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Salinity effects of irrigation water on maize crop production at maizube farms, Minna, Nigeria

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Abstract

The salinity effects of irrigation water on maize crop production were determined by taking samples of the water from three locations at Maizube Farms. Laboratory analysis was conducted on the samples to determine the physicochemical properties. The sodium adsorption ratio (SAR) and the leaching requirement (LR) of the irrigation water were determined. The values obtained were 6.3%, 1.4% and 0.9% for SAR and LF at 100% and 90% yield potentials respectively. The low values of SAR and LR mean that the irrigation water should be used with caution on the maize farm even with low associated sodium hazard. The mean concentrations of sodium (1.83mg/L) and chloride (27.32mg/L) of the irrigation water are below 3mg/L and 70mg/L recommended values. Hence, the irrigation water has a tolerable salinity for maize crop production. The data collected in this research should serve as supplement to the existing information on soil salinity problems in Nigeria.

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Introduction

Soil degradation is a serious environmental challenge in Nigeria. Deforestation, soil erosion, deforestation, soil salinization and water logging form different but often interrelated aspects of soil degradation (Karshenas, 1994). The associated problems with soil degradation are responses to osmotic stress and reduction in plant growth and productivity in the irrigated areas of arid and semi arid regions. These problems are caused by low precipitation and high transpiration leading to disturbance in soil salt balance (Owaiye, 1995). Hence salinity can be defined as the accumulation of water soluble salts in the soil column or regolith to a level thkat has a drastic impact on agricultural production, environmental health and even the welfare of a country (Owaiye, 1995).

The high evapo-transpiration as a result of high temperature in the arid and semi arid zone is the basic cause for salt accumulation on the soil surface (Khalid, 2007). Therefore countries that lies within these regions surfer a lot from the consequential effect of irrigation as a result of low rainfall.

Irrigation brings about the desired yield increase in plant population but most irrigation water supplies contain substantial amount of salts. For example, a water source with an electrical conductivity of 1µS/cm, a quality suitable for irrigating most crop, contains nearly 1 ton of salt in every acre-foot of water applied (FAO, 2005). Irrigation water can therefore contribute a substantial amount of salt to the soil which may either directly affect plant growth or add salt to the soil so that plant growth is eventually affected by the increasing level of soil salinity.

While comparing different crops for their responses to osmotic or salt tolerance Maize has proven to be the crop with most moderately salt sensitive, but there is evident that considerable intra specific genetic variation exits for salt tolerance in Maize (Azevedo *et al.,* 2004, Mansour *et al.,* 2005).

Although the degree of salt tolerance in Maize cultivars observed at early growth stages was not confirmed at later growth stages, germination stage was found to be resistance to salt stress than the seedling stage (Cicek and Cakirlar, 2002).

It was reported recently that the salt sensitivity of Maize plants is due to high accumulation of sodium ion in the leaves. For instance, Maize cultivars were reported to restrict sodium and chloride ions in their roots and subsequently transport them to the shoot (Cicek and Cakirlar, 2002). However due to seasonal changes, geographical and farm locations variations in experimental data are sure to exist. Therefore the objective of this paper is to determine the effects of salinity on Maize crop production at Maizube farms, Minna, Nigeria.

Materials and methods

Sample collection

Samples used were collected from three different locations between the months of June and August, 2010 from the irrigation water of Maizube farms. After running a quality test on the water it was easy to define the total concentration of soluble salts, relative proportion of sodium to other cations present, bicarbonate concentration as related to the concentration of calcium and magnesium and concentration of specific elements and compounds present in the water.

Determination of electrical conductivity and total dissolved solids

The electrical conductivity reflects the capacity of water to conduct electric current and is directly related to the concentration of salts dissolved in water. This is because the salts dissolve into positively charged ions and as well as negatively charged ions that conduct electricity. The electrical conductivity is also temperature dependant. The electrical conductivity of water increases by 2 to 3 % for an increase in 1^oC of water temperature. The relationship between electrical conductivity and total dissolve solute is given below:

$TDS = 670 \times EC$ (Egharevba, 2009) (1)

Where: TDS = Total Dissolved solids (ppm), EC = Electrical Conductivity (dS/m)

Determination of sodium adsorption ratio (SAR)

Plants are detrimentally affected, both physically and chemically, by excess salts in some soils and by high levels of exchangeable sodium in others. Soils with an accumulation of exchangeable sodium are often characterized by poor tilt and low permeability thereby making them unfavourable for plant growth. The SAR is an indicator of the relative proportion of sodium ions in a water sample to those of calcium and magnesium. It is used to predict the sodium hazard in an irrigation water sample. It is also used to predict the potential for sodium to accumulate in the soil provided sodic water was in constant use. Mathematically the following equation was used to compute the SAR of the irrigation water.

$$SAR = \frac{[Na^{+}]}{\sqrt{\frac{[Ca^{2+}]+[Mg^{2+}]}{2}}}$$ (Egharevba, 2009) (2)

Where: $[Na^{+}]$ = sodium ion concentration in meq/L, $[Mg^{2+}]$ = Magnesium ions concentration in meq/L, $[Ca^{2+}]$ = Calcium ions concentration in meq/L

This parameter qualifies the ratio of sodium to calcium and magnesium in terms of the ability of the sodium to donate its electron to the soil. The lower the SAR the less likely the water is to cause structural degradation of the susceptible soils.

Table 1. General Classification of Water Sodium Hazard Based on SAR Values.

SAR Values (%)	Sodium Hazard of Water	Comments
1-9	Low	Use on sodium sensitive crops must be cautioned
10-17	Medium	Amendments such as gypsum and leaching required
18-25	High	Generally unsuitable for continuous use
≥ 26	Very high	Generally unsuitable for use

Source: Egharevba, (2009)

Determination of leaching fraction

There is a continual build up of salt as the farmland is successively irrigated. The salts would accumulate in the rooting depth until it gets to damaging concentrations. A portion of added salt must be leached from the root zone before the concentration affects crop yield. Leaching is carried out by applying sufficient water so that a portion percolates through and below the entire root zone carrying with it a portion of the accumulated salts.

Hence the leaching fraction is the amount of extra irrigation water that must be applied above the amount required by crops in order to maintain acceptable root zone salinity.

Therefore in order to estimate the needed leaching fraction required on Maizube Maize farmland, the following equation is essential.

$$LF = \frac{EC_w}{EC_{dw}}$$ (Egharevba, 2009) (3)

Where: LF = Leaching Fraction, EC_w = Conductivity of irrigation water, EC_{dw} = Salinity of the drainage water

After much successive irrigation, the salt accumulation in the soil will approach some equilibrium concentration based on the salinity of the applied water and the leaching fraction. A high leaching fraction (LF = 0.5 or 50%) results in less salt accumulation than a lower leaching fraction (LF = 0.1 or 10%).

Results and discussions

Salinization commonly occur as a result of agricultural activities, either associated with irrigation or due to long term changes in water flow in the landscape that can follow land clearance or changed water management. Salinization associated with maize production occurs when salts are buildup in the root zone. This is because the drainage of water from the subsoil is not sufficient to prevent saline waters rising into the root zones (Micheal and Andrew, 2002).

Maize is moderately sensitive to salinity and is considered as salt sensitive cereal (Mass and Hoffman, 1977). The yield decrease under increasing soil salinity of maize crop is shown in Table 2.

Table 2. Yield Decrease under Increasing Soil Salinity of Maize Crop.

Yield Potential (%)	Salinity (dS/m)
100	1.7
90	2.5
75	3.8
50	5.9
0	10

Source: Mass and Hoffman, 1977

Table 3 shows physic-chemical properties of irrigation water for maize production at Maizube farms which was carried out at the Federal Ministry of Water Resources, Regional Water Quality Laboratory, Minna, Nigeria. The result reveals the amount of Total Dissolved Solids, Sodium hazard, Alkalinity and specific ions concentrations of the irrigation water.

Computation of sodium adsorption ratio (SAR)

Table 1 gives average values for Calcium, Sodium and Magnesium ions concentrations in mg/L. The sodium adsorption ratio of the irrigation water was computed from equation (2) and is given as follows:

$$SAR = \frac{[Na^{+}]}{\sqrt{\frac{[Ca^{2+}]+[Mg^{2+}]}{2}}}$$

$[Na^{+}]$ = 1.83mg/L $= 1.83/23 = 0.08meq/L$

$[Ca^{2+}]$ = 62.37mg/L $= 2(62.37/20) = 0.6237meq/L$

$[Mg^{2+}]$ = 30.70mg/L $= 2(\frac{30.70}{24}) = 2.56meq/L$

Hence,

$$SAR = \frac{0.08}{\sqrt{\frac{0.6237+2.56}{2}}} = 0.063$$

$$SAR = 0.063 = 6.3\%$$

From Table 3 it can be said that irrigation water at Maizube farms has a low water sodium hazard since the SAR is only 6.3%. Therefore the use of the water on maize crop must be cautioned.

Table 3. Physicochemical properties of irrigation water for maize production at maizube farms.

Parameter	Unit of Measurement	Mean Value	Maximum Value	Minimum Value	Standard Deviation
Conductivity	µS/cm	117.00	133.00	105.00	14.42
pH	-	6.26	6.31	6.18	0.07
Turbidity	NTU	7.95	11.44	1.84	5.31
TDS	Mg/L	78.38	89.11	70.34	9.66
Carbonate	Mg/L	0.00	0.00	0.00	0.00
Nitrate	Mg/L	1.08	2.39	0.36	1.14
Calcium	Mg/L	62.39	93.08	23.02	35.83
Magnesium	Mg/L	30.69	67.06	9.01	31.69
Sulphate	Mg/L	2.67	5.00	0.00	2.52
Phosphate	Mg/L	1.17	2.00	0.02	1.03
Boron	Mg/L	0.0068	0.01	0.005	0.0028
Sodium	Mg/L	1.83	3.00	1.00	1.04
Manganese	Mg/L	0.53	0.90	0.00	0.47
Potassium	Mg/L	4.02	5.36	3.35	1.16
Bicarbonate	Mg/L	14.67	24.00	10.00	8.08
Chloride	Mg/L	27.32	29.49	24.99	2.25
Iron	Mg/L	0.44	0.55	0.33	0.11

Leaching requirement on maize farm

In order to ensure that salt levels in the soil do not exceed that of the irrigation water more water are added to leach the salt beyond the root zone. However, adequate drainage should be ensured to prevent any further environmental damage.

The fraction of irrigation water that must pass through the root zone to control salts at an acceptable level is described as the leaching requirement or leaching fraction (Egharevba, 2009). Equation (3) can be modified to become the following:

$$LR = \frac{EC_W}{(5EC_{ec} - EC_W)} \quad (4)$$

Where: EC_{ec} = Threshold Salinity (dS/m), a user specified value based on knowledge of plant tolerances and soil types. The EC_{ec} for maize crop are 1.7 and 2.5 for 100% and 90% yield potentials respectively (Table 2).

Table 4 shows the leaching requirement for maize crop based on their EC_{ec} specifications and computed from equation (4).

The leaching requirement tells the amount of irrigation water needed to leach the accumulated salt on the maize farm below root zone. And since a high leaching requirement (50%) results in less salt accumulation the maize farm at Maizube has the tendency of accumulating more salt with either 100% or 90% irrigation yield potential.

Table 4. Leaching Requirements for Maize Crop at Maizube Farms.

Threshold Salinity (dS/m)	Yield Potential (%)	Leaching Requirement (%)
1.7	100	1.4 below root zone
2.5	90	0.9 below root zone

Conclusions

The following conclusions are drawn from the investigation into salinity effects of irrigation water on maize crop production at Maizube farms, Minna, Nigeria.

The low sodium adsorption ratio of 6.3% obtained means that the irrigation water should be used with caution on the maize farm even though the associated sodium hazard of the water is significantly low. Caution is necessary in order to avoid build up of sodium on the farm land to a detrimental level.

Continues irrigation of the maize farm will cause salt buildup above the root zone even when leaching is timely effected. This is because at 100% yield potential only 1.4% additional irrigation water is available to leach the accumulated salt below root zone.

Since the mean concentrations of sodium and chloride of the irrigation water are 1.83mg/L and 27.32mg/L respectively and are below 3mg/L and 70mg/L Pescod, (1992) guideline for interpretation of water quality for irrigation, the irrigation water therefore has a tolerable salinity for maize crop production.

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