SALINITY EFFECT IN SUGARCANE RESPONSE TO NITROGEN FERTILIZATION

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ABSTRACT

An experiment using 5 rates of nitrogen (180, 250, 320, 390 and 460 kg/ha) and 5 harvesting ages (12.3, 15.5, 20.0, 23.3 and 26.5 months) was conducted to determine the response of sugarcane to nitrogenous fertilization when soil has high salinity. A factorial experiment was used with 4 replications and a control treatment.

The study was performed in the Chancay-Lambayeque valley in the northern coast of Peru, where more than 30% of the area has the salinity or drainage problem.

In this extremely arid region, alluvial soil is predominant, of recent profile development and without well defined horizons. Soil salinity varies from 2 to 8 mmhos/cm. Under these conditions it was learned that sugarcane yield did not increase with the application of high rates of nitrogen. However, it is necessary to use minimal rates of nitrogenous fertilizers which are a function of soil saline concentration. Besides, it was also found out that the cane and recoverable sugar yield were inversely correlated with soil salinity. Finally, it was also determined that the best age for sugarcane harvesting is when cane are 15.5 months.

INTRODUCTION

Sugarcane response to nitrogenous fertilization under soil salinity conditions has not been studied much. However, there is some information about other crops. For example, Hulsbos[4] found that the use of nitrogenous fertilizers seems to be justified even on a very saline soil when they are used with such plants that are highly tolerant to salts as barley, sweet clover and alfalfa. On the contrary, rice and wheat, which are less tolerant to salts, showed a slight increase in production when they were treated with N on slightly saline soil. On the other hand, Khalil *et al*[8] states that in spite of salinity, considerable yield increase can be obtained through increasing the fertility level by fertilization. Yields of corn and cotton increased sharply as N was applied at different salinity levels, but higher yields were obtained from applying N as salinity was decreased.

Considering the fact that there is a tendency to grow sugarcane in virgin saline areas or in saline areas where plants resistant to salinity have been grown before (rice, cotton, "gramalote") and also considering the fact that in Chancay-Lambayeque valley more than 30% of its irrigated area (90,000 ha) has saline soil (FAO[2]), then it is important to study nitrogenous fertilization on saline soils, with the aim of maximizing the productivity of salt-affected soil through fertilizer application.

The purpose of this study was to find out whether sugarcane grown on saline soil can be successfuly treated with high rates of nitrogenous fertilizers, as in normal soils (non-saline). Another reason for conducting the experiment was to analyze the effect of the different rates of nitrogenous fertilizers on sugarcane which was harvested at different ages, and find out the best age for harvesting.

MATERIALS AND METHODS

The experiment was performed in the field Zapote C-D (recently included as an agricultural area) that belongs to the Agricultural Cooperative Tuman, located in the northern arid coast of Peru (Chancay-Lambayeque valley). On the 22 of May 1974, cultivar H32-8560 was planted in plots of 450 m^2. The factorial design in completely randomized blocks was used. The factors to be studied were: 5 rates of N (180, 250, 320, 390 and 460 kg/ha), 5 harvesting ages (12.3, 15.5, 20.0, 23.3 and 26.5 months), with 4 replications and one plot without N which served as control for each harvesting age. Climate in this region has the following characteristics: there is an average annual precipitation of 28 mm, an average annual evaporation of 4.5 mm/day and an average temperature of 22^{o}C.

Soils are alluvials (entisols) of recent profile development and without well-defined horizons, calcareous, clay loam to sandy clay loam textured. Salinity in the 0.60 cm layer varies from 2 to 8 mmhos/cm. Table 1 shows the results of a soil physical and chemical analysis taken from a representative plot.

Before each of the 5 harvests, 6 samples of burnt sugarcane were taken from each plot and they were mixed in the field to get only 3 compound samples for each plot to be analyzed in the laboratory. The analysis included: pol % (P.), fiber % (F.), reducing sugars % and humidity % cane in addition to brix % and purity % (Pu.) of absolute juice. On the basis of these values the recoverable sugar % (recov. sug. %) was obtained with the formula proposed by Husz[6]:

$$\text{Recov. Sug. \%} = \text{P.} - 0.049\text{F. } 1.6635 - \frac{80.7292}{24.26 + \text{Pu.}} \quad (1)$$

All sugarcane taken from each plot were weighed in order to evaluate the yield in t/ha and to calculate the yield of recoverable sugar (recov. sug. t/ha).

$$\text{Recov. Sug. t/ha} = \text{Cane t/ha} \times \frac{\text{Recov. Sug. \%}}{100} \quad (2)$$

TABLE 1. Some physical and chemical analysis of the representative soil sample

Layer depth cm	Saturation water %	pH paste	ECe mmhos/cm	Mechanical analysis Dimension of fractions in mm		
				2.000–0.50	0.50–0.002	0.002
0 – 30	48.9	7.9	4.46	26	37	37
30 – 60	50.3	7.9	4.16	35	32	33
60 – 90	51.0	8.0	3.71	43	25	32

Layer depth cm	Organic matter %	Total nitrogen %	Ratio C/N	Available nutrients			$CaCO_3$ %
				N* kg/ha	P** ppm	K*** mg/100 g	
0 – 30	2.09	0.132	10.8	68	9.5	63.5	6.5
30 – 60	2.14	0.111	13.2	54	5.4	66.5	6.8
60 – 90	1.76	0.097	12.4	50	6.7	52.7	7.3

Layer depth cm	Water-soluble ions (saturation extract) in mg/100 g of soil						
	Ca^{2+}	Mg^{2+}	K^{+}	Na^{+}	SO_4^{2-}	Cl_3^{-}	HCO_3^{-}
0 – 30	0.496	0.299	0.051	1.796	1.985	0.489	0.159
30 – 60	0.430	0.217	0.058	1.796	1.744	0.553	0.163
60 – 90	0.316	0.173	0.042	1.554	1.710	0.382	0.140

* *Estimated*

** *Olsen method*

*** *Ammonium acetate method*

TABLE 2. F. values and coefficient of variation for the cane yield, recoverable sugar yield, and recoverable sugar %

Age	Analysis of variance					
	Cane (t/ha)		Recov. sugar (t/ha)		% recoverable sugar	
	F	C.V	F.	C.V.	F	C.V.
12.3	0.41	18.7	0.73	19.2	0.22	10.0
15.5	0.61	11.3	0.45	10.4	0.69	6.2
20.0	0.96	22.2	0.82	24.5	0.23	7.8
23.3	2.50	23.4	2.93	23.3	1.90	5.6
26.5	1.15	23.1	1.19	28.4	0.82	9.1

RESULTS AND DISCUSSION

Table 2 shows the statistical values that were obtained after the analysis of variance. These values were obtained without considering the control treatment (no N).

Considering the 5 harvesting ages which were analyzed, and use of different rates of nitrogen there was no significant statistical differences of cane yield and recoverable sugar yield or in terms of recoverable sugar %. The high values of coeficient of variation (C.V.) were due to the influence of salts.

Cane and recoverable sugar yield, in terms of the nitrogen applied

In Figs. 1A and 1B, it can be observed that both cane yield and recoverable sugar yield do not show any change with the increasing rates of N (from 180 kg /ha to 460 kg/ha). It can be seen that yields remained constant practically when cutting took place at 12.3 , 15.5 and 20.0 months. On the other hand, when cutting took place at 23.3 months there was a slight increase in yield with N. but when cutting was at 26.5 months there was a slight yield decrease in spite of the high rates of N applied. None of these differences is, however, significant.

This lack of response of sugarcane when grown on saline soil treated with high rates of N, is different from results obtained in non-saline calcarerous soil (such as the peruvian sugarcane soils), where it has been clearly proved that sugarcane response is positive when treated with rates higher than 300 kg N/ha (Standford", Evans, and Hughan and Booth in Davies and Vlitos[1]; Humbert[5]; Husz[7]; Valdivia and Tello[14]; Tello and Saldarriaga[12]; Tello and Valdivia[13]; Saldarriaga *et al.*[10]; Valdivia *et al.*[16]). However, it is important to remark that on non-saline calcareous soils that are irrigated with filter cake water mixed wih "vinaza" water (sugarcane alcohol factory waste effluent), rich in N, P and K, no response of sugarcane was obtained with nitrogeneous fertilization (Valdivia *et al*[15]; Valdi-

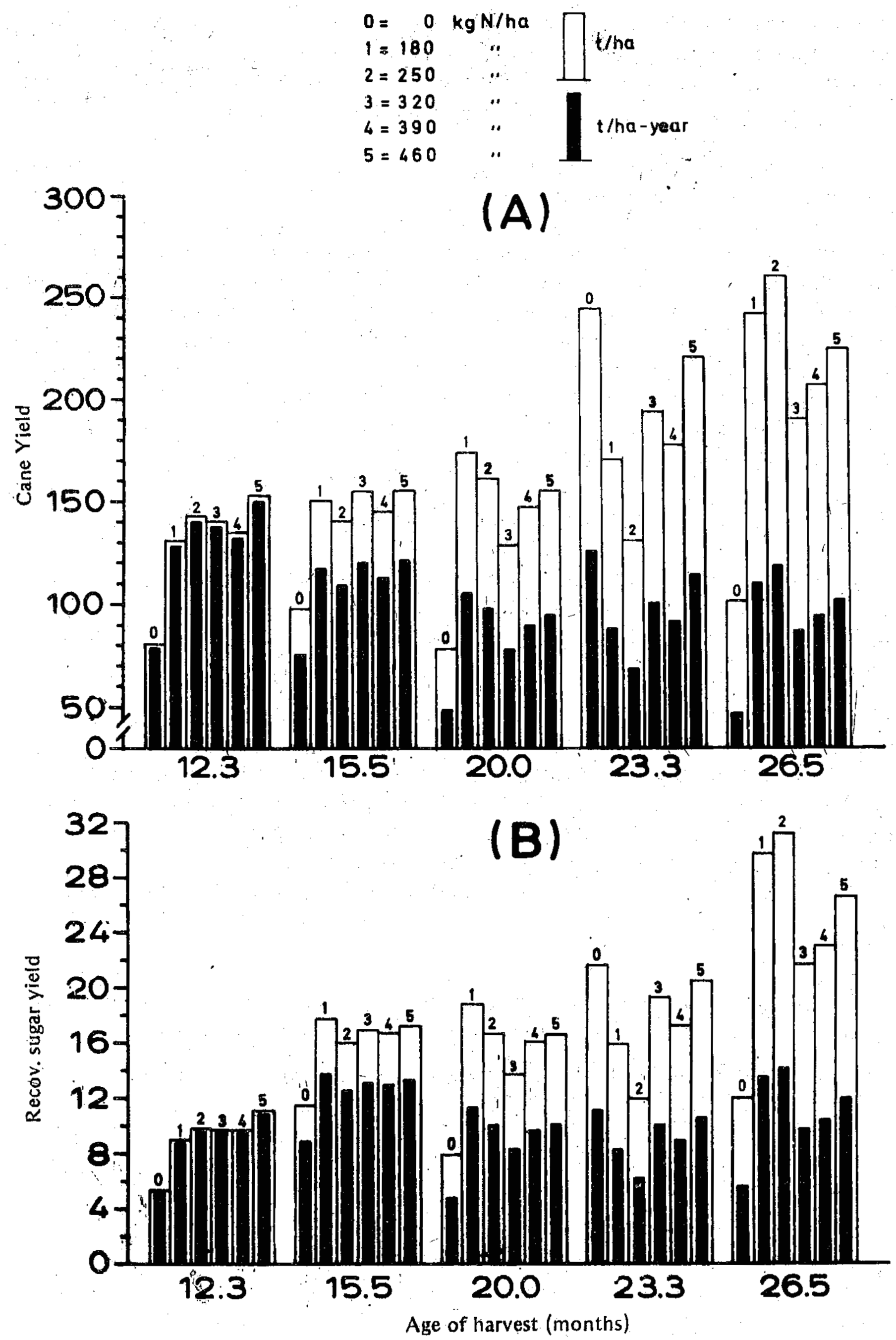

FIGURE 1. Sugarcane yield (A) and recoverable sugar yield (B) variation with harvesting age and N rates in a saline soil

via and Tello[17]). The same results were obtained on organic soil (Gonzales-Velez and Samuels[3]). Besides, on the basis of an experiment in which rates of N were as high as 450 kg/ha, Lopez and Dominguez[9] came to the conclusion that under conditions of drought no more than 168 kg N/ha should be applied.

Although in saline soils, no positive sugarcane response to high N rates was obtained, it can be seen that sugarcane without nitrogenous fertilization (control) produced an obviously lower yield than the one produced by the treatment with the lowest rate of N (180 kg/ha), except when harvesting took place at 23.3 months at which age sugarcane without nitrogen treatment had a yield 40% higher than the treatment with the lowest rate of nitrogen (180 kg/ha). This apparent contradiction, apart from showing how difficult work under conditions of salinity is, can be explained by the fact that the only control plot was located in a place where salinity was relatively low. Besides, it is necessary to say that at 12.3, 15.5, 20.0 and 26.5 months, the control treatment had respectively 38, 33, 56 and 5 % less yield than the treatment with the lowest rate of nitrogen.

Average variation of yield at different harvesting ages

Also without considering the control, it was observed that the fresh matter average yield increases with age. This result was expected because sugarcane lodges with age, new shoots develops and these stems increase the weight of harvested sugarcane (Table 3, Fig. 1).

However, the behavior of recoverable sugar yield was slightly different, it increased in about 72% from 12.3 months age to 15.5 months age (the cane yield increase under these conditions was only 6%). This remarkable increase was due to the fact that cane after 12.3 months was not yet mature but after 15.5 months sugarcane was already matured. Later on, when the canes were 20 months, although the average yield rose, the recoverable sugar yield decreased because at this age there were more suckers with low sugar concentration that decreased the quality of the whole harvested mass and, therefore, the total quantity of harvested sugar.

In Table 3, it can be seen that after 23.3 months the recoverable sugar % continued to decrease; for this reason sugar yield remained the same as the one

TABLE 3. Average yields of cane, recoverable sugar and recoverable sugar %

Age	Cane yield		Recoverable sugar yield		Recoverable sugar %
	t/ha	t/ha-year	t/ha	t/ha-year	
12.3	140.7	137.3	9.85	9.61	7.04
15.5	149.4	115.7	16.96	13.13	11.47
20.0	154.3	92.6	16.57	9.87	10.64
23.3	178.4	91.9	17.02	8.76	9.50
26.5	224.9	101.9	26.51	12.01	11.67

TABLE 4. F values (n = 100) for nitrogen, and for the nitrogen x age interaction effect

	Single effect		Interaction
	Age	Nitrogen	N x age
Cane (t/ha)	7.57**	1.05	1.53
Recov. sugar (t/ha)	13.77**	0.47	0.76
% recov. sugar	34.61**	0.19	0.80

TABLE 5. Linear correlation coefficient between the cane and recoverable sugar yields vs the salinity of the 0–60 cm layer for the different harvesting ages.

	Age (months)				
	12.3	15.5	20.0	23.3	26.5
Cane (t/ha)	– 0.31	– 0.81**	– 0.75**	– 0.83**	– 0.64**
Reco sugar (t/ha)	– 0.29	– 0.69**	– 0.81**	– 0.84**	– 0.67**

obtained when sugarcane was 15.5 months, in spite of the remarkable increase of green mass. Finally, at 26.5 months there was a remarkable yield increase because the treatments; at the last harvesting age were located in a zone with slightly less salinity than the zone where the other treatments were set up. On the other hand, a high sugar yield was obtained because the recoverable sugar average % was the highest value obtained in this experiment.

Frequently, data on the yield per year indicate the best harvesting age so that we can get as much economical profit as possible. For this reason, we have included the yields per hectare-year of both cane and sugar in Figure 1A and 1B. In Figure 1A, the highest cane per hectare – year yield was obtained when harvesting was done at 12.3 months. However, since sugarcane at this age was not yet mature, its sugar production was very low as shown in Fig. 1B. The highest recoverable sugar average yield was obtained when sugarcane was 15.5 months (Table 3), thus, indicating efficient production.

Yield variation in connection with sugarcane age and N rates

To find out the response to N x age interaction, an analysis of variance of all data was performed (n= 100).

Table 4 shows that the F value was highly significant for cane yield, the sugar yield and recoverable sugar % in connection with the simple age effect.

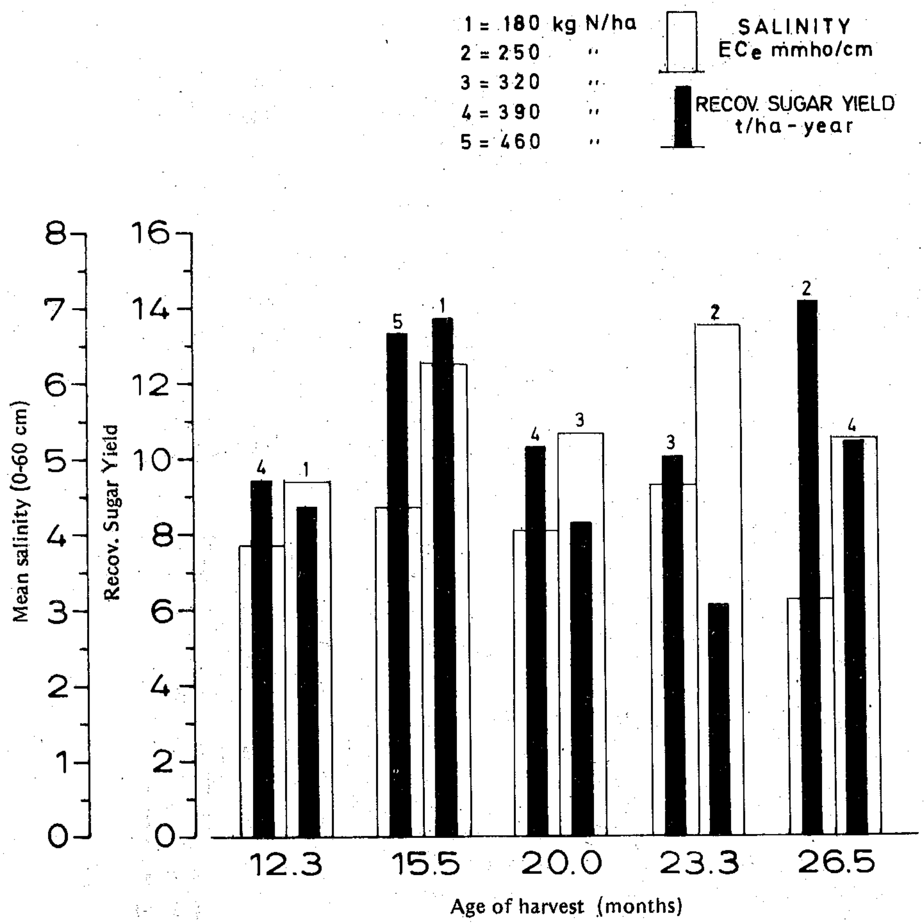

FIGURE 2. Lowest and highest average salinity (of each N treatment) with its average sugar yield, for each age of harvesting

Similarly, we can see that these characteristics are not significant in connection with the simple N effect or the effect of N x age interaction.

Influence of salinity on cane and recoverable sugar yield

Finally, a regression analysis was performed between cane and recoverable sugar yield vs. salinity of the average 0.60 cm layer, and for the 5 ages studied. In Table 5, it can be seen that at 15.5, 20.0, 23.3, and 26.5 months, there was a highly significant inverse correlation between salinity and production of both cane and recoverable sugar. Besides, it was already made clear that the lack of response to increasing N rates was due to the negative influence of salinity.

Fig. 2 shows the average yield the lowest to the highest average salinity (for each N treatment) for each harvesting age. Except at 15.5 months, there was an inverse relation between salinity and recoverable sugar yield, and this relation is higher when harvesting was done at an advanced age.

CONCLUSIONS

For slightly saline soil (from 2-8 mmhos/cm) we have arrived at the following conclusions:

- High rates of nitrogenous fertilizers have not increased cane and/or recoverable sugar yield at any of the 5 harvesting ages.
- The treatment with the lowest rate of N used (180 kg/ha) produced a higher cane and/or recoverable sugar yield than the control which means that only minimal rates of nitrogenous fertilizers are needed in terms of the saline concentration of the soil.
- On soil whose salinity is higher than 2 mmhos/cm it is necessary to use no more than 180 kg N/ha. As saline concentration increased, N application should be decreased.
- Cane yield (harvested green mass) gradually increases with harvesting age. On the other hand, recoverable sugar yield can increase and/or decrease according to harvesting age.
- Cane yield in t/ha-year is not a good indicator to determine the most adequate age for harvesting.
- Evaluation of the best harvesting age (more economical production) must be made by interpreting the data about recoverable sugar yield in t/ha-year.
- The most adequate harvesting age for cane was about 15.5 months.
- Cane and recoverable sugar yields were inversely correlated with the salinity of the soil. This negative influence did not allow us to get a response of sugarcane to fertilization by using high N rates.

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EFECTO DE LA SALINIDAD EL LA RESPUESTA DE LA CAÑA DE AZUCAR EN LA FERTILIZACION NITROGENADA.

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RESUMEN

Desde que no poseiamos informacion acerca de la respuesta de la caña de azúcar a la fertilizacion nitrogenada cuando el suelo tenia alta salinidad, fue diseñado un experimento factorial. En el experimento fueron usadas cantidades de nitrogeno (180, 250, 320, 390 y 460 kg/ha), 5 edades de cosecha (12.3, 15.5, 20.0, 23.3 y 26.5 meses), 4 replicaciones y un testigo.

La investigacion fue realizada en la Costa Norte de Peru, en el Valle de Chancay – Lambayeque, donde mas del 30% del area tiene un pobre drenaje y/o salinidad.

En esta region extremadamente arida, son predominantes los suelos aluviales, de perfil recientemente desarrollados, sin horizontes bien definidos. La salinidad del suelo varia de 2 a 8 mmhos/cm. Bajo estas condiciones se encontró que la cosecha de la caña de azucar no se incrementa aplicando altos niveles de nitrogeno. No obstante, es necesario usar minimas cantidades de fertilizantes nitrogenados y estos porcentajes estan en funcion de la concentracion salina del suelo. Ademas fúe encontrado que la caña y la produccion de azucar estaban inversamente correlacionadas con la salinidad del suelo. Finalmente tambien fue determinado que el mejor momento o epoca para la cosecha de la caña de azucar es cuando las cañas tienen 15.5. meses de edad.