EFFECT OF WATER TABLE DEPTH ON CRITICAL SUGARCANE SALT CONCENTRATION LEVEL

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ABSTRACT

In saline fields with superficial water-table (80 to 110 cm) good yields could be obtained with conductivity as high as 8 mmhos/cm. On the other hand, with deep water-table (under 2 m) conductivity of only 2 mmhos/cm was enough to lower the yield to about 15%. It was also found that in saline-sodic soil, besides the harmful effect of salts, sodium also exert yield depressive effects. The dual negative effect reduce the critical level of salts to as low as 1.6 to 2.0 mmhos/cm.

INTRODUCTION

The effects of soil salinity on sugarcane production have been studied extensively. Different critical levels of salinity exists for different cultivars weather conditions, kind of salts and different soils management.

Robinson and Worker[20] indicated that a conductivity slightly greater than 4.2 mmhos/cm would reduce the yield by 50%. In Taiwan, Shen and Tung (in Liu[12]) and in Puerto Rico, Liu[12], reported that sugarcane varieties differed greatly in salt tolerance. In Iran, Shoji and Sund[22] concluded that soil conductivity of 4 mmhos/cm was the threshold, above which the growth of sugarcane was drastically reduced. In Puerto Rico, Liu reported that in the susceptible varieties of sugarcane, salt injuries developed first on sugarcane in soil with a salt conductivity at 5.4 mmhos/cm. In Natal, Von der Meden (in Mehrad[13]) reported that at soil conductivity below 2 mmhos/cm growth was not affected; between 2 to 4 mmhos/cm growth was reduced, while at conductivities above 4 mmhos/cm yields were seriously affected. Bernstein *et al*[2] studied salt tolerance of NCo varieties and found 25% yield reduction at conductivities of about 5 mmhos/cm. In South Africa it was found that at conductivities above 4 mmhos growth were seriously affected. From 2 to 4, mmhos growth was reduced and it was a good growth with less than 2 mmhos/cm (South African Sugar Association[23]). Leverington in Australia (in Fogliata and Aso[6]), working with Pindar and NCo 310 varieties, found that the growth of sugarcane was satisfactory even at 3.93 mmhos/cm. In Iraq, (Gowing and Rozeff[9]) on the basis of earlier experience, determined

leaching. Syed and El-Swaify[25] found that the tolerance of H50-7209 exceeds that of NCo-310 as dry matter yield reduction for the two cultivars were 23 and 45% at 8 mmhos salinity respectively. Sund and Clements[24] indicated that a soil conductivity of about 3 mmhos is the threshold above which fields of most varieties of sugarcane are severely reduced. Of great interest is the apparent indifference of NCo 376 to moderate saline conditions.

As can be seen, the degree of damage in sugarcane crop change in a wide range of salinity. As such it is very complicated to determine a critical level for different conditions of cultivars, weather, kind of salts and soils management.

As to water table depth effect on sugarcane yield, the different workers did not even agree. Pao and Hung[11] in Juang and Uehara shows pots experiments in which NCo 310 was grown with water table levels held at 50, 100 and 150cm with a fluctuating field water table as a check. The weight of roots and the sugar content of the cane grown over a water table depth of 150 cm were significantly higher than for the other treatments. On the other hand, Fogliata *et al*[7] observed under field conditions that the cane had a good performance with 1.6 to 2.2 water table depth, while it performed at 0.8 to 1.6 m. Wilkins and Ateshian[32] found that for Berbice Fronthand clays, the optimum depth of ground water table, allowing 45 cm for root zone, is about 1.45 meter. Gosnell[8] found that the 25 cm water table caused large reductions in cane yield, the 50 cm water table gave intermediate results, and no differences in growth were observed between 75, 100 and 125 water tables, which gave the best results. Perez *et al*[14] found that in PR 980 variety the treatment with ground water at 120 cm produced the best yield of cane and sugar (around 48% more than the 30-cm treatment). However in PR 1028 and PR 1059 varieties there was no significant difference between treatments. Juang and Uehara[11] reported that the 80 cm water table depth resulted in a significantly higher yield than the 50 and 30 cm depths in the sandy loam soil. In the clay, loam the 80 cm depth missed significance at the 5% level by small margin. Risseeuw[17] indicated that the negative influence of the ground water table on cane and recoverable sugar yield is important if ground water depth is above 25 cm from the bottom of the furrow. In a study about statistical ground water levels realized in cylinders, Bazan[1] found that the water table at 60 cm depth was the best (exceeding in yield 20, 40 and 80 cm). Faber *et al*[4] reported a problem in drainage when the ground water levels are less than 75 cm depth. He also indicated that there are yield reduction with ground water levels less of 1.5 m a month later of a normal irrigation. Sevilla *et al*[21] concluded that when the water table levels are maintained under 140 cm depth sugarcane yields obtained are the maximum.

The present study was conducted to determine the critical level of salts that affect sugarcane yield, under saline and saline-sodic soils conditions. Furthermore, the salinity critical level was integrated with the ground water depth to study whether the water table depth has an important function in the sugarcane response to the different concentration of soil salts.

MATERIALS AND METHODS

The experiment was carried out under field conditions in the Peruvian arid coast, using the sugarcane cultivar, H32-8560.

The soils in the zone are alluvial (entisols), with profile recently developed and without well-defined horizons, poor in N, but rich in P and K. Some differential characteristics for the 3 valleys studied are presented in Table 1.

TABLE 1. Characteristics of studied fields

	Fields		
	Los Angeles	Santa Rosa	Jiron 3-C
Location (valley)	Chancay-Lambayeque	Zaña	Chicama
Cutting or planting date	May, 1974	September, 1972	February, 1977
Crop	Plant	Plant-Ratoon	Ratoon
Annual precip. (mm)	28	34	20
Mean annual evapor. (mm/day)	4.6	5.8	4.5
Average annual temperat. (°C)	21.9	22.2	20.1
Plots area (m^2)	1,800	2,200-1,100[x]	3
Number of plots	50	20 - 40[x]	24
Soil samples/plot	10	7	1
Water table depth (cm)	> 200	40 to 150	80 to 110
Salin. range in water table (mmhos/cm)	5.5 to 20.0	3.0 to 30.0	5.0 to 14.0
Water table salts predominant	Na, Mg, Cl and SO_4	Na, Mg, Cl and HCO_3	Na, Mg, SO_4 and Cl
Soil texture	Clay loam	Sandy loam	Loam
Saturation %	52	26	48
Paste pH	8.0	8.6	8.2
Soluble CO_3^{2-} meq/100 g	0	0.006	0
Exchangeable sodium %	11.4	20.1	8.0
$CaCO_3$ %	4.5	6.7	4.4
Organic matter %	1.6	1.1	1.5
Total nitrogen %	0.076	0.059	0.073
C/N ratio	13.6	11.2	13.3
Available N kg/ha	38	33	38
Available P_2O_5 kg/ha[xx]	3929	1998	2628
Available K_2O kg/ha	1871	2461	1356
Available Ca kg/ha	19,528	10,442	13,403
Soil classification	Saline	Saline-sodic	Saline

x Plant and ratoon cane, respectively
xx Egner-Riehm method

In Los Angeles, field, the experimental plots were delimited by previous soil analysis, but in the Santa Rosa and Jiron 3-C fields the plots delimitation was made by grouping areas uniform on the following characteristics: a) areas where the cane did not sprout, b) those with very stunted or scarcely sprouted cane, c) those with stunted cane, d) areas with middling growth, e) areas with vigorous growth, and f) areas with full-sized vigorous sugarcane. This system also has been used in South Africa by the South African Sugar Association[23].

At harvest, all yield per plot taken in was in t/ha. Likewise in each plot samples of burned cane were taken to evaluate its quality and concentration of recoverable sugar.

To assure the representation of soil salinity of each plot studied, a high number of samples were taken (Table 1) with exception of the Jiron 3-C field where the salinity of each plot was represented only by one sample by depth.

Soils in each plot were sampled at 3 depths from the bottom of the furrow: 0-30, 30-60 and 60-90 cm. Samples of the same depth were joined to form one complex sample which represent the plot and analyzed in the laboratory.

To compare the four experiments, the yield of cane/ha was expressed as a relative % in terms of higher yield. These relative % were correlated with the soil salinity in the 0-60 cm layer. The origin of curves of each one of the regression equations, begun in different percentages, so transformations were done to make uniform the beginning of all equations (in the range of salinity observed) in 100%.

RESULTS AND DISCUSSION

Critical Levels of Salinity

Highly significant correlation between relative yield of cane and soil salinity in the four experiments evaluated was found. Regression equations with their respective values of R and F tests are presented in Table 2.

Bernstein (in Reeve and Fireman[16]) expressed the salt tolerance in terms of 15% yield reduction and the U.S. Salinity Laboratory[26] considered the 50% yield reduction. In the present discussion 15% was considered permissible critical level.

In Fig. 1 it can be seen that ratoon cane of Santa Rosa field was most affected by salinity, with 1.6 mmhos/cm as critical level and a 50% yield decrease with 3.6 mmhos/cm. This indicates that under some conditions only a small variation of salinity is necessary (2.0 mmhos/cm in this case) to produce highly significant differences in sugarcane (Pinna[15]). Cane plant of Santa

TABLE 2. Regression equations for relative yield and soil salinity, including F value of the analysis of variance and correlation coefficient (R) (For Santa Rosa field plant cane (P) and ratoon cane, Los Angeles plant cane and Jiron 3-C ratoon cane).

Field	Regression equation	R	F
Santa Rosa (P)	$Y = 93.4231 - 13.6738X + 0.5225X^2$	0.71^{xx}	xx
Santa Rosa	$Y = 108.4431 - 21.8313X + 1.0665X^2$	0.83^{xx}	xx
Los Angeles	$Y = 101.4719 - 14.2489X + 0.5462X^2$	0.93^{xx}	xx
Jiron 3-C	$Y = 97.9471 - 3.7760X - 0.08699X^2$	0.79^{xx}	xx

xx – Significant at 1% level

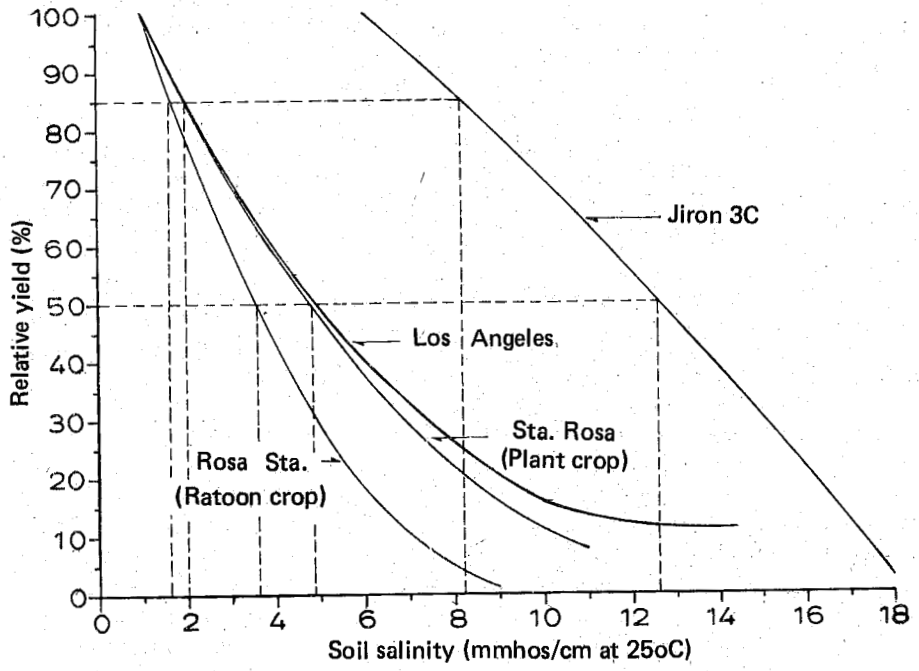


FIGURE 1. Soil salinity effect on sugarcane relative yield.

Rosa and Los Angeles fields practically behaved similarly with 2 mmhos/cm, the critical level in both cases. In these fields, 4.9 mmhos/cm decreased yield by 50%. Considering only these 3 experiments, the critical level varies between 1.6-2.0 mmhos/cm, indicating that sugarcane is sensitive to salts, according to FAO/UNESCO[5]. On the other hand, Jiron 3-C field behaved differently. 8.2 mmhos/cm is the critical level, and a salinity of 12.6 was required to reduce yield by 50%.

Yield Differences Between Plant and Ratoon Cane

Santa Rosa field was affected by relatively low salts concentration, the critical level being 2 mmhos/cm (15% of relative yield reduction) in plant cane and 1.6 mmhos/cm in ratoon. At low salinity level plant and ratoon yields were practically the same, but at high salinity level ratoon cane was strongly affected, yielding much less than plant cane. For an EC of 2 mmhos/cm ratoon yields 7% less and for a EC of 8 mmhos/cm, ratoon yields 77% less than plant cane. The less salts tolerance by ratoon cane has been reported by other workers (Robinson and Worker[20], Bernstein *et al*[2]).

Sodium Negative Effect

The low level of salt affected cane in Santa Rosa field because this field (saline-sodic) also had negative effect on the high exchangeable sodium percentage, which varies between 2 and 45 (Valdivia[27]). This agrees with Bonnet's[3] statement that sugarcane grows poorly in saline lands that contain from 20.0 to 72.9% of exchangeable sodium (pH 8.3 to 9.2) and EC (1:2 soil water suspension) from 1.5 to 3.7 mmhos/cm. Good sugarcane growth was observed when the saline land contained 4.5 to 11.4% of exchangeable sodium and EC from 0.3 to 0.6 mmhos/cm. Likewise, Fogliata and Aso[6], in Tucuman saline-sodic soils, recommended that the EC value should be under 1 mmhos/cm and the exchangeable sodium % under 12 in order to have an acceptable sugarcane yield.

Salinity Ground Water Depth Interaction

Los Angeles and Jiron 3-C fields have very similar climatic and chemical characteristics (Table 1), differing only in the finer texture of Los Angeles field. The principal difference between these two fields was that in Los Angeles, the water table level in general was under 2 m, while in Jiron 3-C the groundwater level fluctuated between 0.8 and 1.1 m. This relatively high water table allow normal cane growth even to salinities as high as 8.2 mmhos/cm. At this salinity level Los Angeles field yielded only 25% of the maximum. In studied valleys where water is scarce, cane is irrigated each 25 to 40 days, so that when the water table level is deep (Los Angeles) the salts damage effects (O.P.) are added to soil dryness conditions (high matric suction). This accounts for the relatively low critical level (2 mmhos/cm) in this field. The contrary occurs in Jiron 3-C field, where cane had a permanent water supply from groundwater. Hunsigi and Srivastava[10] indicated that a water table at depth of about 1 m contributed 65% towards the total Et of sugarcane and had no deleterious effect on growth, yield and quality of cane, and concluded that for optimum growth and yield the water table level should be kept below 1 m. This proves that there is a manifest interaction between salts damage effects and the water table depth as a source of water supplying to the plant. Therefore, it would be convenient to set critical salt concentrations levels for normal cane growth, taking into account the water table depth.

Groundwater must not be excessively shallow to avoid salt damage

because the required percent space for normal growth of sugarcane must be considered. Scarsbrook, (in Robinson[19]) found an adequate range to be 9 to 10%. Furthermore, Robinson[19] found that an average air space of 11% allowed the normal functioning of cane roots. On the other hand, Kamerling (in Van Dillewijn[29]), verified that sugarcane roots respiration continue intensively even when surrounding soil atmosphere contains little oxygen. Likewise, Risseeuw[18] indicated that sugarcane seems to support well excessive humidity conditions during a considerable time. It should also be necessary to take into account that O_2 deficiency causes reductions in root respiration, and a considerable amount of O_2 is required in the soil for mineralization of nutrient elements from organic matter by microbiological activity, although under the Peruvian soil conditions poor in organic matter, mineralization is of lesser importance. Visser (in Wesseling[31]) concluded that a water table depth of 50 to 60 cm below surface is sufficient to fulfill aeration requirements of plants. This would imply that the higher yields obtained at deeper water table can be completely ascribed to additional N becoming available under better aeration conditions. Wesseling[30] indicated that the normal root depth of arable crops in homogenous soils without root-restricting layers is somewhere between 90 and 120 cm. Taking the value of 90 cm the clay soil delivers about 190 mm of water if the drain depth is 100 cm. The sandy soil under the same conditions, however, will provide only about 125 mm of water. Therefore, although the depth of the ground water has no direct influence on crop growth, it indirectly determines the aeration conditions and the prevailing moisture conditions and therefore has an influence on water supply. This is of great importance in sugarcane areas of Peru where drought is frequently decreasing yields strongly, principally in saline soils with deep groundwater (more of 2 m). For this, Risseeuw[18] indicated that lower ground water level dose not always allow more profits. However, under the present conditions where normally ground waters are salines, shallow water tables (less of 1 m) can produce progressive salt accumulation which would damage sugarcane, even though most of the water is absorbed from the zone of low tensions near the water table.

An attempt to integrate above-mentioned factors was made by Valdivia and Pinna[28] who related the total soil suction effect (matric suction + osmotic suction) with the air space %, concluding that 3.5 and 2.2 mmhos/cm, at depths of 0-30 and 30-60 cm respectively, were the theoretical salt effect limit for sugarcane.

CONCLUSIONS

Under irrigation conditions in extremely arids zones and with sugarcane cultivar H32-8560, there was a highly significant correlation between relative cane yield and soil salinity for the four experiments evaluated. To obtain a good sugarcane production in saline and saline-sodic soils, the salinity in the 0-60 cm layer must not be higher than 2.0 mmhos/cm. In saline fields with shallow ground water table (80-110 cm), sugarcane was a salt semi-tolerant crop while in saline fields with deep groundwater table (below 2 m), sugarcane was a salt sensitive crop. In saline fields with shallow groundwater table (80-110 cm) it is possible to obtain good yields even with salinities as high

as 8 mmhos/cm.

In saline-sodic fields it was found that at high salinity, ratoon cane is more affected than plant cane. Furthermore, in said soils aside from the damage effect of salts, damage effect of sodium is added for which the critical level of salinity is low (1.6-2.0 mmhos/cm).

The large distance between irrigations in saline soils with deep ground water (below 2 m) raises salts damage effects, and lowers the salt critical level (2 mmhos/cm). Ground water tables between 80 to 110 cm depth, supplied sugarcane with water. In saline soils, the damage effect of salts is in terms of the groundwater table depth.

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EFECTO DE LA PROFUNDIDAD DE LA NAPA FREATICA EN EL NIVEL CRITICO DE SALES PARA LA CAÑA DE AZUCAR

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RESUMEN

Actualmente se dispone de gran cantidad de trabajos que relacionan la producción de la caña de azúcar con la concentración de sales del suelo, pero los niveles críticos son a veces diferentes. Por otra parte muchos artículos sobre la profundidad optima de la napa freática, han sido publicados, pero el problema, usualmente ha sido tratado como una relación suelo-agua sin tener en consideración la salinidad.

En el presente trabajo se discuten los efectos dañinos de la salinidad en funcion de la profundidad del nivel freatico, encontrandose que en campos salinos con napa freática superficial (80 a 110 cm)

se pueden obtener buenos rendimientos aún con salinidad tan alta como 8 mmhos/cm. En cambio, en campos salinos con napa freatica profunda (por debajo de 2m) soló bastan 2 mmhos/cm para bajar el rendimiento en un 15%. Este efecto tan dañino se explica si se tiene en cuenta que bajo condiciones del estudio (Perú) la caña se riega cada 25 a 40 diás. También se encontró que en suelos salino-sódicos, además del efecto perjudicial de las sales se suma el efecto dañino del sodio, todo lo cual hace que el nivel crítico de afectación por sales sea bajo (1.6 a 2.0 mmhos/cm.).