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Correlation study of soil properties on various forms of Potassium in soils of North Bihar

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Abstract

The present investigation was carried out at Tirhut College of Agriculture, Dholi an unique campus of Dr. Rajendra Prasad Central Agricultural University, Pusa, Samastipur, Bihar in year 2016-2017. Soils of North Bihar extending between 88°17'17.04" E to 83°54'18.02" E longitude and 27°17'4.44" N to 25°29'58.17" N latitude having a vast area of 52,925 sq. km.

The soils developed by sediments deposit of Gandak, Budhi Gandak and Bagmati rivers are calcareous in nature, whereas the soils developed by sediments deposit of Kosi, Adhwara group and Kamala Balan rivers are non-calcareous in nature. One hundred twenty-one samples were collected.

Wide variation in water soluble K (3.5 ppm to 67 ppm), exchangeable K (12 ppm to 274 ppm), available K (17 ppm to 330 ppm), non-exchangeable K (65 ppm to 2101 ppm), nitric acid soluble K (126 ppm to 2431 ppm) and total K (469 ppm to 22471.20 ppm) were recorded in soils of North Bihar and are present in following order *viz.* total K > nitric acid soluble K > non-exchangeable K > available K > exchangeable K > water soluble K.

Significant correlation and regression were found among various soil properties and pools of K. Correlation coefficient with organic carbon and pools of K (Available K, Nitric acid soluble K and Non-exchangeable K) are significantly and positively correlated (r = 0.186*, r = 0.201* and r = 0.182*, respectively) in North Bihar. Non-exchangeable K is significantly and negatively correlated with soil pH (r = - 0.225*). Nitric acid soluble K was significantly and negatively correlated with pH (r = - 0.237**) and cation exchange capacity (r = - 0.253**); non-exchangeable Potassium was significantly and negatively correlated with cation exchange capacity (r = - 0.271**).

Keywords: Soil properties, forms of K

Introduction

Potassium (K) is the third major nutrient after N and P, required by plants for build-up of biomass. It exists in soil in different forms and these forms are in quasi-equilibrium with each other. K is essential in modern agriculture, horticulture and vegetable crops as it makes plants tolerant to drought and frost and resistant to a number of diseases and pest attack besides its impact on yield and quality. Under water stress condition K nutrition helps in morphological and biological changes in the plants. It is involved in the regulation of plant metabolism and improving water use efficiency by regulating the opening and closing of the stomata (Mengal and Kirkby, 1980) [17]. Now a day, K is recognized as an important limiting factor in crop production.

In the absence of adequate K fertilization, significant depletion of soil K reserves takes place, effect of which is substantial yield loss and higher economic risk of farmers. In the year 2020, the deficit of K in Indian agriculture is projected to be around 10 million tonnes/annum while the estimates for N and P balances are positive (Srinivasarao *et al.*, 2001) [39]. Such a deficit will create serious nutrient imbalances with major implications on factor productivity and environment.

Different forms of K play important role in their availability. In soil, K is found in four different forms, namely, constituent of primary minerals (structural/ lattice), non-exchangeable or fixed K, exchangeable K and solution K; these forms are inter-related and tend to maintain equilibrium. The last two i.e. exchangeable and solution K are very important for the growth of plants and microbes. Any depletion in a given form is likely to shift the equilibrium in the direction to replenish it.

The pool of K present in the soil solution is called solution K. A part of the released potassium cation is held around the negatively charged fine particles (colloids) by electrostatic attraction which is called exchangeable K. The third pool of soil K is termed as non-exchangeable K which occupies internal position of clay sheets as well as hexagonal cavities within the interlayer spaces of certain minerals. Although non-exchangeable K reserves are not immediately available, they can contribute significantly to exchangeable or liable pool of soil

K (Martin & Sparks, 1983) [16]. The rate of non-exchangeable K release and its mechanism are controlled by the nature and amount of clay minerals (Feigenbaum, 1986) [6] and organic acids present in soil environment. Total or mineral K is used to describe a much larger fraction of K that remains entrapped within the clay structure.

Among different fractions a large portion of the total potassium (98%) in soil occurs as structural components of soil minerals and is unavailable to plants. Plants can use only the exchangeable potassium (1-2%) that exists on the surface of clay particles and the potassium dissolved in soil water. This often constitutes a very small fraction of the total soil potassium. The importance of non-exchangeable potassium in both the K cycle and plant nutrition is widely recognized. The concentration of K in the soil solution needs to be quite low before non-exchangeable or fixed K can be released to soil solution. So, the categorization of the soils usually analyzing less than 50 mg kg^{-1} are rated low in available K, between 50 and 125 mg kg^{-1} K medium and above 125 mg kg^{-1} K as high in available K (Muhr *et al*., 1965) [22] are irrespective of crops or soils. Further, at low level of available potassium, they are contributed by non-exchangeable K and it will depend on their low, medium and high status. Sachdeva and Khera (1980) [26] reported 80-90% contribution of non-exchangeable K to crop nutrition in an illite dominant alluvial soil. Under intensive cropping, in the absence of K fertilization, initially exchangeable K in soil contributes to plant K nutrition, but with further cropping exchangeable K attains a certain minimal level, thereafter, plant K removal from soil and contribution of non-exchangeable K to K uptake are almost synonymous and accounts for up to 90-95% of the total plant K uptake (Srinivasarao *et al*., 2010) [36]. Due to larger contribution of non-exchangeable K to plant K requirement, lack of crop responses to applied K have been reported even in soils with low exchangeable K.

A significant proportion of potassium (K) needs of plant is met from non-exchangeable fraction of soil K. Under intensive cropping, in the absence of K fertilization, initially exchangeable K in soil contributes to plant K nutrition, but with further cropping exchangeable K attains a certain minimal level, thereafter plant K removal from soil and contribution of non-exchangeable K to K uptake are almost synonymous and accounts for up to 90-95% of the total plant K uptake. Due to larger contribution of non-exchangeable K to plant K needs, lack of crop responses to applied K have been reported even in soils with low exchangeable K. The major sources of non-exchangeable K in soils are K rich 2:1 clay minerals such as micas and vermiculite (Sparks and Huang, 1985; Mengel and Uhlenbecker, 1993) [32, 18]. However, the release of K from the interlayer of these minerals may be very slow process depending upon the weathering stage of these minerals, and therefore, whether the K release rates of soils under cropping are in tune with plant K needs becomes the most important aspect as far as K nutrition of crop plants is concerned.

India has 182 million ha cultivable land with 142.1 million ha net area sown and 121 million farmers. Among the states, Rajasthan has the largest portion of cultivable land followed by Maharashtra, Uttar Pradesh, Madhya Pradesh, Andhra Pradesh, Karnataka and Gujarat. The earlier estimates of soil fertility for K based on data generated from soil testing laboratories in the country indicated discrepancies in the percentage of samples testing high, though the overall soil K fertility of soils declined (Ghosh, 1976; Sekhon, 1995; Subbarao *et al*., 1996) [8, 27, 41]. Besides, existing categorization of soils based on available K status is not able to explain the crop response pattern in many regions of India. Therefore, it has become essential to look into soil dynamics under intensive production systems and confirm which K fraction in soil is predominantly contributing to crop K nutrition (Subbarao *et al*., 1993; Srinivasarao *et al*., 2000) [40, 34, 37]. It was also essential to examine whether imported K fertilizer is efficiently used in Indian agriculture and whether it is applied to right crop or right soil, where K application is a must.

It is worthwhile to note that even the most progressive and productive states like Punjab and Haryana, have most skewed N: P_2O_5: K_2O ratios. The focus has been on N followed by P and very little use of K resulting in a huge imbalance. In the year 2020, the deficit of K in Indian agriculture is projected to be around 10 million tonnes/annum while the estimates of N and P balances are positive (Srinivasarao and Khera, 1994; Srinivasarao *et al*., 2001) [38, 39]. There is obviously an urgent need for delineating the K status of soil and assess the expected responses to applied K so that the K fertilizer management can be taken up with emphasis on efficient use of K and the consequent economy in K use.

Materials and Methods

Soil sampling: From the grid cell (Fig: 1) at random, soil samples for surface (0-15 cm depth) were collected with Khurpi during June, 2016 before onset of monsoon. From one complete grid, six soil samples comprised of two from each, lowland, midland and upland were taken, whereas from incomplete grid less no. (6/3/0) of soil samples collected. All together 121 soil samples were collected and were air dried in shade; the stubbles, pebbles and weeds etc. were discarded; grounded to pass through 2 mm sieve and kept in polythene bags separately along with the proper labels. These samples were analyzed for their physical, chemical properties and forms of K content by standard methodology.

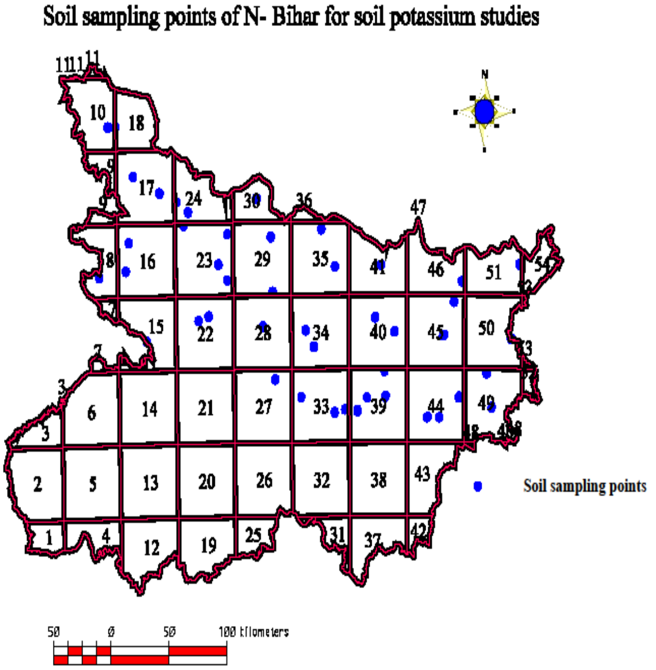

Fig 1: Soil sampling point of North Bihar for pools of K study

Physical analysis

Water holding capacity (WHC) of soil

The water holding capacity of soil was determined by saturating the soils in keens box with the capillary rise of water and then oven drying the soil as per Keen-Rackzowski Box method.

Soil texture

The texture of soil was determined by International Pipette Method as per the procedure given by ISSS (1929). In this method 20 g air dried processed soil treated with 50-60 ml of 6% H_2O_2 in a 500 ml beaker and kept on hot water bath. After complete oxidation of organic matter the beaker allowed to cool and again treated with 25 ml 2N HCl for removal of $CaCO_3$. It is then diluted to 250 ml by distilled water. The soil suspension rubbed with rubber pestle and allowed to react for an hour with interminant shaking, the solution filtered and made Cl^- free and then the soil on filter paper transferred to 1000ml beaker and diluted to 500 ml with distilled water.7ml N/10 NaOH is added for dispersion and separation of coarse sand. The separation of silt and clay fraction was done by making the volume 1000 ml. Suspension was stirred well and after 20 seconds 10 ml suspension taken out carefully with the help of pipette from 10 cm depth and dried at 105 ºC for observation. Again, the suspension was stirred well for one min., sample in the same way at a depth of 10 cm taken immediately after the expiry of the requisite time for clay.

Chemical analysis

The basic properties of soils were determined by following standard procedures as mentioned below.

Soil reaction (pH)

The soil pH was determined in 1: 2.5: soils: water ratio using pH meter as per standard procedure given by (Jackson, 1973) [13]. 20 g air dry soil was passed through 2 mm sieve and taken in a clean beaker, 50 ml distilled water added and stirred intermittently and allowed to stand for 30 min. Soil suspension was stirred once again just before taking the reading. Calibrated and washed electrode of pH meter immersed in soil water suspension and reading recorded. In the same soil water suspension Electrical Conductivity reading noted.

Electrical conductivity (EC)

The soil EC was estimated in 1:2.5: soil: water ratio with Conductivity Bridge as per method given by Jackson, 1973 [13].

Organic carbon (OC)

The organic carbon of soil was determined following the Walkley and Black (1934) [44] rapid titration method as described by Jackson (1973) [13].

Cation exchange capacity (CEC) of soil

The CEC of soil was determined as per standard method given by Jackson, 1973 [13]. The method involved saturation of soil with 1N neutral Ammonium Acetate; their leaching followed by removal of excess salts by washing with alcohol and finally distillation of adsorbed NH_4^+ using magnesia (MgO).

Chemical Analysis for pools of Potassium (K): Water soluble-K

The content of water-soluble K in soils was determined by extracting the soils with distilled water in the 1:5: soil: water ratio and shaken for half an hour. Then the K in the filtrate was estimated with the help of flame photometer as described by USSLS (1954) [43].

Available-K

The available-k of soils was estimated in the leachate which was obtained by equilibrating the soils with the extractant in 1N neutral Ammonium Acetate for five minutes and K determined with the help of flame photometer as per method by Hanway and Heidel (1952) [11].

HNO_3-K

The HNO_3-K known as fixed K was estimated in the soils by boiling 1:10: soil: nitric acid for ten minutes and estimated with the help of flame photometer as per standard method by Wood and De Turk (1940) [39].

Total-K

The total-K was determined in soil by extraction with H_2SO_4, $HClO_4$ and HF mixture in platinum crucible at 220-225 °C using flame photometer by following the standard method of Jackson (1973) [13].

Result and Discussion

Soil reaction (pH)

Data pertaining to soil reaction (pH) of upland, midland and lowland tabulated in table 4.1- 4.4. Analysis of data reveals that soil pH varied from 6.00 to 9.10 with mean value of 7.92 and standard deviation ± 0.72; 6.30 to 8.90 with mean value of 7.96 and standard deviation ± 0.66 and 5.50 to 8.80 with mean value of 7.89 and standard deviation± 0.81 in upland, midland and lowland, respectively. Soil pH of North Bihar irrespective to land situation varied from 9.10 to 5.50 with mean value of 7.92 and standard deviation ± 0.73. Critical examination of soil reaction (pH) of North Bihar reveals alkaline nature in Samastipur, Muzaffarpur and Champaran 28% soil samples were recorded under slightly alkaline, 53% of the soil samples under moderately alkaline and 1% soil samples under highly alkaline reaction. This might be due to the presence of calcereous nature of parent materials in Agro climatic Zone-I soil. Similar results were reported by K. Choudhary (1995) [5].

Electrical conductivity (dS m^{-1} at 25 °C)

Soil analysis data with respect to electrical conductivity (dS m^{-1}) presented in table 4.1- 4.4. According to the table EC of soils varied from 0.07 to 0.40 dS m^{-1} with mean value of 0.20 and standard deviation ± 0.08; 0.09 to 0.38 dS m^{-1} with mean value of 0.19 and standard deviation ± 0.07 and 0.08 to 0.32 dS m^{-1} with mean value of 0.17 and standard deviation ± 0.05 in upland, midland and lowland, respectively. Cumulative EC of North Bihar soil irrespective of physiography varies from 0.07 to 0.40 dS m^{-1} with mean value of 0.18 and standard deviation ± 0.07. However, critical analysis of tabulated data reveals slightly higher EC in upland followed by midland and lowland and have salt concentration within the safe limit. Similar value of EC was observed by K. Choudhary (1995) [5].

Organic carbon (%)

Maximum, minimum, mean and standard deviation of OC of North Bihar are tabulated in table 4.1 to 4.4. The OC of upland soils varied from 0.15 to 1.24% with mean value of 0.56% and standard deviation ± 0.22, in midland 0.29 to 1.13% with mean value of 0.60% and standard deviation ± 0.18 and in lowland 0.12 to 1.18% with mean value of 0.59% and standard deviation ± 0.20. Overall OC content of North Bihar soil samples was found to range between 0.12 and 1.24% with a weighted mean value of 0.58% and standard deviation ± 0.20. Altogether 43% of soil samples have low content of organic Carbon, 41% of soil samples have moderate value and 16% soil samples have high content. Highest value of organic carbon was observed in upland soil of Khagaria followed by soils from Sitamarhi, Madubani, and Vaishali. Similar value of OC was observed by Choudhary (1995) [5].

Soil texture

Wide variations in soil texture recorded in North Bihar soil samples. Soil Texture of coarse, medium and fine observed at different sample point. Soil texture of loamy sand, sandy loam, loam, silty loam, clayey loam and silty clay loam texture recorded during analysis. The soils are dominantly loam (36%); however, sandy loam (23%), silty clay loam (16%), clayey loam (15%), silty loam (10%), and loamy sand (0.04%) soils are also encountered.

Cation exchange capacity [cmol (P^+)/ kg]

The maximum, minimum, mean and standard deviation of Cation exchange capacity (CEC) of North Bihar are tabulated in table 4.1 to 4.4. CEC in different soil samples found to vary between 5.97 [cmol (P^+)/ kg] and 29.85 [cmol (P^+)/ kg] with a weighted mean value of 13.62 [cmol (P^+)/ kg] and standard deviation ± 7.17; 6.00 [cmol (P^+)/ kg] to 29.80 [cmol (P^+)/ kg] with mean value of 13.44 [cmol (P^+)/ kg] and standard deviation ± 7.58 and 5.57 [cmol (P^+)/ kg] to 30.10 [cmol (P^+)/ kg] with mean value of 13.54 [cmol (P^+)/ kg] and standard deviation ± 6.74 in upland, midland and lowland, respectively. CEC of North Bihar soil varies from 5.57 [cmol (P^+)/ kg] to 30.10 [cmol (P^+)/ kg] with mean value of 13.53 [cmol (P^+)/ kg] and standard deviation ± 7.11. Similar values of CEC were observed by Choudhary (1995) [5], Mishra (1992) and Singh (1991). Critical evaluation of data indicates 47.93% of soil samples CEC falls below 10 [cmol (P^+)/ kg] followed by 22.31% in 20-30 [cmol (P^+)/ kg] range, 20.66% in 10-15 [cmol (P^+)/ kg] range. A critical examination of data indicated that the CEC of soils was closely related to clay content. Higher proportion of soil samples under low CEC might be due to majority of medium and coarse texture in the North Bihar.

Water holding capacity (%)

Water holding capacity (%) of North Bihar soil has been presented in table 4.1-4.4. A perusal of data indicates that WHC varies with texture of the soils. The data show that WHC varies from 35.91% to 61.31% with mean value of 50.84% and standard deviation ± 6.09, 39.36% to 71.56% with mean value of 50.95% and standard deviation ± 6.36 and 38.68% to 63.08% with mean value of 50.63% and standard deviation ± 5.91 in upland, midland and lowland, respectively. WHC of North Bihar soil varies from 35.91% to 71.56% with mean value 7.92% and standard deviation ± 6.07. A perusal of data reveals 54.37% samples with 50-60% water holding capacity. This might be due to high clay content (31%) of fine textured soils. The soils having low WHC are generally sandy loam while those with medium to high WHC are silty loam to silty clay loam soils.

Available potassium

Tabulated data for available K (ppm) of North Bihar soil have been presented in table 4.1-4.4. Based on laboratory analysis, the values of available K of soils varied from 26 ppm to 330 ppm with mean value of 82.37 ppm and standard deviation ±64.04, 20.50 ppm to 256.50 ppm with mean value of 81.40 ppm and standard deviation ±57.90 and 17 ppm to 311.50 ppm with mean value of 77.99 ppm and standard deviation ± 55.09 in upland, midland and lowland, respectively. Available K of North Bihar soils varied from 17 ppm to 330 ppm with mean value of 80.56 ppm and standard deviation ±58.58. A critical analysis of different pools of K showed that available K is 1.17%, 1.09% and 1.26% of total K in upland, midland and lowland soils, respectively. On an average available K contributes only 1.17% of total K in North Bihar soil. The values are fairly comparable to the results reported by Sharma *et al.* (2012) for acidic soil of Nagaland. Among 121 samples 54% of the samples recorded low level of available K (<61 ppm), 31% medium level of available K (61-121 ppm) and 15% of samples recorded high level of available K (>121 ppm). Lowland soils showed generally higher values of available K than upland soils. These results are supported by the work of Ram and Singh (1975) [30] and Maharana *et al.* (1976) [15].

Water soluble K

Data for water soluble K are tabulated in table 4.1 – 4.4. Water soluble K of soils varied from 3.50 ppm to 67.00 ppm with mean value of 19.40 ppm and standard deviation ±15.82, 4.06 ppm to 66.50 ppm with mean value of 18.14 ppm and standard deviation ±12.64 and 4 ppm to 60 ppm with mean value of 17.29 ppm and standard deviation ±11.62 in upland, midland and lowland, respectively. On an average Water-soluble K of North Bihar soil varied from 3.50 ppm to 67 ppm with mean value 18.26 ppm and standard deviation ±13.35. A perusal of data pertaining to Available K clearly indicates that the water-soluble K contribute 23.55%, 22.28% and 22.17%, respectively in upland, midland and lowland. On an average water-soluble K contributes 22.67% to available K in North Bihar soils. Similar results were reported by Maharana *et al.* (1976) [15] in his study on old alluvial soils of Bihar. These results are supported by the work of Mishra *et al.* (1970) [12] for the soils of Uttar Pradesh. Ram and Singh (1975) [30] also reported similar type of values for water soluble K in Eastern UP.

Exchangeable K

Exchangeable K, an important component of available K in soils have been presented in table 4.1-4.4. According to the table exchangeable K of soils varied from 2 ppm to 264.50 ppm with mean value of 62.97 ppm and standard deviation ±56.58, 8 ppm to 207 ppm with mean value of 63.26 ppm and standard deviation ±50.27 and 7 ppm to 274 ppm with mean value of 60.70 ppm and standard deviation ±52.56 in upland, midland and lowland respectively. On an average exchangeable K of North Bihar soils varied from 2 ppm to 274 ppm with mean value 62.30 ppm and standard deviation ±52.71. Exchangeable K contributes 76.44%, 77.71% and 77.83% to available K respectively in upland, midland, lowland and overall 77.33% contribute to available K in all over North Bihar. These results were supported by the observations of Ram and Singh (1975) [30], Kumar (1985) [14], and Choudhary (1995) [5].

Nitric acid soluble K

Values pertaining to nitric acid soluble K in table 4.1-4.4, the maximum, minimum, mean and standard deviation of HNO_3 soluble K of soils of North Bihar are shown. According to the table HNO_3 soluble K of soils varied from 126 ppm to 2431 ppm with mean value of 939.36 ppm and standard deviation ±482.36, 164 ppm to 2322 ppm with mean value of 976.56 ppm and standard deviation ±464.38 and 166.50 ppm to 2039 ppm with mean value of 869.45 ppm and standard deviation ±501.28 in upland, midland and lowland respectively. Overall HNO_3 soluble K of North Bihar soils varied from 126 ppm to 2431 ppm with mean value 928.28 ppm and standard deviation ± 480.98. Similar range of nitric acid soluble K in alluvial soils of Bihar have been reported by Tiwari *et al.* (1967) [42], Choudhary (1995) [5] and Ram and Singh (1975) [30] also reported similar values in alluvial soils of U.P. A perusal of data reveals that the nitric acid soluble K contribute 12.20%, 13.03%, 12.83% and 12.33% of total K in upland, midland, lowland and overall soils of North Bihar.

Non-exchangeable K

The maximum, minimum, mean and standard deviation of non-exchangeable K for upland, midland, lowland and overall soils of North Bihar are tabulated in table 4.1-4.4. Non-exchangeable K of soils varied from 67 ppm to 2101 ppm with mean value of 856.98 ppm and standard deviation ±468.42, 121 ppm to 2066.50 ppm with mean value of 895.16 ppm and standard deviation ±451.23 and 65 ppm to 1985.50 ppm with mean value of 791.46 ppm and standard deviation ±499.08 in upland, midland and lowland, respectively. Overall non-exchangeable K of North Bihar soils varied from 65 ppm to 2101 ppm with mean value of 847.72 ppm and standard deviation ±471.44. These results were supported by the work of Mishra and Srivastava (1993) [20] and Choudhary (1995) [5]. It has been observed that 12.20%, 12.03%, 12.83% of total K found in non-exchangeable form and overall 12.33% of total K in the form of non-exchangeable K.

Total K

In table 4.1-4.4, the maximum, minimum, mean and standard deviation of total K of soils of North Bihar are shown. Total K of soils varied from 469 ppm to 14707 ppm with mean value of 7022.63 ppm and standard deviation ±3540.25, 1347 ppm to 22471.20 ppm with mean value of 7438.68 ppm and standard deviation ±4331.18 and 805 ppm to 18562.50 ppm with mean value of 6167.37 ppm and standard deviation ±3822.77 in upland, midland and lowland, respectively. Total K of North Bihar soils varies from 469 ppm to 22471.20 ppm with mean value of 6873.80 ppm and standard deviation ±3921.72. From the data it was also observed that the amount of total K in the lowland soils was higher than that of upland soils. Clay had higher content of total K than both sand and silt. Major portion of total soil K found to be existed in finer fractions. Choudhary (1995) [5] found higher total K content in clay fraction of alluvial soils of Bihar. These results obtained under present investigation are well comparable with the work of Prasad *et al.* (1967) [24], Prakash and Singh (1935) [23] and Choudhary (1995) [5].

Correlation study of soil properties on various forms of K

In order to assess the influence of soil properties on various forms of K, coefficients of correlations (table 4.5-4.8) were worked out. From (Table 4.6) available K, exchangeable K, nitric acid soluble K, non-exchangeable K and total K are positively and significantly correlated with organic carbon (r = 0.395*), (r = 0.401*), (r = 0.385*), (r = 0.342*) and (r = 0.373), respectively in upland soils of North Bihar. Exchangeable K is positively and significantly correlated with organic carbon (r = 0.314*) in midland soil of North Bihar. (Table 4.7).

In table 4.8 it is observed that lowland soils of North Bihar nitric acid soluble K and non-exchangeable K was significantly and negatively correlated with pH and cation exchange capacity (r = -0.370*), (r = 0.347*), (r = -0.393**) and (r = -0.416**), respectively.

Available K, nitric acid soluble K and non-exchangeable K are significantly and positively correlated with organic carbon (r = 0.186*), (r = 0.201*) and (r = 0.182*), respectively in North Bihar soil. Non-exchangeable K is significantly and negatively correlated with soil pH of North Bihar soil. Nitric acid soluble K was significantly and negatively correlated with pH (r = -0.237**) and CEC (r = -0.253**), non-exchangeable K was significantly and negatively correlated with CEC (r = -0.271**) in soils of North Bihar. (Table 4.5).

Multiple correlations were worked out to assess the degree of relationship between influence of soil pH, EC, OC, CEC and WHC and various pools of K in upland, midland and lowland soil and are presented in table 4.9-4.12. Under upland condition water soluble K is found to be significantly and positively correlated with soil reaction with R^2*100 value of 13.69. Exchangeable K, available K and total K have positive and significant correlation with soil organic carbon with good R^2*100 value. Whereas, nitric acid soluble and non-exchangeable K are positively influenced by soil organic carbon and CEC.

The relationship between soil properties and different pools of K- fraction was non-significant in upland soil situation of North Bihar. In lowland soils pH and CEC have great influence on exchangeable K, available K, nitric acid soluble K and non-exchangeable K, exchangeable K and available K are negatively correlated with soil reaction. Whereas, nitric acid soluble K and non-exchangeable K are negatively correlated with CEC of lowland soils.

Cumulative analysis of data for multiple regression presented in table 4.12 indicates significant influence of soil reaction and CEC on exchangeable K (-18.97**). CEC greatly influence nitric acid soluble K (-19.88**) and non-exchangeable K (-20.81**) with a good R^2*100 value. These findings are in agreement with the study of Sharma *et al.* (2009) [27].

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