

Fertilizer Effects on Some Properties of Two Major Soil Series of Sudan

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Abstract: Residual effects of organic and inorganic fertilizers on some physical and chemical properties of Vertisols and Aridisols of Sudan were studied during 1995-96 and 1996-97 seasons in a completely randomized design. Fertilizers significantly improved the saturated hydraulic conductivity of the two soils. The organic fertilizers were more effective than inorganic fertilizers, and the effects were more pronounced for Vertisols compared to Aridisols. The organic fertilizers significantly decreased the soil pH. Green and poultry manures significantly reduced the electrical conductivity of the saturation extract (EC_e). The applied green manure, poultry manure and urea significantly increased Ca and Mg contents, whereas, the other treatments significantly reduced them. The organic manures used may be considered comparable in increasing Ca and Mg contents. Poultry manure significantly increased the Na content, and in Vertisols Na content exceeded that in Aridisols. The K content was not significantly affected by the treatments and it was less in Vertisols compared to Aridisols. The sodium adsorption ratio was significantly reduced by the treatment, whereas the Ca:Mg ratio was significantly improved by poultry manure, urea and superphosphate treatments. There was a significant correlation between Ca:Mg and EC_e ($r = + 0.60$) and P was negatively correlated with soil pH ($r = -0.11$). There was no significant difference in N contents of the two soils. The data also revealed that poultry manure, superphosphate and NPK significantly increased the P content. The amount of P in Aridisols exceeded that of Vertisols.

Key words: Fertilizers, vertisols, aridisols, green manure, poultry manure.

The energy, soil and water resources cannot sustain agriculture at the rate they are being used at present. In most tropical regions, a rapid decline in crop production follows the clearing of forests and savannas and the development of the land for food crop production. Much of this decline can be attributed to exhaustion of nutrients in soil and the deterioration of the soil physical conditions (LeMare, 1974; Greenland and Lal, 1977). Nutrient availability is now a major constraint limiting yield in all countries. It is most certain that efficient

use of fertilizers and their costs poses a pronounced effect on food production. Organic fertilizers contain balanced nutrients that can be released slowly and utilized by the crop. The organic fertilizers are favored because they improve soil structure and reduce crust formation, and consequently they increase infiltration, movement, storage and availability of soil water and the development of plant roots (Lal and Greenland, 1979). To sustain productivity an agricultural system should preserve satisfactory physical and chemical conditions. In most countries inorganic fertilizers have been used much more than

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organic manures to supply plant nutrients (Cooke, 1982). However, inorganic fertilizers are very expensive, especially in the developing countries, and their beneficial effects on the soil physical conditions are less than those of the organic fertilizers. Fertilizers alone, or in conjunction with improved crop varieties and pest and disease control measures, will not maintain productivity if soil physical conditions continue to deteriorate (Wild, 1988). Application of organic fertilizers is essential for maximizing productivity and sustaining soil fertility while minimizing environmental hazards. Hence, the objective of this work was to measure the residual effect of organic and inorganic fertilizers on the hydraulic conductivity and some chemical properties of Vertisols and Aridisols of Sudan.

Materials and Methods

A pot experiment was set in a completely randomized design, with factorial arrangement. Two types of soils were used; Vertisols from Wad el-Hadad, Gezira scheme classified as: very fine mont, isohyperthermic Typic Chromusterts, deep, dark brown, cracking, clayey soil (Adam *et al.*, 1983), and Aridisols of semi-arid zone of Sudan, classified as: fine, mixed, isohyperthermic Typic Camborthid, from Rawakeeb, west of Umdurman (El-Hirika, 1994). Surface soil samples (0-30 cm) were treated with green manure (GM) (11.9 t ha⁻¹), poultry manure (CHM) (11.9 t ha⁻¹), urea (190.4 kg ha⁻¹), superphosphate (TSP) (119 kg P₂O₅ ha⁻¹), potassium sulphate (190.4 kg K₂SO₄ ha⁻¹) and NPK. The treatments were replicated thrice. Some relevant characteristics of the two soils

Table 1. Selected properties of Vertisols (Wad El Haddad), Aridisols (El Rawakeeb) and organic manures examined

Properties	Vertisols Wad El Haddad	Aridisols El Rawakeeb	Green manure	Poultry manure
Sand %	12	51.6	-	-
Clay %	68	35.5	-	-
Silt %	20	13.4	-	-
pH	7.7	7.8	6.8	7.2
E _{Ce} (dS m ⁻¹)	4.12	3.23	2.99	7.5
SAR (mmol L ⁻¹)	3.84	2.85	0.53	1.7
Na (mmolc L ⁻¹)	14.41	9.3	0.89	1.61
K (mmol L ⁻¹)	0.83	1.32	0.58	0.38
Ca (mmol L ⁻¹)	19.28	14.25	3.73	5.98
Mg (mmol L ⁻¹)	8.95	7.1	1.96	3.54
OC %	0.12	0.07	33.28	51.32
N %	0.024	0.007	0.044	0.77
CEC (mmole /100 g soil)	51.50	33	-	-
P%g/g	12.75	13.5	13.13	15.45
Ca:Mg ratio	2.15	2.01	1.90	1.69

and the organic fertilizers are given in Table 1. The soils were ground in a wooden mortar and passed through a 2 mm sieve. Pots were filled with 2.5 kg soil. The fertilizers were mixed with the top soil and the pots were tapped on the working bench to attain a bulk density of 1.3 Mg m^{-3} . Five certified seeds of corn were sown in each pot (0.0254 m^2) in the greenhouse facilities of the Faculty of Agriculture, Shambat, University of Khartoum (long. $32^\circ 32'E$; latit. $15 14'N$). The water applied at each irrigation, Q (mm), was approximated by the following relationship:

$$Q = K \times E_p \times F$$

where,

K is an empirical constant equals 0.50, 0.85 and 1.05 for the three successive growing months of the crop. E_p is US class A pan evaporation (mm day^{-1}) estimated from a previous data collected during 1989-1994, and F is the frequency of irrigation, which was seven days (FAO, 1979). Similar seasonal quantities of Nile water (winter season) with an $EC = 0.56 \text{ dS m}^{-1}$; $pH = 7.9$; $Ca = 3.2 \text{ mmole L}^{-1}$, $Mg = 1.1 \text{ mmole L}^{-1}$; $Na = 1.44 \text{ mmole L}^{-1}$ and $K = 0.03 \text{ mmole L}^{-1}$, were applied to all treatments. Soil samples were taken at the end of the experiment for analysis. No leaching was observed during the course of the experiment.

Soil samples were dried, ground and sieved through a 2 mm sieve and kept for analysis. The soil physical and chemical properties were determined adopting standard methods (Klute, 1986; Page *et al.*, 1982). The pH of the soil paste was measured using Corning pH meter. Electrical conductivity of the saturation

extract (ECe) was measured by conductivity TDS meter. The cation exchange capacity was measured as described by Polemio and Rhoades (1977).

Results and Discussion

In Vertisols the seedlings emerged after three days while in Aridisols seedlings emerged five days after sowing in both the years. The treatment effects were same in the two seasons. The shoot fresh weight was significantly increased by all treatments, except with K application, compared to the control. This may be due to high K-fixing capacity of both the soils. The organic fertilizers gave the higher fresh yields compared to inorganic fertilizers. Poultry manure was superior relative to the other treatments in both the seasons (Fig. 1). This was because the organic manures may have the ability to improve soil physical properties and to supply N and other macro and micronutrients slowly upon decomposition. The combination of inorganic fertilizers (NPK) had a significant effect compared to single application of these fertilizers. Vertisols out-yielded Aridisols in all treatments i.e., fertilizers are more effective on Vertisols compared to Aridisols. This may be due to the improvement of the physical conditions that are more limiting in Vertisols compared to Aridisols.

Saturated hydraulic conductivity

The organic and inorganic fertilizers significantly improved the saturated hydraulic conductivity of the two soils by improving the stability of soil aggregates, aggregate size distribution and structural pores. The effect of organic fertilizers was more evident than that of inorganic

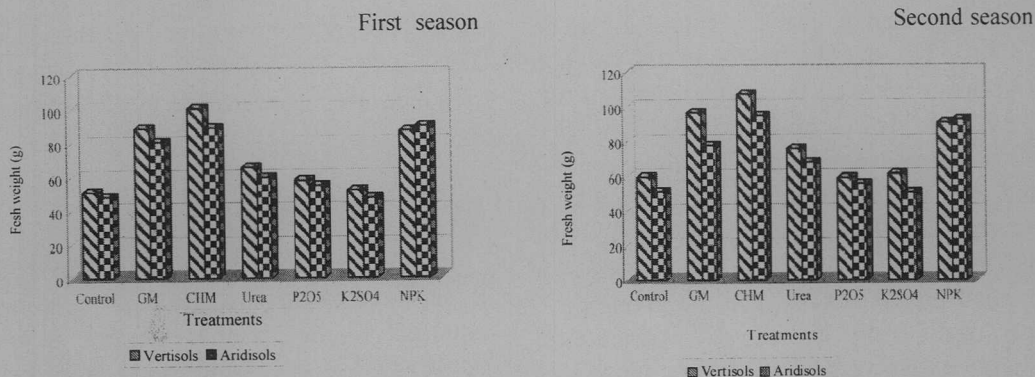


Fig. 1. Fertilizer effects on corn fresh weight (g) grown in two soil types.

fertilizers, and was more pronounced on Vertisols compared to Aridisols. The green manure incorporation in the soil was superior over other fertilizer treatments (Fig. 2). The organic fertilizers were superior due to favorable effects on soil aggregate stability, aeration, aggregate size distribution and decreasing soil bulk density (physical effect) induced by organic matter decomposition (Tisdall and Oades, 1982; Chaney and Swift, 1984; Smith and Elliot, 1990; Obi and Ebo, 1995). The effects

on Aridisols were similar and are therefore not presented here.

Soil pH

The analysis of the soil samples showed that organic fertilizers significantly decreased the pH relative to the control in both the soils (Fig. 3). The applied manure reduced the soil pH by intensifying the microbial activity and hence increasing the rate of decomposition of organic substances, which result in more organic acids (DeDatta, 1995).

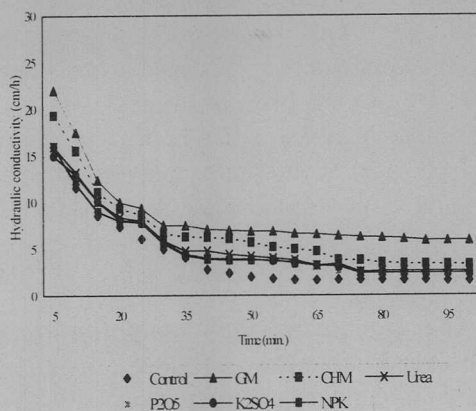


Fig. 2. Hydraulic conductivity of Vertisols as affected by different treatments.

The electrical conductivity (ECe) of the saturation extract of the soil

Figure 3 also indicated that green and poultry manures significantly influenced the ECe of both soils. This finding agreed with that of Abdalla (1989). Urea decreased the ECe in both soils, but the reduction was not significant. The ECe reduction was due to the improvement of the soil physical conditions brought about by the microbial activity and root growth that stabilizes soil aggregates and created channels for downward movement of water and hence leaching of salts.

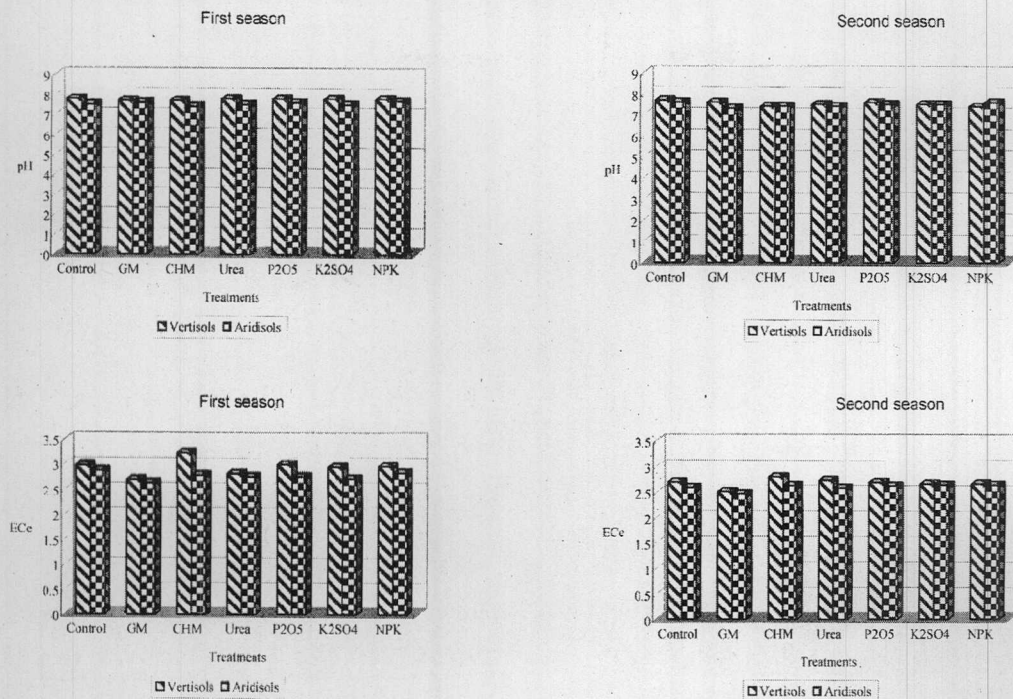


Fig. 3. Soil pH and electrical conductivity of the saturation extract (ECe) as affected by organic and inorganic fertilizers.

Soil calcium, magnesium and sodium contents

The applied green manure, poultry manure and urea fertilizers significantly increased the Ca content, whereas, the other treatments significantly reduced it in both the soils (Fig. 4). The decomposition of organic fertilizers and root respiration will generate carbon dioxide and consequently a weak carbonic acid that reacts with CaCO_3 in soil to release Ca, in addition to Ca already contained in the added fertilizers. This finding is similar to that of Penalosa *et al.* (1994). The reduction in the Ca content by the phosphate and sulphate bearing fertilizers may be due to the formation of calcium-phosphate complex (hydroxyapatite) and gypsum that goes out

of solution under calcareous condition (Sposito, 1989; Afif *et al.*, 1993). The Mg content significantly increased by green and poultry manures, whereas the other treatments significantly decreased the magnesium content in both the soils. The increase in the Mg content may be due to the release of Mg from the decomposing organic manures. Poultry manure significantly increased the Na content in both the soils, whereas, other treatments significantly decreased the Na content. This result is similar to that observed by Elamin (1991). There was no significant difference in Na concentration between poultry and green manures. The Na content of Vertisols exceeded that of Aridisols by 12.7%. This is because the release of Na from clay

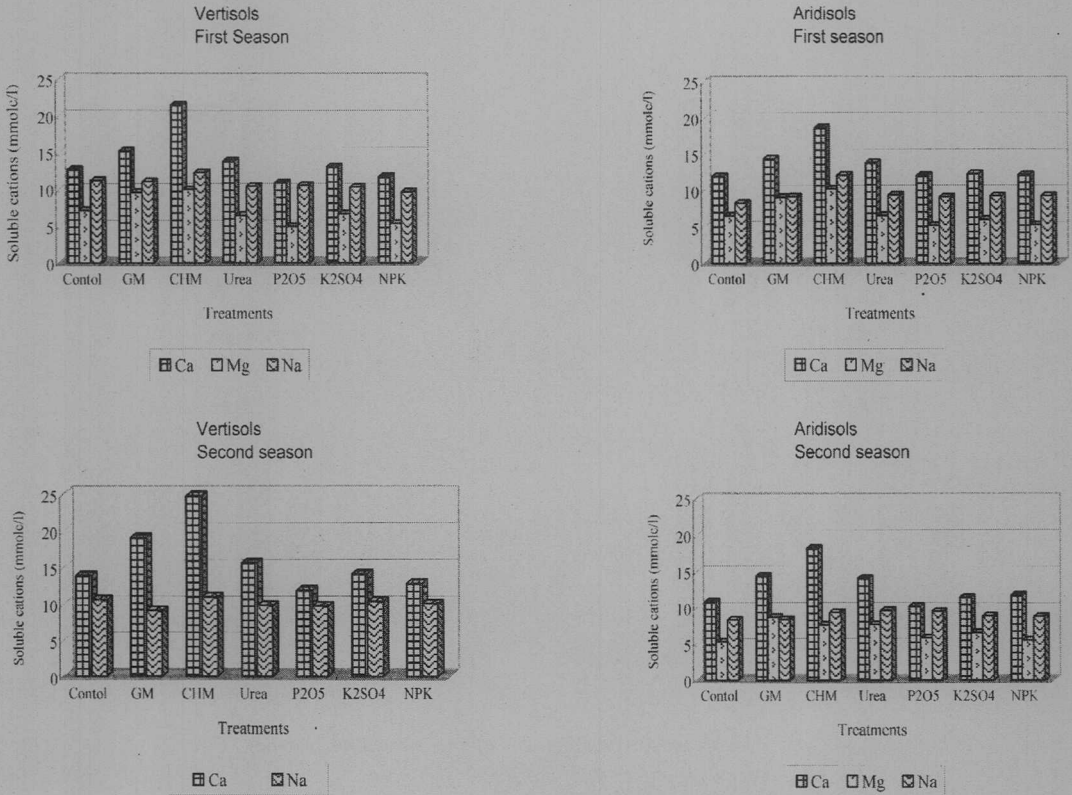


Fig. 4 Water soluble calcium, magnesium and sodium (mmol L^{-1}) of the two soil types as affected by organic and inorganic fertilizers.

soil was significantly higher than from sandy soil (Elamin, 1991).

Sodium adsorption ratio (SAR)

The treatments significantly lowered the sodium adsorption ratio (SAR) relative to the control (Fig. 5). Generally, the reduction in SAR may be attributed to the improvement in the soil physical conditions and hence, the leaching of Na ions below the root zone (Gabor, 1984). The Ca:Mg ratio was significantly improved by poultry manure, urea and superphosphate treatments in both the soils (Fig. 5). The correlation

was significant between Ca:Mg and ECE ($r = + 0.60$) and it was negative between pH and P ($r = -0.11$) in both the soils.

Soil nitrogen, phosphorus and potassium contents

There was no significant difference in soil N contents in the two soils treated with organic and inorganic fertilizers relative to the control in both the soils (Fig. 6). This is because these soils are deficient in nitrogen (Mustafa and Abdelmagid, 1982). Besides, nitrogen compounds suffer several types of losses

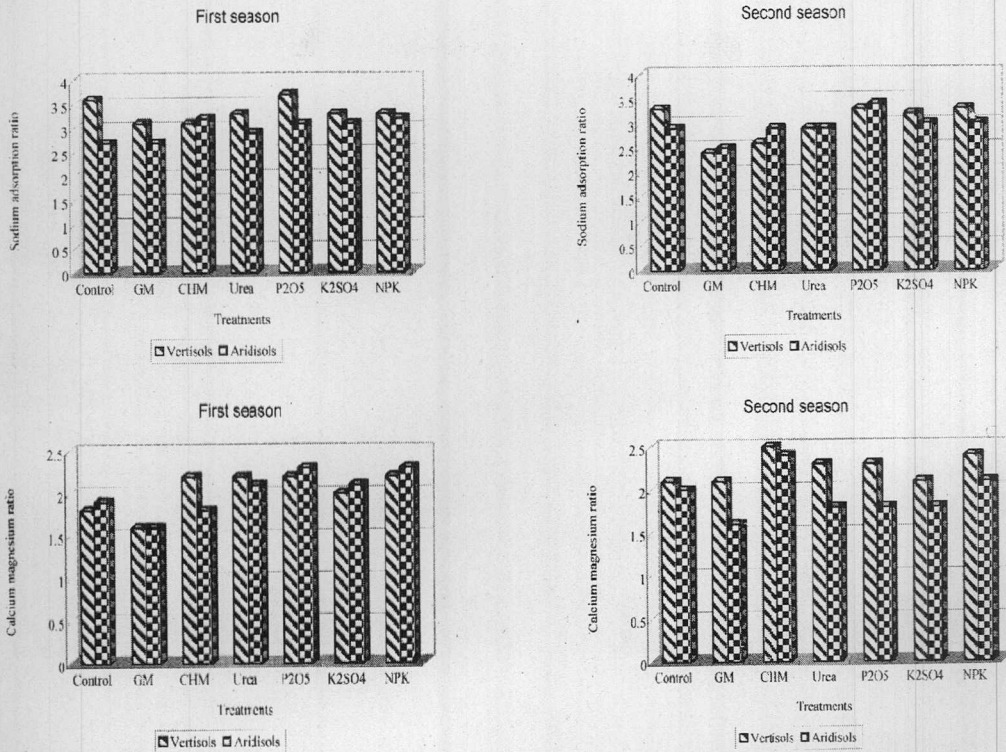


Fig. 5. Effects of organic and inorganic fertilizers on sodium adsorption ratio (SAR) and calcium magnesium ratio of the two soil types.

from the soil. They may be taken up by growing plants and/or assimilated into the bodies of microorganisms, converted into volatile compounds and lost into the atmosphere, or may be leached out of the root zone (Wild, 1988). The data also revealed that poultry manure, superphosphate and NPK (phosphorus containing treatments) significantly increased the phosphorus content in both the soils. Moreover, these treatments significantly improved aggregation, which is related to P sorption, soil buffering capacity, and P release from soil. It is

likely that aggregation affects P availability (Liquist *et al.*, 1997). The other fertilizer treatments had no significant effect on the phosphorus content in both the soils. The amount of phosphorus in Aridisols exceeded that of Vertisols by 11.8% in the first year and 12.5% in the second year due to increased P adsorption with increasing clay content especially for calcareous soils (Elmahi and Mustafa, 1980). Potassium content was not significantly affected by the treatments in both the years. The potassium content in Vertisols was less than that in the Aridisols by 19% and 8.68%

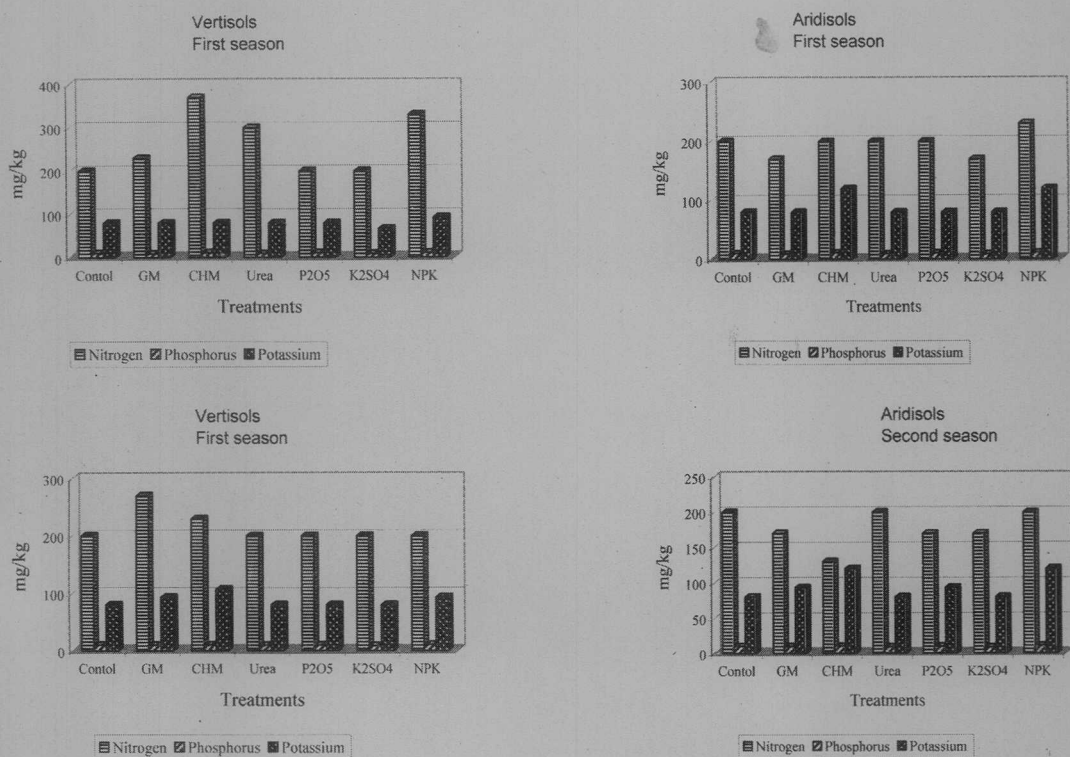


Fig. 6. Effects of organic and inorganic fertilizers on nitrogen, phosphorus and potassium contents (mg kg^{-1}) in the two soil types.

in the first and second year, respectively. This could be explained by the high potassium fixing capacity of Vertisols (Harter, 1986) and the fact that the release of potassium from sandy soil was significantly higher than the clay soil (Elamin, 1991).

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