Original Research Article

Impactof Nutrient Management Practices on Exchangeable K, Ca, Mg, CEC and Its Correlations withSoil Properties Under Maize-Wheat Cropping System

ABSTRACT

In order to study the impact of nutrient management practices on exchangeable K, Ca, Mg, CEC and its correlations with soil properties in two depths (0-15 cm and 16-30 cm) under maize-wheat cropping system,a long term experiment was conducted at farm research centre of department of soil science falling under the jurisdiction of Birsa Agricultural University. The experiment consisted of nine treatmentsreplicated thrice in a randomized block design were selected for the study. The selected treatments were T_1-control, T_2-100% N only where 100% N was applied through Urea fertilizers,T_3-FYM where 100% N was supplied through FYM (full dose 22 t/ha), T_4-100% NP here 110 and 90 kg ha^{-1}were supplied through Urea and SSP fertilizers, respectively, T_5-100% NPK here 110:90:70 kg ha^{-1}were supplied through Urea: SSP: MOP fertilizers, T_6- 1/2(N+FYM)+P(A-X/2)+K(B-Y/2) (INM) where 50% of the nutrient need was supplied through Urea, SSP & MOP fertilizer and the rest 50% need through FYM and T_7-100% NPK + Lime where NPK applied through Urea, SSP & MOP fertilizer along with lime application in LR once in 4 years, T_8-Lime+ FYM+ $P_{(A-X)}$+$K_{(B-Y),}$ the 100% N need of the crop was met by application of FYM whereas the P & K need was met by the application of SSP & MOP fertilizer, T_9-Lime+N the 100% N dose was supplied through Urea along with lime.The results indicated that exchangeable K was found to be significantly highest in T_8than rest of the treatments followed by T_7 and T_5 while lowest was in T_4 treatment in both depths respectively. The exchangeable $Ca^{2+}$was found to be highest in treatment T_7followed by T_8 and T_3than rest of the other treated plot while lowest amount was found in T_2 in both the depths. The trend of exchangeable magnesium was found to be significantly different in 0-15 cm and 15-30 cm soil depths as the highest amount was observed in treatments such as T_8 followed by T_3 and T_6 in surface depths (0-15 cm) while in sub-surface depths (15-30 cm) the highest amount was found in treatments T_3 followed by T_8 and T_6 while the lowest amount was found in T_2 treated plot in both depths. Cation exchangeable capacity (CEC) is one the vital soil parameters concerning to soil fertility measured in terms of c mol (p+) kg^{-1} of soil and it is significantly varied in surface soils as well as in sub-surface soil depths. The CEC was significantly higher in FYM treated plot as compared to Non-FYM treated plot. Therefore, the highest CEC was recorded in T_3 treated plot than rest of the other treatment while the lowest one was recorded in T_2 plot in surface soils as well as sub-surface soils. The correlation coefficient (r) values worked out among the various soil parameters at these depth of soil where pH was significantly and positively correlated with exchangeable Ca^{2+} and exchangeable Mg^{2+}. Similarly organic carbon shows positive correlation with exchangeable Mg^{2+} and exchangeable K^+. Whereas EC and CEC shows non-significant but positive correlation with the parameters taken under study. The result of the present study will be highly useful for improving the soil fertility by using suitable and judicious combination of nutrient management with various cropping system side by side and hence provides a scientific scope for further research work.

Key word: Nutrient Management,Soil Properties, synthetic fertilizers,Indian agriculture

1. INTRODUCTION

“India and its sub-continent has made tremendous progress in agriculture after the green revolution or after the 1960’s. The success of agricultural production has been widely depend on the use of several inputs such as high yielding varieties, synthetic fertlizers, irrigation etc. Among these inputs, use of fertilizers arise as a vital input and become the kingpin for the transformation of indian agriculture from subsistence to surplus”(Ravindra Chary *et al., 2019).*“After the resounding success of the green revolution, a decline in the growth rate of food production is seen during the recent past in respect of crop productivity and input use response. Presently, the major concern in agriculture is to arrest any further decline in crop productivity and soil quality. Although high yielding nutrient responsive crop varieties resulted in higher productivity, it led to the overexploitation of soil reserves and other resources.In general, Indian soils are poor infertility, as these have been consistently depleted of their finite nutrient resources due to continuous cultivation for centuries, adoption of modern agricultural technologies, and imbalanced use of fertilizers and poor use efficiency of fertilizers”(Davari and Mirzakhani 2009; Kannan *et al.,* 2013).“It is essential to enhance the productivity of prominent crops of the country like paddy, wheat, maize etc. through location- specific nutrient management practices. To augment major food crops production, Food and Agriculture Organization (FAO) conceptualized the idea of plant nutrients in a crop and cropping system for better resource use. It is not only a reliable way of obtaining fairly higher yields with substantial fertilizer economy, but also a concept that is ecologically sound leading to sustainable agriculture. None of the nutrient sources alone can meet the total plant nutrients. Integration of inorganic and organic sources nutrient sources is the most efficient way to supply plant nutrients for sustained crop productivity and improved of soil fertility” (Singh and Singh, 2002). Generally cereal crops like maize, wheat, paddy etc. belongs to graminaeae being,exhaustive crops, capable to removes large amount of nutrients such as N, P, exchangeable K^+, Ca^{2+}, Mg^{2+} from soil.

“It is therefore necessary to judiciously manage the inflow of organic sources of nutrients, and their integration with fertilizers, and organic manure. Application of organic materials along with inorganic fertilizers leads to increased productivity of the system and sustained soil health for a longer period” (Gawai and Pawar, 2006). Due to escalation of fertilizer prices and associated environment problem the crisis has necessitated in search for alternative sources of manures for integrated nutrient management, which includes inorganic, organic manures, lime etc. to sustain the cereal based cropping system.

2. MATERIALS AND METHODS

2.1 Experimental Details

The field study was as a part of an ongoing Permanent Manurial Trial (PMT) initiated in 1956 on the maize-wheat cropping system on acidic red loamy soil at the Experimental Farm (85^0 19’ E longitude, 23^0 17’ N latitude) of Birsa Agricultural University, Kanke, Ranchi, Jharkhand. The experiment was laid out in Randomized Block Design with 3 replications and 9 treatments in each replication having a plot size of 10 m^2. The treatment details are presented in Table 1. The recommended dose of N: P_2O_5: K_2O are 110, 90, and 70 kg ha^{-1}, respectively, since 1976. Lime is applied as per lime requirement in treatments once in four years. FYM is applied based on N content as per the treatments@ 22 t ha^{-1} 15 days before the sowing of each crop. Phosphorous and potassium are applied as basal and nitrogen is applied in splits for both the crops. The sources of N, P, and K were urea, single superphosphate (SSP), and muriate of potash (MOP), respectively. The varieties Suwan composite and HD 2967 for maize and wheat were used as a test crop respectively.

Table 1: Details of the various treatments of the long-term field experiment

Treatment No.	Treatment description	Particulars
T_1	Control	No fertilizer, manure, or lime
T_2	100 % N	110 kg N ha^{-1} as urea
T_3	FYM	FYM was applied @ 22 t ha^{-1}, 15 days before sowing of Maize-wheat crop
T_4	100 % NP	110 kg N ha^{-1} as Urea + 90 kg P_2O_5 kg ha^{-1} as Single Super Phosphate (SSP)
T_5	100 % NPK	110 kg N ha^{-1} as urea + 90 Kg P_2O_5 Kg ha^{-1} as SSP+70 Kg K_2O as MOP
T_6	½ (N+FYM) + $P_{(A-X/2)}$ + $K_{(B-Y/2)}$ (INM)	50% N substituted through FYM and NPK (55.0 kg N ha^{-1} as urea + 55.6 kg P_2O_5 kg ha^{-1} as SSP+42.9 kg K2O as MOP
T_7	100 % NPK + Lime	Lime as per LR (once in four years) + NPK (110 kg N ha^{-1} as urea + 90 kg P_2O_5 kg ha^{-1} as SSP+70 Kg K_2O as MOP)
T_8	Lime+ FYM+$P_{(A-X)}$ +$K_{(B-Y)}$	Lime as per LR (once in four years) + FYM (22 t ha^{-1}) + 55.6 kg P_2O_5 kg ha^{-1} as SSP+42.9 kg K_2O as MOP
T_9	Lime + N	Lime as per LR (once in four years) + N @110 kg N ha^{-1} as Urea

2.2 Collection and Analysis of Soils

A total of 54 composite soil samples were collected at two different depths *viz.* 0-15 cm (surface depth) & 16-30 cm (sub-surface depth) after the harvest of crop from each plot of the experimental field of the nine selected treatments replication wise. The soil samples collected were air-dried in shade, gently ground using wooden pestle and mortar to pass through 2 mm sieve. The sieved samples were preserved in stoppered plastic containers for further analysis.Processed and well-dried soil samples were used to analyze the various forms of potassium by using the standard soil:extractant ratio with standard and specific methods for each.

2.2 Methods Used for Analysis of Soil Parameters

Table 2. Methods Used for Soil ParametersAnalysis

Sl.No	Soil Parameters	Methods
1.	Exchangeable Ca	Versanate Titration
2.	Exchangeable Mg	Versanate Titration
3.	Cation Exchange Capacity (CEC)	1N Ammonium Acetate
4.	pH	Soil:Water Suspension (1:2)
5.	Electrical Conductivty (EC)	Soil:Water Suspension (1:2)
6.	Organic Carbon (OC)	Walkley and Black
7.	Water Soluble K	Flame Photometer
8.	Available K	Flame Photometer
9.	Exchangeable K	Available K-Water Soluble K

2.4 Detailing of Methods for Soil Exchangeable Calcium, Magnesium and Exchangeable Potassium

Exchangeable Calcium and Magnesium

Exchangeable Ca plus Mg were extracted by using neutral normal ammonium acetate and estimated by complexometric titration method (versanate titration method) as described in Baruah and Barthakur (1999). The concentrations of calcium and magnesium ions were determined by complexometric titration with EDTA (Hesse, 1971), using calcon red indicator for calcium and erichrome black T(EBT) indicator for calcium plus magnesium. Magnesium concentration was estimated by subtraction.

Water soluble K

Water soluble K was determined by flame photometer after extraction of soil with doubled distilled water (Hanway and Heidal, 1952) in soil solution ratio 1:5 (w/v).

Available K

Available potassium was determined by Flame photometer after extraction of soil with neutral ammonium acetate (Jackson 1973) in soil to solution ratio 1:5 (w/v).

Exchangeable K

Exchangeable K was estimated by deducting the value of water soluble K from available K.

2.5 Statistical Analysis

The data sets were processed for analysis of variance as applicable to randomized block design using the least significant difference as described in Gomez and Gomez (1984). Treatment means were compared at 1% or 5% level of significance. Correlation studies were carried out among the parameters of soil using Microsoft Excel.

3. Results and Discussions

The present investigation entitled "Impact of Nutrient Management Practices on Exchangeable K, Ca, Mg, CEC and Its Correlations with Soil Properties Under Maize-Wheat Cropping System" was conducted during 2017-18 on the Permanent Manurial Trial at Experimental farm of Birsa Agricultural University, Ranchi. Attempts have been made to present different observations on changes on soil exchangeable potassium, calcium, magnesium fraction as well as CEC and their correlations with soil properties at two depths i.e. surface soil (0-15 cm) and sub-surface (16-30 cm) have been discussed. Simultaneously, assessment of water soluble and available potassium also carried out in order to assess the exchangeable potassium.

3.1Impact of Nutrient Management Practices on Different forms of Potassium

To assess the exchangeable potassium it is necessary to assess the water soluble and available potassium from the surface soil and sub-surface depth of soil which is presented in tablesand graphs.

3.1.1Water Soluble Potassium

Perusal of data (Table-3 & Table-4) indicated that under different nutrient- management treatments, the concentration of water soluble K in the surface soil (0-15 cm depth) ranged from 6.4 to 24.24 kg ha^{-1} and sub-surface soil (16-30 cm) ranged from 6.03 to 23.91 kg ha^{-1}. The highest amount of water soluble was observed in treatment T_8which is at par with T_5 and T_7 and followed by T_2. The lowest amount was observed in treatment $T_{4.}$ Almost similar trend was found in both depths w.r.t. various treatment combination except $T_2$and T_6. On critical examination of data it was also observed that water soluble K was numerically lower in sub-surface (16-30 cm) soil than surface (0-15 cm) soil. This could be attributed to release of labile K from organic residues, application of K containing fertilizers and upward translocation of K from lower soil depths with capillary rise of groundwater Lakaria *et al*., (2012) and Mazumdar *et al*., (2014).This may be due to continuous cropping without addition of K for the last 62 years. Similar findings were reported by (Sharma and Paliyal 2015). It was also observed that water soluble K of 100% NP treated plot was also significantly lower than that of 100% N treated plot. This may be due to the yield of 100% NP treated plot was more than that of 100% N treated plot. The higher content of water soluble K was recorded in treatment-8 where fertilizer with FYM was applied. This may be due to, in this treatment, K was applied in higher quantity (in the form of 100% K_2O+ FYM) than others since the inception of this experiment. The increased status of water soluble K with Lime, FYM,P_2O_5,K_2O treatment may also be due to stimulating effect of FYM in reducing K fixation, thereby bringing in more K into available form(Jatav *et al*., 2010) and similar findings reported by Kumari (2017).

3.1.2 Available potassium

Perusal of data (table-3 & table-4) indicated that under different nutrient- management treatments, the concentration of Available K in the surface soil ranged from 62.9 to 225 kg ha^{-1} and in sub-surface soil ranged from 57.7 to 219.8 kg ha^{-1}. In surface soil, the highest Available K status was found when plot was treated with full dose of Lime, FYM, P_2O_5 and K_2O fertilizers (T_8), which was significant higher than other treatments. It was followed by 100% NPK (T_5) treated plot. It was also observed that Available K of 100% NP treated plot (T_4) was significantly lower than all the treatments. Similar trend of Available K status was also found in sub-surface soil. The higher content of water soluble K was recorded in treatment-8 where fertilizer with FYM was applied. This may be due to, in this treatment, K was applied in higher quantity (in the form of 100% K_2O+ FYM) than others since the inception of this experiment. The increased status of water soluble K with Lime, FYM,P_2O_5,K_2O treatment may also be due to stimulating effect of FYM in reducing K fixation, thereby bringing in more K into available form(Jatav *et al*., 2010) and similar findings reported by Kumari (2017).While the lower availability in T_4 was due to continuous cropping without addition of K.Similar findings were reported by (Sharma and Paliyal 2015).On critical examination of data it was also observed that water soluble K was numerically lower in sub-surface (16-30 cm) soil than surface (0-15 cm) soil. This could be attributed to release of labile K from organic residues, application of K containing fertilizers and upward translocation of K from lower soil depths with capillary rise of groundwater Lakaria *et al*., (2012) and Mazumdar *et al*., (2014).

3.1.3 Exchangeable potassium

Perusal of data (Table-3 &Table-4) indicated that under different nutrient- management treatments, the concentration of Exchangeable K in the surface soil ranged from 56.5 to 200.76 kg ha^{-1} and in the sub-surface soil ranged from 51.67 to 195.89 kg ha^{-1}. . In surface soil, the highest Exchangeable K was found when plot was treated with full dose of Lime, FYM, P_2O_5 and K_2O fertilizers (T_8), which was significant higher than other treatments. It was followed by 100% NPK (T_5) treated plot. It was also observed that Exchangeable K of 100% NP treated plot (T_4) was significantly lower than all the treatments. Similar trend of Exchangeable K status was also found in sub-surface soil.The highest exchangeable K concentration under Lime+FYM+P_2O_5+K_2O(T_8)was also might be due to the fact that addition of FYM could increase the CEC of soil, which can hold more exchangeable K and convert K from Non-exchangeable form to exchangeable form ,consequent to mass action effect. Bhattacharyya *et al.,(*2006)reported that higher amount of K attribute to the process of structural K release through increasing the area of exchangeable surfaces, and due to the acceleration weathering of the interlayer K by application of FYM. The higher concentration of Exchangeable K under K fertilized plots in surface soil could be attributed to the addition of K through plant residues, manure and fertilizers (Sharma *et al.,* 2009 and Jadhao *et al*., 2018) in the plot. While the lower availability in T_4 was due to continuous cropping without addition of K.Similar findings were reported by (Sharma and Paliyal, 2015).It was also observed that the concentration of exchangeable K was numerically lower in sub – surface soil as compare to surface soil in all the treatments which may be due to comparatively more weathering vegetation and supply of K from organic residues in surface layer in lower depth. Sharma *et al.,* (1994) and Mazumdar *el al.,*(2004). Similar findings was reported by Sheela Swamy (2006), Lakaria *et al*., (2012) and Divya *el al*., (2016).

Table-3: Effect of nutrient management practices on different forms of K in surface soil.

Surface soil 0-15 cm				
Treatments		**Water soluble K (kg ha^{-1})**	**Exchangeable K (kg ha^{-1})**	**Available K (kg ha^{-1})**
T_1	Control	9.14	79.56	88.7
T_2	100 % N	13.8	111.3	125.1
T_3	FYM	11.5	98.23	109.7
T_4	100 % NP	6.40	56.5	62.9
T_5	100 % NPK	14.89	116.11	131
T_6	½ (N+FYM) + P (A-X/2) + K (B-Y/2) (INM)	12.63	103.07	115.7
T_7	100 % NPK + Lime	20.90	83.6	104.5
T_8	Lime +FYM+P(A-X)+K(B-Y)	24.24	200.76	225
T_9	Lime + N	8.23	67.27	75.5
CD(P=0.05)		**0.90**	**3.85**	**4.04**
CV(%)		**4.37**	**2.23**	**2.09**

Table- 4: Effect of nutrient management practices on different forms of K in sub-surface soil

Subsurface soil 16-30 cm				
Treatments		**Water soluble K(kg ha^{-1})**	**Exchangeable K (kg ha^{-1})**	**Available K (kg ha^{-1})**
T_1	Control	8.67	75.53	84.2
T_2	100 % N	12.85	106.85	119.7
T_3	FYM	11	93.47	104.6
T_4	100 % NP	6.03	51.67	57.7
T_5	100 % NPK	13.3	113	126.3
T_6	½ (N+FYM) + P (A-X/2) + K (B-Y/2) (INM)	12.11	98.39	110.5

T_7	100 % NPK + Lime	20.45	76.95	97.4
T_8	Lime +FYM+P(A-X)+K(B-Y)	23.91	195.89	219.8
T_9	Lime + N	8.10	63.2	71.3
CD(P=0.05)		**0.97**	**5.60**	**5.72**

3.2 Impact of Nutrient Management Practices on Exchangeable Calcium, Magnesium and Cation Exchange Capacity

3.2.1 Exchangeable Calcium

Under different nutrient- management treatments, the concentration of Exchangeable calcium in the surface soil ranged from 2.5 to 8.1 meq 100g^{-1} and in sub-surface soil ranged from 2.1 to 7.7 meq 100g^{-1} respectively. In the surface soil, the amount of exchangeable calcium was 8.1 meq 100g^{-1} (T_7) when plot was treated with 100 % NPK, Lime fertilizer which was significant higher than other plots. It was followed by (T_8) Lime, FYM, P_2O_5, K_2O treated plot. It was also observed that Exchangeable calcium of 100% N treated plot (T_2) was significantly lower (2.5 meq 100g^{-1}) than all the treatments. The exchangeable Ca status of continuously fertilized acid soil increased due to the application of lime and FYM. Application of lime increased exchangeable Ca whereas FYM application increased Prasad *et al.,* (1996) suggested that the high level of Ca in FYM treated plots was due to increased biomass production and its incorporation in the soil. Babu *et al.,* (2007) also reported increase in exchangeable Ca with the application of FYM. An increase in pH of the soil is also associated with the increased availability of Ca and Mg ions (Brady and Weil, 2002).Similar findings reported by Verma (2017). While the lower amount of exchangeable calcium might be due reduced pH as well as continuous removal of Ca by the crops. Several authors have reported that in multiple cropping systems, higher fertilizer levels decreased the availability of calcium in soils. On critical examination of data it was also observed that exchangeable Ca was decreased in sub-surface (16-30 cm) soil than surface (0-15 cm) soil and exchangeable Ca of surface and sub-surface soil followed the same trend.

3.2.2 Exchangeable Magnesium

Under different nutrient-management treatments, the concentration of exchangeable Magnesium in the surface soil ranged from 0.7 to 3.9 meq 100g^{-1} and in the sub-surface soil ranged from 0.13 to 3.60 meq 100g^{-1}. In the surface soil, the amount of exchangeable magnesium was 3.9 meq 100g^{-1} (T_8) Lime, FYM, P_2O_5, K_2O treated plot which was significantly higher than other plots. It was followed by (T_3)FYM treated plot.It was also observed that exchangeable magnesium of 100% N treated plot (T_2) was significantly lower (0.7 meq 100g^{-1}) than all the treatments.Exchangeable Mg content were lowest for N treatment, which might be due reduced pH as well as continuous removal of Mg by the crops. Several authors have reported that in multiple cropping systems, higher fertilizer levels decreased the availability of Mg in soils. The exchangeable Mg status of continuously fertilized acid soil increased due to the application of lime and FYM. Application of lime increased exchangeable Mg whereas FYM application increased Prasad *et al,.*(1996) suggested that the high level of Mg in FYM treated plots was due to increased biomass production and its incorporation in the soil. Babu *et al.* (2007) also reported increase in exchangeable Mg with the application of FYM. An increase in pH of the soil is also associated with the increased availability of Mg ions (Brady and Weil, 2002). Whereas in sub-surface soil, the amount of exchangeable magnesium was 3.60meq 100g^{-1} (T_3) FYM, treated plot which was significantly higher than other plots. It was followed by (T_8) Lime, FYM, P_2O_5, K_2O treated plot.It was also observed that exchangeable magnesium of 100% N treated plot (T_2) was significantly lower (0.13meq 100g^{-1}) than all the treatments. On critical examination of data it was also observed that exchangeable Mg was decreased in sub-surface (16-30 cm) soil than surface (0-15 cm) soil.

3.2.3 Cation Exchange Capacity

Under different nutrient- management treatments, the concentration of CEC in the surface soil ranged from 6.7 to 13.2 cmol(p+) kg^{-1} and in sub-surface soil ranged from 5.83 to 11.6 cmol(p+) kg^{-1}respectively. The highest CEC in surface soil was 13.2 cmol (p+)kg^{-1}of soilrecorded in (T_3), when plot was treated with FYM fertilizer which was significant higher than other plots. It was followed by (T_8) treated plot 12.8 cmol (p+)kg^{-1} of soil. It was also observed that CEC of 100% N treated plot (T_2) was significantly lower (6.7meq 100g^{-1}) than all the treatments. The CEC value of soils was comparatively high in the FYM-treated plots, which might be due to the higher organic colloids in these plots. Moreover, the increase in CEC with the addition of FYM can be attributed to the increase in root biomass and crop residues production and their incorporation in the soil. Similar findings were reported by Prasad *et al*., (1996) and Sharma (2004) and similar findings reported by Meena *et al., (*2017).The lowest CEC in treatment T_2(Non-FYM) might be due to the acidifying effect of fertilizers resulting in reduced pH values in the 100% N-treated plots. While in sub-surface soil the highest CEC was obtained in T_3, FYM treated plot followed by T_1 and T_8. The lowest CEC was obtained in T_2 treated plot.CEC of all treatments in surface soil is higher than the subsurface soil. This may be due to organic matter content in surface soil is more than subsurface soil and organic matter could increase the CEC of the surface soil.

Table-5: Effect of nutrient management practices on exchangeable Ca, Mg and CEC of surface soil

Surface Soil 0-15 cm				
Treatments		**Exch. Calcium (meq100g^{-1})**	**Exch. Mg (meq100g^{-1})**	**CEC [cmol (p+)kg^{-1}]**
T_1	Control	4.1	2.8	11.8
T_2	100 % N	2.5	0.7	6.7
T_3	FYM	6.2	3.8	13.2
T_4	100 % NP	3.1	0.9	9.84
T_5	100 % NPK	3.4	1	11.2
T_6	½ (N+FYM) + P (A-X/2) + K (B-Y/2) (INM)	5.3	3.2	12.7
T_7	100 % NPK + Lime	8.1	1.6	11.6
T_8	Lime +FYM+P(A-X)+K(B-Y)	7.9	3.9	12.8
T_9	Lime + N	5.7	2.1	8.2
CD(P=0.05)		**0.37**	**0.36**	**0.27**
CV(%)		**4.07**	**9.38**	**1.54**

Table-6: Effect of nutrient management practices on exchangeable Ca, Mg and CEC of sub-surface soil

Subsurface soil 16-30 cm				
Treatments		**Exch. Calcium (meq100g^{-1})**	**Exch. Mg (meq100g^{-1})**	**CEC [cmol (p+)kg^{-1}]**
T_1	Control	3.8	1.1	10.9

T_2	100 % N	2.1	0.13	6.08
T_3	FYM	5.9	3.6	11.6
T_4	100 % NP	2.9	0.4	8.73
T_5	100 % NPK	3	0.7	10.3
T_6	½ (N+FYM) + P (A-X/2) + K (B-Y/2) (INM)	4.8	2.5	11.6
T_7	100 % NPK + Lime	7.7	1.3	10.2
T_8	Lime+FYM+P(A-X)+K(B-Y)	7.6	2.7	10.9
T_9	Lime + N	5.4	1.9	7.83
CD(P=0.05)		**0.46**	**0.42**	**0.43**
CV(%)		**5.51**	**5.11**	**2.72**

3.4 Correlation of Exchangeable K, Ca, Mg, CEC with Various Soil Parameters

3.4.1 Correlation studiesExchangeable K, Ca, Mg,CEC with Various Soil Parameters (0-15 cm depth)

The correlation coefficient (r) values worked out among the various soil parameters at two different depth of soil (0-15cm and 16-30 cm) in the Maize Wheat cropping system.

From the table (Table-7) it was evident that the pH was found to be highly significant and positively correlated with Exchangeable Calcium (r=0.863**).Soil colloids acquires their charges either by dissociation of H^+ from or onto the active functional group (Van Ranst, 2006) and as the pH of the soil increases, the H^+ ions on the functional groups of organic matter dissociate, resulting in the creation of negative charges on the organic matter. The negative charges created therefore have affinity for K^+ ions, hence the positive correlation between organic carbon and the K forms observed. Amoakwah and Frimpong (2013). The parameter Electrical conductivity was observed to be non-significant and positively correlated with all the parameters under study. Organic Carbon was significant and positively correlated with Exchangeable Magnesium, Available K, Water soluble K,and Exchangeable K (r=0.780**, 0.771**, 0.748**,& 0.773** respectively). All the K forms positively correlated ($P < 0.05$) with organic carbon. This observation contradicts the findings of Acquaye (1973) who found no significant correlation of K with percentage organic carbon. Water Soluble and exchangeable K forms positively correlated with organic matter, with correlation coefficients (r) of 0.748*and 0.773* for water soluble K and exchangeable K respectively. This observation may be attributed to the fact that, tropical soils are often characterized by a variable charge systems (i.e., pH dependent charges) (Van Ranst, 2006) indicative that the creation of charges on tropical soil colloids depends on soil pH. Thus, the charge generated could either be positive or negative depending on the pH of the soil. Soil colloids acquires their charges either by dissociation of H^+ from or onto the active functional group (Van Ranst, 2006) and as the pH of the soil increases, the H^+ ions on the functional groups of organic matter dissociate, resulting in the creation of negative charges on the organic matter. The negative charges created therefore have affinity for K^+ ions, hence the positive correlation between organic carbon and the K forms observed and similar findings reported by Amoakwah and Frimpong (2013). Exchangeable Calcium was highly significant and positively correlated with pH (r=0.863**).Exchangeable Magnesium was significantly and positively correlated with Organic Carbon (r=0.780*).Cation exchange capacity (CEC) was found to be non-significantly and positively correlated with all the other parameters under study. Percentage K saturation values found in the soils also were high, but the overall low CEC values measured in the soil suggest that the soils are not adequately supplied with available K. It can therefore be concluded that potash fertilization would be required for sustainable crop production in the soils studied. Amoakwah and Frimpong(2013). Available K was found to be highly significant and positively correlated with Water soluble K and Exchangeable K (r=0.997**& 0.997**, respectively. In agreement with Samadi *et al.,* (2010) the study showed significantly ($P < 0.05$) positive correlation (r = 0.977*) between water soluble K and exchangeable, and between water soluble K and available K (r = 0.977*, $P < 0.05$). This observation was not unexpected because exchangeable potassium is usually released into the soil solution from the exchange complex when plants deplete the soluble potassium, indicative that the size of the exchangeable potassium pool will determine the effectiveness of K re-supply, as well as the concentration of K in the soil solution. Similar to findings made by Ghiri *et al.,* (2011), also made similar observations to confirm the positive correlation previously found between exchangeable and available forms of potassium by Kasker *et al.,* (2001) and Kozak *et al.,* (2005). Water soluble K was highly significant and positively correlated with available K, exchangeable K (r=0.997** & 0.997**, respectively). It was significant and positively correlated with organic carbon (r=0.748*). In agreement with Samadi *et al.,* (2010) the study showed "significantly ($P < 0.05$) positive correlation (r = 0.997*) between water soluble K and exchangeable, and between water soluble K and available K (r = 0.997*, $P < 0.05$). This observation was not unexpected because exchangeable potassium is usually released into the soil solution from the exchange complex when plants deplete the soluble potassium, indicative that the size of the exchangeable potassium pool will determine the effectiveness of K re-supply, as well as the concentration of K in the soil solution". Similar to findings made by Ghiri *et al.,* (2011), exchangeable K concentrations in the soils positively correlated with available K (r = 0.997*, $P < 0.05$) also made similar observations to confirm the positive correlation previously found between exchangeable and available forms of potassium by Kasker *et al.,* (2001) and Kozak *et al.,* (2005) and Amoakwah and Frimpong(2013).Exchangeable potassium was highly significant with Available K (r=0.997**) and with Water soluble K (r=0.997**). Whereas it was significantly and positively correlated with organic carbon (r=0.773*) .Exchangeable-K showed positive relationship with Organic Carbon (r =0.773*) which is very much expected because of the fact that higher content of Organic Carbon in the soil leads to higher CEC resulting in higher adsorption of the cations including K (Shankhayan *et al.,* 1996). All the K forms positively correlated ($P < 0.05$) with organic carbon. This observation contradicts the no significant correlation of K with percentage organic carbon. Soluble and exchangeable K forms positively correlated with organic matter, with correlation coefficients (r) of 0.567and 0.701 for water soluble K and exchangeable K respectively. This observation may be attributed to the fact that, tropical soils are often characterized by a variable charge systems (i.e., pH dependent charges) (Van Ranst, 2006), indicative that the creation of charges on tropical soil colloids depends on soil pH. "These results have indicated the existence of dynamic equilibrium between forms of K in soils of western plain of Rajasthan" (Dixit *et al.,* 1993; Chand and Swami, 2000; Prasad, 2010).

3.4.2 Correlation studies Exchangeable Ca, Mg, CEC and Potassium with Various Soil Parameters

From the (table-8) it was evident that the pH was found to be highly significant and positively correlated with Exchangeable Calcium (r=0.879**), and was significant and positively correlated with Exchangeable Magnesium (r=0.669*). The parameter Electrical conductivity was observed to be non-significant and positively correlated with all the parameters under study. Organic carbon was significant and positively correlated with Exchangeable Magnesium, Available K, Water soluble K, and Exchangeable K (r=0.729*,0.751*,0.751*,&0.753*). Exchangeable Calcium was highly significant and positively correlated with pH (r=0.879**). It was significant and positively correlated with Exchangeable Magnesium (r=0.685*). Exchangeable Magnesium was significantly and positively correlated with pH, Organic carbon and Exchangeable Calcium(r=0.669*, 0.729* & 0.685*) respectively. Cation exchange capacity (CEC) was found to be non-significantly and positively correlated with all the other parameters under study. Available K was found to be highly significant and positively correlated with Water soluble K and Exchangeable K (r=0.999** &0.997**respectively).

It was significant and positively correlated with Organic carbon (r=0.754*) respectively. Water soluble K was highly significant and positively correlated with Available K and with Exchangeable K (r=0.999** & 0.999**) respectively. And it was significant and positively correlated with Organic carbon (r=0.754* & 0.796*) respectively. Exchangeable K in the surface soil depth correlated with exchangeable K in the 16-30 cm soil layer. Significant and positive correlations between water-soluble K and exchangeable K forms indicate the faster rate of equilibrium between these forms. Similar interrelationships have been reported by Singh *et al*., (1993), Dixit *et al*., (1993), and Dan *et al.,* (2004). Significant correlations between different forms indicate the existence of dynamic equilibrium among different K fractions. Thus, it can be postulated that each form of K influences another directly or indirectly. Hence, all forms are important in one way or other for K availability in soil (Girija and Badrinath, 1996). Similar finding was reported by Lakaria *et al., (*2012). Exchangeable K was highly significant with Available K and with Water soluble (r=0.997** & 0.999**, respectively). Whereas it was significantly and positively correlated with Organic Carbon (r=0.745*) respectively).

Table-7: Correlation coefficient of different nutrients in surface soil under Maize-wheat cropping system

	pH	EC (dSm-^{1})	O.C. (g kg^{-1})	Exch. Calcium (meq 100g^{-1})	Exch.Mg (meq 100g^{-1})	CEC cmol(p^{+}) kg^{-1}	Available K (kg ha^{-1})	Water soluble K(kg ha^{-1})	Exchangeable K (kg ha^{-1})
pH	1								
EC(dSm-^{1})	-0.357	1							
O.C. (g kg^{-1})	0.292	0.280	1						
Exch. Calcium (meq 100g^{-1})	0.863^{**}	0.045	0.448	1					
Exch. Mg (meq 100g^{-1})	0.644	-0.136	0.780^{*}	0.628	1				
CEC cmol(p^{+}) kg^{-1}	0.034	-0.314	0.609	0.066	0.614	1			
Available K (kg ha^{-1})	0.180	0.437	0.771^{*}	0.301	0.462	0.167	1		
Water soluble K(kg ha^{-1})	0.141	0.439	0.748^{*}	0.256	0.424	0.157	0.997^{**}	1	
Exchangeable K (kg ha^{-1})	0.185	0.436	0.773^{*}	0.307	0.466	0.168	0.997^{**}	0.997^{**}	1

****Significant at 1%level of significance**

***Significant at 5%level of significance**

Table-8: Correlation coefficient of different nutrients in sub-surface soil under Maize-wheat cropping system

	pH	**EC (dSm-^{1})**	**O.C. (g kg^{-1})**	**Exch. Calcium (meq 100g^{-1})**	**Exch.Mg (meq 100g^{-1})**	**CEC cmol(p^{+}) kg^{-1}**	**Available K (kg ha^{-1})**	**Water soluble K(kg ha^{-1})**	**Exchangeable K (kg ha^{-1})**
pH	1								
EC(dSm-^{1})	-0.172	1							
O.C. (g kg^{-1})	0.263	0.297	1						
Exch. Calcium (meq 100g^{-1})	0.879**	0.240	0.413	1					
Exch.Mg ((meq 100g^{-1})	0.669*	0.126	0.729*	0.685*	1				
CEC cmol(p^{+}) kg^{-1}	0.015	-0.270	0.608	0.005	0.463	1			
Available K Kg ha^{-1}	0.168	0.369	0.754*	0.298	0.348	0.172	1		
Water soluble K(Kg ha^{-1})	0.166	0.384	0.751*	0.296	0.351	0.163	0.999**	1	
Exchangeable K (Kg ha^{-1})	0.168	0.367	0.753*	0.297	0.346	0.173	0.997**	0.999**	1

****Significant at 1%level of significance**

***Significant at 5%levelofsignificance**

4. Conclusions

The results indicated that exchangeable K was found to be significantly highest in T_8 than rest of the treatments followed by T_7 and T_5 while lowest was in T_4 treatment in both depths respectively. The exchangeable Ca^{2+} was found to be highest in treatment T_7 followed by T_8 and T_3 than rest of the other treated plot while lowest amount was found in T_2 in both the depths. The trend of exchangeable magnesium was found to be significantly different in 0-15 cm and 16-30 cm soil depths as the highest amount was observed in treatments such as T_8 followed by T_3 and T_6 in surface depths (0-15 cm) while in sub-surface depths (15-30 cm) the highest amount was found in treatments T_3 followed by T_8 and T_6 while the lowest amount was found in T_2 treated plot in both depths. Cation exchangeable capacity (CEC) is one the vital soil parameters concerning to soil fertility measured in terms of c mol (p+) kg^{-1} of soil and it is significantly varied in surface soils as well as in sub-surface soil depths. The CEC was significantly higher in FYM treated plot as compared to Non-FYM treated plot. Therefore, the highest CEC was recorded in T_3 treated plot than rest of the other treatment while the lowest one was recorded in T_2 plot in surface soils as well as sub-surface soils. The correlation coefficient (r) values worked out among the various soil parameters at these depth of soil where pH was significantly and positively correlated with exchangeable Ca^{2+} and exchangeable Mg^{2+}. Similarly organic carbon shows positive correlation with exchangeable Mg^{2+} and exchangeable K^{+}. Whereas EC and CEC shows non-significant but positive correlation with the parameters taken under study. Hence, the result of the present study will be highly useful for improving the soil fertility by using suitable and judicious combination of nutrient management with various cropping system side by side and hence provides a scientific scope for further research work.

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