Response of Groundnut (*Arachis hypogaea* Linn.) to Sodium Chloride Salinity in a Semi-Arid Area of Northeastern Nigeria.

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Abstract

The effect of NaC1 salinity on the yield components, plant nutrient concentrations and water use efficiency of groundnut under field conditions was investigated. Three salinity levels, viz., 0.75, 3.06 and 5.76 dS/m designated as Control (S_O), (S_1) and (S_2), respectively were imposed with four replications. Nodulation was reduced by 45 and 69 percent in S_1 and S_2 treatments, respectively. Although kernel yield was not significantly affected by salinity, haulm yield was reduced by 23 and 41 percent at S_1 and S_2 treatment levels, respectively. Insensitivity of kernel yield to treatment effect was partly explained by higher pod damage by termites under the control treatment (55%) compared to the S_1 and S_2 treatments, which suffered 11 and 7 percent damage, respectively. Salinity appreciably increased C1 concentration in most plant parts. Kernel water use efficiency in the S_1 and S_2 treatments was reduced by 21 and 45 percent respectively. The results of the study have shown, perhaps for the first time, that effective control of certain pests, especially soil pests, may be an incidental benefit of high salinity.

Key words: salinity, yield, groundnut, water-use-efficiency

Introduction

Groundnut, a major export crop in Nigeria, is produced largely in the semi-arid Northern Nigeria, north of latitude 11°N (Phillips 1977) where rainfall is erratic and inadequate in amount and distribution. The climatic situation thus necessitates the use of irrigation for crop production with associated salinity problems. A considerable proportion of irrigated lands in the groundnut producing areas of Nigeria is salt-affected (Maurya 1981). However, very limited information is available on the response of groundnut to salinity under field conditions.

While sodium chloride and sodium sulphate salinity have been reported to reduce growth and create ionic imbalance in groundnut (Malakondalah and Rajeswararao 1979; Chavan and Karadge 1980)., the crop has also been considered an important crop in rotations commonly recommended during the process of amelioration of saline and alkali soils (Abrol *et. al.* 1973). Lower shoot water potential due to soil salinity was observed in rice by Asch *et. al.*, (1995) and in maize by Grant, (1995). These workers attributed the reduction in shoot water potential to the reduction in osmotic potentials in the saline soils leading to reduced water use and crop growth. At salinity levels commonly found in agricultural soils, reductions in crop growth are associated with reductions in water use (Schimidhalter and Oertli 1991; van Hoorn *et al.* 1993).

Salinity induced reductions in crop growth had also been associated with reduction in the uptake of nutrients by crop plants. Munns and Termaat, (1986) reported that the adverse effect of NaCl on white clover and white lupin is either through an effect of the excessive accumulation of Na and C1 ions on metabolism in the leaves, or on the uptake and transport of essential nutrients.

The specific objective of this study was to determine the effects of NaCl salinity on the crop yield, nutrient concentration and water use efficiency of groundnut under field conditions.

Materials and Methods

The study was conducted at the University of Maiduguri Research Farm. The soil of the study site is sandy-loam and is classified as *Typic Ustipsamment* according to the U.S.D.A. classification system (Soil Survey Staff 1990).

The soil of the study site was analysed for pH, electrical conductivity of saturation extract (ECe), Cl and exchangeable sodium percentage (ESP) before the plots were laid out. The threshold level of groundnut for salinity tolerance is ECe 3.2 dS/m (Landon 1991). Treatments consisted of three levels of salinity: 0.75, 3.06 and 5.76 dS/m designated as control (S_O), (S_1) and (S_2) respectively. Basal levels of N, P and K fertilizers were also applied to all plots at the rate of 25 kg N/ha as Urea, 25 kg P/ha as SSP and 25 kg K/ha as muriate of potash respectively. The treatments were laid down in a randomised block design with four replications.

Each experimental plot was 16 m^2 and the edges of the plots were raised to minimize runoff. Salinity levels were developed with NaCl. The salt was evenly spread on the plot and subsequently mixed thoroughly to a depth of 0.2 m. Light but frequent irrigations were given for four weeks before planting to facilitate exchange reactions (U.S. Salinity Laboratory Staff 1954). A neutron access tube was thereafter installed in the middle of each plot to facilitate periodic measurement of soil water profile for the assessment of crop water use. Seeds of groundnut (*Arachis hypogaea*) variety Ex-Dakar were planted with between and within row spacing of 0.25 m and 0.15 m respectively to give a plant population equivalent to 230,000 plants per hectare.

At harvest, different plant components were sampled for elemental analyses. Concentrations of N, P, K, Na, Ca, Mg and C1 in different plant parts were determined according to standard procedures (Chapman and Pratt 1961). Using the profile water content measurements, crop water use was calculated using the water balance equation, while water use efficiency was estimated as the ratio of the yield to crop water use (Power 1983). Damage to groundnut pods caused by termites and other soil pest was determined by weighing 100 g of pods from each plot following a thorough mixing of the harvested pods. From the 100 g samples, 100 pods were randomly selected. The damaged pods were separated and counted, and the percentage of damaged pods determined. Nodule count was carried out 47 days after planting. Five plants per plot were randomly selected, washed carefully and the nodules counted. The groundnut crop was harvested at approximately 12 weeks after seeding.

Results and Discussion

Selected soil properties averaged over the growing season are presented in Table 1. The ECe, ESP and chloride concentration varied considerably between treatments as a result of sodium chloride salinization.

Root nodules

The number of nodules per plant was reduced by 45 and 69 percent (relative to the control) at the S_1 and S_2 treatment levels, respectively (Table 2). Significant differences in nodulation observed among the salinity treatments could possibly be due to the adverse effect of salinity on the nodulating micro-organisms. Pillai and Sen, (1966) reported that salinity can limit nodule formation by reducing the population of *Rhizobium* in the soil or by impairing their ability to infest root hairs. This result has significant implications on nitrogen fixation by groundnut in salt-affected soils.

Yield parameters

Differences in pod and kernel air-dry weight amongst treatments were not significant (Table 2). This could be due to relatively lower values of electrical conductivity of the saturated extract observed at the time of pod formation (*data not shown*). It was also observed that appreciable damage was done to many of the harvested pods by termites and possibly other soil pests particularly in the control plots. This prompted the assessment of the degree of pod damage for each of the treatments. Pod damage was highest under the control and least under the S_2 treatment (Table 2). The wide range in soil pest damage among the salinity treatments possibly obliterated whatever differences in pod yield that might have been due to treatment effect. The S_1 salinity level was probably adequate for minimizing soil pest damage but not high enough to suppress pod yield appreciably. This would explain the higher pod and kernel yields (though not significant) observed under S_1 compared to the other treatments. These results seem to suggest that a certain level of salinity, adequate for controlling termites and other soil pests, but not high enough to suppress yields appreciably, may be beneficial in groundnut growing areas where termites and other soil pests constitute a major problem, especially under tropical climate. Further studies in this direction will be desirable. The haulm air-dry weights were significantly different (Table 2). Haulm yields for the S_1 and S_2 treatments were 23 and 41 percent lower than for the control. The depressive action of salinity on haulm yield might have resulted from possible interference in nutrient absorption and physiological water stress created by high salt concentration in the root zone (Hamid and Talibudeen 1976; Shukla and Mukhi 1985; Grant 1995).

Significant effect of salinity on shoot/root ratio was observed (Table 2). The shoot/root ratio was reduced by 21% due to the S_1 treatment. There was however no significant difference in shoot/root ratios of the S_1 and S_2 treatments. These results would seem to suggest greater deleterious effect of salinity on the shoot growth than on root growth.

Table 1. Selected soil properties under the various salinity treatments

Treatments	pH*	ECe** (dS/m)	ESP (%)	C1 (Cmol kg^{-1})
S_0*** (Control)	6.98	0.75	9.84	7.99
S_1	7.37	3.06	17.55	14.93
S_2	7.48	5.76	22.25	20.15

*1:1 ($H_2$0)

** Saturation extract

*** S_0 = ECe, 0.75 dS/m, S_1=ECe, 3.06 dS/m, S_2 = ECe, 5.76 dS/m

Table 2. Salinity treatment effect on yield components of groundnut.

Treatment	Number of nodules per plant	Pod air-dry weight	Kernel weight	Haulm air-dry weight	Shoot/Root ratio	Pod damage* (%)
		_________Kg/ha___________				
S_0**	37.0	887.89	544.68	2824	39.9	55
S_1	20.0	1037.78	639.06	2178	31.3	11
S_2	11.0	879.22	540.43	1669	32.8	7
LSD(0.05)	6.1	NS***	NS	394	5.6	2.5

*Pod damage due to termites and other soil pests.
** S_0 = ECe, 0.75 dS/m, S_1=ECe, 3.06 dS/m, S_2 = ECe, 5.76 dS/m
***NS = not significant

Table 3. Salinity treatment effect on nutrient concentrations in shoots and roots of groundnut

Treatment	N	P	K	Na	Ca+Mg	C1
	_______________g/kg Dry matter_____________________					
			Shoot			
S_0*	28.1	0.96	28.39	16.33	35.98	6.75
S_1	28.2	0.74	27.42	16.72	25.14	25.90
S_2	30.6	0.67	26.00	16.89	39.55	32.66
LSD(0.05)	NS**	NS	NS	NS	NS	3.83
			Root			
S_0	48.1	1.03	20.28	17.78	38.88	7.42
S_1	46.0	0.76	15.44	23.00	23.71	27.73
S_2	45.5	0.83	13.61	29.00	28.79	40.51
LSD(0.05)	NS	0.14	2.29	3.79	8.77	4.22

* S_0 = ECe, 0.75 dS/m, S_1=ECe, 3.06 dS/m, S_2 = ECe, 5.76 dS/m
**NS = not significant

Nutrient concentrations in plant tissues

Shoot: Except for chloride, the nutrient concentrations were not significantly affected by salinity (Table 3). Concentration of chloride in plant shoot increased (relative to control) by 284 and 384 percent for the S_1 and S_2 treatments, respectively. Differential absorption of Na and C1 ions in favour of C1 in plants grown in NaC1 medium had been reported by several workers (Strogonov *et al.* 1970; Lessani and Marshner 1978; Fowler *et al.* 1988; Francois *et al.* 1990)

Root: Concentrations of N, P and Ca + Mg in plant roots were significantly reduced by salinity (Table 3). Na and C1 concentrations were however increased appreciably due to treatment effect. No significant difference in root concentration of N resulting from treatment effect was observed. It is interesting to note that treatment effect resulted in increased uptake of both Na and C1 by the roots but most of the excess Na was retained in the roots. Translocation of C1 from the roots to the shoots, however, appeared uninhibited. Reduced uptake of K and Ca + Mg observed in this study is consistent with earlier reports (Malakondalah and Rajeswararao 1979; Francois *et al.* 1990)

Kernels and shells: Concentration of N in Kernels was significantly reduced by salinity (Table 4). This result has significant implication on the protein content of groundnut kernels when cultivated in salt-affected soils. The concentration in shell was however not affected by salinity. Concentrations of P, K and Na in both kernels and shells were not affected by the salinity treatments. As observed in shoots and roots, salinity appreciably increased chloride concentrations in kernels and shells.

Cation ratios: Salinity did not affect (Ca + Mg)/Na ratio in the shoots (Table 5), but the ratio was reduced in the roots and to a lesser extent in the kernels and shells. No consistent trend in (Ca + Mg/K) ratio with increasing salinity was observed in the plant tissues. There was a general increase in Na/K ratio with increasing salinity levels in all plant parts. This result was probably due to the preferential uptake of Na over K and possibly to antagonistic effect of Na on K uptake. Similar observations had been made for corn (Shukla and Mukhi 1985). and Chickpea (Manchanda and Sharma 1989).

Water use efficiency (W.U.E.)

Increasing salinity resulted in a general reduction in W.U.E for both kernels and haulms (Table 6), although differences in W.U.E. for kernels amongst treatments were not significant, kernel W.U.E. was reduced (relative to the control) by 21 and 45 percent for S_1 and S_2 treatments respectively. Similar reductions of 26 and 38 percent in W.U.E. of haulms were observed for the S_1 and S_2 treatments respectively. The observed reductions in W.U.E. could be due to the combined effect of NaC1 on soil and plant. Sodium affected soils are known for their low infiltration characteristics (Dubey and Mondal 1994) which constrain soil water recharge due to increased run-off losses. High salt concentration within the root zone may also reduce root permeability to water and ions (Waisel 1972), thereby reducing water uptake.

Table 4. Nutrient concentrations in groundnut kernels and shells as affected by salinity treatments

Treatment	N	P	K	Na	Ca+Mg	C1
	g/kg Dry matter					
			Kernel			
S_0*	74.8	0.76	8.51	12.17	34.20	6.00
S_1	68.5	0.48	8.67	12.68	26.62	22.07
S_2	66.7	0.60	9.07	13.62	28.25	23.08
LSD(0.05)	6.0	NS**	NS	NS	NS	3.93
			Shell			
S_0	32.7	0.32	13.30	11.89	34.31	5.00
S_1	29.4	0.62	11.45	10.97	32.21	22.01
S_2	31.0	0.61	12.07	12.56	28.92	29.73
LSD(0.05)	NS	NS	NS	NS	6.93	6.32

* S_0 = ECe, 0.75 dS/m, S_1=ECe, 3.06 dS/m, S_2 = ECe, 5.76 dS/m

**NS = not significant

Table 5. Ratios of cations in groundnut parts as affected by salinity treatment

Treatment	Ratios of cations		
	(Ca+Mg)/Na	(Ca+Mg)/K	Na/K
		Shoot	
S_0*	2.20	1.27	0.58
S_1	2.10	1.28	0.61
S_2	2.30	1.50	0.65
		Root	
S_0	2.19	1.92	0.88
S_1	1.03	1.54	1.49
S_2	0.99	2.12	2.49
		Kernel	
S_0	2.81	4.09	1.43
S_1	2.10	3.07	1.46
S_2	2.30	3.12	1.50
		Shell	
S_0	2.88	2.58	0.89
S_1	2.12	2.04	0.96
S_2	2.30	2.40	1.04

* S_0 = ECe, 0.75 dS/m, S_1=ECe, 3.06 dS/m, S_2 = ECe, 5.76 dS/m

Table 6. Water use efficiency of groundnut as affected by salinity treatments.

Treatment	Water Use Efficiency (kg ha^{-1} mm^{-1})		
	Haulm	Kernel	Total
S_0*	8.94	2.29	11.24
S_1	7.10	1.69	8.79
S_2	4.94	1.42	6.36
LSD(0.05)	2.42	NS	3.61

* S_0 = ECe, 0.75 dS/m, S_1=ECe, 3.06 dS/m, S_2 = ECe, 5.76 dS/m

Conclusion

Sodium chloride salinity impaired nodulation, reduced haulm yield, increased uptake of Na and C1 and reduced water use efficiency of groundnut. Although, nodulation was adversely affected, salinity appeared to reduce pod damage associated with termites and other soil pests. Further study is however required to assess the feasibility of using NaC1 for termite control while minimizing its adverse effects, especially amongst resource-poor farmers that produce more than 90% of groundnut in Nigeria. Depression in N concentration in groundnut kernels observed in this study suggests a possible adverse effect of salinity on the protein content of groundnut. Reduced nodulation due to the salinity treatments also has significant implications on N-fixing capacity of groundnut crop in salt-affected soils. This is particularly relevant to the situation of resource-poor farmers in developing countries that cannot afford sufficient quantities of inorganic N-fertilizers and therefore rely on groundnut in crop rotations to provide much of the N required by cereals. Reduced water use efficiency due to treatment effect as observed in this study re-emphasizes the need for drought-tolerant cultivars of groundnut in salt-affected soils.

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