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EFFECT OF PHOSPHORUS AND POTASSIUM ON SOIL FERTILITY AND PRODUCTIVITY OF RICE (*Oryza sativa* L.)

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Abstract: *A field experiment was conducted during 2013-14 to study the effect of phosphorus and potassium fertilization on soil fertility and productivity of rice (Oryza sative L.) on alluvial soil. Six treatments consisting of various combination of phosphorus potassium and FYM were replicated thrice in a randomized block design. Results revealed that all level of phosphorus and potassium maintained higher nutrients availability and productivity over control. Results indicated that highest nutrients availability and productivity were associated with treatment containing FYM in combination with fertilizers. Among the in organic source, application of 80 Kg* $ha^{-1}P_2O_5$ *+80 Kg* ha^{-1} K_2O *recorded significantly higher organic carbon content, available NPK and S as well as higher growth eate trms of plant height number of tillers and also yield as compared to other treatments. Application of 40 Kg* $ha^{-1}P_2O_5$ *+40 Kg* ha^{-1} K_2O *+10 t FYM recorded significantly higher (NPK and S) uptake by crop. The over all results demonstrated that 50% P K from inorganic fertilizers with FYM gave higher soil fertility and productivity*
Key words: *Phosphorus, Potassium, Soil fertility, productivity, Nutrients uptake, Plant growth, Rice.*

Introduction: Rice is the most important food crops of India in term of both area, production and consumer preference. Phosphorus is one of the major limiting plant nutrients and plays a key role in balanced nutrition of plants. Major part of water-soluble phosphorus of added P fertilizers soon becomes unavailable due to its chemical fixation in soil. Hence solubilisation of fixed soil P through use of mobilizing solubilizing microorganisms is a viable option to augment the availability of P in easily assimilable form by the crops. Vesicular arbuscular mycorrhizal fungi and rhizosphere microorganisms within the rhizosphere can influence their mutual development due to synergistic interactions [1]. The quantity of potassium absorbed is either equal to or more than of nitrogen for most of cultivated plants. Its content in soil varies depending upon the composition of parent rocks and minerals from which they are formed degree of weathering, climatic conditions and cropping pattern. The soils which were rated sufficient in available Potassium are becoming deficient and have started showing response to Potassium under intensive use of N and P. Field crops generally absorb Potassium faster than the other nutrients. Where farmers do not apply Potassium, the crops withdraw it entirely from soil reserves. The rate at which soil potash is depleted and crop responses start appearing is not same under all the condition. To improve the production efficiency of rice, it is necessary to apply required dose of N, P, K and organic matter. There is a scope to reduce the recommended dose of fertilizer by use of organic source like, carpet waste, FYM, Biofertilizers and green manure in rice field [2]. Intensive cultivation and growing of exhaustive crops, accompanied by restricted use of organic manures and biofertilizers have made the soils not only deficient in the nutrients but also deteriorated the health resulting in decline in crop response to the recommended dose of N –fertilizers in the region. Non judicious enhancement of the N – fertilization further worsens the situation. Under such a situation, integrated plant nutrient system (IPNS) has assumed a great importance and has vital significance for the maintenance of soil productivity.Use of chemical fertilizers in combination with the organic manures is essential to improve soil health [2]**.** When manure (FYM) was applied in conjuction with chemical fertilizer in rice crop for efficient grown of crop, declined organic carbon was arrested and the gap between potential yield and actual yield was bridged to large extant. Continuous recycling of the green manures with organic amendments enhances the organic matter and also supplement the nutrient pool of the soil. Extensive use of chemical fertilizer caused to occur in environmental pollution and ecological damage and increased production cost [3,4,5]. Under these circumstances, integrated use of organic manure, inorganic fertilizers and biofertilitzers has assumed great importance for sustainable production and maintaining soil health [6].The major objective of this experiment was to evaluate the effects of phosphorus, potassium and FYM on the promotion of plant growth (rice) and improvement in soil properties by means of field experiment.

Materials and Methods

A field experiment was conducted in rabi season (2010-2011) at agricultural form of U.P. Autonomous College, Varanasi developed on alluvium deposited. The soil of experimental site was sandy clay loam in texture, slightly saline and non-alkaline in reaction. The initial physico-chemical properties of experimental soil were bulk density 1.39 g cm^{-3}, particle density 2.65 g cm^{-3}, pH (1:2.5) 7.98, EC 0.48 dS m^{-1}, organic carbon 0.39%, water holding capacity 41.5 %, available nitrogen 216.7 kg ha^{-1}, available phosphorus 10.51 kg ha^{-1}, available potassium 184 kg ha^{-1} and available sulphur 6.20 kg ha^{-1}. The various treatments applied to rice crop were control (T_1), 80 kg P_2O_5 + 80 kg K_2O ha^{-1} (T_2), 80 kg P_2O_5 + 80 kg K_2O ha^{-1} (T_3), 60 kg P_2O_5 + 60 kg K_2O ha^{-1} (T_4), 40 Kg P_2O_5 + 40 kg K_2O ha^{-1} +10 t FYM ha^{-1} (T_5) and 20 kg P_2O_5 + 20 kg K_2O ha^{-1} (T_6). Recommended dose of N (120 kg ha^{-1}) was applied in all plots through urea and P_2O_5 and K_2O were applied as per treatments through single super phosphate (SSP), muriate of potash (MOP), respectively. Half dose of nitrogen through urea full dose of phosphorus and potassium were applied as basal dressing and rest amount of N was applied in two equal splits, first at tillering and second at ear head initiation stage as top dressing. Organic manures such as FYM applied as per treatment before 15 days of transplanting. The treatments were triplicated in randomized block design (RBD). The composition of FYM was 0.5% N, 0.2 % P_2O_5, 0.5% K_2O. Soil samples from 0-15 cm depth were collected in plastic bag from individual plots at 30 DAT and after harvest of the crop. One soil sample of each plot was air- dried, processed to pass through 2 mm round hole sieve and analysed for oxidizable organic carbon (1N $K_2Cr_2O_7$), available N (0.32% alkaline $KMnO_4$ oxidizable), P (0.5 M $NaHCO_3$ extractable), K (1 *N* neutral ammonium acetate extractable) and S (0.15% $CaCl_2$) following the methods described [7-11]. Soil pH was determined in 2:1 soil: water suspension with the help of glass electrode in digital pH meter and electrical conductivity of soil was measured in the supernatant liquid of soil water suspension (1:2) by conductivity bridge [12]. Bulk density in undisturbed samples collected with metal cores of 4.2 cm diameter and 5.8 cm height was measured.

30 days old rice seedlings of cultivar Mansuri were transplanted at spacing of 20×10 cm. Five plants are marked randomly in each replicated plot and height was measured from base of plant to the tip of the upper most fully matured and stretched leaf before emergence of ear and from the base of plant to tip of ear after it emergence for calculating mean plant height at 30 and 120 days after transplanting (DAT). Number of tillers per meter in row length at different growth stages (30 DAT and at maturity) of crop were recorded. Dry matter of plants is taken at 60 DAT by cutting the plants in one meter row length in each plots then kept in shade for dry and weighed. After harvesting and threshing the weight of grain was recorded. Straw yield was calculated by subtracting grain yield from biological yield. Plant samples (grain and leaf) drawn at harvesting were dried in shade and then kept in oven at 70^0C for 12 hours to make free from moisture. After there, samples were ground in grinder and the total P, K and S content in plant samples were determined by digesting the samples with di–acid (HNO_3:$HClO_4$ in 10:4) mixture [12] while N was determined by chromic acid [13]. Plant uptake of NPK and S were computed by multiplying the yield with the respective nutrient content. The data collected from field and laboratory were analyzed statistically using standard procedure of randomized block design [14]. Critical difference (C.D.) and standard error of mean (SEM) were calculated to determine the significance among treatment means

Results and Discussion

Organic Carbon: Significantly higher organic carbons content of soil were found in treatments receiving farm yard manure in combination with P and K as compared to those treatments receiving chemical fertilizer alone. Reason attributed is the direct incorporation of organic matter, better root growth and more plant residues addition after harvest of crops. These findings are in agreement with the observations [1]. The addition of FYM might have created environment conducive for formation of humic acid, which ultimately resulted in an increase in organic carbon content of soil [2]. The organic carbon content of soil increased significantly with increasing levels of P_2O_5 and K_2O (Table-1). The highest organic carbon in soil was found with 80 kg P_2O_5 + 80 kg K_2O ha^{-1} and lowest in no P and K application. Results indicated that organic carbon content of soil increased with rise in dose of P_2O_5 and K_2O may be due to higher left over plant residues in the form of tissue and plant roots exudates owing to higher biomass production under higher level of P and K were also made by [15] in mustard crop. The effect of different treatments on organic carbon content of soil was found in the order $T_5 > T_2 > T_3 > T_4 > T_6 > T_1$ and the values varied between 0.53 to 0.58, 0.50 to 0.57, 0.49 to 0.55, 0.47 to 0.53, 0.45 to 0.50, 0.43 to 0.47 percent under respective treatments.

Table 1. Effect of phosphorus and potassium fertilization on organic carbon, available N.P.K. and S of soil under rice crop.

Treatments	Organic carbon (%)		Available nutrients (kg ha^{-1})							
			N		P		K		S	
	30 DAT	At harvest	30 DAT	At harvest	30 DAT	At harvest	30 DAT	At harvest	30 DAT	At harvest
T_1	0.47	0.43	213	198	16.00	11.00	231	199	11.50	6.20
T_2	0.57	0.50	242	218	26.00	20.25	254	223	17.00	11.00
T_3	0.55	0.49	237	213	24.20	19.00	250	219	15.5	9.50
T_4	0.53	0.47	231	209	21.00	15.60	240	210	14.00	9.00
T_5	0.58	0.53	251	225	22.60	17.20	245	214	19.00	13.00
T_6	0.50	0.45	227	204	17.5	13.50	237	204	13.00	8.00
SEm(±)	0.0013	0.0008	8.90	16.766	0.262	4.7954	11.3	32.366	5.485	2.937
CD(P=0.05)	0.0466	0.0372	3.8375	5.2671	2.776	2.8168	4.32	7.3181	3.012	2.2044

DAT=Days after transplanting

Available Nitrogen: The results indicate that available N content of soil continuously decreased with advancement in crop growth stage under all treatments. Decline in nitrogen content with increasing growing time could be attributed to higher N requirement for crop with age [16]. The effect of different treatments of chemical fertilizers and FYM on available nitrogen content of soil was found in the order $T_5 > T_2 > T_3 > T_4 > T_6 > T_1$. The available nitrogen content differed significantly due to addition of various levels of chemical fertilizers. Alike organic carbon, significantly higher available N content was recorded in treatment consisting of chemical fertilizers and FYM in soil (Table -1). The increase in available N might be attributed to the enhanced multiplication of microbes by the incorporation of manure for the conversion of organically bound N to inorganic form. Results corroborate the findings [17]. The favourable soil conditions under organic manure application might have facilitated the mineralization of soil N leading to build up of higher available nitrogen [18]. These results are in line with finding [19]**,** who also observed that available nitrogen content in soil increased with the use of recommended dose of fertilizer in combination with manure. Increasing level of P and K produced significant effect on N content in soil. Nitrogen content was significantly increased with the increase in level of P and K might be due to the addition of higher organic matter through leaf fall, roots and plants residue decomposition [20].

Available Phosphorus: Results presented in table showed that the variable P increased consistently with increase in rates of P application in the soil; P content increased from 11.0 kg ha^{-1} in content to 20.25 kg P ha^{-1} with application of 60 kg P ha^{-1}. Similar results were also observed [21]. The available phosphorus content of soil increased significantly in the plots that had received chemical fertilizers plus organic manure (FYM) than in the plots that have received chemical fertilizers alone (Table 1). The increase in available P content of soil due to the incorporation of FYM may be attributed to the direct addition of P as well as solubilization of native P through release of various organic acids during decomposition. Similar improvement in available P status due to integrated use of manure and fertilizers has been noted [23].

Available Potassium: Data show that increasing levels of P and K increased potassium availability from control to 80 kg ha^{-1} and significantly higher available potassium content was recorded under 80 kg P + 80 kg K ha^{-1}(T_2) treated plots as compared to other treatments. Depletion in soil available K content due to continuous cropping without K supply and its build-up in the K fertilized plots in alluvial soil has also been reported [24]. The available potassium content differed significantly due to addition of organic in combination with inorganic fertilizers (Table -1). The beneficial effect of FYM available K status may be ascribed to the direct potassium addition in the potassium pool of the soil**.** Reported higher contents of available K under conjoint use of organics and fertilizers than the sole use of fertilizers [25].

Available Sulphur: As evident from results, the available sulphur content of soil of rice plots under various treatments varied from 13.00 to 19.00 kg ha^{-1}. Further, the available sulphur content of soil decreased with days of transplanting. Addition of 40 kg P_2O_5 + 40 kg K_2O + 10 t FYM ha^{-1} have shown a remarkable significant increase in available sulphur content of experimental soil. The superiority of T_5 (40 kg P_2O_5 + 40 kg K_2O + 10 t FYM ha^{-1}) over T_2 (80 kg P_2O_5 + 80 kg K_2O ha^{-1}) has been seen at all growth stages of rice during experiment (Table-1). Treatment T_5 recorded maximum available S followed by T_3, T_4, T_6, and T_1. The increase in available S content of soil due to the incorporation of farm yard manures (FYM) may be attributed to the direct addition of sulphur. Similar improvement in available S status due to effect use of P_2O_5 and K_2O fertilizers and FYM has been noted [26]. Among the various levels of P and K through inorganic source, available sulphur content increased significantly with increasing levels of P and K might be due to addition of higher amount of organic residue at higher level of P and K.

Soil pH: Results clearly indicated that application of FYM decreased the pH of soil as compared to chemical fertilizers alone. The pH of soil water suspension increased with day after transplanting and highest values were recorded at harvesting of crop might be attributed to decrease in organic matter content with time. Organic matter (FYM) treated plots recorded low pH as compared to chemical fertilizer alone may be due to release of organic acids during decomposition of added organic manures (Table-2). Lower soil pH with incorporation of organic manures (FYM) has also been reported [27]. Generally, the soil pH decreased with the increase in the level of applied P and K and lowest pH was found with 80 kg P and K ha^{-1} application. Soil pH decreased with increasing level of P and K might be attributed to higher amount of crop residue at higher dose of P and K.

Table 2: Effect of phosphorus and potassium fertilization on physico-chemical properties of soil under rice crop.

Treatments	Soil pH		EC (dS m^{-1})	
	30 DAT	At harvest	30 DAT	At harvest
T_1	7.60	8.1	0.63	0.70
T_2	7.20	7.59	0.53	0.59
T_3	7.30	7.61	0.55	0.63
T_4	7.36	7.65	0.58	0.65
T_5	7.04	7.55	0.48	0.55
T_6	7.50	7.68	0.60	0.68
SEm(±)	0.00087	0.0323	0.0002	0.0012
CD (P=0.05)	0.0380	0.2315	0.0206	0.0448

Electrical Conductivity: Analytical data of experimental soil revealed that the electrical conductivity under different treatments of phosphorus, potassium and FYM varied from 0.63 to 0.70 d Sm^{-1}. The effect of different treatments on soil EC could be arranged in order T_1> T_6> T_4> T_3> T_2> T_5. EC of soil and decreased significantly with increasing level of P and K (Table-2). The reason attributed is higher contribution of biomass to the soil in the form of larger root biomass, crop stubbles and residues. Further, the soil EC also decreased significantly with the application of FYM might be due to release of acids during decomposition of FYM which reduce the salt content be exchange phenomenon.

Effect of the Phosphorus and Potassium Nutrition on Performance of Rice Crop

Plant Height: It is evident from results that the plant height of rice crop increased continuously with advancement in growth stages up to the harvest under all treatments and was found in the order T_5> T_2> T_3> T_4> T_6> T_1. Significantly higher plant height was recorded with the application of 40kg P_2O_5 + 40 kg K_2O + 10 t FYM ha^{-1} (T_5) over rest of treatments but was at par with the application of 80 kg P_2O_5 + 80 K_2O ha^{-1} (T_2) (Table-1). Such beneficial effect of phosphorus and potassium fertilization along with FYM corroborated the earlier findings [27, 26]. Data indicated that due to P and K application, there was significant increase in plant height over control. Potassium and phosphorus play crucial role in meristematic growth through its effect on the synthesis of phyto-harmones. Among various plant harmones cytokinin plays important role in growth of tillers and buds [28].

Number of Tillers: Application of 40 kg P_2O_5 + 40 kg K_2O ha^{-1} +10 t FYM kg ha^{-1}(T_5) was recorded significantly higher number of tillers followed by T_2 (80 kg P_2O_5 + 80 kg K_2O ha^{-1}), T_3 (60 kg P_2O_5 + 60 kg K_2O ha^{-1}) T_4 (40 kg P_2O_5 + 40 kg K_2O ha^{-1}), T_6 (20 kg P_2O_5 + 20 kg K_2O ha^{-1}) and T_1(Control). The number of tillers per meter row length of rice under different treatments increased with time and reached maximum at 60 DAT (Table-1). It was also recorded that effect of phosphorus and potassium fertilization with FYM significantly increased the number of tillers as compared to chemical fertilizer alone. The numbers of tillers at time of harvesting were 44, 55, 50, 49, 60 and 47 under T_1, T_2, T_3, T_4, T_5 and T_6 treatments, respectively. It was also found that increasing levels of P and K significantly increased the number of tillers. Better physico-chemical properties under integrated use of FYM and inorganic fertilizers responsible for higher number of tillers.

Dry Matter, Straw and Grain Yield: Dry matter yield of rice recorded at 60 DAT significantly increased over control and chemical fertilizers alone due to application of and phosphorus and potassium fertilization with FYM. It might be attributed to higher number of tillers and plant height under organic manure and inorganic fertilizers applied plot similar results was also observed [29]. It was also found that among the inorganic fertilizers dose, dry matter yield significantly increasing with increasing level of P and K might be due to higher plant growth at increased level of P & K The effect of various treatments on dry matter production could be arranged in order of T_5> T_2> T_3> T_4> T_6> T_1 and the values were 82.35, 67.00, 62.60, 47.66. 45.33 and 40.00 g m^{-1} row length respectively. Significantly higher yield of rice was recorded under all the treatments over control (Table-3).

Table 3: Effect of phosphorus and potassium fertilization on plant growth, dry matter (g m^{-1} row length), grain and straw yield (q ha^{-1}) of rice crop.

Treatments	Plant height (cm)		No of tillers (m^{-1} row length)		Dry matter at 60 DAT (g m^{-1} row length)	Grain yield (Q ha^{-1})	Straw yield (Q ha^{-1})
	30 DAT	At harvest	30 DAT	At harvest			
T_1	55.00	70.66	25	44	40.00	33.40	43.65
T_2	65.70	86.44	35	55	67.00	44.19	62.00
T_3	61.40	80.20	31	50	62.60	40.65	54.00
T_4	59.00	75.32	30	49	47.66	39.55	49.35
T_5	67.52	90.10	38	60	82.35	47.55	65.60
T_6	56.58	71.86	29	47	45.33	37.00	47.45S
SEm(±)	8.199	2.690	2.10	1.90	5.002	7.248	13.600
CD (P=0.05)	3.683	2.110	1.864	1.773	2.876	3.463	4.743

Further, the yield was significantly superior under the conjoint use of phosphorus, potassium and FYM over the sole use of chemical fertilizers. Application of FYM with 50% recommended dose of P and K produced statistically similar rice grain yield to that obtain with 100% recommended P and K treatment, the yield of rice was lowest under control, where it was highest in the plots, fertilizer with 50% recommended inorganic P and K fertilizers combined with FYM. The combined application of P and K and FYM was observed to increases the productivity of rice [30]. On the basis of data, the superiority of the treatments may be arranged as: T_5 >T_2 >T_3 >T_4 >T_6 and T_1. Further, among inorganic source, phosphorus and potassium application significantly increased the rice grain and straw yield of rice. The increased yield with P and K fertilizers might be due to increased availability absorption and translocation of P and K nutrient [31, 24, 32, 33] also observed the significantly effect of K application in sesame, mustard groundnut and wheat. Alike gain yield, straw yield also recorded significantly higher in T_5 (40 Kg P_2O_5 + 40 kg K_2O ha^{-1} + 10 t FYM ha^{-1}) as compared to other treatments. Without FYM, increasing levels of P and K significantly increased the straw yield. The effect of various treatments on straw yield could be arranged in order of T_5> T_2> T_3> T_4> T> T_1 and values were 65.60, 62.00, 54.00, 49.35, 47.45 and 43.65 q ha^{-1}, respectively.

The beneficial effect of organic manures (FYM) on yield might be due to additional supply of plant nutrients as well as improvement in physical and chemical properties of soil [34]. It could also be attributed to the fact that after decomposition and mineralization, the manures supplied available nutrients directly to plants and also had solubilizing effect on fixed form of nutrients [29].

Nutrients Uptake through Rice Plant as Influenced by Phosphorus and Potassium Fertilization: Nutrient (N, P, K and S) uptake by the rice increased significantly and consistently with the addition of phosphorus and potassium over control. Data indicated that total nutrients uptake followed the trend similar to grain and straw yields of rice application of 50% of recommended inorganic P and K fertilizer with FYM significantly impressed the total uptake of N,P,K and S by rice as compared to 100% recommended P and K (Table-4). These results are in consonance with the findings [25]. The effect of various treatments on N, P, K and S uptake could be arranged in order of $T_5 > T_3 > T_6 > T_4 > T_2 > T_1$ and among the treatments, the uptake on N varied from 14.00 to 24.80 kg ha^{-1}, P from 8.60 to 16.70 kg ha^{-1}, K from 75.60 to 130.50 kg ha^{-1} and S from 8.00 to 14.50 kg ha^{-1}. The substantial improvement in nutrient uptake indicate the requirement of integration of nutrient supply sources for rice crop and also for over all improvement in soil's physico-chemical properties and biological environment. These results are on conformity with those reported [35].

Table4: Effect of phosphorus and potassium fertilization on uptake of N, P, K and S in kg ha^{-1} by rice.

Treatments	Uptake of nutrients (kg ha^{-1})			
	N	P	K	S
T_1	14.00	8.60	75.60	8.00
T_2	22.50	15.50	116.60	13.00
T_3	20.34	14.60	109.60	11.60
T_4	16.20	12.67	84.00	9.60
T_5	24.80	16.70	130.50	14.50
T_6	15.20	9.20	80.00	8.20
SEm(±)	1.156	0.331	1.066	0.020
CD (P=0.05)	1.383	0.740	1.328	0.181

The over all results demonstrated that 50% P K from inorganic fertilizers with FYM gave higher soil fertility and productivity. Thus 50% dose of P K fertilizer can be substituted with FYM as replacement beyond 50% may not be favourable. This equal proportion of organic and inorganic source of nutrient also favoured mineralization of organic source of optimum rate to maintain supply of nutrients.

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