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HORIZONTAL DISTRIBUTION OF PHOSPHORUS IN SOILS OF IRRIGATION DITCHES

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ABSTRACT

The cultivation of vegetable crops during the dry season is an age-long practice by peasant farmers in northern Nigeria. The water for the irrigation of the plots is supplied by shallow streams, or ponds and wells dug along the banks of the streams. Phosphorus is an important plant nutrient. The effect of flowing irrigation water on the horizontal distribution of phosphorus in soils of irrigation ditches of five vegetable plots located along the banks of the stream in Bosso village, Niger state, Nigeria, was investigated. Higher P levels and lower organic matter content were found close to the upper end of the ditches where the irrigation water was applied. Mean P values of individual ditch soils which produced a definite but unexpected pattern of distribution of the element are also presented. Data on pH and phosphorus values of the stream water provided the level of the contribution from this source. Non-significant correlations were found between soil P and stream water P on one hand, and between soil pH and stream water pH on the other, indicating that the irrigation water may indeed, have had little or no influence on the properties of the ditches' soils.

KEYWORDS: Extractable phosphorus, Phosphorus movement, Irrigation ditches, Irrigation water, Organic matter.

INTRODUCTION

Fairly intensive irrigated crops cultivation is practiced by peasant farmers along the banks of the stream that runs in a south-western direction across Bosso village on the outskirts of Minna Metropolis in Niger state, Nigeria, during the dry months of the year. Farming activities during this period helps to sustain the production of certain vegetable crops beyond the normal farming season (May-October). Crops irrigation becomes important during this period especially when the water holding capacity of the soil, and perhaps organic matter content are low. Irrigation systems, therefore help to maintain the soil water status within the upper and lower limits determined by the soil type and the crop concerned (Duke and Scholberg, 2005; Zotarelli *et al*; 2007). Portions of the stream dry up during this period, leaving behind slow flowing or stagnant pools of water. The vegetable plots are flooded by pumping water from the stream and made to flow along the shallow and narrow ditches that are banked by metal sheets or wooden planks. Outlets from the ditches are opened during flooding.

Irrigation water from whatever source is reported to contain both dissolved and solid matter, and the constituent nutrients tend to enrich the soil due to their concentration by evaporation and transpiration processes (Rhoads, 1972). However, very soluble and mobile ions are rapidly leached into the subsoil (Zotarelli *et al*, 2007). Beek, *et al* (1980), reported phosphate enrichment of soils treated with sewage water, and according to Al-Khateeb, *et al* (1986), phosphorus is immobilized or becomes less soluble in soil either due to adsorption, chemical precipitation, or both. Extractable and total levels of phosphorus and sulphur have also been shown by Peverill and Briner (1980), to decrease markedly with increasing depth of soil. An earlier report on the movement of solute in soils shows that the movement followed a predicted pattern on the basis of the physical and chemical properties of the soil (Korte *et al*, (1976).

Solid-solution exchange reactions occur in soil and contribute considerably to ion retention. During flooding, it is obvious that the movement of solutes in the soil would be in two directions; a vertical downward movement aided by gravity, and a horizontal movement conceived as the leaching of solutes in the direction of the flowing water. Iwugo (1986), reported that horizontal flow of water in channels' soils leads to the retention of coarser solids in the first part of the channel and the finest in the other end.

This study was initiated to obtain preliminary data that would provide information on the horizontal distribution of phosphorus and organic matter in soils of irrigation ditches.

MATERIALS AND METHODS

Three samples of surface soils were collected from each of five points along the irrigation ditches of five vegetable plots located along the banks of the stream that runs in a south-western direction across Bosso village, in Niger state, Nigeria. Samples were taken at intervals of 4 meters and 0-20cm depth of soil. Samples were also taken at corresponding points of adjacent uncultivated plots which did not receive irrigation water. The samples from each sampling point were bulked together, thoroughly mixed and foreign matter, including stones and other solid matter were removed. They were then air-dried and sieved to pass through a 2mm screen. Soil P was determined by spectrophotometric method after extraction with sodium hydrogen carbonate (iv) solution (Olsen and Dean, 1965), while organic matter content was estimated by

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the wet oxidation procedure of Walkley-Black (Allison,1965). pH, on the other hand, was determined in a 1:1 water-soil suspension.

Water samples were taken at the points in the stream from where the irrigation water was pumped. Sampling was carried out once weekly for seven weeks. Each weekly sample was analysed for pH and total phosphorus, and a mean value was calculated. Total P was determined by the vanadomolybdophosphoric acid method after the sulphuric-nitric acid digestion procedure (American Public Health Association, 1980).

RESULTS AND DISCUSSION

Data on ditches soils are presented with those of the adjacent uncultivated soils in Table 1. The relatively higher mean pH values of the ditches soils compared to those of the corresponding soils of uncultivated plots is consistent with the findings of Rhoads (1972). This author reports that the amount of soil-water salinity resulting from the use of irrigation water

Table 1: Mean values of selected parameters of soils and irrigation water

	Ditches Soils			Uncultivated Plots Soils			Irrigation Water	
Plot	pH (H_2O)	*O.M. (%)	Available P ($mg\ dm^{-3}$)	pH (H_2O)	O.M. (%)	Available P ($mg\ dm^{-3}$)	pH	Total P ($mg\ dm^{-3}$)
F_1	7.6	0.04	0.61	7.1	0.30	0.56	7.7	1.45
F_2	7.9	0.04	0.50	7.0	0.23	0.38	7.7	1.62
F_3	7.5	0.04	0.48	6.9	0.42	0.62	7.6	1.24
F_4	7.5	0.06	0.31	7.1	0.29	0.32	7.6	1.23
F_5	7.4	0.04	0.23	7.1	0.17	0.68	7.6	1.20

***O.M. – Organic Matter**

was related to the latter's salinity, composition and the amount of leaching achieved. In contrast to the trend observed for pH, organic matter content and extractable phosphorus were generally lower in the ditches soils than in the uncultivated soils. It is also obvious from the P levels of the irrigation water and those of ditches soils that the composition of the former may not have had any noticeable influence on that of the latter, with respect to extractable soil phosphorus. A more recent report indicated significant phosphate load, besides other nutrients, in the experimental stream which receives domestic and agricultural wastes constantly from nearby homes and farms (Maji *et al*, 2006). Soil enrichment by the nutrients in the water would help to boost the yield of the vegetable crops without extra cost to the farmers who are not empowered economically to afford the procurement of commercial fertilizers. However, if nutrient enrichment of the soils by the irrigation water has not been achieved as the result of this study tends to indicate, it leads to the suggestion that available soil P estimate may not be very suitable for the study of soil-irrigation water P relationship. This view is supported by the report of Zhang, *et al* (1997), that a substantial proportion of P in soil is organically bound. McGechan and Lewis (2002), have also observed that fast reversible sorption of mineralized phosphorus onto surface sites of soils occur besides other slower processes, including reactions which deposit P in soil. Therefore, the element may not have been readily available for extraction by the extracting reagent (sodium hydrogen carbonate) employed in this study. An added complication to the interpretation of this finding is the possibility of the lack of a basis for the comparison of data on total water P and available soil P.

A noteworthy, but not surprising feature of the results of the study was the generally higher levels of organic matter content of the soils at the lower end of the ditches, away from the end where the irrigation water was applied (Fig.1a). Similarly, linear curves (Fig. 1b) were obtained for phosphorus, but indicating accumulation of the element at the upper end of the ditches. This observation in respect of phosphorus is consistent with an earlier report (Taylor and Gurney, 1965) which showed that the element is readily fixed and immobilized on application to soil. Such reactions have been shown to be rapid and diffusion-controlled, and are virtually completed instantaneously in a stirred system (Harter and Lehmann, 1983). The mobile system represented by the flowing irrigation water in this study may be equated to the stirred system referred to by these authors.

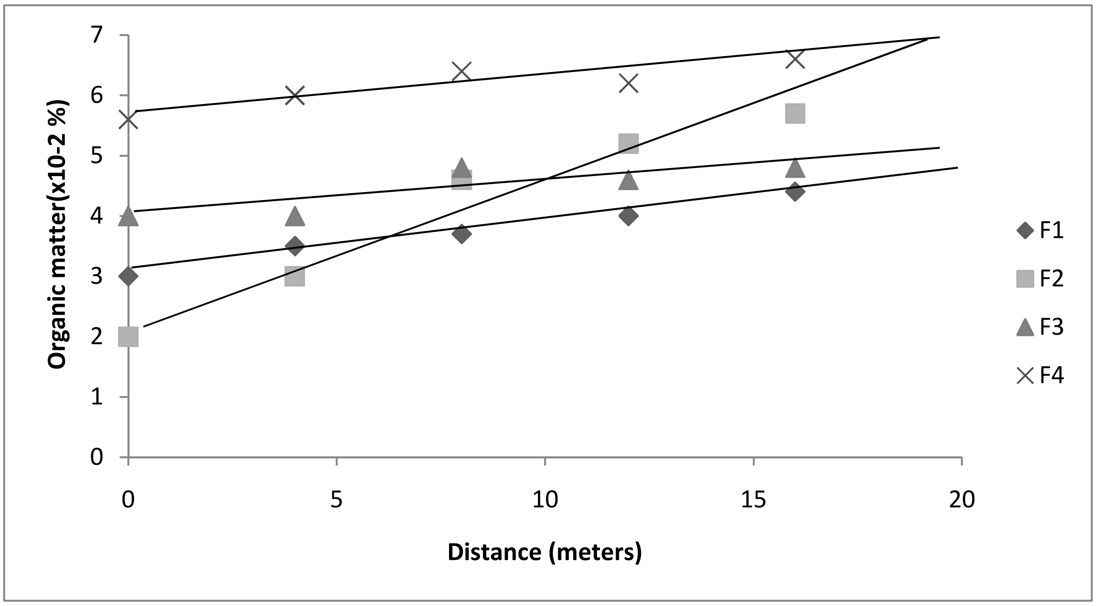

Fig 1a: Horizontal distribution of organic matter in ditches soils

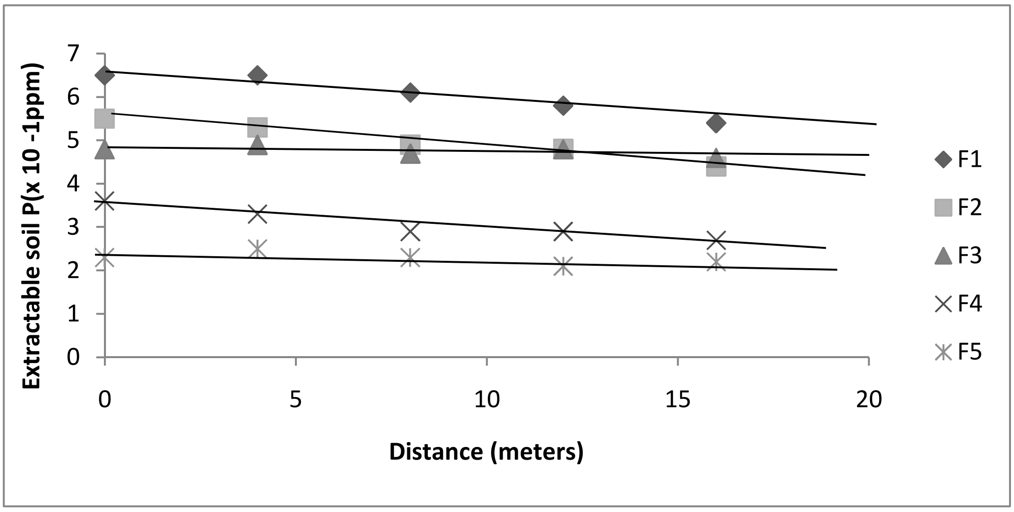

Fig 1b: Horizontal distribution of P in ditches soils.

The displacement of loosely bound ions in the soil by others in the relatively more concentrated irrigation water is aided by the force provided by the flowing water. The declining levels of phosphorus towards the lower end of the ditches, as indicated in Figure (1b), may also be considered in line with the reported slow release of the element from solid surfaces (Ako *et al*, 2001).

Attention is also drawn to the steady decrease in extractable P in the ditches soils from plot F_1 to F_5 (Table 1). The trend is difficult to explain taking into account the corresponding mean levels of phosphorus in the irrigation water. Nevertheless, it is pertinent to mention that levels of phosphorus in the irrigation water were found to be lower in those portions of the stream with higher plant density due, probably, to greater metabolic activities in these portions by the plants which drew their nutrient supply directly or indirectly from the water. The increased plant population at the points under consideration, some of which are located at bends in the stream, is also aided by the lower flow rate of the water around the inner portions of the bends. As an essential nutrient for crop and livestock production, phosphorus is known to accelerate freshwater eutrophication even in small concentrations. (Hellmann, 1987; Zhang *et al*, 1987; Nikoladze *et al*, 1989; Sharpley *et al*, 2003).

The higher extractable P levels towards the upper end of the ditches may be explained by suggesting that fast exchange reactions which may have taken place between the relatively highly charged phosphate ion and the other nonspecifically adsorbed anions of smaller charge and greater solubility during flooding, may be responsible. The greater binding force and ease of fixing of the phosphate ion and other ions which are constituents of the irrigation water may also lead to the release of OH^- ions into the soil solution (Zhang *et al*, 1987; Bolan etal, 1993; Houlbrooke et al, 2008), and may be held to account for the differences in pH values observed between the ditches soils and the uncultivated plots soils. The non-significant correlation (Table 2) between ditches soils pH and irrigation water pH does not in any way weaken this view of the contribution of the irrigation water to the pH of the ditches soils.

Table 2: Coefficient of correlation of parameters of ditches soils and irrigation water.

	Irrigation water pH	Ditches soils P
Ditches soils pH	0.356	0.230
Irrigation water P	0.634	0.016

Without doubt, down the irrigation ditches where the flow rate of water is lower, the vertical leaching of soil solutes should dominate the horizontal movement, and concomitantly with the accumulation of organic matter at this end should be the enhancement of the amount of ions that were weakly bound to exchange sites at the upper end. Therefore, that phosphate levels at the lower end were lower than predicted by this thinking goes to strengthen the report of immobilization of the element in soil, and that of its retention in the organic fraction (Al-Khateeb *et al*, 1986; Zhang *et al*, 1987). The decreasing levels of phosphorus in the soils down the ditches is, in addition to the reasons already adduced, in agreement with the findings of Barrow (1978) and Barrow, *et al*, (1981). These authors' reports on the kinetics of phosphate adsorption by soils revealed characteristically rapid reaction followed by a slow one, and rates were shown to depend on concentration of phosphorus and the adsorbent.

Not unexpectedly, no regular trend emerged from both the organic matter content and phosphorus levels of the corresponding points of the uncultivated plots. Nevertheless, data obtained from them have given clear indication of the effect of flowing irrigation water on the soils of the experimental plots.

CONCLUSION

The immobility and ease of fixing of phosphorus in soils, as severally reported, is not limited to the vertical movement down soil profiles, but includes the horizontal movement under the force of flowing irrigation water. Consequently, the element tends to accumulate more, close to the point of application of the irrigation water. Very weak correlations were found to exist between ditches soil pH and stream water pH and between ditches soil extractable phosphorus and total phosphorus of stream water, indicating that the irrigation water probably had little or no effect on these two parameters of the ditches soils. Organic matter increased down the ditches, as the solid and suspended particles in the water were carried along with the flowing irrigation water from the point of application.

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