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Effect of exchangeable calcium and magnesium as essential for soil chemistry and plant nutrition in organic manures- treated soils for sustainable agriculture.

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Abstract

Calcium and magnesium are important secondary nutrients that contribute to soil fertility, nutrient balance, and sustainable crop production. This study evaluated the mineralization of soil exchangeable Ca^{2+} and Mg^{2+}. The study was conducted at the Teaching and Research Farm of the Federal University of Agriculture, Abeokuta. The experiment was a randomized complete block design with three replications. Cured cattle, goat and poultry manures were applied at 5, 10, 20, 40, 60, 80, 120 and 150 t ha^{-1} once at first cycle and $N_{15}P_{15}K_{15}$ at 0.4 t ha^{-1} per cycle. At two weeks intervals, soil samples were collected and analyzed for exchangeable calcium and magnesium. Pretreatment soil and manures were analyzed for Electrical Conductivity (EC), pH, ammonium-nitrogen, nitrate-nitrogen, total phosphorus, potassium, sodium, calcium and magnesium, using standard procedures. Across cycles, soil Ca^{2+} and Mg^{2+} values were not increase consistently according to increase in manures rates. High Mg^{2+} contents were observed between 8 – 10 WAI for cattle and poultry manure treatments while goat manure treatment was between 10 - 14 WAI during the experiment at first, second and third cycles of planting, respectively. Addition of cattle, goat and poultry manures at 6 WAP improved the soil Ca^{2+} and Mg^{2+} with highest values during first and second cycles and 4 WAP during third cycle which could be due to solubilization. The lowest values of Ca^{2+} and Mg^{2+} during third cycle could suggest uptake by plant and leaching.

Keywords: Exchangeable calcium, magnesium, organic manure, sustainable agriculture.

Introduction

Calcium and magnesium are one of the essential secondary nutrients for plants and animals (Strawn *et al.*, 2015) and plants require them in quantities that is similar to phosphorus (Kenneth, 1996). They present in the soil solution and as exchangeable cations on soil colloids. Both are essential for soil chemistry and plant nutrition. They impact physical soil properties, nutrient availability and biological activity. They are not readily leached from the soil and the amounts are rarely deficient in soils. In most highly productive soils, Ca^{2+} dominates the adsorption sites on mineral surfaces. Soils from regions that have intense rainfall and high weathering rates have less Ca^{2+} than less weathered soils (Strawn *et al*., 2015). Calcium behaves the same way as Mg^{2+} in the soil due to similar chemical properties. Their mobility is very low and also loss through leaching is very low. Davis *et al*. (2012) reported that high levels of Ca^{2+} and Mg^{2+} can cause imbalances and induce nutrient deficiencies.

Although, Mg^{2+} is the second most abundant exchangeable cation, it is the least-studied ion among the cations (Strawn *et al*., 2015). Most likely because excessive or deficient amounts of Mg^{2+} for plant growth are uncommon. Adsorption of Mg^{2+} as exchangeable cation is similar to Ca^{2+}, though Mg^{2+} is slightly less preferentially adsorbed than Ca^{2+} (Strawn *et al*., 2015). The main sources of magnesium that can be made available in soils are secondary minerals (Mosaic company, 2013[b]; Salmon, 1963). According to Ken *et al*. (1990), high concentration of Mg^{2+} in the soil reduce Ca^{2+} absorption by plants. Crops take up Mg^{2+} from exchange sites on clay particles or from soil solution which is the easily available form and is less than 10 % of the total soil Mg^{2+} (Chung and Leon, 1985). Calcium and magnesium are held more tightly to the exchange sites than NH_4^+ and K^+ ions (James, 2001). They behave very much the same in the soil due to similar chemical properties. These nutrients can be improve in the soil to support plants growth by applying soil amendments like manure.

Cattle, goat and poultry manures are some of the animal manures that can be amended to the soil for improving soil nutrients. Cattle manure enhance plant growth and productivity because of the physical and chemical properties. Atiyeh *et al*. (1999) reported that cowdung usually enhanced seedling growth and development, and increase the productivity of a wide variety of crops. Levi – Minzi *et al*. (1986) reported that the storage of organic wastes over a period of time could alter the biochemistry of the organic matter and this could eventually lead to the stabilization of the cowdung. Goat manure contains adequate amounts of the nutrients that plants need for optimal growth. The pelletized goat droppings allow more airflow into the soil (Gardening, 2015). It is less messy than many other types of animal manure. Goat manure does not attract insects or burn plants as does manure from cows or horses. Goat manure is virtually odorless and is beneficial for the soil (Navindra, 2011). Researches confirm that poultry manure has effective nutrient sources for increasing yield and nutrient status of crops such as maize, amaranth, sorghum and pepper (Adeniyan and Ojeniyi 2005; Babatola *et al*., 2002). Poultry manure contains high percentage of nitrogen and phosphorus for the healthy growth of plants (Ewulo, 2005). Poultry manure can also be used as liming material in addition to being source of nutrients (Adeniyan and Ojeniyi 2003, Ewulo *et al*., 2008). According to Adenawoola and Adejoro (2005), organic matter and soil nutrients increased with application of poultry manure while Abubakar and Majeed (2000) reported greater than 50 % reduction in nematode population with poultry manure.

Organic farming in relation with sustainable agriculture are being promoted by the government as a way of eliminating unsustainable agriculture. The study benefits for a field-based experimental design, inclusion of multiple manure sources, a wide range of application rates, repeated sampling, and assessment of residual effects across successive cropping cycles. Despite the benefits that organic farming brings to farmers and environments, its adoption rate is still low in Nigeria. More so, exchangeable Ca^{2+} and Mg^{2+} are rarely studied compared with nitrogen, phosphorus and potassium. These probed the study on the influence of cattle, goat and poultry manures on the exchangeable Ca^{2+} and Mg^{2+} and the period of mineralization and appropriate manure type and rate. Residual effects were also determined to testify the leaching and plant uptake effects and also to determine the improvement level on soil and plant. The objective of the research was to determine the effects of cattle, goat and poultry manures and their residual effects on soil exchangeable Ca^{2+} and Mg^{2+} at different periods.

Materials and Methods

Location of the study area

This study was carried out at the Teaching and Research Farm of the Federal University of Agriculture, Abeokuta, Ogun State, Nigeria which located between latitude 7° 12ˈ N and longitude 3° 20ˈ E (FUNAAB, 2013). The maximum rainfall occurs during the months of July and September with a dry spell in August. The annual rainfall is about 1,200 mm and a mean monthly temperature of 27° C.

Experimental design

The experiment was a randomized complete block design (RCBD) with three replications. Cattle, goat and poultry manures were applied at the rates of 0, 5, 10, 20, 40, 60, 80, 120 and 150 t ha^{-1} differently. NPK 15-15-15 fertilizer was used as check for each manure treatment and applied at the rate of 0.4 t ha^{-1} (Schippers, 2000).

Sources of manures and N.P.K. fertilizer

The cattle, goat and poultry manures were sourced from the College of Animal Science and Livestock Production Farm at the Federal University of Agriculture Abeokuta, Ogun State, Nigeria. Cattle dung was collected from the paddock of both bulls and cows free of beddings where semi-intensive system was practiced. The goat droppings that had been mixed with remains of feed materials were obtained from the pen of both Billies and Nannies under intensive system. The droppings were sieved to remove the feed residues and plant materials were removed manually by hand picking but still contained minute quantity of furs. The poultry droppings were collected from the pen of layers underneath battery cage system with no bedding.

Area of the farmland

The total experimental site was 18 × 20 m^2, vegetable gross plot size was 1.5 m × 1.5 m and a spacing of 0.5 m was left between the adjacent beds to avoid beds edge contact and also to serve as walking path. The vegetable net plot size was 1.5 × 0.6 m^2 and the two edge rows were avoided to prevent border effect. However, the distance of 0.15 m was left on each bed between the bed edge and first drill while a planting distance of 0.30 m was left within each drill. NPK 15-15-15 fertilizer was applied at 0.10 m distance from seeded drills.

Manures and fertilizer application

The cured cattle, goat and poultry manures were weighed prior to application using Top loading balance with the model Camry Emperors (20 kg × 50 kg) and thoroughly worked onto the prepared beds to attain homogeneity of the manures and the soil at the rate of 5, 10, 20, 40, 60, 80, 120 and 150 t ha^{-1} prior to first cycle of planting. This was allowed to equilibrate with the soil two weeks before planting (Lalljee and D'Costa, 1995; Azeez *et al*., 2010). NPK 15-15-15 fertilizer was weighed using Gulex medical and scientific electronic balance (mode JT502N) and applied at the rate of 0.4 t ha^{-1} a day before each cycle of planting.

Collection of manures and soil samples for laboratory analysis

Pretreatmentl soil samples were taken randomly from nine points on the field immediately after second ploughing, at a depth of 0 - 30 cm using soil auger prior to manures incorporation. The soil samples collected were bulked, air-dried, crushed using pestle and mortal, passed through 2 mm sieve and packaged for soil analysis in the laboratory. The chemical properties analyzed in the soil were: pH (Van Reeuwijk, 1993), EC (Richards, 1954), NH_4^+- N (Okalebo *et al.*, 1993), NO_3^-–N (Okalebo *et al.*, 1993), available P (Murphy and Riley 1962), exchangeable (K^+, Na^+, Ca^{2+} and Mg^{2+}) (Anderson and Ingram, 1993). At two weeks intervals, exchangeable Ca^{2+} and Mg^{2+} were analyzed, these were extracted with 1N Ammonium-acetate solution in 1:10 soil solution ratio and were analyzed with Atomic Absorption Spectrophotometer (AAS) (Anderson and Ingram, 1993). Particle size analysis was determined using the hydrometer method (Bouyoucos, 1965).

Statistical analysis

The data obtained were subjected to Analysis of Variance (ANOVA) using Statistical Analysis System (SAS), version 1999. Duncan Multiple Range Test at 5 % level of probability was used to determine differences in the treatment rates means and the control.

Results

Pretreatment physical and chemical properties of the soil used for the research

The soil used for the research had very slightly saline EC (0.69 dS m^{-1}), with slightly alkaline pH (7.6) while total nitrogen was low (0.8 g kg^{-1}) (Table 1). Ammonium – nitrogen was 0.13 g kg^{-1}

Table 1: Pretreatment physical and chemical properties of the soil used for the research

Physical and chemical properties	Values
pH Soil: H_2O (1: 2)	7.60
Electrical conductivity (dS m^{-1})	0.69
Macro nutrients:	
Total nitrogen (g kg^{-1})	1.20
Ammonium- nitrogen (g kg^{-1})	0.13
Nitrate- nitrogen (g kg^{-1})	0.14
Available phosphorus (mg kg^{-1})	7.50
Exchangeable bases:	
Potassium ($cmol^+$ kg^{-1})	0.42
Sodium ($cmol^+$ kg^{-1})	0.82
Calcium ($cmol^+$ kg^{-1})	10.96
Magnesium ($cmol^+$ kg^{-1})	1.34

Particle size distribution:	
Sand (g kg^{-1})	770.00
Silt (g kg^{-1})	68.00
Clay (g kg^{-1})	162.00
Textural class	Sandy clay loam

while NO_3^-- N was 0.14 g kg^{-1}. The value of available P was 7.5 mg kg^{-1}. Exchangeable bases; K^+, Na^+, Ca^{2+} and Mg^{2+} had the values of (0.42, 0.82, 10.96 and 1.34) $cmol^+$ kg^{-1}, respectively. The percentage of sand, silt and clay were 770, 68 and 162 g kg^{-1}, respectively.

Pretreatment chemical properties of the cattle, goat and poultry manures used for the research

The EC of the cattle, goat and poultry manures were very strongly saline (12.4, 8.8 and 16.4 dS m^{-1}), respectively. The pH of the cattle, goat and poultry manures were 7.9, 7.7 and 7.8, respectively (Table 2). The total N of the cattle, goat and poultry manures were 45.1, 48.2 and 27.8 g kg^{-1}, respectively. Ammonium – nitrogen stimulated the values of 0.42, 0.32 and 1.47 g kg^{-1} while NO_3^-- N resulted to 0.44, 0.36 and 1.49 g kg^{-1} for cattle, goat and poultry manures, respectively. However, total P were 3.2, 0.7 and 16.2 g kg^{-1}, total K recorded the values of 7.4, 3.7 and 3.9 g kg^{-1}, total Na had the values of 9.3, 4.6 and 4.9 g kg^{-1}, the values of total Ca were 29.6, 18.1 and 17.7 g kg^{-1}, total Mg gave 9.5, 10 and 5.3 g kg^{-1} for cattle, goat and poultry manures, respectively.

Influence of cattle manure rates and NPK fertilizer (t ha^{-1}) on mean soil Ca^{2+} ($cmol^+$ kg^{-1}) at various week intervals of first cycle

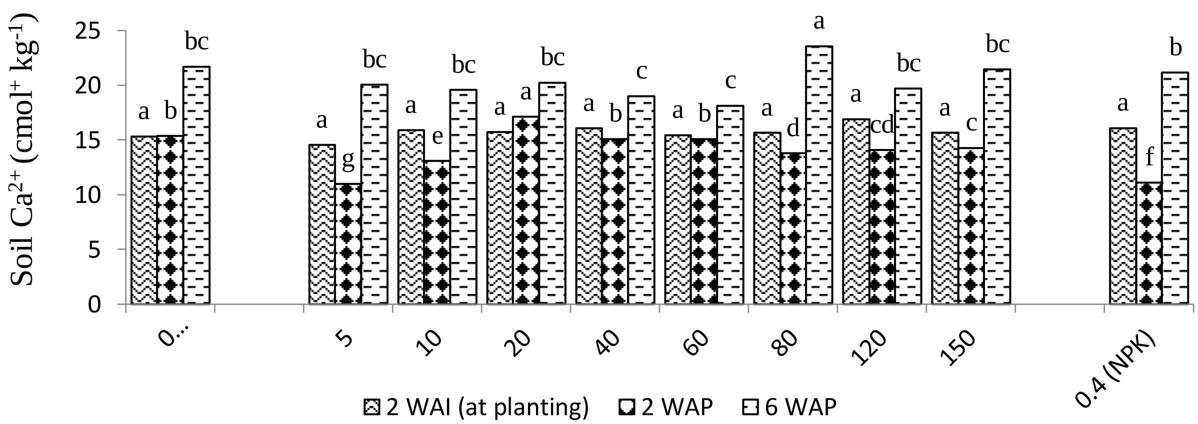
At 2 WAI, (a day after application of NPK), statistical analysis revealed that all the cattle amendment rates and NPK fertilizer were not significantly different from control, though, the values varied depending on the rates. At 2 WAP, cattle manure rate of 20 t ha^{-1} gave highest Ca^{2+} value of 17.12 $cmol^+$ kg^{-1} with increase of 11 % over the control. At 6 WAP, cattle manure rate of 80 t ha^{-1} gave highest Ca^{2+} value of 23.59 $cmol^+$ kg^{-1} with increment of 9 % relative to control, Figure 1(A).

Table 2: Pretreatment chemical properties of the cattle, goat and poultry manures used for the research.

Chemical properties	Values			
	Cattle	Goat	Poultry	NPK
pH Soil: H_2O (1: 2)	7.90	7.70	7.80	-
Electrical conductivity (dS m^{-1})	12.40	8.80	16.40	-
Total nitrogen (g kg^{-1})	45.10	48.2	27.8	150
Total phosphorus (g kg^{-1})	3.20	0.70	16.2	150

Total potassium (g kg^{-1})	7.40	3.70	3.90	150
Total sodium (g kg^{-1})	9.30	4.60	4.90	-
Total calcium (g kg^{-1})	29.60	18.10	17.70	-
Total magnesium (g kg^{-1})	9.50	10.00	5.30	-
Total organic carbon (g kg^{-1})	178.80	223.00	59.30	-
Ammonium- nitrogen (g kg^{-1})	0.42	0.32	1.47	-
Nitrate- nitrogen (g kg^{-1})	0.44	0.36	1.49	-
Carbon: Nitrogen (g kg^{-1})	3.97	4.63	2.13	-

A



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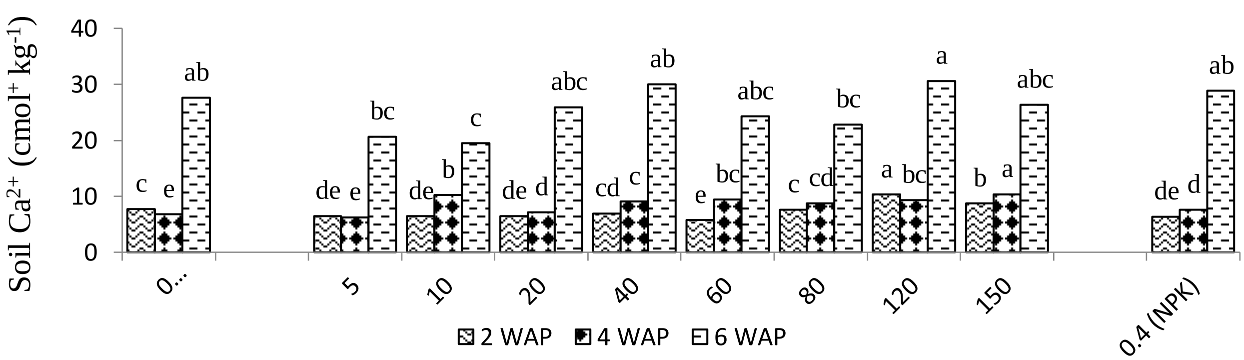

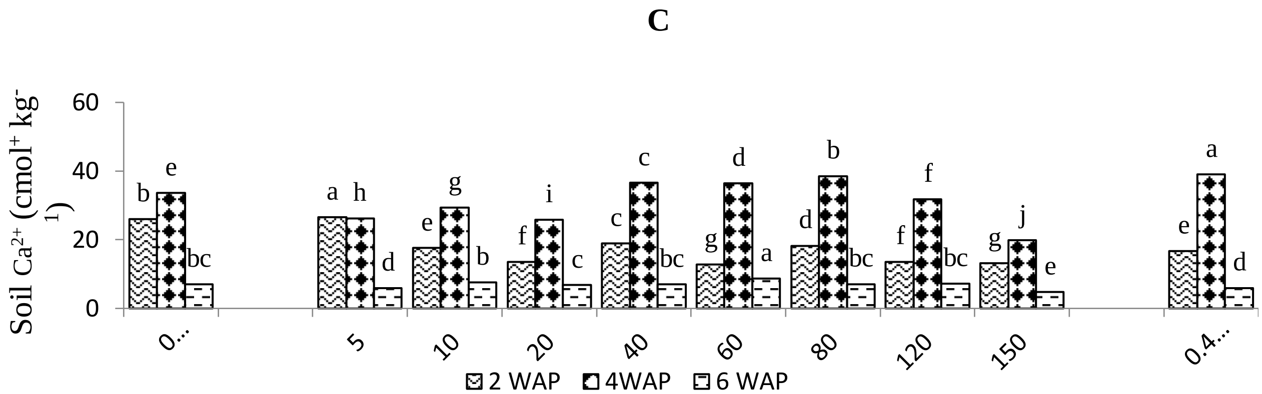

Figure 1: Influence of cattle manure rates and NPK fertilizer (t ha^{-1}) on mean soil Ca^{2+} (cmol$^+$ kg^{-1}) at two weeks interval under first (A), second (B) and third (C) cycles
WAI = weeks after incorporation of manures. WAP = weeks after planting.

Influence of cattle manure rates and NPK fertilizer (t ha^{-1}) on mean soil Ca^{2+} (cmol$^+$ kg^{-1}) at two weeks interval of second cycle

Cattle manure rate of 120 t ha^{-1} gave highest Ca^{2+} value of 10.29 cmol$^+$ kg^{-1} with increase of 33 % over the control. However, all other amendment rates reduced compared with control at 2 WAP (two weeks after application of NPK). At 4 WAP, cattle manure rate of 150 t ha^{-1} gave highest Ca^{2+} value of 10.37 cmol$^+$ kg^{-1} with highest increase of 54 % relative to control while NPK fertilizer gave Ca^{2+} value of 7.56 cmol$^+$ kg^{-1} with the least increase of 12 % over the control. At 6 WAP, 120 t ha^{-1} of cattle manure treatment stimulated Ca^{2+} value of 30.59 cmol$^+$ kg^{-1} with highest increase of 11 % over the control. However, NPK fertilizer recorded Ca^{2+} value of 28.81 cmol$^+$ kg^{-1} which had the lowest increase of 5 % compared with control. There were significant differences in the amendment rates, Figure 1(B).

Influence of cattle manure rates and NPK fertilizer (t ha^{-1}) on mean soil Ca^{2+} (cmol$^+$ kg^{-1}) at two weeks interval of third cycle

The cattle manure rate of 5 t ha^{-1} with highest Ca^{2+} value of 26.58 cmol$^+$ kg^{-1} which increased by 2 % more than control. At 4 WAP, NPK fertilizer gave highest Ca^{2+} value of 39.01 cmol$^+$ kg^{-1} which increased by 16 % over the control. At 6 WAP, cattle manure rate of 60 t ha^{-1} resulted to highest Ca^{2+} value of 8.69 cmol$^+$ kg^{-1} with increment of 24 % compared with control. There were significant differences in the amendment rates. Increments and reductions of soil Ca^{2+} according to the amendment rates were varied, Figure 1(C).

Influence of goat manure rates and NPK fertilizer (t ha^{-1}) on mean soil Ca^{2+} (cmol$^+$ kg^{-1}) at various weeks interval of first cycle

At planting (a day after application of NPK), NPK fertilizer resulted to Ca^{2+} value of 16.43 cmol$^+$ kg^{-1} with highest increment of 5 % more than the control while NPK was significantly higher followed by control compared with all the goat amendment rates. At 2 WAP, control gave highest Ca^{2+} value of 15.37 cmol$^+$ kg^{-1} while NPK had the lowest value. At 6 WAP, control recorded Ca^{2+} value of 21.70 cmol$^+$ kg^{-1} and was significantly higher compared with all the goat amendment rates and NPK fertilizer. The rate of 5 t ha^{-1} and NPK were not significantly different from control. There were significant differences in the amendment rates, Figure 2(A).

Influence of goat manure rates and NPK fertilizer (t ha^{-1}) on mean soil Ca^{2+} ($cmol^+$ kg^{-1}) at two weeks interval of second cycle

Goat manure rate of 150 t ha^{-1} with Ca^{2+} value of 11.74 $cmol^+$ kg^{-1} recorded the highest increase of 52 % over the control at 2 WAP (two weeks after application of NPK). At 4 WAP, goat manure rate of 150 t ha^{-1} stimulated highest Ca^{2+} value of 12.04 $cmol^+$ kg^{-1} with increase of 79 % over the control. Though, the rate of 120 t ha^{-1} was not significantly different from 150 t ha^{-1}. Goat manure rate at the rate of 5 t ha^{-1} gave Ca^{2+} value of 34.99 $cmol^+$ kg^{-1} at 6 WAP recorded the highest increment of 30 % over the control. The rate of 60 t ha^{-1} gave Ca^{2+} value of 27.94 $cmol^+$ kg^{-1} which had the lowest increment of 4 % in relation to control, Figure 2(B).

Influence of goat manure rates and NPK fertilizer (t ha^{-1}) on mean soil Ca^{2+} ($cmol^+$ kg^{-1}) at two weeks interval of third cycle

Figure 2(C) showed that at 2 WAP, control with Ca^{2+} value of 25.13 $cmol^+$ kg^{-1} was significantly higher in soil Ca^{2+} compared with the amendment rates. However, the amendment rates were significantly different from one another. NPK was noticed to have the lowest value. Decreases in soil Ca^{2+} according to the amendment rates were not consistent. At 4 WAP, goat manure rate of 60 t ha^{-1} gave Ca^{2+} value of 50.26 $cmol^+$ kg^{-1} which was significantly higher compared with other amendment rates and control. At 6 WAP, goat manure rate of 20 t ha^{-1} recorded Ca^{2+} value of 7.98 $cmol^+$ kg^{-1} significantly higher compared with other amendment rates but other amendment rates decreased compared with control. Increment and reduction of soil Ca^{2+} varied according to the amendment rates, Figure 2(C).

Influence of poultry manure rates and NPK fertilizer (t ha^{-1}) on mean soil Ca^{2+} ($cmol^+$ kg^{-1}) at various week intervals of first cycle

Virtually, every amendment rates were not significantly different from control at planting (a day after application of NPK). At 2 WAP, poultry manure rate of 20 t ha^{-1} stimulated Ca^{2+} value of 16.56 $cmol^+$ kg^{-1}. This increased the soil Ca^{2+} level by 8 % while other poultry manure rates and NPK decreased compared with control. At 6 WAP, poultry manure at the rate of 60 t ha^{-1} with Ca^{2+} value of 25.92 $cmol^+$ kg^{-1} gave highest increase of 27 % above the control. However, NPK fertilizer stimulated Ca^{2+} value of 21.15 $cmol^+$ kg^{-1} and gave the lowest increase of 4 % over the control. Reductions of 13 % and 23 % were recorded in 5 t ha^{-1} and 10 t ha^{-1}, respectively relative to control, Figure 3(A).

Influence of poultry manure rates and NPK fertilizer (t ha^{-1}) on mean soil Ca^{2+} ($cmol^+$ kg^{-1}) at two weeks interval of second cycle.

Poultry manure rate of 120 t ha^{-1} recorded a Ca2+ value of 7.86 cmol+ kg-1, with the highest increase of 7%, while 5 t ha-1, with a Ca2+ value of 7.47 cmol+ kg-1, recorded the lowest increase of 2% relative to the control at 2 WAP (two weeks after application of NPK). At 4 WAP, poultry manure rate of 40 t ha^{-1} resulted to Ca^{2+} value of 10.66 $cmol^+$ kg^{-1} with highest increase of 66 % over the control. The poultry manure rate of 40 t ha^{-1} gave Ca^{2+} value of 34.21 $cmol^+$ kg^{-1} with increment of 30 % over the control, Figure 3(B).

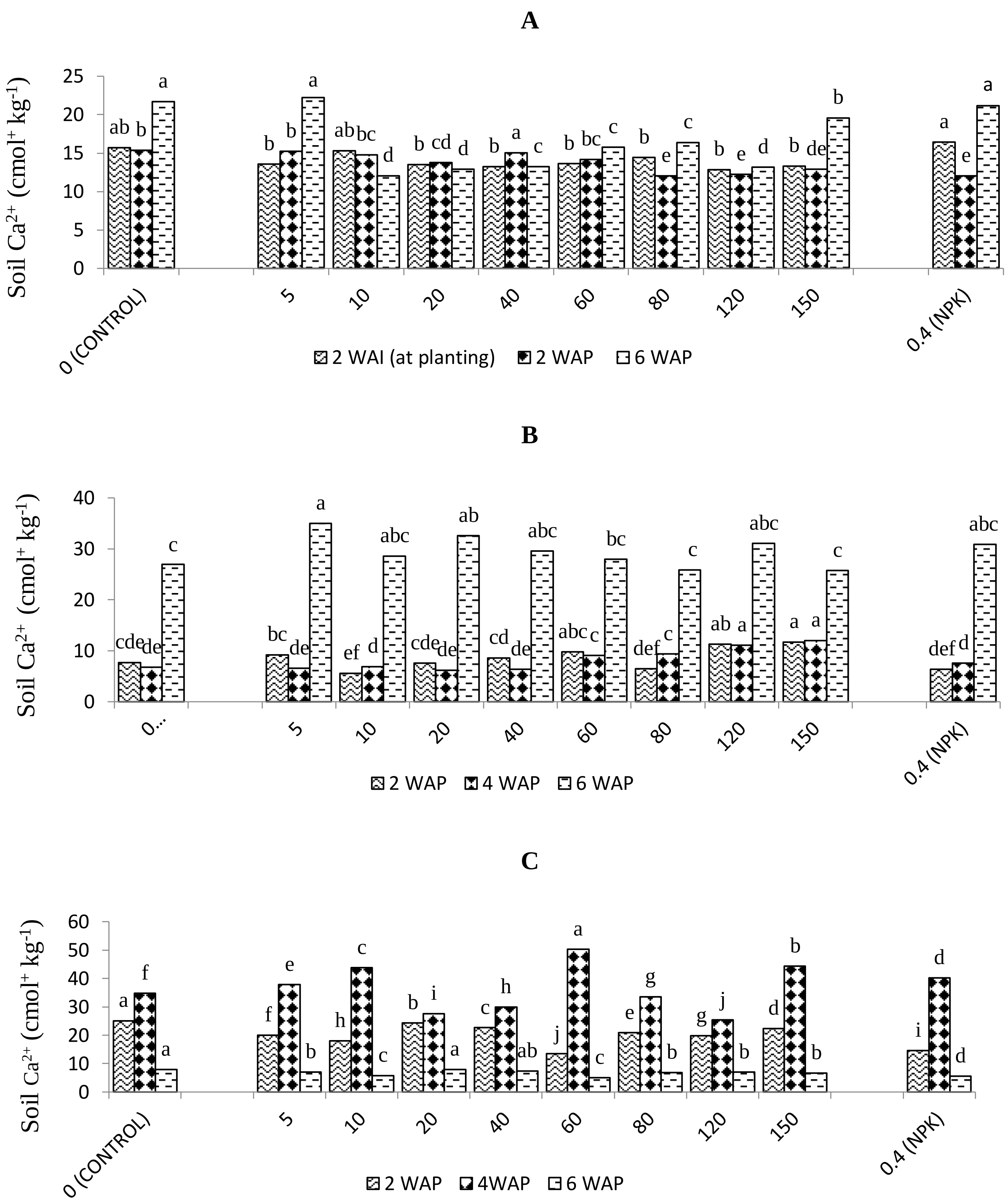

Figure 2: Influence of goat manure rates and NPK fertilizer (t ha^{-1}) on mean soil Ca^{2+} ($cmol^{+}$ kg^{-1}) at two weeks interval under first (A), second (B) and third (C) cycles

WAI = weeks after incorporation of manures. WAP = weeks after planting *Corchorus olitorius.*

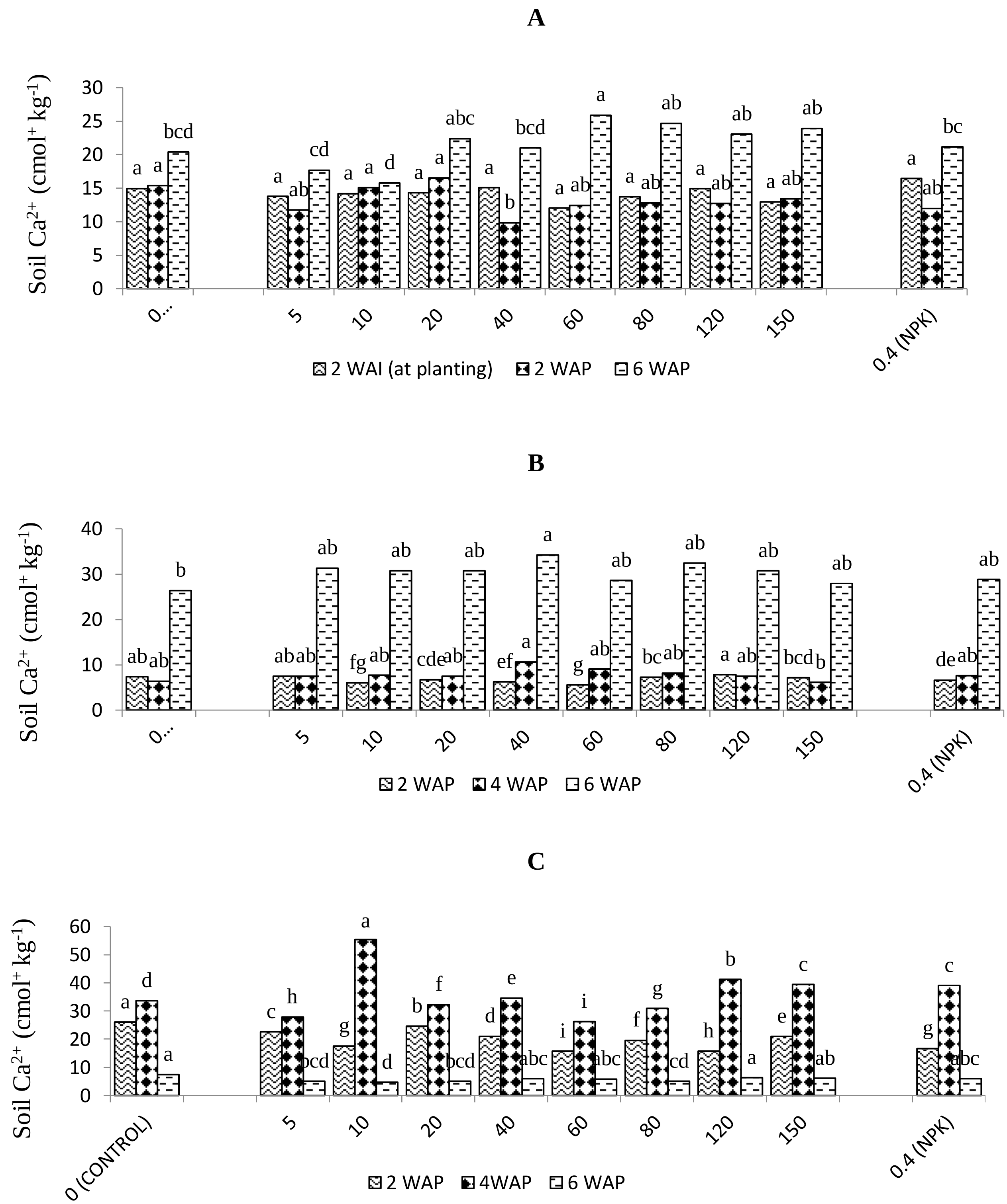

Figure 3: Influence of poultry manure rates and NPK fertilizer (t ha^{-1}) on mean soil Ca^{2+} (cmol^{+} kg^{-1}) at two weeks interval under first (A), second (B) and third (C) cycle

WAI = weeks after incorporation of manures. WAP = weeks after planting *Corchorus olitorius.*

Influence of poultry manure rates and NPK fertilizer (t ha^{-1}) on mean soil Ca^{2+} (cmol$^+$ kg^{-1}) at two weeks interval of third cycle.

The control with Ca^{2+} value of 26.07 cmol$^+$ kg^1 was significantly higher in soil Ca^{2+} while the other poultry amendment rates decreased at 2 WAP. At 4 WAP, poultry manure rate of 10 t ha^{-1} gave Ca^{2+} value of 55.38 cmol$^+$ kg^{-1} with the highest increase of 65 % over the control. The amendment rates differed significantly from one another. Increments and reductions according to the amendment rates were erratic. At 6 WAP, control with Ca^{2+} value of 7.49 cmol$^+$ kg^{-1} was significantly higher compared with other amendment rates, Figure 3(C).

Influence of cattle manure rates and NPK fertilizer (t ha^{-1}) on mean soil Mg^{2+} (cmol$^+$ kg^{-1}) at various week intervals of first cycle.

A day after application of NPK, cattle manure rate of 60 t ha^{-1} gave Mg^{2+} value of 4.26 cmol$^+$ kg^{-1}. This recorded the highest increment of 73 % while 10 t ha^{-1} with Mg^{2+} value of 3.20 cmol$^+$ kg^{-1} recorded the least increment of 30 % compared with control. The amendment rates were significantly different from one another, though; control was not significantly different from 5 t ha^{-1}. At 2 WAP, cattle manure rate of 20 t ha^{-1} with Mg^{2+} value of 2.07 cmol$^+$ kg^{-1} gave the greatest increase of 96 % while the rate of 5 t ha^{-1} stimulated Mg^{2+} value of 2.61 cmol$^+$ kg^{-1} with the lowest increase of 2 % over the control, Figure 4(A). At 6 WAP, cattle manure at the rate of 150 t ha^{-1} with Mg^{2+} value of 13.01 cmol$^+$ kg^{-1} gave the highest increment of 231 % over the control while the rate of 60 t ha^{-1} stimulated Mg^{2+} value of 5.75 cmol$^+$ kg^{-1} recorded the lowest increment of 46 %, Figure 4(A).

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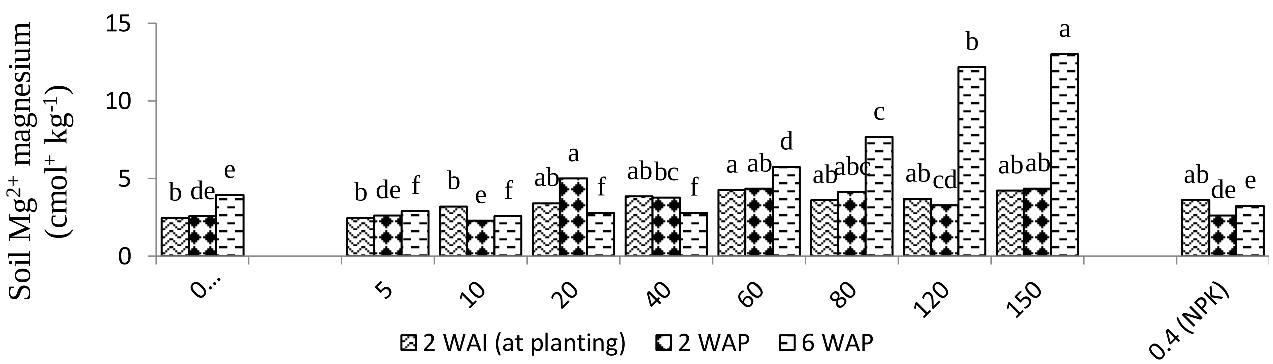

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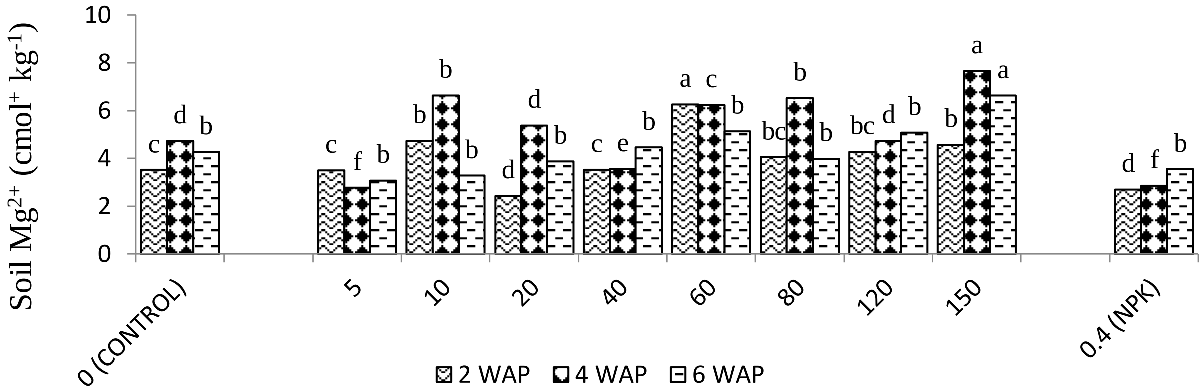

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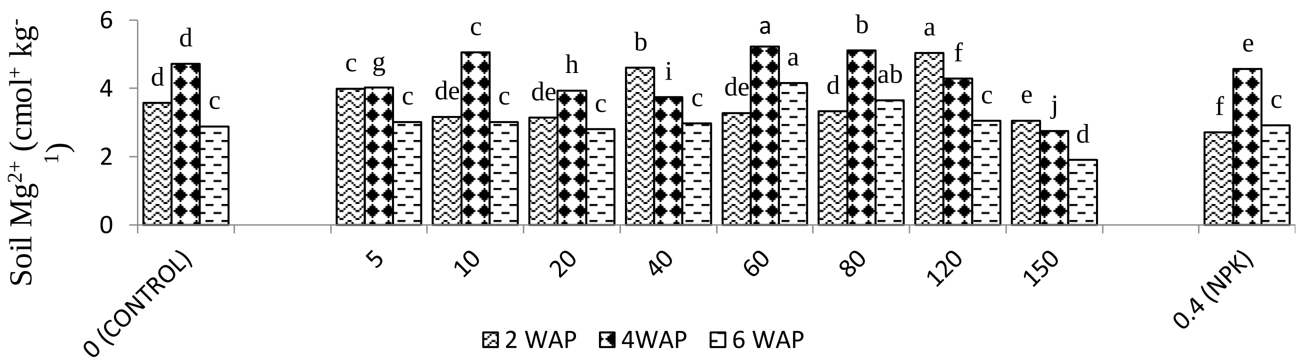

Figure 4: Influence of cattle manure rates and NPK fertilizer (t ha^{-1}) on mean soil Mg^{2+} (cmol^{+} kg^{-1}) at two weeks interval under first (A), second (B) and third (C) cycles of planting.

WAI = weeks after incorporation of manures. WAP = weeks after planting.

Influence of cattle manure rates and NPK fertilizer (t ha^{-1}) on mean soil Mg^{2+} (cmol^{+} kg^{-1}) at two weeks interval of second cycle of planting

At 2 WAP (two weeks after application of NPK), cattle manure rate of 60 t ha^{-1} resulted to Mg^{2+} value of 6.26 cmol^{+} kg^{-1} recorded the highest increment of soil Mg^{2+} by 78 % over the control while the rate of 40 t ha^{-1} had Mg^{2+} value of 3.53 cmol^{+} kg^{-1} recorded the least increment of 1 % compared with control. Cattle manure rate of 150 t ha^{-1} with Mg^{2+} value of 7.66 cmol^{+} kg^{-1} was significantly higher by 62 % over the control which gave Mg^{2+} value of 4.73 cmol^{+} kg^{-1} at 4 WAP relative to control. At 6 WAP, cattle manure at the rate of 150 t ha^{-1} stimulated Mg^{2+} value of 6.62 cmol^{+} kg^{-1}. However, the level of reductions and increments of soil Mg^{2+} according to the amendment rates and in comparison with the corresponding rates at 4 WAP were varried, Figure 4(B).

Influence of cattle manure rates and NPK fertilizer (t ha^{-1}) on mean soil Mg^{2+} (cmol^{+} kg^{-1}) at two weeks interval of third cycle.

At 2 WAP (two weeks after application of NPK), cattle manure rate of 120 t ha^{-1} with

Mg^{2+} value of 5.04 $cmol^{+}$ kg^{-1} was significantly higher while at 4 WAP, cattle manure rate of 60 t ha^{-1} gave Mg^{2+} value of 5.22 $cmol^{+}$ kg^{-1} was significantly higher compared with other poultry manure rates, control and NPK. At 6 WAP, cattle manure at the rate of 60 t ha^{-1} gave Mg^{2+} value of 4.16 $cmol^{+}$ kg^{-1} recorded the highest increase of 44 % while NPK with the Mg^{2+} value of 2.92 $cmol^{+}$ kg^{-1} recorded the least increase of 1 % relative to control, Figure 4(C)

Influence of goat manure rates and NPK fertilizer (t ha^{-1}) on mean soil Mg^{2+} ($cmol^{+}$ kg^{-1}) at various weeks interval of first cycle of planting.

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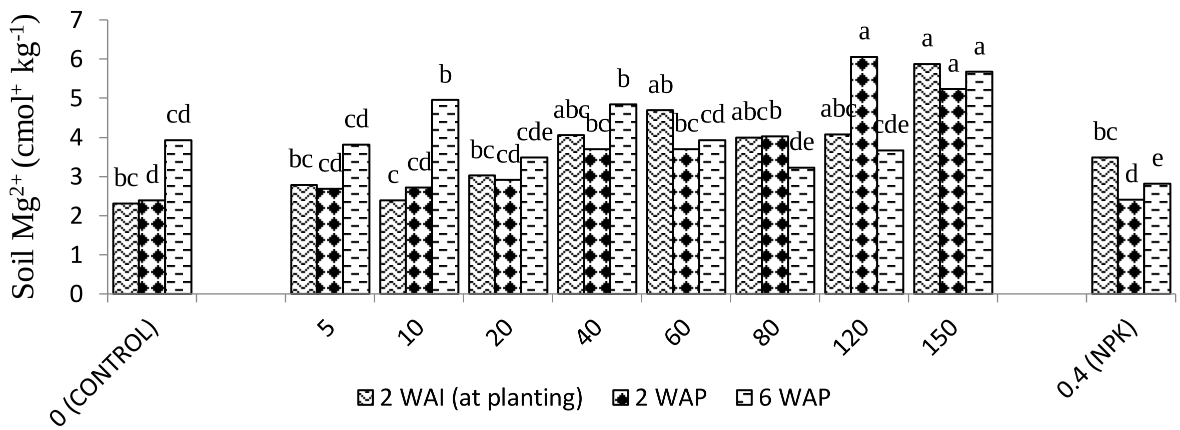

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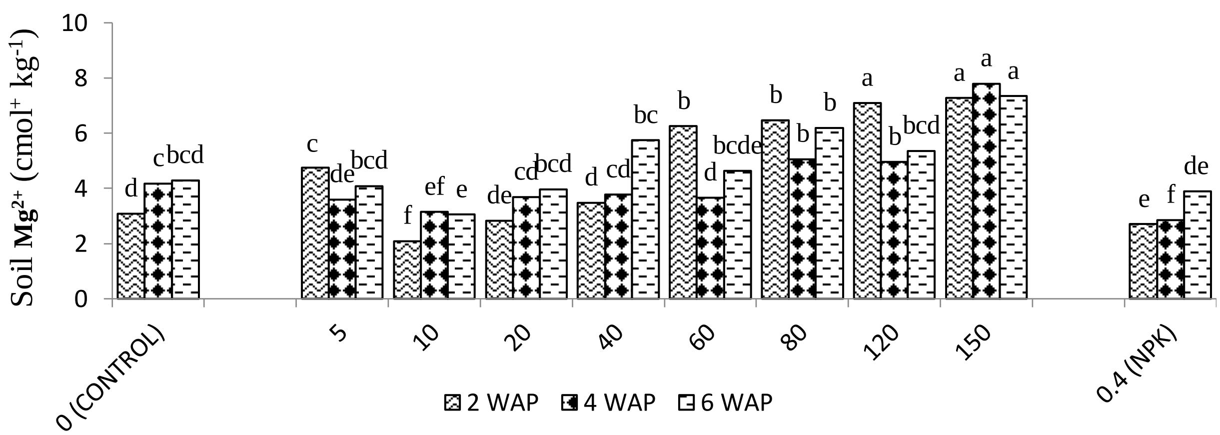

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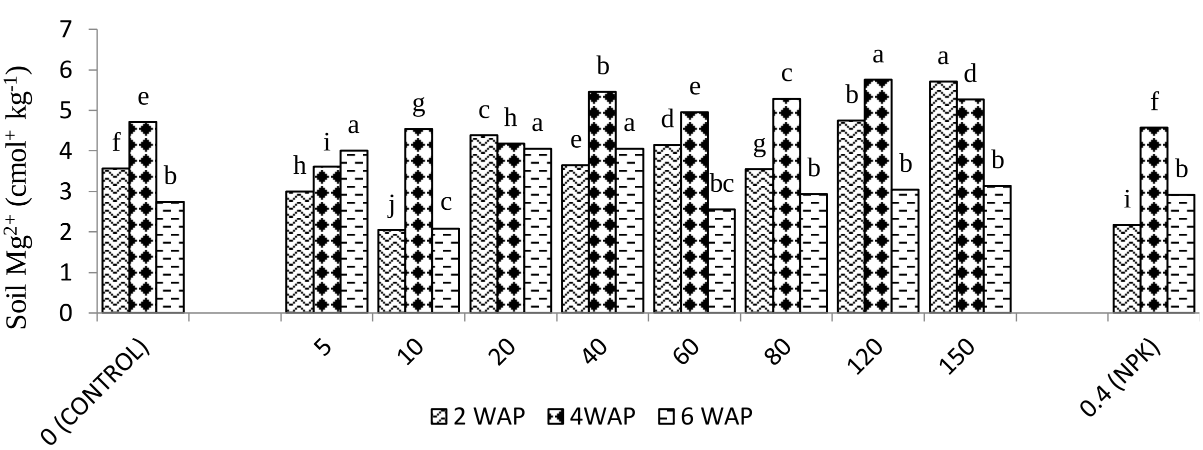


Figure 5: Influence of goat manure rates and NPK fertilizer (t ha^{-1}) on mean soil Mg^{2+} (cmol$^+$ kg^{-1}) at two weeks interval under first (A), second (B) and third (C) cycles

WAI = weeks after incorporation of manures. WAP = weeks after planting

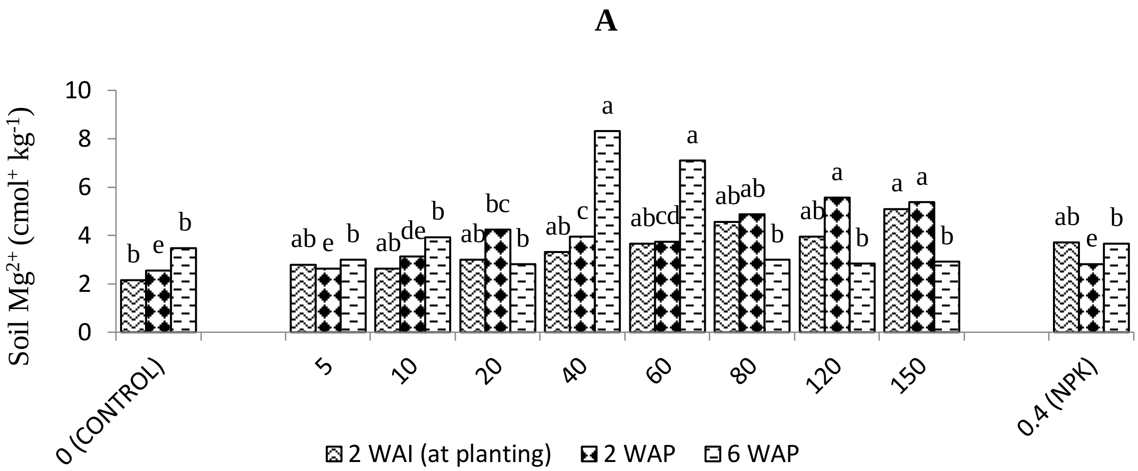
At 2 WAI (a day after application of NPK), goat manure rate of 150 t ha^{-1} had Mg^{2+} value of 5.88 cmol$^+$ kg^{-1} recorded the highest increment of 96 % in soil Mg^{2+} while the rate of 20 t ha^{-1} with Mg^{2+} value of 3.02 cmol$^+$ kg^{-1} recorded the least increment of 1 % more than the control, Figure 5(A). At 2 WAP, 120 t ha^{-1} had Mg^{2+} value of 6.06 cmol$^+$ kg^{-1} gave the greatest increase of 154 % while NPK fertilizer with Mg^{2+} value of 2.41 cmol$^+$ kg^{-1} recorded the lowest increase of 1 % relative to control. At 6 WAP, goat manure rate of 150 t ha^{-1} resulted to Mg^{2+} value of 5.67 cmol$^+$ kg^{-1} and gave the highest increment of 44 % over the control.

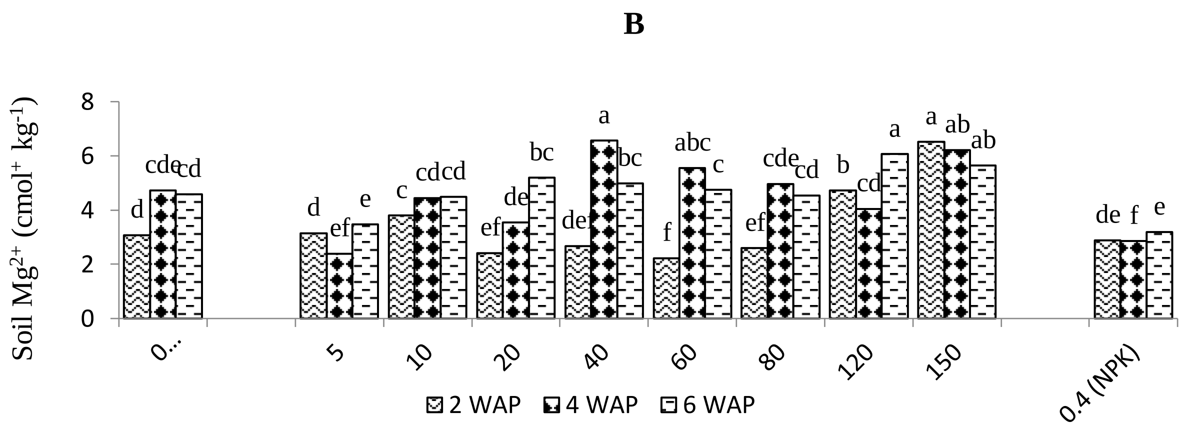
Influence of goat manure rates and NPK fertilizer (t ha^{-1}) on mean soil Mg^{2+} (cmol$^+$ kg^{-1}) at two weeks interval of second cycle.

At 2 WAP (two weeks after application of NPK), 4 WAP and 6 WAP, goat manure rate of 150 t ha^{-1} with Mg^{2+} values of 7.27, 7.80 and 7.34 cmol$^+$ kg^{-1} was significantly higher compared with other cattle amendment rates, control and NPK, Figure 5(B).

Influence of goat manure rates and NPK fertilizer (t ha^{-1}) on mean soil Mg^{2+} (cmol$^+$ kg^{-1}) at two weeks interval of third cycle.

At 2 WAP (two weeks after application of NPK), goat manure rate of 150 t ha^{-1} with Mg^{2+} value of 5.71 cmol$^+$ kg^{-1} was significantly higher compared with other goat manure rates, control and NPK. At 4 WAP, goat manure rate of 120 t ha^{-1} with Mg^{2+} value of 5.75 cmol$^+$ kg^{-1} was significantly higher in relation to other amendment rates and control. At 6 WAP, the goat manure rates of 20 and 40 t ha^{-1} with the same Mg^{2+} value of 4.06 cmol$^+$ kg^{-1} were significantly higher in





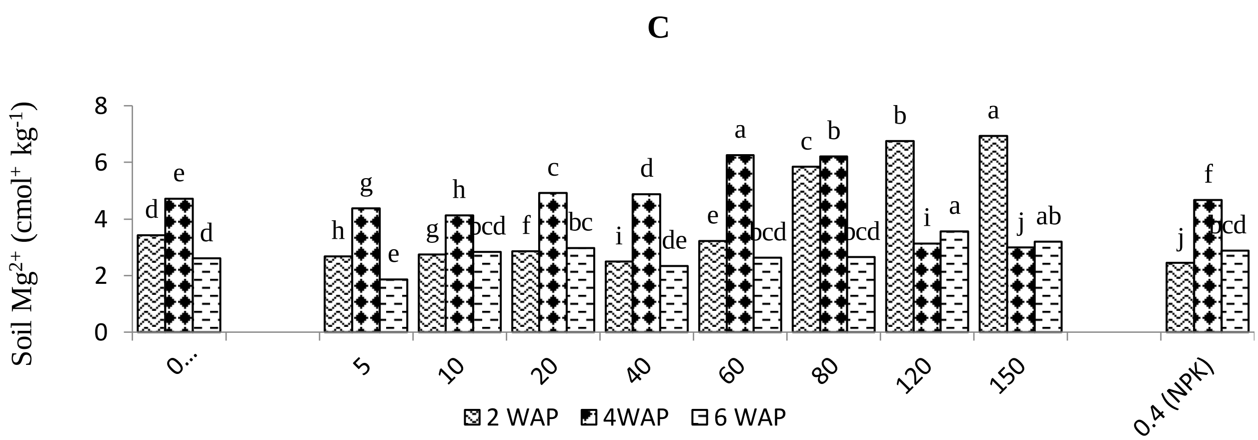


Figure 6: Influence of poultry manure rates and NPK fertilizer (t ha^{-1}) on mean soil Mg^{2+} (cmol^{+} kg^{-1}) at two weeks interval under first (A), second (B) and third (C) cycles.

WAI = weeks after incorporation of manures. WAP = weeks after planting.

comparison with other goat manure rates. There were variations in the level of soil Mg^{2+} according to the amendment rates, Figure 5(C).

Influence of poultry manure rates and NPK fertilizer (t ha^{-1}) on mean soil Mg^{2+} ($cmol^{+}$ kg^{-1}) at various weeks interval of first cycle.

At 2 WAI (a day after application of NPK), poultry manure rate at 150 t ha^{-1} recorded Mg^{2+} value of 5.10 $cmol^{+}$ kg^{-1} recorded the highest increment in soil Mg^{2+} by 136 % over the control while the rate at 10 t ha^{-1} with Mg^{2+} value of 2.64 $cmol^{+}$ kg^{-1} recorded the least increment of 22 % compared with control. At 2 WAP, poultry manure at 120 t ha^{-1} stimulated Mg^{2+} value of 5.56 $cmol^{+}$ kg^{-1} with increase of 118 % while 5 t ha^{-1} recorded Mg^{2+} value of 2.63 $cmol^{+}$ kg^{-1} and gave the lowest increase of 3 % relative to control, Figure 6(A). At 6 WAP, poultry manure at 40 t ha^{-1} recorded Mg^{2+} value of 8.31 $cmol^{+}$ kg^{-1} with the highest increment of 139 % more than control.

Influence of poultry manure rates and NPK fertilizer (t ha^{-1}) on mean soil Mg^{2+} ($cmol^{+}$ kg^{-1}) at two weeks interval of second cycle.

At 2 WAP (two weeks after application of NPK), poultry manure rate of 150 t ha^{-1} recorded Mg^{2+} value of 6.52 $cmol^{+}$ kg^{-1} was significantly higher while at 4 WAP, 40 t ha^{-1} recorded Mg^{2+} value of 6.56 $cmol^{+}$ kg^{-1} was significantly higher compared with other goat manure rates, control and NPK. But at 6 WAP, poultry manure at 120 t ha^{-1} with Mg^{2+} value of 6.06 $cmol^{+}$ kg^{-1} was significantly higher compared with other cattle amendment rates, control and NPK.

Influence of poultry manure rates and NPK fertilizer (t ha^{-1}) on mean soil Mg^{2+} ($cmol^{+}$ kg^{-1}) at two weeks interval of third cycle.

Poultry manure rate at 150 t ha^{-1} stimulated Mg^{2+} value of 6.94 $cmol^{+}$ kg^{-1} was significantly higher in soil Mg^{2+} followed by 120 and 80 t ha^{-1} with Mg^{2+} value of 6.75 and 5.84 $cmol^{+}$ kg^{-1}, respectively, Figure 6(C) but at 4 WAP, poultry manure at the rate of 60 t ha^{-1} had Mg^{2+} value of 6.26 $cmol^{+}$ kg^{-1} and was significantly higher while at 6 WAP, poultry manure at 120 t ha^{-1} recorded Mg^{2+} value of 3.57 $cmol^{+}$ kg^{-1} compared with control and other amendment rates.

Discussion

The very slightly saline soil (LAS, 2014) used for the research would support availability of the Ca^{2+} and Mg^{2+}, since these nutrients naturally occur in very slightly saline soils and they make up the dissolved salts in the soil. They are the dominant ions in highly saline soils (FAO, 2026). As the soil was slightly alkaline (Pam and Brian, 2007), availability of Ca^{2+} and Mg^{2+} would be high and plants roots would be easily absorb them. At this point, these nutrients begin to lock up and micronutrients like iron and zinc would be unavailable (Fidel, 2026). The deficiency of total nitrogen (USDA-SCS, 1974; McBride, 2015) would reduce the plants overall absorption of Ca^{2+} and Mg^{2+}. This is because nitrogen promotes the root development needed to take up Ca^{2+} and Mg^{2+}, and plants could absorb higher amounts of Ca^{2+} when the nitrogen is in form of nitrates. Moreover, the NH_4^{+}- N content of 0.13 g kg^{-1} of the soil was high. Mg^{2+} acts as the central atom of the chlorophyll molecule, and the synthesis depends on nitrogen. Defficiency of nitrogen could lead to non-utilization of absorbed Mg^{2+} by plants. Mg^{2+} were moderate while Na^{+} and Ca^{2+} were high. High NO_3^{-}- N content of 0.14 g kg^{-1} of the soil could be as a result of low rainfall during this period. High nitrate could attracts more Ca^{2+} and Mg^{2+} as basic cations since nitrates are negatively charged, and this could balance the electrical charges. The Available P content of 7.5 mg kg^{-1} was low (Mallarino, 2000; ENDMEMO, 2015), and this could distrupts the absorption and balance of both Ca^{2+} and Mg^{2+}. Exchangeable K^{+} and Mg^{2+} were moderate (Pam and Brian, 2007) and were optimal for performance of the crop.

High exchangeable Na^+ and Ca^{2+} content of 0.82 and 10.96 $cmol^+ kg^{-1}$ of the soil support the reports (Pam and Brian, 2007). These high salts of Na^+ and Ca^{2+} of the soil could be attributed to the decomposition of the organic matter content of the soil due to high temperature, evaporation rate, sunshine hours/ day and low rainfall during the research. This confirmed the studies of some researchers (Davidson and Jannssens, 2006; Friedlingstein *et al*., 2006). High Na^+ in the soil could lead to dispersion of ions in the soil which could cause reduction in water holding capacity and low aeration of the soil and support the report of McCauley *et al*. (2009). The soil was sandy clay loam (USDA, 2010). As it was reported (Virginia, 2009) that a given amount of salt in sandy soils will be more concentrated in its effect on plant roots than an equivalent amount in clay soils. More so, sandy clay loam retains Ca^{2+} and Mg^{2+} well due to its clay contents.

Cattle manure was moderately alkaline while goat and poultry manures were mildy alkaline. The EC of the cattle, goat and poultry manures applied were considered very strongly saline (LAS, 2014). This could be as a result of high concentration of cationic salts in the manures. More so, the highest EC value of poultry manure compared with the cattle and goat manures support the findings (Azeez and Van Averbeke, 2010[a]; 2010[b]), that poultry manure had greater EC values than cattle or goat manures. This could be attributed to the highest NH_4^+- N, NO_3^-- N and total P contents in poultry manure. The pH of the pure goat and poultry manures values were considered mildy alkaline whereas, that of cattle manure was moderately alkaline corroborated the report of Pam and Brian (2007). This would allow for nutrients availability in the soil after mineralization. The poultry manure had higher NH_4^+- N, NO_3^-- N and total phosphorus compared with cattle and goat manures. It was observed from the result that cattle manure had the highest of total K^+, total Na^+ and total Ca^{2+} over the goat and poultry manures. However, goat manure was higher in total N, Mg and OC in relation to cattle and poultry manures. Furthermore, very low value of total P in goat could be as a result of the nutrient concentrations of the feed given to the animals. This is because they were fed with elephant grass and wheat offal under intensive system although, the nutrient content of the feed were not measured.

The effect of application of cattle, goat and poultry manures on Ca^{2+} were erratic across the first, second and third cycles of planting. This could be attributed to the high sodicity of the soil which resulted from very high concentration of Na^+ ions as a result of high rates of cattle, goat and poultry manures applied into the soil which would had displaced the Ca^{2+} from the exchange sites. This corroborated with the report of GRDC (2013), that sodicity results from the build-up of sodium ions in preference to calcium ion on the soil cation exchange complex. The reason behind the dynamics of high Ca^{2+} contents (Pam and Brian, 2007) observed at 8, 14 and 20 WAI during the experiment at first, second and third cycles.

The application of cattle, goat and poultry manures increased the soil Mg^{2+} but the increment trend were according to the manures rates applied to soil. This support the study of Gordon, (1998) that the use of poultry manure traced to its high K^+, Ca^{2+} and Mg^{2+} contents. This followed similar trend with the soil Ca^{2+} in the soil during the three cycles of planting cattle, goat and poultry manures but with slight difference in terms of increase and could be related to (Steven, 2004) that Ca^{2+} and Mg^{2+} behave very much the same in the soil due to similar chemical properties. Moreover, high Mg^{2+} contents were observed between 8 – 12 WAI for cattle and poultry manure treatments while goat manure treatment was between 10 - 14 WAI during the experiment at first, second and third cycles of planting, respectively. The reasons behind these could not be explained.

Conclusions

Organic farming is recognized as one source that help agriculture to develop sustainably. Addition of cattle, goat and poultry manures at 6 WAP improved the soil Ca^{2+} and Mg^{2+} with highest values during first and second cycles and 4 WAP during third cycle which could be due to solubilization. The lowest values of Ca^{2+} and Mg^{2+} during third cycle could suggest uptake by plant and leaching.

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