Pineapple yield and quality on a banana soil of the Canary Islands irrigated with acid and saline water

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Pineapple (*Ananas comosus* L. Merr) plants, cultivar 'Red Spanish', were grown in a greenhouse in 300-L containers, with soil from a banana plantation, and irrigated with saline and acid waters. Essential chemical soil characteristics were a pH of 6.9, electrical conductivity (EC) 1,26 dS m^{-1}, and available nutrient status 188 ppm P, 11.95 meq $(100\text{-g})^{-1}$ Ca, 5.35 meq $(100\text{-g})^{-1}$ Mg, 3.96 meq $(100\text{-g})^{-1}$ K, and 2.17 meq $(100\text{-g})^{-1}$ Na. Irrigation water treatments consisted of control (tap water); 7, 14, 21, and 28 meq L^{-1} NaCl; 10, 15, 20, and 25 meq L^{-1} $NaHCO_3$; and 75 meq L^{-1} H_2SO_4. Sodium chloride at levels of 14 meq L^{-1} and above in water affected fruit yield and quality adversely. Neither acid water nor bicarbonated waters had any effect on the fruit, except for the highest level of $NaHCO_3$.

Keywords: Pineapple; Acidification; Salinity; Yield; Quality

In the Canarian Archipelago, pineapples (*Ananas comosus* L. Merr.) are mostly grown in soils formerly used for the culture of bananas; many of these soils have a neutral or alkaline pH (Díaz, 1975). The optimum soil pH values for pineapples are between 4.5 and 5.5, but yields decrease more rapidly with an increase in acidification than an increase in alkalinization outside that pH range (Py *et al.*, 1987). The main pineapple cultivar in the Canary Islands ('Red Spanish') responds well to neutral pH conditions (Alvarez *et al.*, 1987), though practices to reduce the pH are encouraged. Farmers in the Canarian Archipelago have to use waters with high contents of NaCl and (or) $NaHCO_3$ to irrigate pineapples. However, since pineapples are generally cultivated in rainy regions, the problems related to irrigation with these types of waters have not received attention, with the exception of chloride damages related to sea-water sprays and KCl fertilizer use. Sideris (1955) observed that pineapple plants exposed to wind-blown sea-water sprays developed leaf-tip necrosis. Chloride solutions applied to pineapple plants grown in fields beyond the range of wind-blown sea-water sprays produced symptoms of leaf-tip necrosis and materially reduced the yields and quality of the fruits. Sideris and Young (1954) reported that pineapples cultivated in nutrient solutions containing chlorides developed similar foliar symptoms to those of plants affected by sea-water sprays. The chlorine ion from KCl fertilizers also produces leaf necrosis and has a depressive effect on fruit weight (Samuels and Ganda, 1960; Marchal *et al.*, 1981). However, chloride increases fruit acidity and, therefore, KCl is recommended (1/4 to 1/3 of total quantity of K) when fruits lack acidity (Py *et al.*, 1987). In this study the effect of progressive acidification and irrigation with low-quality waters on pineapple yield and quality on a neutral pH soil, formerly cultivated with bananas in Tenerife (Canary Islands), is assessed.

*Regrettably died in March 1995

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Materials and Methods

The experiment was conducted in a greenhouse with pineapple (*A. comosus* L. Merr.) plants, cultivar 'Red Spanish'. The plants were grown in a soil prepared with a mixture of soil and peat (10:1) in 300-L containers, four plants per container. The soil was from a banana plantation of La Orotava (Tenerife) and it was similar to the soils on which pineapples are cultivated. The chemical characteristics of the original soil are given in Table 1.

Suckers, uniform in appearance, and total fresh weight (250 g) were chosen. Daily and nocturnal temperatures varied between 30 ± 4°C and 12 ± 3°C, and the relative humidity was 55–75%. The greenhouse was shaded to avoid excessive temperature during late spring, summer, and early autumn.

The plants received 10 L of water per container at each irrigation, scheduled according to data obtained from irrometers placed in 10 containers chosen at random. Chemical analysis of the tap water (control) is given in Table 2. The saline treatments consisted of NaCl or $NaHCO_3$ salts added to the 10 L of tap water to obtain the following concentrations: 7, 14, 21, and 28 meq L^{-1} NaCl and 10, 15, 20, and 25 meq L^{-1} $NaHCO_3$. These concentrations were chosen in accordance with the most frequent range of low-quality waters in Tenerife (Fernández and Pérez, 1974). The acid treatment consisted of 75 meq L^{-1} H_2SO_4 added to the 10 L of tap water. The experiment was a randomised complete block design with five replications per treatment and four plants per replication.

The suckers were planted in July 1986, and each plant received 14 g of N as ammonium sulphate, 2 g of P as monoammonium phosphate, and 7 g of K as potassium sulphate. Fertilizers were applied in irrigation water during the pineapple culture until flower induction was performed.

Artificial flower induction was made in July 1987 with 25 mL per plant of 5% calcium carbide, and the plants were harvested between November 1987 and March 1988.

Soil analysis

Soil samples from every replication of the treatments were taken in November 1986 and July 1987. The samples were dried in air and passed through a 2-mm mesh. The pH was measured in a soil:water ratio of 2:5 after shaking and allowing to settle for 10 min.

Available cations were extracted with a 1M ammonium acetate solution at a pH of 7 and determined by atomic absorption spectrophotometry. Available phosphorus was extracted by the method of Olsen *et al.* (1954) and determined by the method of Watanabe and Olsen (1965).

Soluble ions and electrical conductivity (EC) were determined from the saturated water extract; Na, K, Ca, and Mg were measured by atomic absorption spectrophotometry; bicarbonates were determined by the Rettemeier method (Rodier 1981); and chlorides were measured by titration with silver nitrate (Chapman and Pratt, 1961).

Foliar analysis

Standard "D" leaves (Py and Pélegrin, 1958) from every replication of the treatments were sampled in July 1987. The samples were washed in distilled water and their lengths, widths, and fresh weights were measured. Dry weights were determined after drying to constant weight in an oven at 80°C. Dried leaves were ground to a powder and 0.2 g used to determine N by the Kjeldahl method (Cottenie, 1980). A further 1 g of the powder was ashed in an oven at 480°C for 4 h and then digested in 6M HCl (Chapman and Pratt, 1961). Potassium, Ca, Mg, and Na were determined by atomic absorption spectrophotometry, and P by the vanadate–molybdate method (Chapman and Pratt, 1961). A sample of 2 g of the powder was shaken in 20 mL of water for 30 min, and filtered. Chlorides were determined in this water extract by the Mohr method (Johnson and Ulrich, 1959).

Fruit analysis

Total weight, weight without crown, perimeter, and length of every fruit were measured. Free acids content was determined by titrating 10 mL of fruit juice with 0.1N NaOH. Sugar content of the juice was measured with a digital refractometer.

Data were subjected to analysis of variance and correlation analysis using SPSS/PC+ statistical program (Norusis, 1988).

Results and Discussion

The pH of the soil samples taken in November 1986 (four months after the treatments began) were not significantly affected by any of the treatments. However, samples taken in July 1987

Table 1 Chemical characteristics of the original soil

pH	P (ppm)	Available cations [meq (100-g)$^{-1}$] Ca	Mg	Na	K	Soluble ions (meq L^{-1}) Na	Ca	Mg	Cl	HCO_3^-	EC (dS m^{-1})
6.92	188	11.95	5.35	2.17	3.96	6.52	3.60	3.80	3.2	1.0	1.26

EC is electrical conductivity

Table 2 Mean and standard deviation (SD) of the chemical characteristics of the tap water

	pH	EC (ds m^{-1})	Ca	Mg	Na	K	Cl	HCO_3^-
			- - - - - - - - - -	(meq L^{-1})	- - - - - - - - - -			
Mean	8.21	0.67	1.05	3.34	4.15	0.50	0.81	6.99
SD	0.177	0.083	0.189	0.415	0.648	0.178	0.134	0.785

EC is electrical conductivity

showed that the pH was significantly reduced by sulphuric acid and significantly increased by $NaHCO_3$. Sodium chloride at all concentrations did not affect the pH (Tables 3 and 4).

Soil P contents were very high compared to the values of 16.1–34.5 ppm established by Dalldorf and Langenegger (1978; cited by Py *et al.*, 1987) as medium. Although soil P was not affected by the treatments, plants irrigated with dilute H_2SO_4 showed higher leaf P levels. This finding may be explained by H^+ cotransport whereby phosphate uptake is promoted by low pH in the outer medium (Ullrich-Eberius *et al.*, 1981). All the leaf P values exceeded the minimum level (0.1%) recommended by Ramírez and González (1983).

The treatments did not affect leaf N and K levels (Table 5), except for the reduction of K concentration observed in the plants that received NaCl at 7 and 21 meq L^{-1}. Leaf K and N values exceeded the levels (1.29% for N and 2.28% for K) accepted by Chapman (1966).

Saline treatments significantly increased available and soluble Na but did not affect Na con-

Table 3 Means of soil chemical characteristics from the different treatments sampled in November 1986

Treatment	pH	P (ppm)	Available ions [meq (100-g)$^{-1}$] Na	Ca	Mg	Soluble ions (meq L^{-1}) Na	Ca	Mg	Cl	HCO_3^-	EC (dS m^{-1})
Control	6.88	463	3.26	15.40	7.05	9.13	5.60	5.80	4.4	1.5	2.31
H_2SO_4	6.63	444	2.61	15.00	6.89	10.87	9.40*	10.60*	3.0	2.0	2.89
NaCl 7 [meq (100-g)$^{-1}$]	6.93	477	2.61	14.45	6.40	9.13	4.40	5.60	3.4	1.2	1.89
NaCl 14 [meq (100-g)$^{-1}$]	6.93	444	2.61	14.85	6.64	11.30	6.40	7.60	5.6	1.1	2.41
NaCl 21 [meq (100-g)$^{-1}$]	6.94	444	3.26	16.10	7.30	11.74	6.20	6.80	8.2*	1.0	2.43
NaCl 28 [meq (100-g)$^{-1}$]	6.94	470	3.48	14.50	6.64	10.87	5.60	6.80	8.4*	0.6	2.29
$NaHCO_3$ 10 (meq L^{-1})	7.03	470	3.04	15.10	6.97	8.70	4.80	5.00	2.8	1.1	2.09
$NaHCO_3$ 15 (meq L^{-1})	6.94	438	3.48	13.45	6.23	10.00	5.40	6.00	4.0	1.0	2.33
$NaHCO_3$ 20 (meq L^{-1})	7.09	477	3.48	13.55	6.56	10.87	4.00	5.60	3.0	1.3	2.28
$NaHCO_3$ 25 (meq L^{-1})	6.99	432	2.61	13.75	6.40	9.13	4.80	4.80	3.0	1.3	2.11

Values within the same column followed by an asterisk (*) are significantly different from the control at the 0.05 level
EC is electrical conductivity

Table 4 Means of soil chemical characteristics from the different treatments sampled in July 1987 at floral induction

Treatment	pH	P (ppm)	Available ions [meq (100 g)$^{-1}$] Na	Ca	Mg	Soluble ions (meq L^{-1}) Na	Ca	Mg	Cl	HCO_3^-	EC (dS m^{-1})
Control	5.78	430	1.09	12.05	5.00	8.61	19.01	8.10	4.2	1.4	3.66
H_2SO_4	5.10*	398	1.15	18.05*	7.38*	11.13	24.10*	35.32***	4.6	1.4	5.32*
NaCl 7 [meq (100-g)$^{-1}$]	6.18	470	1.91	12.45	5.05	14.52*	15.21	11.00	10.0***	1.4	3.80
NaCl 14 [meq (100-g)$^{-1}$]	5.84	515	2.64*	10.85	4.26	22.43**	14.60	11.11	15.4***	2.2	4.82
NaCl 21 [meq (100-g)$^{-1}$]	6.05	460	4.13**	12.45	5.25	32.83***	18.00	12.83	28.8***	2.3	6.60**
NaCl 28 [meq (100-g)$^{-1}$]	6.13	443	4.85**	12.25	4.92	29.13***	15.23	10.80	28.3***	1.7	5.67*
$NaHCO_3$ 10 (meq L^{-1})	6.22*	470	2.78*	12.60	5.08	20.69**	16.61	12.43	5.0	3.5*	4.65
$NaHCO_3$ 15 (meq L^{-1})	6.65*	552	3.04**	11.90	5.41	20.26**	15.93	11.93	4.0	4.0**	3.53
$NaHCO_3$ 20 (meq L^{-1})	6.79*	563	5.26***	12.20	5.58	33.74***	17.00	12.20	6.0	5.0***	5.37*
$NaHCO_3$ 25 (meq L^{-1})	6.85*	550	6.19***	11.95	5.25	36.96***	16.11	11.95	5.2	6.0***	5.52*

Values within the same column followed by *, **, or *** are significantly different from the control at the 0.05, 0.01, or 0.001 level, respectively
EC is electrical conductivity

Table 5 Means of leaf nutrient concentration from the different treatments sampled in July 1987 at floral induction

Treatment	N	P	K	Ca	Mg	Cl	Na (ppm)
	- - - - - -	- - - - - -	- - - - - -	%	- - - - - -	- - - - - -	
Control	1.52	0.22	3.26	0.26	0.19	0.89	315
H_2SO_4	1.76	0.34***	3.15	0.26	0.20	0.90	318
NaCl 7 [meq $(100\text{-g})^{-1}$]	1.44	0.21	2.63*	0.25	0.16	0.98	225
NaCl 14 [meq $(100\text{-g})^{-1}$]	1.51	0.22	3.06	0.22	0.20	1.19*	405
NaCl 21 [meq $(100\text{-g})^{-1}$]	1.41	0.22	2.73**	0.21	0.18	1.19*	300
NaCl 28 [meq $(100\text{-g})^{-1}$]	1.46	0.27	3.06	0.37	0.18	1.43***	850***
$NaHCO_3$ 10 (meq L^{-1})	1.46	0.23	2.99	0.28	0.18	0.94	260
$NaHCO_3$ 15 (meq L^{-1})	1.70	0.27	2.99	0.25	0.16	0.90	328
$NaHCO_3$ 20 (meq L^{-1})	1.43	0.21	2.95	0.26	0.17	0.91	366
$NaHCO_3$ 25 (meq L^{-1})	1.47	0.22	2.94	0.22	0.16	0.94	564**

Values within the same column followed by *, **, or *** are significantly different from the control at the 0.05, 0.01, or 0.001 level, respectively

centration of the leaves, except for plants which received the highest levels of NaCl and $NaHCO_3$. Leaf Na contents were similar to those observed in pineapple plantations from El Hierro island (López, 1984).

Available Ca and Mg contents were high. Calcium levels from 4 to 10 meq $(100\text{-g})^{-1}$ are considered to be sufficient (Aubert, 1973; Giacomelli and Py, 1981), whereas an adequate range for Mg is 2.5–3.5 meq $(100\text{-g})^{-1}$ (Godefroy *et al.*, 1977). Sulphuric acid in the irrigation water dissolved Ca and Mg salts in the soil and increased soluble Ca and Mg, producing a significant increase in soil electrical conductivity (EC). However, the levels of these elements in the leaves were similar to those of the control and exceeded the minimum levels (0.19% for Ca and 0.16% for Mg) indicated by Chapman (1966).

As expected, water-soluble soil chloride and bicarbonate contents were related to the levels of NaCl and $NaHCO_3$. Sodium bicarbonate treatments did not affect nutrient (N, P, K, Ca, Mg, and Cl) concentrations of the leaves, except for Na, and NaCl treatments increased both Na and Cl. Leaf Cl was always high, exceeding more than twice the upper level of its normal range (0.11–0.43%) in 'Red Spanish' pineapple (Chapman, 1966). No symptoms of chloride damage were observed in the leaves, but NaCl treatments decreased weight, length, and perimeter of the fruits (Table 6) when leaf Cl attained 1.19%. Marchal *et al.* (1981) reported a decline in

Table 6 Total weight (TW), weight without crown (WWC), length, perimeter, free acids (FA), and sugar content (SC) of the fruits from the different treatments

Treatment	TW (g)	WWC (g)	Length (cm)	Perimeter (cm)	FA (meq%)	SC (%)
Control	596	534	8.65	32.74	21.15	16.18
H_2SO_4	541	487	8.54	32.57	15.25*	15.60
NaCl 7 [meq $(100\text{-g})^{-1}$]	625	564	8.89	32.42	15.80*	16.83
NaCl 14 [meq $(100\text{-g})^{-1}$]	444**	402*	7.71*	29.87*	14.90**	13.96***
NaCl 21 [meq $(100\text{-g})^{-1}$]	453**	409*	8.13	30.56*	18.41	13.81***
NaCl 28 [meq $(100\text{-g})^{-1}$]	463**	409*	7.81*	30.26*	14.44**	15.09*
$NaHCO_3$ 10 (meq L^{-1})	544	486	8.12	30.75	20.13	15.52
$NaHCO_3$ 15 (meq L^{-1})	545	490	8.51	32.33	15.70*	15.92
$NaHCO_3$ 20 (meq L^{-1})	532	485	8.53	31.69	16.28*	16.09
$NaHCO_3$ 25 (meq L^{-1})	489*	437	7.74*	31.04	13.33***	16.50

Values within the same column followed by *, **, or *** are significantly different from the control at the 0.05, 0.01, or 0.001 level, respectively yields when leaf Cl in 'Cayenne Lyssa' pineapples exceeded 1.8%.

Except for the highest level of 25 meq L^{-1}, $NaHCO_3$ did not influence fruit yields. Since Na is common in both $NaHCO_3$ and NaCl salts, the depressive effect of NaCl on fruit weight may be principally due to the Cl^- anion, corroborating the observations made by Sideris and Young (1954), Sideris (1955), Morard and García (1977), and Marchal *et al.* (1981).

Sodium chloride also decreased fruit sugar content. Sideris and Young (1954) reported that sugar accumulations in the plant tissues of pineapples were inversely related to chloride concentrations.

Most of the treatments reduced fruit free acids content, but their levels always exceeded the lower limit reported by Antoni and Leal, (1981).

The sulphuric acid treatment failed to increase yields above those of the control, though it lowered the soil pH to the optimum range. This fact may be explained by the increase in soil EC produced by solubilization of soil salts, so that it actually was similar to EC from some NaCl and $NaHCO_3$ treatments. This finding emphasizes the necessity for controlling soil EC when planning soil acidification needs and selecting irrigation water quality and irrigation schedules of pineapples in the Canary Islands.

References

Alvarez, C.E., Carracedo, A.E., García, C. and Fernández, M. (1987) Influencia del pH del suelo sobre el desarrollo y producción de la piña tropical, II. Desarrollo vegetativo y medidas, acidez y producción del fruto, *Anal. Edaf. Agrob.* **46** 1441–1456

Antoni, M.G. and Leal, F. (1981) Influencia de niveles de N, P, K sobre el rendimiento y calidad de la piña (*Ananas comosus* (L) Merr.) var. Española Roja, *Rev. Fac. Agron.* **29** 25–42

Aubert, B. (1973) La situation actuelle de la culture de l'ananas aux iles Hawaii, *Fruits* **28** 19–32

Chapman, H.D. (1966) Pineapple, in: *Diagnostic Criteria for Plants and Soils*, University of California, Division of Agricultural Sciences, Riverside, CA, U.S.A.

Chapman, H.D. and Pratt, P.F. (1961) *Methods of Analysis for Soils, Plants and Waters*, University of California. Division of Agricultural Sciences, Riverside, CA, U.S.A.

Cottenie, A. (1980) Soil and plant testing as a basis of fertilizer recommendations, *FAO Soils Bull.* **38** 98

Dalldorf, D.B. and Langenegger, W. (1978) Macroelement fertilization of smooth Cayenne pineapples, *Farming in South Africa, Pineapple Ser. E.* **2** (cited by Py *et al.*, 1987)

Díaz, A. (1975) Estudio de la fertilidad de los suelos y nutrición mineral en los cultivos de plátanos de Tenerife, *PhD Thesis*, University of La Laguna, Tenerife, Spain, 320 pp.

Fernández, E. and Pérez, V. (1974) *Características químicas de las aguas subterráneas de las Islas Canarias Occidentales (Tenerife, Palma, Gomera y Hierro)*, Aula de Cultura del Excmo. Cabildo Insular de Tenerife, Tenerife, Spain

Giacomelli, E.J. and Py, C. (1981) L'ananas au Bresil, *Fruits* **36** 645–687

Godefroy, J., Gaillard, J.P. and Haury, A. (1977) Evolution des caractéristiques chimiques d'un sol brun eutrophe du Cameroum sous culture d'ananas, *Fruits* **32** 591–597

Johnson, C.M. and Ulrich, A. (1959) *11 Analytical Methods for Use in Plant Analysis*, Div. Agr. Sci., Univ. of California, Bull. **766** 26–72

López, I. (1984) Experiencia en el cultivo de la piña en la isla de El Hierro, in: *Jornadas sobre Piña Tropical*, Excmo. Cabildo Insular de Tenerife, Tenerife, Spain

Marchal, J., Pinon, A. and Tiesson, C. (1981) Effets de la forme d'engrais potassiques sur la qualité de l'ananas en Côte d'Ivoire, *Fruits* **36** 737–743

Morard, P.H. and García, M. (1977) La salinité due au chlorure de sodium et les vegetaux superieurs, *Fruits* **34** 263–267

Norusis, M.J. (1988) *SPSS/PC+ Studentware*, Chicago, U.S.A., SPSS Inc.

Olsen, S.R., Cole, C.V., Watanabe, F.S. and Dean, L.A. (1954) *Estimation on Available Phosphorus in Soils by Extraction with Sodium Bicarbonate*, USDA, Circular **939**, 19 pp.

Py, C. and Pélegrin, P. (1958) Prevision de récolte en culture d'ananas, *Fruits* **13** 243–251

Py, C., Lacoeuilhe, J.J. and Teisson, C. (1987) *The Pineapple, Cultivation and Uses* (ed. Maisonneuve, G.P.), Paris, France

Ramírez, C.T. and González, E. (1983) Spacing, nitrogen and potassium on yield and quality of Cabezona pineapple, *J. Agr. Univ. Puerto Rico* **67** 1–10

Rodier, J. (1981) *Análisis de aguas* (ed. Omega, S.A.), Barcelona, Spain

Samuels, G. and Ganda, H. (1960) Effects of potassium chloride and sulphate on pineapple yields and quality, *J. Agr. Univ. Puerto Rico* **44** 16–20

Sideris, C.P. (1955) Effects of sea water sprays on pineapple plants, *Phytopathology* **45** 590–594

Sideris, C.P. and Young, H.Y. (1954) Effects of chlorides on the metabolism of pineapple plants, *Am. J. Bot.* **41** 847–854

Ullrich-Eberius, C.I., Novacky, A., Fischer, E. and Luttge, U. (1981) Relationship between energy-dependent phosphate uptake and the electrical membrane potential in *Lemna gibba* G1, *Plant Physiol.* **67** 797–801

Watanabe, F.S. and Olsen, S.R. (1965) Test of an ascorbic acid method for determining phosphorus in waters and sodium bicarbonate extract from soil, *Soil Sci. Am. Pro.* **29** 667–668