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Dynamics of Different Fractions of soil Potassium in an Inceptisol under Subtropical Rice-Rice System

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Authors' contributions

This work was carried out in collaboration between both authors. Author RN performed the statistical analysis, managed the literature searches, wrote the protocol and wrote the first draft of the manuscript. Author KR designed the study and managed the analyses of the study. Both authors read and approved the final manuscript.

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ABSTRACT

Field studies were carried out in 2014-15 rabi season and 2015 kharif season at central farm of OUAT, Odisha, India to evaluate different fractions of potassium at different soil depth at different stages of rice crop. The experiment was laid out in randomized block design with 12 treatments and 4 replications. The study revealed that water soluble K, exchangeable K and non exchangeable K content was highest in 100%NPK+FYM+Lime.Watersoluble K decreased from tillering to harvesting for all the treatments in both the seasons. Exchangeable K decreased in rabi season but increased in kharif season through the stages of growth. Non exchangeable K increased from tillering to harvesting in both seasons. Lime application has increased three forms of potassium over 100%NPK treatment. There was decrease in potassium content with depth. Potassium content in kharif season is less than rabi. The correlation between grain yield is highest with non exchangeable K in rabi and exchangeable K in kharif. The K uptake is best correlated with non exchangeable K in rabi and water soluble K in kharif season.

Keywords: Water soluble K; exchangeable K; non exchangeable kharif; rabi; kharif.

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1. INTRODUCTION

Rice (*Oryza spp*.), a major crop cultivated in many countries across the globe with an annual production of 758.9 million tons and average productivity of 4641.5 kg/ha [1]. In India, rice is cultivated in 42.5 m ha with production of 165.3 mt and productivity of 3632.9 kg/ha [1] It is necessary to further enhance productivity of rice by application of plant nutrients to meet the consumption demand of ever increasing population. Sufficient K supply is required for optimal plant growth and development. because it is one of the essential macronutrients, which is important for many physiological processes in plant cells, like osmo regulation, and enzyme activation [2]. Modern high-yielding rice varieties mines higher amount of K than phosphorous (P) and nitrogen (N) [3]. Potassium is taken in large amounts by upland rice plants [4]. On the other hand un balanced use of fertilizers has disturbed the sustainability of production resulting in imbalanced consumption ratio of NPK of 5.2: 2.1:1.0 against the desirable ratio of 4:2:1. So there is report of negative balance of 104 kg K $ha^{-1}yr^{-1}$ in rice- rice system [5]. Sahu [6] has also observed negative balance of 7-90 kg K $ha^{-1}yr^{-1}$ in different treatments under rice- rice systems in laterite soil of Odisha. Other studies also show that intensive cropping cause heavy depletion of potassium under long-term experiments [7]. But the effect of negative balance of soil potassium is not reflected in soil test of NH_4OAc extracted form which is considered as available fraction of K [8]. According to (Darunsontaya et al. [9] based on degree of availability, soil potassium can be classified into four forms that is solution k> exchangeable k> non exchangeable k> mineral k. The solution k is the form readily available for uptake by microbes and plants. The exchangeable K is electro statically bound to outer space complex of the surface of clay minerals and humic substances. Non exchangeable K is referred as fixed K, interlayer K, slowly available K or slowly exchangeable K [10]. It is held between adjacent layers of the di octahedral and tri octahedral mica. Availability of these forms depends on physicochemical properties of soil [11]. The K content in soil and its availability to plant is related with distribution of K forms and equilibrium between them [12]. Since potassium release behavior of soil depends on soil pH, clay content, nature of clay, cation exchange capacity, interaction with other cations,liming,textue,wetting and drying along with different doses of K application [13,14]. The suitability of different form as an index of plant available K is controversial. Mengel [15] has reported monocots uptake non exchangeable form of K. Similar report is there by Srinivas Rao et al. [16] and Wang et al. [10]. According to Jena et al. [17] in rice- rice system in Bhubaneswar, there is release of non exchangeable K under acidic environment by application of NPK+FYM . The NH_4OAc- K has poor correlation with K balance in 15 year long-term study, whereas HNO_3 extracted K has a significant correlation with k balance [17]. Contribution of subsurface k to crop uptake is observed by Srinivasa Rao et al. [18]. Research result by scientists also reveals that there is significant change of K fractions due to submergence in rice soil [19,20]. Crop demands for K varies with crop growth behavior, nutrient needs at different stages and crop productivity levels. Therefore judicious application of potassic fertilizer is required for sustainable crop production [21]. To maintain sustainability and achieves increasing demand of rice production integration of organic and inorganic fertilizer is needed as suggested by Datta & Singh [22]. For the decision on optimum potassium application module, knowledge on different K fractions in soil, the periodic uptake, accumulation of K to different tissues in a rice plant should receive urgent attention. So it is pertinent to assess depth wise distribution of K fractions at different stages of growth of rice crop. Long-term fertilizer experiments are very useful to generate knowledge on K dynamics in soil and its availability to crops. With this objective, the present research was taken in a 10 year long term fertilizer experiment field in an inceptisol where integration of organic, inorganic, micronutrient fertilizers, lime application treatments were imposed under rice-rice cropping system to study change in different fractions of soil K at different growth stages of rice crop during kharif and rabi season.

2. MATERIALS AND METHODS

2.1 Description of Experimental Site

The study was conducted during 2014-15 rabi and 2015 kharif in the experimental field of All India Coordinated Research Project (AICRP) on LTFE of ICAR at OUAT, Bhubaneswar, India (20°17′ N, 85°49′ E and 30 m above mean sea level) which was started since 2005-06. The location of the experimental site is characterized as sub-humid subtropical climate with dry season from October to June and wet season from July to September. The soil of the experimental site was sandy loam in texture, having 71% sand12% silt and 17% clay, acidic (pH 5.8) EC-0.12ds/m,OC-4.3g/kg, available NPK 187, 19.4, 43.4 kg/ha respectively belonging to family mixed hyperthermic vertic ustocrept in comparison to other inceptisol in the same locality as reported by Mohapatra [23] was sandy loam texture with pH 5.87,EC-0.2ds/m,OC-3.9 g/kg, available N-170.0, available P-21.0 and available K-57.95 kg/ha.

2.2 Treatment Details

Rice cultivar Swarna (MTU 7029) was grown under flooded condition in both kharif and Lalat in rabi season of every year. Twelve treatments viz., T_1=100%PK, T2=100%NPK, T3=150% NPKT_4=100%NPK+Zn,T_5=100%NPK+FYM,T_6=100%NPK+Lime+FYM, T_7=100%NPK+B+Zn, T_8=100% NPK+S+Zn, T_9=100%N, T_{10}=100%NP, T_{11}=100%NPK+Lime and T_{12}= control(without any fertilizer) were applied. 100% N @ 80 kg ha-1 of N in the form of urea, 100% NP @ 80 kg ha-1 of N and 40 kg ha-1 of P_2O_5 in the form of DAP and urea, 100% NPK@ 80:40:40 kg ha-1 of N:P_2O_5:K_2O in the form of DAP, urea and MOP; FYM was applied at the time of puddling @ 5 t ha-1. Nitrogen was applied in three splits *i.e.* 25% as basal, 50% at 18 days after transplanting and 25% at panicle initiation stage. Total P was applied as basal and K was applied 50% as basal and 50% at panicle initiation stage. Rice seedlings were transplanted at a spacing of 20 cm × 10 cm with 2-3 seedlings per hill. Necessary intercultural, water management and plant protection measures were undertaken in general until the crop was matured for harvesting. The experiment was laid out in randomized block design (RBD) with four replications.

2.3 Collection and Preparation of Soil Sample from Field

The soil samples from each experimental plot was collected at a depth of 0-15cm, 15-30cm and 30-45cm at three different growth stages of crop i.e. maximum tillering, panicle initiation(PI) and at harvest. The samples were collected both in rabi (2014-2015) and kharif (2015) season to determine the potassium fractions. All the soil samples were air dried, grinded and passed through a 2 mm sieve. Different forms of potassium were determined following standard procedure.

2.4 Water Soluble-K: Kanwar & Greweal [24]

5 gm of air dried soil sample was taken into a 250 ml conical flask and 25 ml of distilled water was added and shaken for 1hour in a mechanical shaker. The soil suspension was filtered through the filter paper (No. 42).K was determined by flame photometer

2.5 Ammonium Acetate Extractable K: Pratt [25]

5 gm soil was taken in a 250 ml conical flask.25 ml of neutral 1 N NH_4OAc was added followed by shaking for 5 minute. It was filtered by whatman filter paper No1, the potassium reading was taken in flame photometer against standard.

2.6 Exchangeable K: Jackson [26]

It was calculated by subtracting the water soluble potassium from ammonium acetate potassium

2.7 Non Exchangeable K: Boiling Nitric Acid Extraction Method: Pratt [25]

2.5 g of soil sample was taken, 25 ml of 1N HNO_3 was added to it. The suspension was boiled exactly for 10 min. The flask was removed and the contents were filtered in a 100 ml volumetric flask. The soil was washed 4 times with 15 ml portions of 0.1N HNO_3. Volume was made up. K was determined by a flame photometer using K standards prepared using 0.1N HNO_3. Ammonium acetate extracted potassium was subtracted from 1N HNO_3 potassium to get non-exchangeable potassium.

2.8 Collection and Analysis of Plant Sample

To study the K uptake by rice plants, four rice plants from each treatment plants were collected randomly at maximum tillering stage (25 days after transplanting) and panicle initiation stage (60 days after transplanting) and at harvest (90 days after transplanting). The collected plant samples were dried under Sun, then inside oven at 70 ± 5°C. The dried samples were weighted, chopped to small pieces and preserved for chemical analysis. Plant samples (0.5 g grain/straw) were transferred into digestion flask. 10 mL of di-acid mixture (HNO_3:$HClO_4$ = 9:4) was added into the flask. After leaving for a while, the flask was heated at a temperature slowly raised at 150°C. Heating was stopped when the dense white fumes of $HClO_4$ occurred. After words the contents were transferred to a 50 mL volumetric flask. Potassium reading was taken by flame photometer against standard.

2.9 Statistical Analysis

Simple correlations were worked out between different forms of potassium by standard statistical method by Gomez and Gomez [27].

3. RESULTS AND DISCUSSION

3.1 Water Soluble K

The water-soluble K at 0-15 soil at tillering stage of rabi season varied from 17.7- 30.24 kg/ha in different treatments (Fig 1.a). Similarly the T7 and T8 treated plots shows that effect of sulphur and boron is same for water soluble K content in the soil. Singh et al. [13] has reported similar result of non significant effect of sulphur and zinc on available K status of soil in rice crop. At PI stage there is less ws K content in all the treatment than tillering stage. There is difference among treatments which is significant except T1 & T2. At the harvesting stage, the highest amount is recorded in 100% NPK+FYM+lime treated plot. The higher amount of water soluble K in FYM treatment may be due to addition of K through organic matter [28].

At a soil depth of 15 to 30 cm (Fig 1.b) the ws K content varies from 13.8 to 29.6 kg/ha which is less than upper layer. During PI stage, the ws K varies from 12.7 kg/ha to 27.9 kg/ha. At the harvesting stage of crop at 15 to 30 cm layer water soluble k is less than PI stage in all the treatments.

The ws K at 30 to 45cm soil layer is less than upper 0-15 and 15-30 cm layer (Fig. 1.c). There is significant difference between treatments except for T_1 & T_2, T7 & T_8 which are at par. The higher amount of ws K in FYM treated plot in all the depths is due to less k fixation by FYM [29]. Similar result is also reported by Jatav et al. [30].

During kharif season (Fig. 1.d) the ws K is 14.9 kg /ha to 31.83 kg/ha at tillering, 15.03 to 28.43 kg/ha at PI and 13.43-27.30 kg/ha at harvesting stage of rice crop in upper layer. The values indicate the potassium content is less in kharif season than rabi season. This may be due to fact that oxidation of Fe^{+2} to Fe^{+3} takes place during rabi leading to desorption of K^+ ions to maintain electrical neutrality in crystal lattice of minerals in dry season. It helps in more concentration of K^+ in soil solution [31]. The trend between treatments is same as that of rabi season.

The K content 15 to 30 cm (Fig. 1.e) is less than upper layer. There is more ws K by lime application over 100%NPK alone. This is due to presence of Ca^{+2} in lime replaces more potassium from exchangeable source and brings it to solution [20].

3.2 Exchangeable K

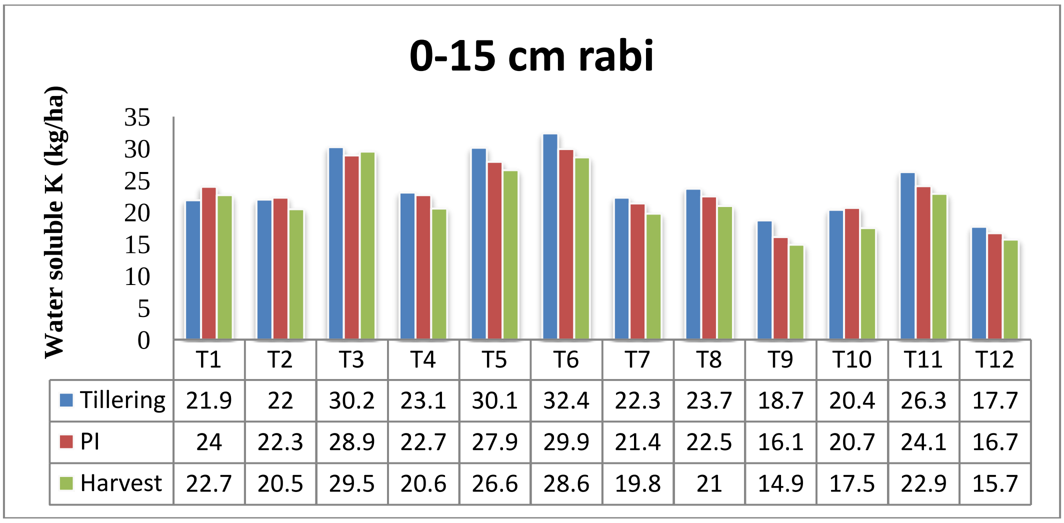
Exchangeable K at different growth stage at 0-15 cm is presented in Fig. 2.a. It is the lowest of 89.0 kg/ha in the control and highest of 119.1 kg /ha in 10% NPK+FYM treated plot. During PI stage the content is 72.6 kg/ha to 94.3 kg/ha and at harvesting stage it varies from 62.1 to 91.3 kg/ha. At harvesting time the highest amount of 91.3 kg/ha is noticed in T_6 treatment which is at par with T_3 & T_5 treated plot.

The exchangeable K content in 15 to 30 cm layer (Fig. 2.b) is less than upper soil layer. It varies from 82.9 to 110.2 kg/ha at tillering, 68.8 to 87.9 kg /ha at PI and 58.5 to 88.0 kg/ha at harvesting stage.

The decrease in exchangeable k in sub surface layer is noticed in all the treatments including the one where no potassium was applied (NP, N and Control plots).This is similar to finding of Jadhao et al [29] where the scientist has reported more exchangeable k on sub surface soil than surface for N, NP and control treatment only in sorghum-wheat system. But in this experiment the result indicates that rice crop take up potassium from subsurface layer so that the exchangeable K content is less in subsurface than surface layer even in control, N and NP treatment.

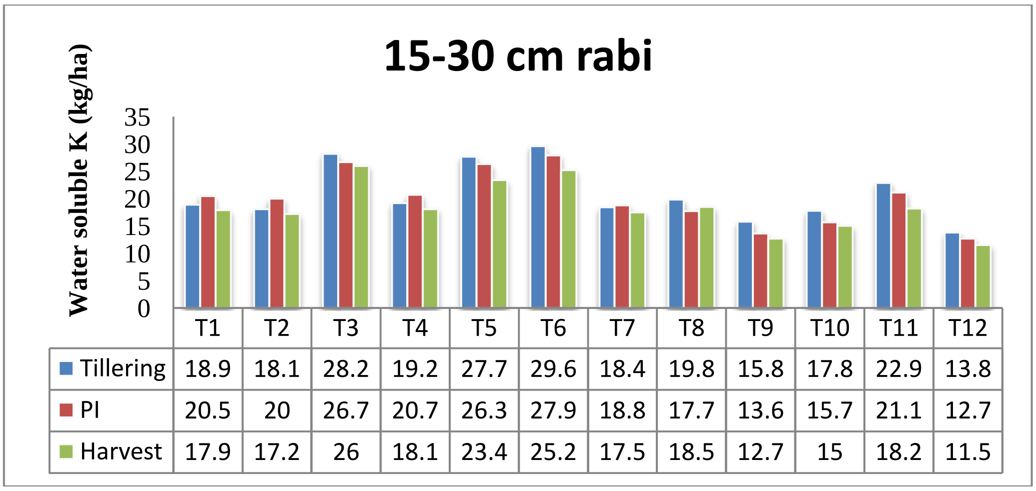
The Fig. 2.c shows exchangeable K content at 30 - 45 cm soil layer during rabi season. The exchangeable K content is less than upper layer at respective growth stage.

The exchangeable K content during kharif season is presented in Figs. 2.d,e & f. in different layers at different growth stages. At the surface layer it is 72.6 to 87.8 at tillering, 65.0 to 95.4 kg/ha at PI and 71.3 to 88.5 kg/ha at harvest stage.



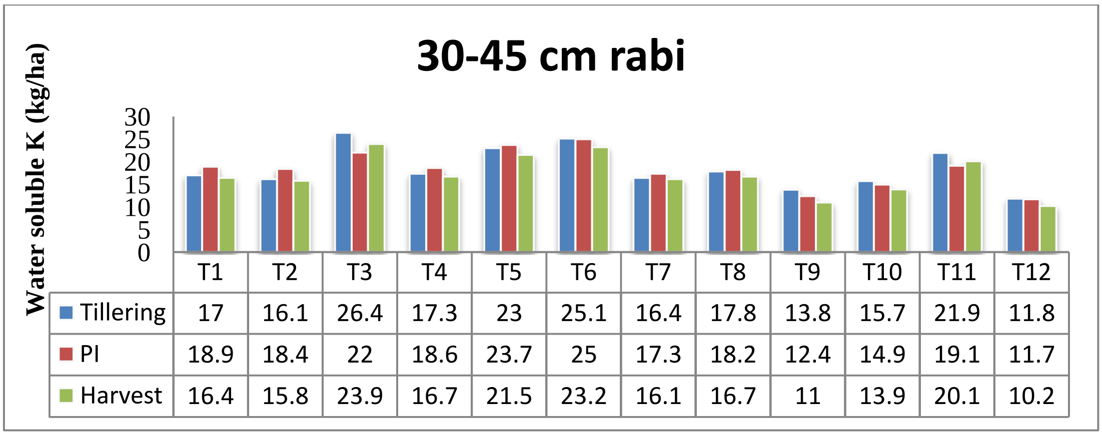
	T1	T2	T3	T4	T5	T6	T7	T8	T9	T10	T11	T12
Tillering	21.9	22	30.2	23.1	30.1	32.4	22.3	23.7	18.7	20.4	26.3	17.7
PI	24	22.3	28.9	22.7	27.9	29.9	21.4	22.5	16.1	20.7	24.1	16.7
Harvest	22.7	20.5	29.5	20.6	26.6	28.6	19.8	21	14.9	17.5	22.9	15.7

Fig. 1.a. Water soluble K at 0-15 cm layer at different stages of rabi2014-15 season



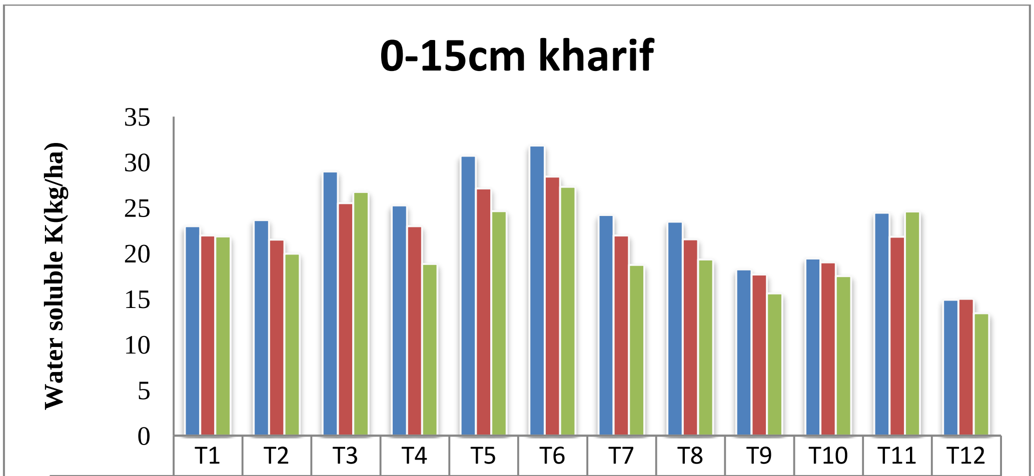
	T1	T2	T3	T4	T5	T6	T7	T8	T9	T10	T11	T12
Tillering	18.9	18.1	28.2	19.2	27.7	29.6	18.4	19.8	15.8	17.8	22.9	13.8
PI	20.5	20	26.7	20.7	26.3	27.9	18.8	17.7	13.6	15.7	21.1	12.7
Harvest	17.9	17.2	26	18.1	23.4	25.2	17.5	18.5	12.7	15	18.2	11.5

Fig. 1.b. Water soluble K at 15-30 cm layer at different stages of rabi 2014-15 season



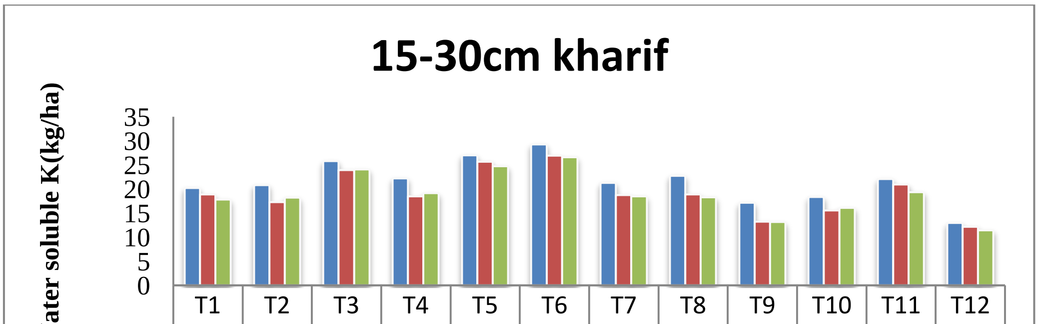
	T1	T2	T3	T4	T5	T6	T7	T8	T9	T10	T11	T12
Tillering	17	16.1	26.4	17.3	23	25.1	16.4	17.8	13.8	15.7	21.9	11.8
PI	18.9	18.4	22	18.6	23.7	25	17.3	18.2	12.4	14.9	19.1	11.7
Harvest	16.4	15.8	23.9	16.7	21.5	23.2	16.1	16.7	11	13.9	20.1	10.2

Fig. 1.c. Water soluble K at 30-45 cm layer of rabi 2014-15 season



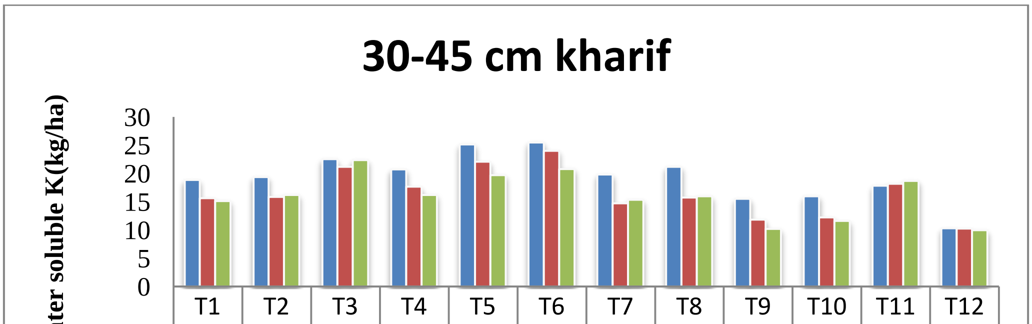
	T1	T2	T3	T4	T5	T6	T7	T8	T9	T10	T11	T12
Tillering	22.99	23.67	28.98	25.27	30.7	31.83	24.2	23.47	18.24	19.45	24.48	14.91
PI	21.96	21.5	25.53	22.98	27.13	28.43	21.98	21.55	17.68	19.03	21.83	15.03
Harvest	21.85	19.98	26.73	18.85	24.63	27.3	18.73	19.33	15.6	17.53	24.6	13.43

Fig. 1.d. Water soluble K at 0-15 cm layer at different stages of kharif 2015 season



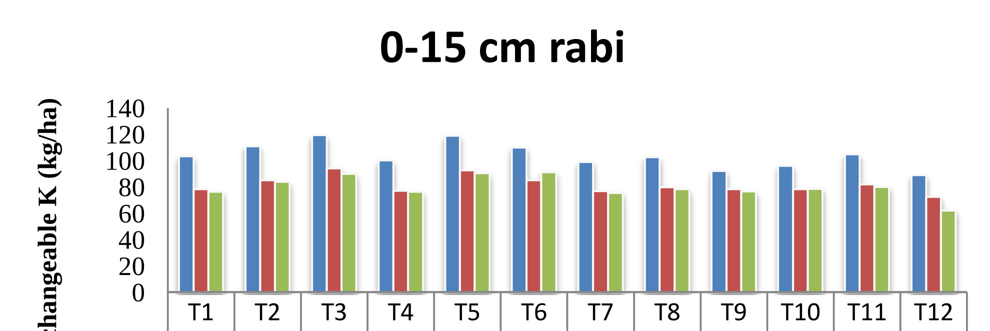
	T1	T2	T3	T4	T5	T6	T7	T8	T9	T10	T11	T12
Tillering	20.23	20.83	25.78	22.24	27.02	29.28	21.29	22.75	17.12	18.33	22.05	12.94
PI	18.85	17.28	23.95	18.46	25.7	26.93	18.76	18.89	13.25	15.55	20.95	12.15
Harvest	17.83	18.19	24.08	19.14	24.71	26.63	18.46	18.26	13.15	16.08	19.37	11.43

Fig. 1.e. Water soluble K at 15-30 cm layer at different stages of kharif 2015 season



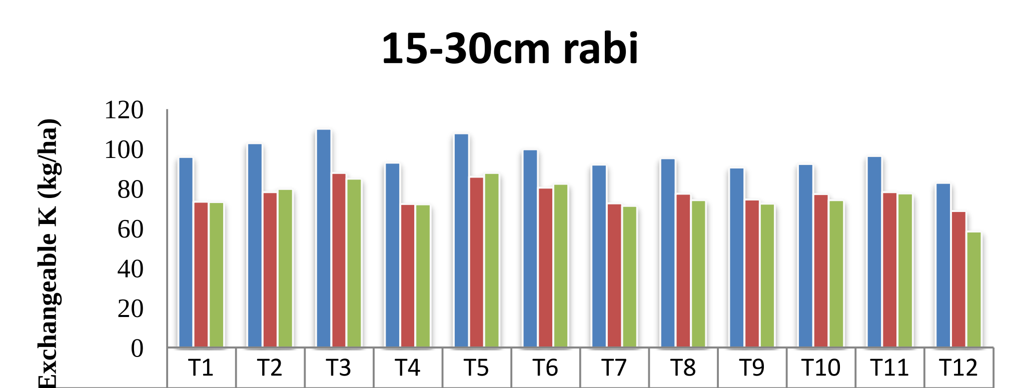
	T1	T2	T3	T4	T5	T6	T7	T8	T9	T10	T11	T12
Tillering	18.82	19.37	22.5	20.68	25.13	25.48	19.8	21.15	15.5	15.96	17.83	10.28
PI	15.59	15.85	21.15	17.63	22.05	24	14.72	15.74	11.84	12.23	18.18	10.25
Harvest	15.13	16.18	22.33	16.2	19.68	20.79	15.33	15.93	10.18	11.58	18.68	9.95

Fig. 1.f. Water soluble K at 30-45 cm layer at different stages of kharif 2015 season



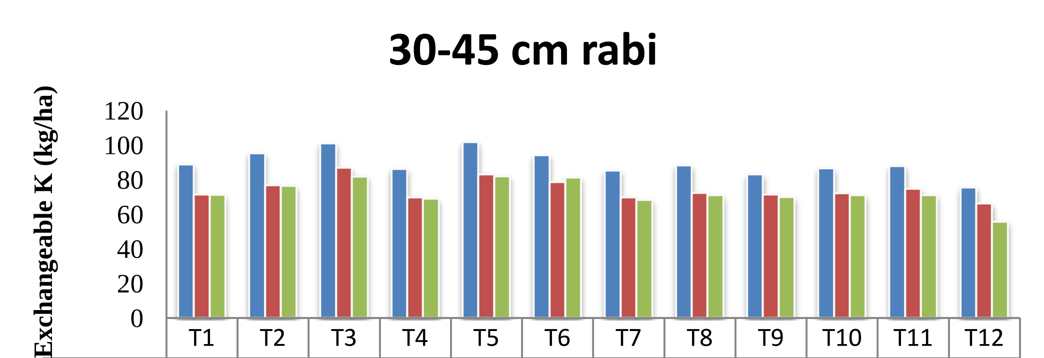
	T1	T2	T3	T4	T5	T6	T7	T8	T9	T10	T11	T12
Tillering	103	111	119	100	119	110	99.1	103	92.2	96.1	105	89
PI	78.3	85.3	94.3	77.3	92.7	85.3	76.9	79.9	78.3	78.3	82.1	72.6
Harvest	76.5	83.9	90	76.4	90.5	91.3	75.6	78.3	76.7	78.6	80.2	62.1

Fig. 2.a. Exchangeable K at 0-15 cm layer at different stages of rabi 2014-15 season



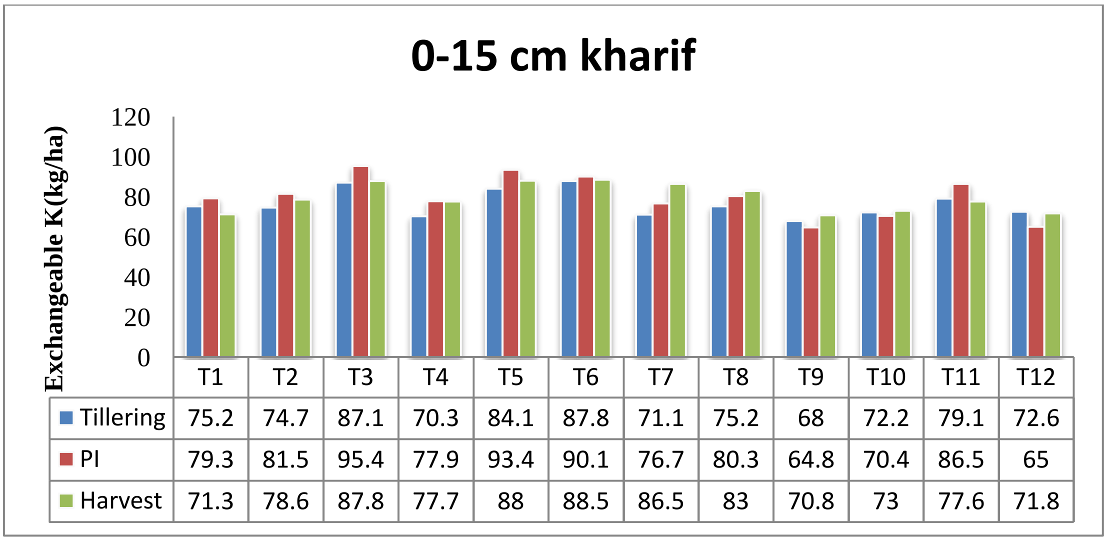
	T1	T2	T3	T4	T5	T6	T7	T8	T9	T10	T11	T12
Tillering	95.9	102.9	110.2	93.1	107.9	99.8	92.1	95.3	90.7	92.5	96.4	82.9
PI	73.4	78.3	87.9	72.3	86	80.5	72.7	77.5	74.6	77.3	78.3	68.8
Harvest	73.3	79.9	85.1	72.1	88	82.4	71.3	74.3	72.5	74.3	77.6	58.5

Fig. 2.b. Exchangeable K at 15-30 cm layer at different stages of rabi 2014-15 season



	T1	T2	T3	T4	T5	T6	T7	T8	T9	T10	T11	T12
Tillering	88.7	95.2	101	86.1	101.7	94	85.2	88.1	82.9	86.5	87.8	75.4
PI	71.4	76.7	86.8	69.7	82.9	78.5	69.6	72.3	71.4	72.1	74.7	66.1
Harvest	71.2	76.4	81.7	69	81.9	81.2	68.2	71	69.9	70.9	70.9	55.6

Fig. 2.c. Exchangeable K at 30-45 cm layer at different stages of rabi2014-15 season



	T1	T2	T3	T4	T5	T6	T7	T8	T9	T10	T11	T12
Tillering	75.2	74.7	87.1	70.3	84.1	87.8	71.1	75.2	68	72.2	79.1	72.6
PI	79.3	81.5	95.4	77.9	93.4	90.1	76.7	80.3	64.8	70.4	86.5	65
Harvest	71.3	78.6	87.8	77.7	88	88.5	86.5	83	70.8	73	77.6	71.8

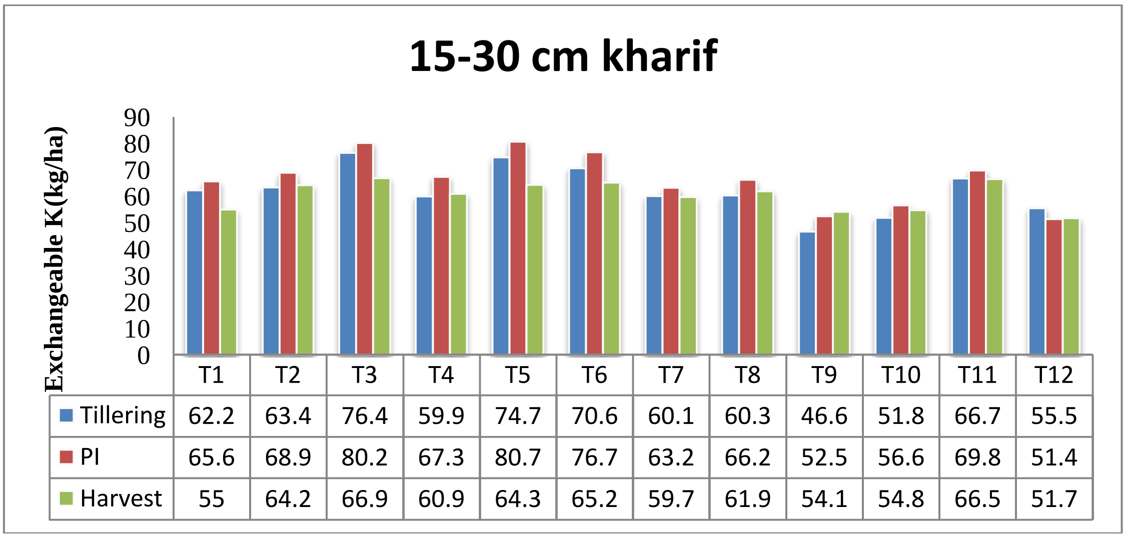
Fig. 2.d. Exchangeable K at 0-15 cm layer at different stages of kharif 2015 season

At a soil layer of 15-30 cm, the exchangeable K content varies from 55.5 to 74.7 kg/ha, 51.4 to 80.7 kg/ha and 51.7 to 69.2 kg/ha at tillering, PI and harvest stage respectively.

In 30-45 cm layer during kharif season, (Fig 2.f.) the data reveals that the exchangeable K varies from 50.0 kg/ha (T_{12}) to 69.4kg/ha in T_6 at tillering, 46.0(T_{12}) to 74.1(T_6) at PI and 48.4(T_{12}) to 62.5(T_6) at harvesting stage. In general the increase in exchangeable K by FYM application as compared to NPK due to more amount of soil organic carbon which gives additional potassium [32]. FYM also provides more cation exchange sites for maximum accumulation of this form [33]. The more amount of exchangeable K by lime application over NPK is due to occupancy of Ca^{+2} in exchange sites which facilitates conversion of non exchangeable form to exchangeable form [20].

3.3 Non Exchangeable K

The amount of non exchangeable K (3.a) shows that at surface layer of rabi season, T_6 treatment which includes FYM and lime in addition to NPK recorded highest amount of non exchangeable K. The nitrogen treated plot (T_9) shows less non exchangeable potassium than nitrogen and phosphorus treated plot (T_{10}).This result corroborates to the finding of Nayak et al. [34].



	T1	T2	T3	T4	T5	T6	T7	T8	T9	T10	T11	T12
Tillering	62.2	63.4	76.4	59.9	74.7	70.6	60.1	60.3	46.6	51.8	66.7	55.5
PI	65.6	68.9	80.2	67.3	80.7	76.7	63.2	66.2	52.5	56.6	69.8	51.4
Harvest	55	64.2	66.9	60.9	64.3	65.2	59.7	61.9	54.1	54.8	66.5	51.7

Fig. 2.e. Exchangeable K at 15-30 cm layer at different stages of kharif 2015 season

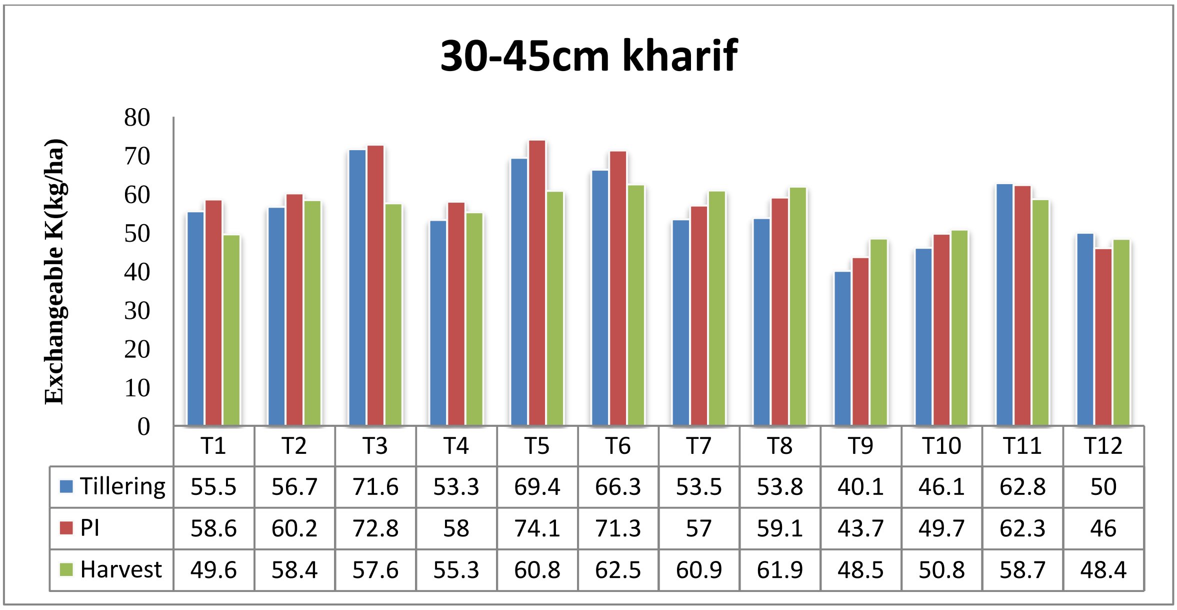


Fig. 2.f. Exchangeable K at 30-45 cm layer at different stages of kharif 2015 season

The non exchangeable K in soil layer of 15-30 cm during rabi season is presented in Fig. 3.b.

At the lower layer of 30-45 cm the non exchangeable K content is less than other layer (Fig. 3.c). The data of vertical distribution shows there is a decrease in non exchangeable K content with respect to increase in depth. It is due to more weathering process in surface soil [35].

The Figs. 3.d, e & f. depicts the non exchangeable k content at different growth stages during kharif season. It is 170.9 to 252 kg/ha at tillering, 173.7 to 262.8 at PI and 198.8 to 283.2 kg/ha at harvesting stage in upper layer. The value for 15 to 30 cm and 30 to 45 cm layer is less as compared to upper surface layer. Similar finding is also observed by Nayak et al [34].Increase in non exchangeable K in lime applied plots may be explained due to precipitation of hydroxyl aluminium and iron polymers and also due to expansion and weathering of clay lattice which releases lattice clay as non exchangeable K [20]

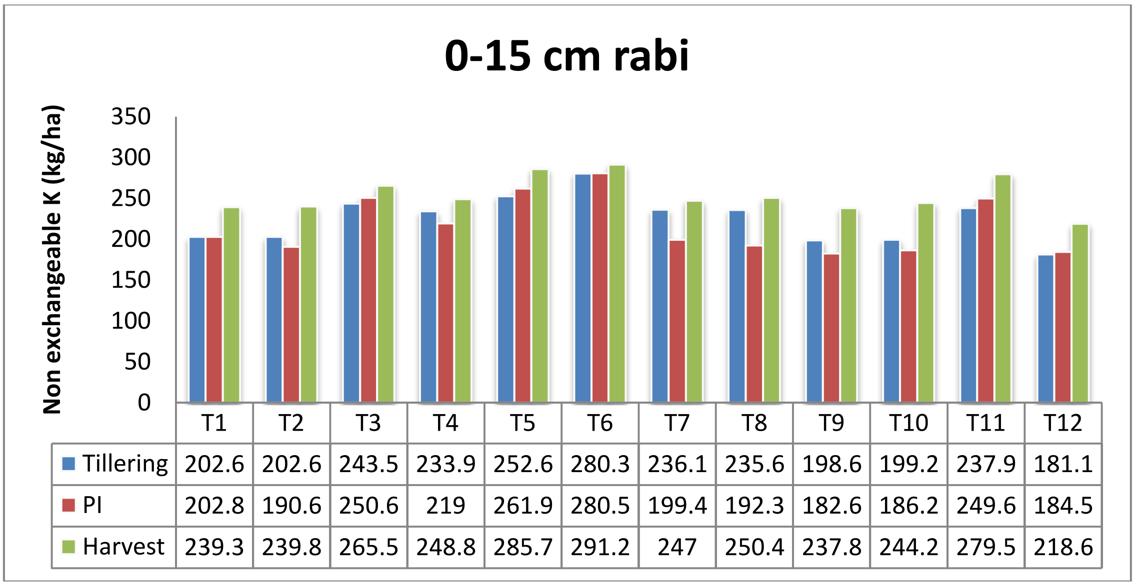
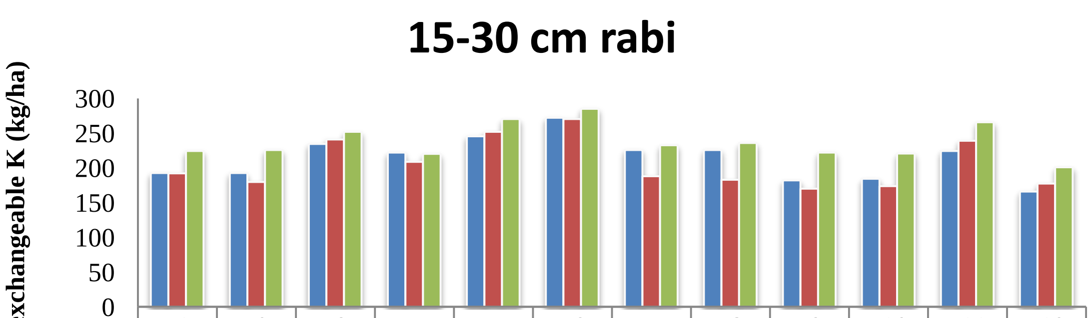
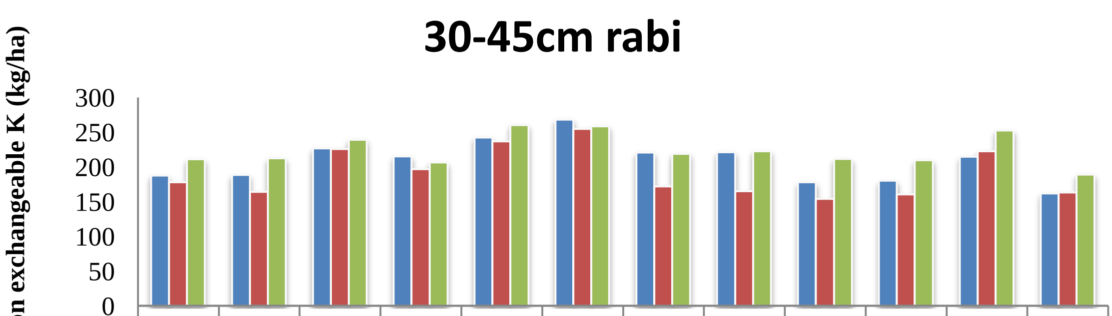


Fig. 3.a. Non exchangeable K at 0-15 cm layer at different stages of rabi2014-15 season



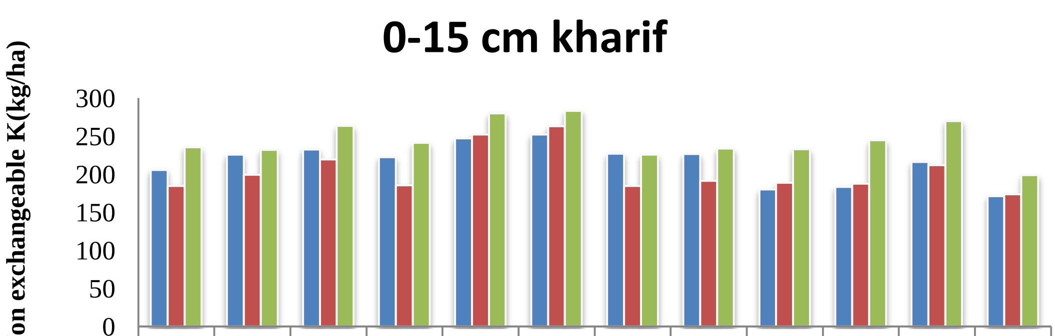
	T1	T2	T3	T4	T5	T6	T7	T8	T9	T10	T11	T12
Tillering	192.7	192.8	234.4	222	245.7	272.1	226	226	182	184.5	224.7	166.3
PI	192.4	180.1	241.2	209	252.3	270.6	188.3	183.3	170.3	174	239	177.6
Harvest	224.5	225.7	251.9	220.3	270.3	285.3	232.7	235.8	222.2	220.9	265.7	201.1

Fig. 3.b. Non exchangeable K at 15-30 cm layer at different stages of rabi2014-15 season



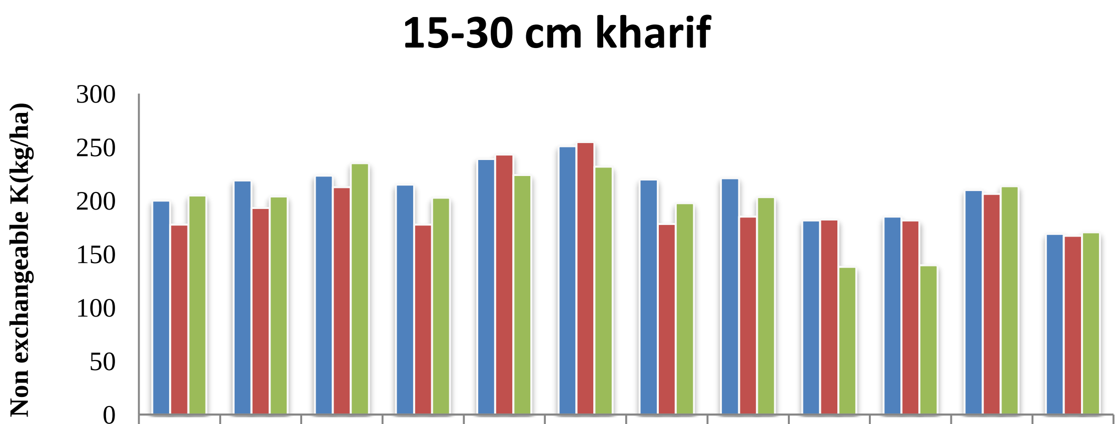
	T1	T2	T3	T4	T5	T6	T7	T8	T9	T10	T11	T12
Tillering	187.8	188.5	226.9	215.4	242.5	268.4	220.8	221.2	177.9	180.3	214.7	161.8
PI	177.9	164.1	225.9	196.7	236.9	255	171.9	165.3	154.2	160.7	222.9	163.2
Harvest	211.1	212.5	239.4	206.8	260.4	258.6	219.1	222.9	211.6	209.9	252.5	189.2

Fig. 3.c. Non exchangeable K at 30-45 cm layer at different stages of rabi2014-15 season



	T1	T2	T3	T4	T5	T6	T7	T8	T9	T10	T11	T12
Tillering	205.4	225.7	232.5	222.4	247	252	226.8	226.4	180	183.4	215.9	170.9
PI	184.6	199.4	219.2	185.4	252	262.8	184.3	191.4	188.5	187.6	211.9	173.7
Harvest	235.4	231.9	263.5	241.1	279.7	283.2	225.8	233.7	232.6	244.5	269.8	198.8

Fig. 3.d. Non exchangeable K at 0-15 cm layer at different stages of kharif 2015 season



	T1	T2	T3	T4	T5	T6	T7	T8	T9	T10	T11	T12
Tillering	200.1	218.9	223.5	214.9	239	250.9	219.7	221	181.5	185	209.8	169
PI	177.6	193.2	212.6	177.5	243.2	254.7	178.1	185.2	182.3	181.4	206.3	167.2
Harvest	204.7	204	234.9	202.7	224	231.7	197.5	203.3	138.1	139.7	213.4	170.3

Fig. 3.e. Non exchangeable K at 15-30 cm layer at different stages of kharif 2015 season

3.4 Correlation among k Forms, Yield and Update

The simple correlation among K fractions at a different layer, grain yield and potassium uptake is presented in Tables 1 and 2. The highest correlation Coefficient at 0 to 15 cm layer with the grain yield in rabi season is for non exchangeable K(r=0.795).. For 15 to 30 cm the highest r=0.774 between ws K and grain yield. Similarly for 30 to 45 cm layer (r=0.812) between ws K and grain yield. The results revealed that in rabi season at surface layer non exchangeable K has immediate beneficial effect on crop yield, where as in 15 to 30 cm and 30-45 cm layer ws K is more influencing to yield. Similarly in kharif season the exchangeable K(r=0.809), ws K(r= 0.832) and exchangeable K(r=0.821) at 0-15, 15-30, 30-45 cm layer respectively have immediate beneficial effect for rice grain yield. The potassium uptake by rabi influenced by non exchangeable K form of potassium at 0 to 15 cm and 15 to 30 cm where as ws K is important at 30 to 45 cm soil layer. In kharif rice, K uptake by grain is immediately influenced by exchangeable K at surface layer, but ws K is beneficial at 15-30 and 30-45 depth. The correlation of rice yield with K fractions is reported by different researchers which differ in opinion. This may be due to potassium release behavior of soils differ depending on situation. Sharma et al. [36] has reported exchangeable K having highest correlation with kharif rice yield and uptake. Our result also similar for kharif season at surface layer The research result of Mohapatra [23] also shows that available K at 15 to 30 cm soil layer strongly correlated with kharif grain yield whereas reserve k at surface and subsurface layer correlates with grain yield in rabi season. Divya et al. [37] has reported at surface layer, the uptake is highly correlated with non exchangeable K (r=0.86) and in subsurface layer exchangeable K(r= 0.900 has highest correlation. In the present experiment there is highest 'r' for non exchangeable K in rabi and highest 'r' for exchangeable K in kharif. Karwade et al. [38] has found that exchangeable form of K has highest correlation with grain yield of paddy followed by water soluble k, but there is no correlation between non exchangeable K and paddy yield.

Table 1. Correlation coefficient between potassium fractions and grain yield of rice

K fractions	Rabi season			Kharif season		
	0-15cm	15-30 cm	30-45 cm	0-15 cm	15-30 cm	30-45 cm
WSK	0.706*	0.774**	0.812**	0.699*	0.832**	0.769**
Exchangeable K	0.760**	0.748**	0.718**	0.809**	0.810**	0.821**
Non exchangeable K	0.795**	0.724**	0.722**	0.776**	0.578*	0.635*

Table 2. Correlation coefficient between potassium fractions and K uptake by grain

K fractions	Rabi season			Kharif season		
	0-15cm	15-30 cm	30-45 cm	0-15 cm	15-30 cm	30-45 cm
WSK	0.709**	0.770**	0.821**	0.833**	0.947**	0.910**
Exchangeable K	0.766**	0.761**	0.717**	0.901**	0.842**	0.761**
Non exchangeable K	0.842**	0.786**	0.790**	0.744**	0.765**	0.822**

* *Significance at P=0.05*
** *Significance at P=0.01*

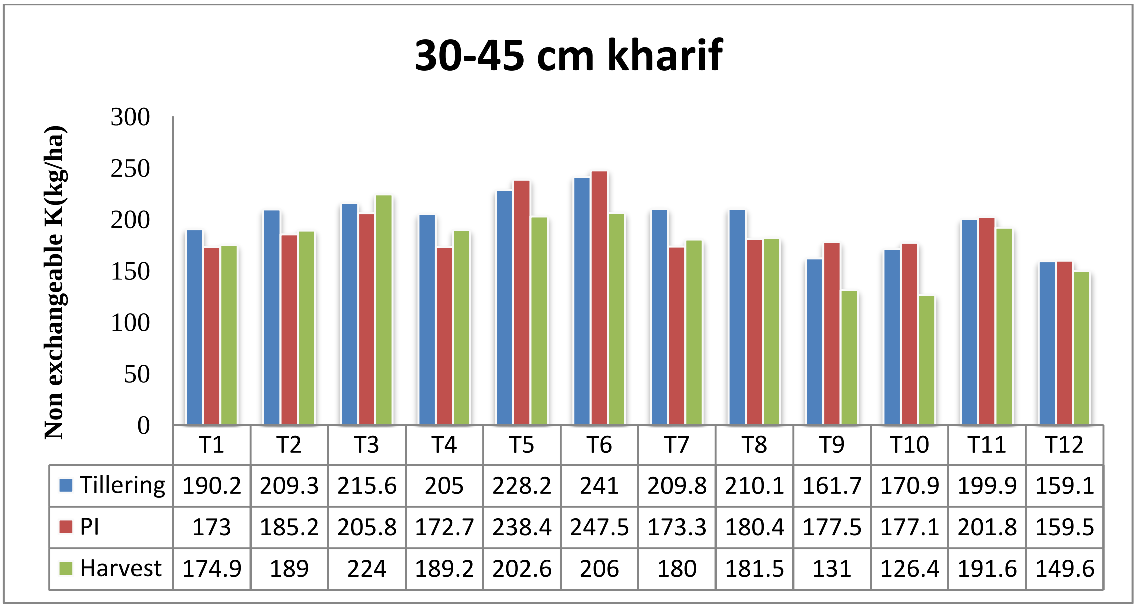


Fig. 3.f. Non exchangeable K at 30-45 cm layer at different stages of kharif 2015 season

4. CONCLUSION

The present experiment result indicates that by continuous application of organic and inorganic fertilizer application in an inceptisol in subtropical rice rice system over a period of 20 crop cycles, the water soluble, exchangeable and non exchangeable K increased by application of FYM along with lime in addition to full dose of NPK. The rice plant utilizes non exchangeable form of potassium even from subsurface zone. In rabi season at surface layer non exchangeable k has highest correlation with crop yield, where as in 15 to 30 cm and 30-45 cm layer ws k is more influencing to yield. But in kharif season the exchangeable K(r=0.809, 0.821), better correlates with grain yield at 0-15 and 30-45 layer whereas ws k(r= 0.832) have immediate beneficial effect on rice yield.

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COMPETING INTERESTS

Authors have declared that no competing interests exist.

REFERENCES

1. FAO Statistical data; 2017. Available:http:stat. www.faostat.org.in
2. Marschner H. Mineral Nutrition of Higher Plants. Academic Press, San Diego, California, USA; 1995. 2nd ed
3. Sharma S, Chander G, Verma TS, Verma, S. Soil potassium fractions in rice wheat cropping system after twelve years of Lantana residue incorporation in a North-East Himalayan Alfisol. J. Of Plant Nutrient. 2013;36:1809-1820.
4. Fageria NK, Moreira A, Coelho AM. Yield and yield components of upland rice as influenced by nitrogen sources. J. of plant nutria Philadelphia. 2011;34(1):361-370.
5. Biswas B, Ghos DC, Dasgupta MK, Trivedi N, Timsina J, Dobermann A. Integrated

assessment of cropping system in Eastern India gangetic plain. Field crops Res. 2006;99:35-47.
6. Sahu PK. Distribution of different forms of potassium and its release pattern in rice growing soils ofAthagarh. M.Sc. (Ag) Thesis, OUAT. 1994;1-93.
7. Singh AK, Meena MK, Bharati RC and Gade RM. Effect of sulphur and zinc management on yield, nutrient uptake, changes in soil fertility and economics in rice (*Oryza sativa*)–lentil (*Lens culinaris)* cropping system**.** Indian Journal of Agricultural Sciences*.* 2013;83(3):344–348.
8. Jibrin M. Forms of potassium and potassium sorption in some fadama soils of Nigeria savannah. Journal of Agriculture. 2010;5:53-60.
9. Darunsontaya T, Suddhaprikarn A, Kheoruenromne I, Prakongkep, Gilkes RJ. The forms and availability to plants of soil potassium as related to mineralogy for upland Oxisols and Ultisols from Thailand. Geoderma. 2012;170:11-24.
10. Wang HY, Cheng W, Li T, Zhou JM, Chen XQ. 2016. Can non exchangeable potassium be differentiated from structural potassium in soils? Pedosphere. 2016;26**:**206–215.
11. Lalitha M, Dhakshinamoorthy M. Forms of Soil potassium- A Review. Agricultural Reviews. 2014;35**:**64-68.
12. Pavlov KV. The assessment of the potassium status of soil by the proportion between different forms of potassium. Eurasian Journal of Soil Science. 2007;40:792-794.
13. Zeng Q, Brown PH. Soil potassium mobility and uptake by corn under differential soil moisture regimes. Plant and Soil. 2000;221:121-134.
14. Barre P, Velde B, Fontaine C, Catel N, Abbadie L. Which 2: 1 clay minerals are involved in the soil potassium reservoir? Insights from potassium addition or removal experiments on three temperate grassland soil clay assemblages. Geoderma*.* 2008;146:216-223.
15. Mengel K. Dynamics and availability of major nutrients in soils. Advances in Soil Science. 1985;65-113.
16. Srinivasarao Ch, Rappa BK, Jakkula VS, Kundu S, Venkateswarlu B, Pharande AL, Manideep VR, Naik PR, Venkanna K. Nutrient balance after thirteen years of organic and chemical nutrient management and yield sustainability of groundnut-finger millet rotation in rain fed Alfisols of semi arid India. Journal of the Indian Society of Soil Science. 2014;62:235-247.
17. Jena D, Pal AK, Rout KK. Potassium management for crops in soils of Orissa**.** Proceedings IPI-OUAT-IPNI International Symposium. 2009;417-433.
18. Srinivasarao Ch, Rupa TR, Subbarao A, Singh SP. Bansal SK. Kinetics of non-exchangeable potassium release from important benchmark soils of India: Effects of mineralogy, soil depth and extraction media. Communications in Soil Science and Plant Analysis. 2006b;36**:**1-19.
19. Thenabadu MW. Chemistry of rice soils and the principle of fertilizer use. Paper presented at the Symposium of Chemistry in Food and Agriculture, Chemical Society of the Ceylon and the Royal Institute of Chemistry, Ceylon;1967.
20. Das R, Saha D. Effect of liming on the changes of different forms of potassium in an acid soil treated with N and K fertilizers. J. Indian Chem. Soc. 2014;91:1-7.
21. Swamanna J. Potassium release characteristics and response to potassium application in rice (*Oryza sativa* L.) growing soils of Kurnool district. M. Sc. (Ag.) Thesis. Angrau, Hyderabad, India; 2015.
22. Datta M, Singh NP. Nutrient management in Rice – based cropping systems as influenced by applying cattle manure alone or in combination with fertilizers in upland acid soils of Tripura. J. Indian Soc. Soil Sci. 2010;58(1):94–98.
23. Mohapatra S. Optimization of Potassium (K) supply and plant nutrition through different K management practices under rice-rice system in Odisha. M.Sc (Ag) Thesis. Department of Soil science & Agricultural Chemistry College of Agriculture Orissa University of Agriculture and Technology; 2015.
24. Kanwar S, Grewal JS. Forms of potassium in Punjab soils. J Ind Soc Soil Sci. 1966;14:63- 67.
25. Pratt PF. Potassium Chemical and Microbiological properties. In Page AL, Miller RH, Kenney DR (ed). Methods of soil analysis. Agron soil soc Am, Madison, Wisconsin, USA. 1982;225-46.
26. Jackson ML. Soil Chemical Analysis. Prentice Hall of India Pvt. Ltd., New Delhi. 1973;498.

27. Gomez KA, Gomez AA. Statistical Procedures for Agricultural Research. New York: John Wiley and Sons Inc; 1984.
28. Sood B, Subehia SK, Sharma SP. Potassium fractions in acid soil continuously fertilized with mineral fertilizers and amendments under maize-wheat cropping system. Journal of the Indian Society of Soil Science. 2008;56:54-58.
29. Jadhao SD, Dipali A, Mali DV, Singh M, Kharche VK, Wanjari RH, P.R., Kadu PR, Sanune BA, Magare PN. Effect of Long-Term Manuring and Fertilization on Depth Wise Distribution of Potassium Fractions under Sorghum-Wheat Cropping Sequence in Vertisol. Journal of the Indian Society of Soil Science. 2018;66(2):172-181
30. Jatav MK, Sud KC, Trehan SP. Effect of organic and inorganic sources of phosphorus and Potassium on their different fractions under potato radish cropping sequence in a Brown Hill Soil. Journal of the Indian Society of Soil Science. 2010;58:388-393.
31. Reichenbach H von. Potassium in soil, Proc 9th Colloq International Potash Institute, Berne, Switzerland. 1972;33-42
32. Singh M, Shri Ram, Wanjari RH, Sharma P. Balance and forms of potassium under rice-wheat system in a 40-year-old long-term experiment on Mollisols of Pantnagar. Journal of the Indian Society of Soil Science. 2014;62:38-44.
33. Blake L, Mercik S, Koerschens M, Goulding KWT,Stempen S, Weigel A, Poulton PR, Powlson DS. Potassium content in soil, uptake in plants and the potassium balance in three European long term field experiments. Plant and Soil. 1999;216:1-14.
34. Nayak T, Bajpai RK, Bachkaiya V. Vertical distribution of potassium under organic and inorganic nutrient management in a Vertisol planted to rice. The Ecoscan. 2014;8(3&4):257-261
35. Mandal D, Dey SK, Baruah TC. Forms of potassium and their distribution in rubber growing Soils of Tripura. Ann. Pl. Soil Res. 2011;13(2):75-79.
36. Sharma S, Chander G, Verma T S, Verma SR**.** soil potassium fractions in rice-wheat cropping system after twelve years of lantana residue incorporation in a northwest Himalayan acid alfisol. Journal of Plant Nutrition. 2013;36:1809–1820.
37. Divya M. Studies on effect of long term soil fertility management on behavior of potassium in rice-cowpea cropping system. Thesis department of soil science and agricultural chemistry University of agricultural sciences. Bangalore; 2013.
38. Karwade SG, Badole WP, Patel J, Thombe S. Forms of soil potassium under different soils of paddy growing areas of Nagpur district and their relationship with yield of paddy. International Journal of Chemical Studies. 2020;8(2):1539-1543

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