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The Effects of Four Sources of Irrigation Water on Soil Chemical and Physical Properties

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Abstract: The aim of the study was to examine the effects of four sources of irrigation water on soil chemical and physical properties at Kpong in the Manya Krobo District. The chemical and physical variables were measured using the top soil (0-15 cm) to compare soils irrigated with four sources of water. The sources of irrigation water used by the farmers in the District include: river, canal, tap and well. Each water source was used to irrigate tomatoes. Chemical variables determined were: soil pH, Electrical Conductivity (EC), Sodium (Na), Magnesium (Mg) and % total NH_4-N. These variables were monitored for a period of three months. Two core samples were taken from each of the plots before planting of the tomato and subsequent samples taken at the same spots monthly, after planting, for a period of three months and sent for analysis. Water quality was established according to its chemical composition. The pH decreased (from 6.6 to 6.4 in T_4 and from 6.6 to 6.2 in T_3), EC (from 4.1 to 3.7 ds m^{-1} in T_3), Na^+ (from 13 to 11.5 cmol kg^{-1} in T_3 and from 13 to 12.4 cmol kg^{-1} in T_4), Ca (from 36.5 to 32.05 cmol kg^{-1} in T_3 and from 36.5 to 33.9 cmol kg^{-1} in T_4), Mg (from 9.2 to 8.3 cmol kg^{-1} in T_3 and from 9.2 to 8.67 cmol kg^{-1} in T_2) and % total NH_4-N (from 0.25 to 0.2 in T_4 and from 0.25 to 0.16 in T_3). Continuous irrigation lowered values of the variables and values of soil nutrient. However, the water quality and soil chemical and physical data suggest that the sodification process and the increased soil erosion risk must be controlled in order to achieve a sustainable high production system. Soils irrigated with river water was the most preferred for growing tomato by virtue of their optimum level of pH, EC, Na, Mg and NH_4-N.

Key words: Sodification, evapotranspiration, infiltration, leaching and acidification

INTRODUCTION

Crop growth is usually affected by the water use for irrigation during the dry period by water deficit that significantly decrease crop yields. Irrigation is needed when natural precipitation is not adequate to secure vegetables grain and forage production (Abu-Awwad and Kharabsheh, 2000). Depending on the size of the farm and the type of irrigation system, application of water is often made possible by using modern power sources from well pumps, taps, canal and storage of large quantities of water in reservoirs, ponds, streams and rivers. Soil and water losses by erosion and runoff must be controlled in order to allow for sustainable agriculture. On relatively sandy soil with low organic matter content, Truman and Rowland (2005) found high erosion risk when a supplementary irrigation system was used. Natural water has different salt concentrations and qualities and contains principally salts of high solubility like sodium, calcium, magnesium and potassium chlorides and sulfates. Salinisation and sodication could limit the soil's productivity, leading to fertility reduction (Al-Zubi, 2007). If the level of Na^+ in the soil is high, the colloidal fraction behavior will be affected.

The level of Na^+ in soil is usually quantified by the Exchangeable Sodium Percentage (ESP) or by its estimator, the sodium adsorption ratio SAR. When SAR increases, then the rate of the soil sodication process also increases (Herrero and Coveta, 2005). Suarez *et al.* (2006) found that a SAR increase caused by irrigation water had an adverse impact on water infiltration for two types of soil, clay and loam. For the clay soil, even an increase from SAR 2 to SAR 4 resulted in a significant increase in infiltration rate, while in loam soil the increase in infiltration time was significant. Sodic soils are associated with structural changes that principally affect soil's permeability. With high ESP and low electrolyte concentration, clay, as well as organic matter, begins to swell and disperse, causing negative physical effects such as restricted aeration and permeability. Damage to physical properties soon appears at low salt concentrations. Clay and organic matter swelling and dispersion are unavoidable after irrigation with water of low quality (Kamphorst and Bolt, 1978). Boivin *et al.* (2002) found that the increase in alkalinity and Mg concentration in arid vertisol soil was caused partly by the composition of the irrigation water and partly by the reduction and dissolution of Fe oxides and Fe^{2+} fixation on exchange sites of the clay minerals. Hydraulic conductivity (k) reduction is irreversible, or very difficult to restore, because of soil matrix changes caused by

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swelling and dispersion of clay and organic matter. Chen and Banin (1975) used microscopic observation to show that fine particle re-organization arranges a continuous net of fine material that fills all the void spaces. The salt effect on soil hydraulic properties should not be ignored because it can lead to great mistakes in soil management with irrigation (Dane and Klute, 1977). The changes in clay dispersion and hydraulic conductivity are very sensitive to low ESP and salinity levels (Pupisky and Shainberg, 1979). On the other hand, Lieffering and Mclay (1995) did not detect negative effects on soils in the pampean region when farms were irrigated with carbonated water, suggesting that in deep, well drained and calcium rich soils, sodication is controlled by natural processes.

The objective of this study was to assess water irrigation impact on soil physical and chemical at Kpong in the Manya Krobor Distrit of Eastern Region in Ghana with the use of four different sources of water which include river, canal, tap and well. This study is therefore part of a research work conducted on the use of four sources of water for irrigation of tomato. It specifically reports on the effect of the four sources of water on soil chemical and physical properties.

MATERIALS AND METHODS

Experimental design: Randomized Complete Block Design (RCBD) was used and the treatments were the four sources of water with four replications. The soil analyses were carried out at the Soil Science Laboratory of the School of Agriculture, University of Cape Coast on August 1st 2007, September 1st 2007, October 1st 2007 and December 1st 2007.

Soil sampling: Soil samples (0-15 cm) were randomly taken at the site. Two core samples were taken from each of the four plots before planting of the tomato and subsequent samples taken at the same spots monthly, after planting, for a period of three months.

Sample preparation: The soil samples were air-dried, to pass through 2 mm sieve to obtain the fine earth fraction. The sieved soils were then mixed thoroughly.

Chemical properties: The soils were analyzed for the following chemical propertie: pH, EC, Na, Ca, Mg and %total NH_4-N.

Initial properties of the soil: The initial properties of the soil after the fertilization are as follows:

- pH, 6.6; Electrical conductivity, 4.12 dS m^{-1}; Na, 13.1 cmolc kg^{-1}; Ca, 36.4 cmolc kg^{-1}; Mg, 9.2; cmolc kg^{-1} and % total NH_4-N, 0.21

- **pH:** The method used to determine the soil pH was according to Deveral and Fujii (1990)
- **EC:** The method for determining EC was according to Rowell (1994)
- **Ca, Mg, %Total NH_4-N and Exchangeable Na^+:** The methods used to determine Na, Ca, Mg and % Total NH_4-N levels were according to Page *et al.* (1992)

Data analysis: The Mstat-C software was used for the Analysis of Variance (ANOVA) of data and the mean comparisons were done using Duncan's Multiple Range Test.

Treatments: The treatments comprised the following:

- Soil irrigated with river (T_1)
- Soil irrigated with canal (T_2)
- Soil irrigated with tap (T_3)
- Soil irrigated with well (T_4)

RESULTS

Changes in pH: There was no significant difference in the mean values of the treatments over the three month period. T_4 recorded the highest mean pH value (6.4) at the end of the third month and T_3 recorded the least mean pH value (6.12) (Fig. 1).

Changes in EC of soil: There was significant difference in the mean values of the treatments in the second month. However, there was no significant difference in the third month. The least mean value was 3.7 dS m^{-1} in T_3 in the third month (Fig. 2).

Changes in exchangeable Na^+: There was no significant difference in the mean values of the treatments in month two. However, there were significant differences in the values in the third month. T_3 recorded the least mean value (11.5 $cmol_c$ kg^{-1}) in the third month whilst T_4 recorded the highest mean value (12.4 $cmol_c$ kg^{-1}) (Fig. 3).

Changes in Calcium (Ca) of soil: Significant differences were recorded in the mean values of Ca in the second month. The mean values of exchangeable Ca ions ranged between 33.22-36.3 $cmol_c$ kg^{-1} (Fig. 4). The least mean value of the Ca recorded in the third month was 32.05 $cmol_c$ kg^{-1} in T_3 and the maximum value recorded in T_4 (33.9 $cmol_c$ kg^{-1}).

Changes in Magnesium (Mg) of soil: There was no significant difference in the mean values of the treatments over the three month period. The values ranged between 8.3-9.18 $cmol_c$ kg^{-1}. The maximum mean value of Mg was recorded in T_2 (8.67 $cmol_c$ kg^{-1}) and the least mean value recorded in T_3 (8.3 $cmol_c$ kg^{-1}) in the third month (Fig. 5).

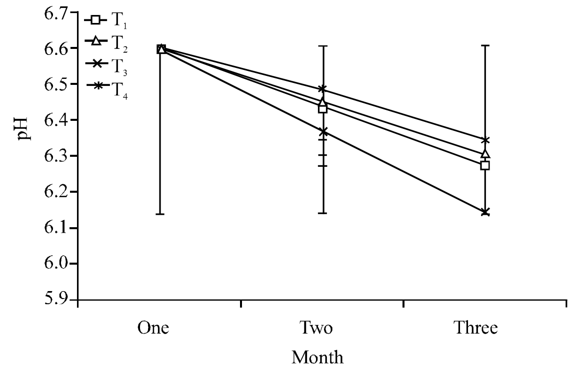

Fig. 1: Changes in pH of Soil over three months with error bars (SD value = 1)

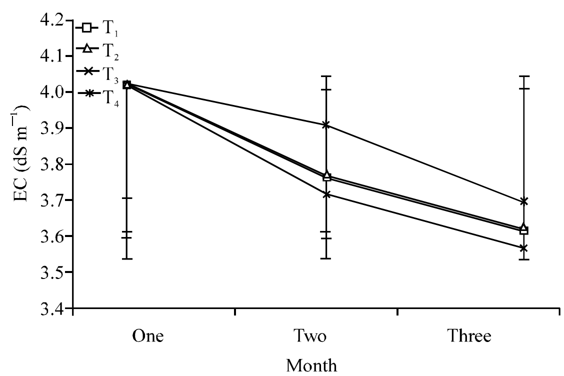

Fig. 2: Changes in EC of soil over three months with error bars (SD value = 1)

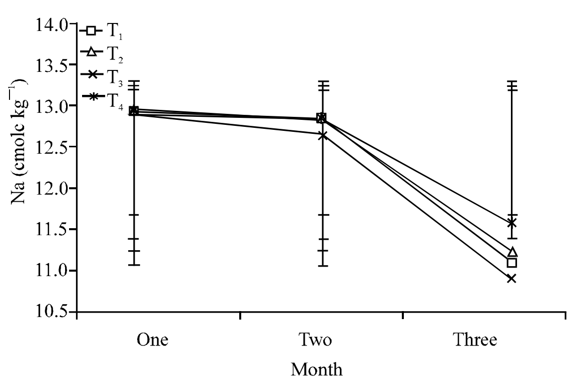

Fig. 3: Changes in exchangeable Na^+ of soil over three months with error bars (SD value = 1)

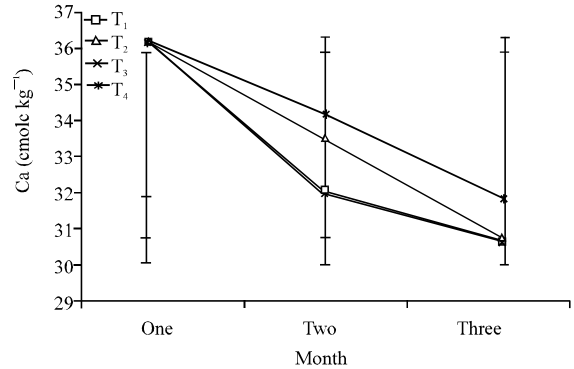

Fig. 4: Changes in Ca of soil over three months with error bars (SD value = 1)

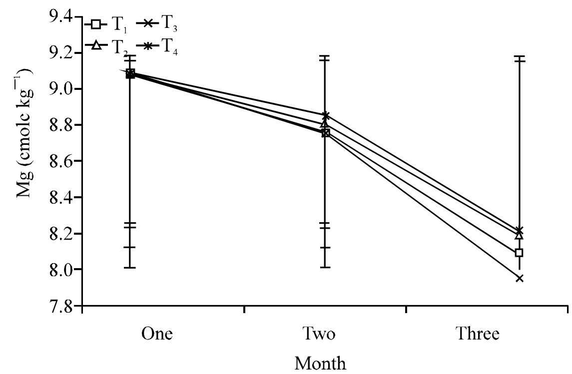

Fig. 5: Changes in Mg of soil over three months with error bars (SD value = 1)

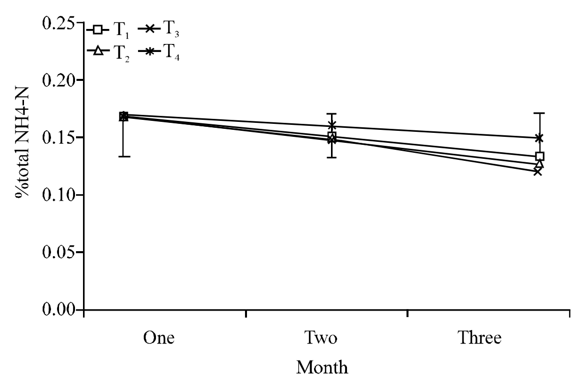

Fig. 6: Changes in %total NH_4-N of soil over three months with error bars (SD value = 1)

Changes in %total NH_4-N of soil: There was no significant difference in the mean values of the percentage total NH_4-N in the second month. The maximum mean value of total NH_4-N was recorded in T_4 (0.20%) in the third month whilst the minimum mean value was recorded in T_3 (0.16%) (Fig. 6).

DISCUSSION

Frequent irrigation had significant effect in some of the studied parameters. The mean values of the pH decreased from month one to month three. According to Deveral and Fujii (1990), the relative effect of exchangeable sodium in raising pH is more than that of exchangeable Ca^{2+} and Mg^{2+} because sodium hydroxide is a strong base. From the crop production point of view, the optimum soil pH should range between 6.4 to 8.3 (FAO, 1992). Thus, pH values within this range would undoubtedly increase the availability of nutrients in the soil.

EC also decreased from month one through to month three. Irrigation plays the role of promoting leaching of salts as a result of flocculation of some soils of the dispersed soil matrix and sometimes improvement in hydraulic conductivity (Valenzo *et al.*, 2001). This could be the probable cause of the decrease in EC. The decrease in EC values are in line with Richard (1984) who found a decrease in EC level through leaching when he conducted experiment to investigate leaching of nutrients. According to, Richard (1984) salinity of soil is decreased when a soil is repeatedly irrigated. In this study, the slightly higher (EC and TDS) mean values in T_4 than T_1, T_2 and T_3 in the third month might have been due to less leaching of the salt and this could affect the osmotic potential of the plants grown on such soil. This does also reduce nutrients uptake by the plant root and delays leaf appearance, thereby decreasing plant growth and development. This consequently reduces yield. This effect seems to be acceptable for desirable chemical soil conditions. However, it is known that high ESP values combined with low electrolyte levels are favorable for colloid (clay and organic matter) dispersion. In this case and in agreement with Suarez *et al.* (2006), there would be a reduction in fertility, causing a decrease in the soil productivity and physical soil properties would be affected.

Mean values of percentage sodium in the soil decreased from month one through month three. According to Deveral and Fujii (1990) the cations of sodium in the solution phase are usually in equilibrium with those of soil colloid. Hence as the cations in the solution phase are leached out, some of the colloids tend to come into solution and this may result in the decrease in the sodium level in the soil irrigated with tap water. The decrease in sodium values could also be attributed to the fact that Ca^{2+} displaces Na^{+} at the exchange sites. This agrees with the fact that the removal of Na^{+} ions from the soils exchangeable complex and replacement with the Ca^{2+} ions result in reduction in salt level of a soil. This can be observed in Fig. 3. The sodium values in T_3 were slightly lower than the values in T_1, T_2 and T_4 and were likely to result in acidic condition when used for irrigation. These results are in agreement with Truman and Rowland (2005), who showed that there is a higher soil erosion risk for lands under irrigation.

There was a decrease in calcium in the soil solution. This may be due to the displacement effects that calcium can have over sodium and magnesium at the exchangeable site. According to Al-Zubi (2007), damages to soil's physical properties were probably produced by salt concentration in the irrigate water. These results differ from Lieffering and Mclay (1995), in relation to the negative effects in pampean region soils to farms irrigated with carbonated waters. From their study, supplementary irrigation was not the principal cause of the current soil degradation degree. In the zone where this work was carried out, about 50 years of land cropping without conservation planning led to high levels of physical degradation.

In an experiment to determine the response of soil chemical properties on irrigation, Pupisky and Shainberg (1979) noted that salt in soil influences Ca uptake and distribution throughout the plant. In line with this study, the reduction in the mean value of the Ca from month one to month three might be due to the uptake of the Ca by the plants as the plants grew.

The mean values of Mg also decreased with daily irrigation. The least mean value of 8.4 $cmol_c\ kg^{-1}$ in T_3 soil in month three was within the range of 1-30 $cmol_c\ kg^{-1}$ for growing tomato; when Mg value of soil is less than 30 $cmol_c\ kg^{-1}$, there is no restriction for the use of such soil for growing crops (Dewis and Freitas, 1970). Based on this recommendation the soil is therefore considered suitable for growing crops.

Percent total NH_4-N at the beginning of the experiment amounted to 0.19% in T_4, 0.19% in T_2, 0.19% in T_1 and 0.19% in T_3. These mean values indicate that in addition to the initial available total N of 0.19%, the total NH_4-N loss had amounted to 0.04% at the end of the third month possibly through the uptake by the plants.

CONCLUSION

Repeated irrigation had much effect on the soil since there were significant differences in the mean values of EC, Ca, % total NH_4-N, Mg and total N in the treatments in the third month.

T_3 recorded low mean values of EC, Ca, Na, Mg and % total NH_4-N among the treatments. It was followed by T_1, T_2 and T_4 in that order.

With the results obtained and when compared with the FAO Soils Bulletin 10 (Dewis and Freitas, 1970), which gives recommended guidelines of soil properties for growing crop, soils with pH range of 6.5-7.2, EC range of 3.5-4.8 dS m^{-1}, Ca of range 35-38.5 $cmol_c\ kg^{-1}$ and %total NH_4-N range of 0.18-0.20%.

It can be concluded that all the four sources of water can be used for cultivating tomato. Indeed, their use reduced the values of the investigated properties, but within acceptable limits for crop growth.

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