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MAUI
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