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Influence of Sodium Chloride Salinity on Soil Properties and Early Growth of Groundnut (*Arachis hypogaea L.*)

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Abstract

The effects of NaC1 salinity on soil properties and growth of groundnut were investigated. Treatments consisted of three levels of salinity, having exchangeable sodium percentage (ESP) of 7.90, 12.81 and 19.97 respectively with corresponding saturation extract having electrical conductivity (ECe) of 0.75, 3.06 and 5.76 dS m^{-1}*. Sodium chloride salinity resulted in reduction of steady-state infiltration rate and cumulative water intake by 47-76% and 39-69% respectively. Seedling emergence of groundnut was delayed and appreciably reduced by NaC1 salinity. Plant height, leaf relative water content and leaf area index were reduced by 27-44%, 8-23% and 37-41% respectively.*

Key words: salinity, soil properties, growth, groundnut, infiltration

Introduction

Groundnut (*Arachis hypogaea L.*), also known as peanut, is a major export crop in Nigeria. The bulk of the crop is produced in the semi-arid zones of the country where drought and salinity are potential production constraints.

The general effects of soluble salts in soils are well known (Michael 1978; Khan 1998). High concentrations of soluble salts in soils lead to unfavourable soil-water-plant relations. The presence of salts in soils is usually associated with an alteration of the physical arrangement of the soil matrix. These physical rearrangements of the soil particles may either improve or impair the soil physical properties depending on the nature and amount of salts, reaction products and the initial chemical conditions of the soil (Michael 1978). Moderate salt concentration, in the absence of high proportion of sodium on the soil exchange complex, may improve water intake characteristics of soils (Shainberg et al., 1981; Shainberg and Gale 1982). But high exchangeable sodium on the exchange complex will lead to dispersion of the surface soil with the resultant reduction in water intake rates (Yaron and Thomas 1968; Alperovitch et al., 1981) coupled with increased surface runoff and erosion (Singer et al., 1982; Tanko and Essiet 2001). High level of neutral soluble salt in soils is believed to affect many aspects of plant growth, from germination to crop yield production (Poljakoff-Mayber 1975; Hussain and Rehman 1993; Rehman and Hussain 1998). Salt-affected soils are usually associated with poor stands of crops arising from poor seed germination due to soil salinity (Uhvits 1946; Assadian and Miyamoto 1987). Unfavourable plant water relations due to soil salinity (Stark and Jarell 1980; Asch et al., 1995) and reduced crop growth and yield (Nassery and Jones 1976; Fowler et al., 1988; Grant 1995) have earlier been reported. However, most of these workers have studied soil salinity effects on growth of cereals and forage crops. Very little information is available on the effects of soil salinity on the growth of groundnut. This paper reports the influence of sodium chloride salinity on soil properties and early growth of groundnut.

Materials and Methods

This study was conducted at the University of Maiduguri Research Farm (11° 54'N, 13° 5'E, altitude 352m above the mean sea level) in northeast Nigeria. 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 characterised for physical and chemical properties before the plots were laid out. Mean annual rainfall is about 553mm and displays a uni-modal pattern, starting on average in mid June and lasting until the end of September. The natural vegetation in the study area is grassland with few scattered herbs and trees typical of the sudano-sahelian savanna. The threshold level of groundnut for salinity tolerance is $6.5 dSm^{-1}$(ESP, 15)(Landon 1991). Treatments consisted of three levels of salinity designated as control (S_0), (S_1) and (S_2), respectively. Basal application of N, P and K fertilizers were made to all plots at the rate of 25kgN/ha as Urea, 25kgP/ha as SSP and 25kgK/ha as muriate of potash respectively. Each treatment had four replications in a randomised complete block design.

Each experimental plot was $16m^2$ and the edges of the plots were raised to minimize runoff. The salinity treatments were imposed by applying 0, 3 and 6 kg of sodium chloride per plot to correspond to S_0, S_1, and S_2 respectively. The salt was evenly spread on the plot and subsequently mixed thoroughly to a depth of 0.2m. 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.

Infiltration rate was measured using the double-ring infiltrometer with a constant 20mm water head. Particle size distribution was assessed using the hydrometer method (Klute 1986). Soil samples were analysed for soil pH using 1:1 soil:solution ratio (McLean 1982), organic carbon (Nelson and Sommers 1982), total nitrogen (Bremner and Mulvaney 1982), available phosphorus (Olsen and Summers 1982), exchangeable bases (Thomas 1982) and electrical conductivity (Page et al., 1982).

Seeds of groundnut (*Arachis hypogaea L.)* variety Ex-Dakar were planted in rows 0.25m apart and at 0.15m within the rows to give a plant population of 230,000 plants per hectare. Leaf area index and leaf relative water content were determined as described by Kramer, (1969).

Results and Discussion

It is an established fact that the salinity status of salt-affected soils is subject to tremendous temporal variability during the growing season (Michael 1978). The salinity status of the experimental plots was monitored at different periods during the growing season; early in the season, mid-season and at harvest (Table 2). Although the pH showed no appreciable change during the season, significant ($P<0.05$) changes in the electrical conductivity (ECe) of the saturation extract and exchangeable sodium percentage (ESP) were observed. The ECe values of the 0-0.15m depth during the mid-season and at harvest were about one to four orders of magnitude smaller than the mean ECe early in the season for the S_1 and S_2 treatments. Similarly, ESP during mid-season and at harvest were 15-57 percent greater than the ESP at early season at the S_1 and S_2 treatment levels. Exchange reaction between the soil solution and the soil exchange complex is a continuous process. Obviously as the season progressed, more and more of the Na in the soil solution (resulting from the applied NaCl) got into the exchange complex thereby lowering the electrical conductivity of the soil solution and increasing the relative proportion of sodium on the soil exchange complex.

Infiltration rate

The steady-state infiltration rate of the soil decreased with increasing salinity. Reductions of 47 and 76% in steady-state infiltration rate (relative to the control) were recorded for the S_1 and S_2 salinity levels, respectively (Table 3). Similarly, salinity resulted in appreciable reduction in cumulative water intake within the measurement period of 345 minutes (Table 3). Cumulative water intake for the S_1 and S_2 treatments was 39 and 69% respectively lower than the control. The reduction in both steady-state infiltration rate and cumulative water intake due to treatment effect was probably associated with the dispersion and surface sealing that accompanied the application of NaCl and the resulting high ESP. Aggassi et al. (1985) reported similar results indicating a drop in water infiltration due to increasing levels of sodium concentration in irrigation water while working with two sodic soils. Conversely, Dubey and Mondal, (1994) did not observe a reduction in water infiltration under continuous irrigation with saline water in a highly sodic soil, probably because of the rise in the electrolyte concentration of the applied water thereby resulting in the rapid replacement of sodium by calcium on the cation-exchange complex. However, Quirk and Schofield, (1955) and Yaron and Thomas, (1968) also reported a linear relationship between soil hydraulic conductivity and soil ESP. These workers attributed the reduction in soil hydraulic conductivity with increasing ESP to increased Na-ions on the soil exchange complex, which would be expected to result in swelling, dispersion and deflocculation of the soil particles with subsequent alteration of soil voids and a reduction in soil hydraulic properties.

Seedling emergence

Emergence of groundnut seedling was appreciably delayed and reduced by soil salinity (Table 4). Seedling emergence was essentially completed (95% emergence) within 9 days in the control plots while it took 30 days to achieve 92% emergence under the S_1 level of salinity, a delay of more than 21 days. Similarly, at the S_2 level of salinity, only 79% emergence was recorded 30 days after planting. Seedling emergence count was terminated 30 days after planting although some germinating seeds were still observed to be emerging up to 60 days after planting in the S_2 plots.

The delay and reduction in seedling emergence might be due partly to the effect of lowering of the soil water potential by the added salt on the germinating seeds and partly to the effect of Na on the soil physical properties. High exchangeable Na in the exchange complex leads to dispersion of surface soil aggregates giving rise to the formation of hard crusts and resulting in low permeability of the soil to water and air. Furthermore, such hard crusts offer mechanical impedance to seedling emergence. Studies have shown (Barzegar et al., 1994) that the natural processes of soil hardening are influenced by both sodicity and salinity. On hard setting soils, plant roots cannot penetrate dried soils due to high soil strength (Khan et al., 2001) and low accessibility of soil water and nutrients (Barzegar et al., 1996) thereby leading to reduced yield. Our results are in agreement with the general observation that salt-affected soils are associated with poor and sparse crop stands (Poljakoff-Mayber and Gale 1975). Uhvits, (1946), Redman, (1974) and Assadian and Miyamoto, (1987) reported reductions in germination and emergence of alfalfa seeds with increased soil salinity levels. Fowler et al. (1988) also reported delayed germination and a 19.5% reduction in final germination of a forage crop (Russian Thistle) at 10.1 dSm^{-1} salinity level. The results from this study further confirm the earlier report of Waisel, (1972) that germination of both halophytes and glycophytes may be reduced by salinity.

Plant height

Plant height was significantly ($P<0.05$) reduced by salinity (Table 5). Both (S_1) and (S_2) levels of salinity resulted in 27 and 44% reduction in plant height, respectively when measured 30 days after planting. This was probably due to the depressive effect of soil salinity on the root growth which affected both nutrient and water intake by the roots. This consequently resulted in reduction in plant height. Ashour and Abd-El Hamid, (1970) also reported reduction in the height of seedlings and the number of leaves per seedling due to soil salinity in certain varieties of Egyptian cotton. Hussain and Rehman, (1993) also reported a reduction in growth of sunflower seedlings due to salinity stress.

Leaf relative water content

An inverse relationship was observed between the imposed salinity levels and leaf relative water content (Table 5). Seventy days after planting, leaf relative water content for the S_1 and S_2 treatments were about 12 and 10% lower than for the control. However, salinity effect on leaf relative water content appeared to decrease with increase in age of the plant. For example, at 70 and 80 days after planting, there was no significant difference in leaf relative water content for the S_1 and S_2 treatments. There was however, a significant ($P<0.05$) difference in leaf relative water contents of the control and that of the S_1 and S_2 treatments, with the S_1 and S_2 treatments having significantly lower leaf relative water contents than the control at both 70 and 80 days after planting. The corresponding decrease due to S_2 treatment was 10 and 23%, respectively. Lower leaf relative water content due to soil salinity was also reported for *Celosia argentea L.* (Oputa 1981). Lower shoot water potential due to soil salinity was also observed in rice by Asch et al. (1995) and in maize by Grant, (1995). These workers attributed the reduction in the shoot water potential to the reduction in osmotic potentials in the saline soils leading to reduced water use and crop growth. The observations in this study provided a confirmation of possible water stress that may be associated with salinity stress.

Leaf area index (LAI)
Significant effect of soil salinity on leaf area index of groundnut was observed (Table 5). However, this was only manifested at a later stage of growth (50 days after planting). No such effect was observed 30 days after planting. The LAI for the S_1 and S_2 treatments were respectively 37 and 41% lower than the control by 50 days after planting. Rehman and Hussain, (1998) also reported a reduction of 22, 9 and 37% in the height, leaf number and leaf area of sunflower, respectively, at 10 dSm^{-1} salinity level. Similarly, Malakondalah and Rajeswararao, (1979) also reported a reduction in the leaf area of peanut plants with increasing soil salinity. Reduction in LAI due to soil salinity was probably associated with the general effect of salinity on physiological growth process. Chavan and Karadge, (1980) attributed reduction in growth of peanut plants to the effect of salinity on the chlorophyll formation and the associated reduction in the rate of photosynthesis. In the S_1 and S_2 plots, the number of nodules per plant was reduced by 45 and 69% respectively, relative to the control, but differences in pod and kernel air-dry weight among treatments were not significant (Folorunso et al., 2004). 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.

Conclusion

Soil salinity significantly reduced water intake of the soil which consequently led to significant reduction in seedling emergence, plant height and leaf relative water content. Significant effect of soil salinity on leaf area index was observed in the later stage of growth (50 days after planting). Apparently, there was a delayed effect of salinity on leaf area index. The results showed that NaC1 salinity adversely affected water intake characteristics of the soil and various early growth parameters of groundnut.

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Table 1. Initial soil properties of the experimental site

pH 1:1 (H_20)	7.30
1:1 (1N KC1)	5.75
ECe (dS m^{-1})	0.86
Total N (g kg^{-1})	0.08
Available P (mg kg^{-1})	10.50
Exchangeable K (cmo1kg^{-1})	0.34
Na (cmo1kg^{-1})	0.62
Ca + Mg (cmo1kg^{-1})	5.00
Cation exchange capacity (cmo1kg^{-1})	7.85
Exchangeable sodium percentage ESP (%)	7.90
Organic carbon (g kg^{-1})	1.2
Maximum water holding capacity (%)	34.35
Particle size distribution	
Sand (%)	76.08
Silt (%)	10.20
Clay (%)	13.72
Field texture	Sandy-loam

Table 2. Chemical properties of the top 0.15m soil layer during the crop growing season

Treatments	Planting	Flowering	Harvest
		pH	
S_0[1]	7.38	7.36	6.77
S_1	7.63	7.67	7.82
S_2	7.64	7.84	7.47
$LSD_{0.05}$	NS[1]	NS	NS
		ECe (dSm^{-1})	
S_0	0.91	0.82	0.62
S_1	5.03	3.85	1.33
S_2	11.06	6.05	2.55
$LSD_{0.05}$	0.731	1.578	0.809
		ESP (%)	
S_0	7.90	9.73	11.54
S_1	12.81	20.12	19.12
S_2	19.97	23.05	23.16
$LSD_{0.05}$	2.100	3.577	4.485

[1] S_o, S_1 and S_2 are the salt levels corresponding to ECe values of 0.75, 3.06 and 5.76 dSm^{-1} respectively

[2] NS= Not significant

Table 3. Effect of salinity treatments on the infiltration rate of the soil

Treatments	Steady state infiltration rate ($mmhr^{-1}$)	Reduction in steady state infiltration rate (%)	Cumulative infiltration rate (mm)	Reduction in cumulative infiltration rate (%)
S_0[1]	8.9	-	556.1	-
S_1	4.7	47.2	337.1	39.4
S_2	2.1	76.4	172.3	69.0
$LSD_{0.05}$	1.1		72.1	

[1] S_o, S_1 and S_2 are the salt levels corresponding to ECe values of 0.75, 3.06 and 5.76 dSm^{-1} respectively

Table 4. Effect of salt treatments on germination of groundnut seeds

	Days after planting																	
	5		7		9		11		13		15		17		21		30	
Treatments	Av. germ[2]	% germ[3]	Av. germ	% germ	Av. germ	% germ	Av. germ	% germ	Av. germ	% germ	Av. germ	% germ	Av. germ	% germ	Av. germ	% germ	Av. germ	% germ
S_0[1]	18	4.9	165	14.8	350	95.1	3.53	95.1	353	95.1	353	95.1	354	96.2	354	96.2	354	96.2
S_1	7	1.9	40	10.9	226	61.4	300	81.5	314	85.3	319	86.7	320	87.0	327	88.9	340	92.4
S_2	4	1.1	25	6.8	159	43.2	236	64.1	252	68.5	256	69.6	262	71.2	276	75.0	284	79.2
$LSD_{0.05}$	4.1		15.4		87.7		62.4		18.4		32.4		16.3		25.12		8.14	

[1]S_o, S_1 and S_2 are the salt levels corresponding to ECe values of 0.75, 3.06 and 5.76 dSm^{-1} respectively

[2]Average germination

[3]Percentage germination

Table 5. Salinity treatment effects on growth characteristics of groundnut

Treatments	Plant height (m)	Leaf area index (LAI)			Leaf relative water content (%)	
	30 DAP[2]	30 DAP	50 DAP	60 DAP	70 DAP	80 DAP
S_0[1]	0.65	2.76	5.76	46.9	47.7	47.4
S_1	0.47	3.39	3.64	39.0	42.1	36.3
S_2	0.36	2.72	3.40	29.4	42.7	36.7
$LSD_{0.05}$	0.05	NS[3]	0.31	7.5	4.1	9.0

[1] S_o, S_1 and S_2 are the salt levels corresponding to ECe values of 0.75, 3.06 respectively and 5.76 dSm^{-1} respectively

[2]Days after planting

[3]Not significant