Effect of organic manures and inorganic phosphorus on soil fertility status (N, P and K) in *Kharif* rice

ABSTRACT

The present study attempts to relate the phosphorus dynamics in relation to nutrient management in rice- black gram cropping sequence with respect to changes in soil fertility. Results of two years (2017-2019) experimentation revealed that at all growth stages of rice, significantly highest available nitrogen, phosphorus and potassium in soil were recorded with application of RDNK+*Dhaincha* @ 10t ha^{-1} (M_3) and this was on par with RDNK+ Sunhemp @ 10t ha^{-1}(M_2), whereas lowest was recorded in RDNK (M_0) alone in all four seasons of study. Among the P levels the available nutrient status (N, P and K) were increased with the increasing level of P from 0 (P_1) to 120 kg P_2O_5 (P_5) ha^{-1}, irrespective of the nutrients imposed to rice crop. Significantly highest was recorded in P_5 (120 kg P_2O_5 ha^{-1}) and this was on par with P_4 (90 kg P_2O_5 ha^{-1}), whereas the lowest was recorded in treatment P_1 that received 0 kg P_2O_5 ha^{-1}.

Comment [a1]: The present study attempts to relate the phosphorus dynamics in relation to nutrient management in rice blackgram cropping sequence with respect to changes in soil fertility. Results of two years (2017-2019) experimentation revealed that at all growth stages of rice, significantly highest available nitrogen, phosphorus, and potassium in soil were recorded with the application of RDNK+Dhaincha 10 t ha^{-1} (M3) and this was on par with RDNK+ Sunhemp 10 t ha^{-1}(M2) In contrast, the lowest was recorded in RDNK (M0) alone in all four study seasons. Among the P levels, the available nutrient status (N, P, and K) was increased with the increasing level of P from 0 (P1) to 120 kg P_2O_5 (P5) ha^{-1}, irrespective of the nutrients imposed on the rice crop. Significantly highest was recorded in P5 (120 kg P_2O_5 ha-1), which was on par with P4 (90 kg P2O5 ha-1), whereas the lowest was recorded in treatment P1 received 0 kg P_2O_5 ha-1.

Key words: *Organic manures, Phosphorus fertilizer, Soil fertility status, rice.*

Introduction

Rice based cropping systems are the major production systems contributing to food production. Current crop production systems are characterized by inadequate and imbalanced uses of fertilizers *e.g.*, blanket fertilizer recommendations over large domains with least regard to the variability in soil fertility and productivity. Future gains in productivity and input use efficiency require soil and crop management technologies that are tailored to specific characteristics of individual farms or fields. To meet the food requirement of the growing population, the rice and pulse production has to be enhanced with good management practices with shrinking availability of land and water resources condition. A large part of the problems that have not been sufficiently clarified yet can be solved only by using integrated nutrient management techniques. The supply of soils with soil organic matter and the elaboration of suitable methods to determine optimal humus contents and the factors of the humus balance. Since many decades, we have optimal values for all macro- and micronutrients in the soil, we have also limit values for pollutants, however, we have no optimal values for the most important elements in soil, *i.e.*, carbon and nitrogen. The effect of crop rotations on the crop yields, soil health and chemical, physical and biological soil characteristics. We owe predominantly to the results of the integrated nutrient management techniques for the contemporary knowledge regarding the sustainable land use. Integrated nutrient management experiments will also be indispensable in future, as they cannot be replaced by new analytical techniques or models; on the contrary, they are an indispensable basis for the calibration and validation of these techniques. Krishna Agroclimatic Zone is the potential tract in the traditional rice based cropping systems cultivated area of Andhra Pradesh. Rice-blackgram is the most common cropping system existing in Krishna Agroclimatic Zone of Andhra Pradesh. Therefore it was decided to study the effect of different treatment combinations in *kharif* rice to monitor soil fertility status.

Comment [a2]: Rice-based cropping systems are the major production systems contributing to food production. Current crop production systems are characterized by inadequate and imbalanced uses o fertilizers e.g., blanket fertilizer recommendations over large domains with least regard to the variability in soil fertility and productivity. Future gains in productivity and input use efficiency require soil and crop management technologies that are tailored to specific characteristics of individual farms or fields. To meet the food requirements of the growing population, rice and pulse production have to be enhanced with good management practices with the shrinking availability of land and water resources condition. A large part of the problems that have not been sufficiently clarified yet can be solved only by using integrated nutrient management techniques. The supply of soils with soil organic matter and the elaboration of suitable methods to determine optimal humus contents and the factors of the humus balance. For many decades, we have had optimal values for all macro- and micronutrients in the soil, we have also limited values for pollutants, however, we have no optimal values for the most important elements in soil, i.e., carbon and nitrogen. The effect of crop rotations on crop yields, soil health, and chemical, physical, and biological soil characteristics. We owe predominantly to the results of the integrated nutrient management techniques for the contemporary knowledge regarding sustainable land use. Integrated nutrient management experiments will also be indispensable in the future, as they cannot be replaced by new analytical techniques or models; on the contrary, they are an indispensable basis for the calibration and validatior of these techniques. Krishna Agro-climatic Zone is the potential tract in the traditional rice-based cropping systems cultivated area of Andhra Pradesh Rice-blackgram is the most common cropping system existing in the Krishna Agro-climatic Zone of Andhra Pradesh. Therefore, it was decided to study the effect of different treatment combinations in kharif rice to monitor soil fertility status.

MATERIAL AND METHODS

The present experiment in rice based cropping system *viz.*, rice - blackgram was started at Agricultural College Farm, Bapatla (15^0 54’ N latitude, 80^0 25' E longitude, 5.49 meters above the mean sea level) during June, 2017-19. During normal years, the annual rainfall is 1200 mm of which around 70 % is received during September to October (South East monsoon). The climate of the experimental site is sub tropical monsoon type. Rice crop transplanting in August and harvest in December was grown under irrigated conditions. The soil of the experimental site is clay loam texture. Here, we are discussing the results of two consecutive years. The initial analytical data of the available N (156.60 kg ha^{-1}), phosphorus (35.20 kg ha^{-1}) and potassium (385.23 kg ha^{-1}). The Experiment was laid out in a split block design with 20 treatments and three replications. Nitrogen was applied in three equal splits for *kharif* rice (transplanting, tillering ,and the panicle initiation), while phosphorus was applied entirely as basal and potassium in two equal splits (as basal and at panicle initiation stage). The fertilizers used were urea, single super phosphate, muriate of potash. For treatments of organic manures (M_2 and M_3), sunhemp (2.43 % N, 0.48 % P and 1.96% K and 2.51 % N, 0.53 % P and 2.03% K), *dhaincha* (3.20 % N, 0.57 % P and 1.70 % K and 3.40 % N, 0.65 % P and 1.91 % K) was incorporated @ 10 t ha^{-1} and FYM (0.70 % N, 0.27 % P and 0.56% K and 0.76 % N, 0.29 % P and 0.59% K) @ 5 t ha^{-1} (M_1) in both 2017-18, 2018-19 on dry weight basis, respectively.) was incorporated as main plots and five phosphorus levels of 0 kg P_2O_5 ha^{-1} (P_1), 30 kg P_2O_5 ha^{-1} (P_2) and 60 kg P_2O_5 ha^{-1} (P_3), 90 kg P_2O_5 ha^{-1} (P_4) and 120 kg P_2O_5 ha^{-1} (P_5) as sub- plot treatments for *kharif* rice.

Need based plant protection measures were taken up against pest and diseases. The chemical properties of soil *viz.,* available nitrogen, phosphorus and potassium was analysed by different chemical methods as described below.

Available nitrogen: Available nitrogen was estimated by alkaline permanganate method by using macro Kjeldahl distillation unit (Subbiah and Asija, 1956).

Available phosphorus : Available phosphorus in the soil samples was extracted with 0.5 M $NaHCO_3$ buffered at pH 8.5 and the phosphorus in the extract was estimated by ascorbic acid method using spectrophotometer at 660 nm (Watanabe and Olsen, 1965).

Available potassium : It was extracted with neutral normal ammonium acetate and estimated with the help of flame photometer (Jackson, 1973).

RESULTS AND DISCUSSION

Available NPK status of soil was significantly influenced by different organic manures along with inorganic fertilizers and also by inorganic phosphorus fertilizer levels during both the years of the study. However, the interaction effect was not significant.

Nitrogen

Data pertaining to the soil available nitrogen at all stages of rice was presented in the tables 1, 2 and 3 which revealed that available N in the soil did differ significantly due to organic manure treatments and levels of phosphorus, but not by their interaction during both the years of study. At tillering, among the different sources of organic manures, the higher soil available nitrogen was recorded with the RDNK+ *Dhaincha* 10 t ha^{-1} (M_3-229.05 and 237.87 kg ha^{-1}) which was on par with the application of RDNK+sunhemp 10 t ha^{-1} (M_2-226.68 and 235.18 kg ha^{-1}), while these two treatments were followed by RDNK+FYM (M_1-214.29 and 220.69 kg ha^{-1}) and found significantly superior over application of RDNK (M_0-198.97 and 203.40 kg ha^{-1}) alone during 2017 and 2018, respectively. Similar trend was observed at panicle initiation and harvest of rice also.

The results of the present study revealed that combined application of organics and inorganics recorded the highest available nitrogen content. This might be due to positive response of green manuring with inorganic fertilizers on soil N status and may be attributed to N mineralization from organic sources or by retaining N in labile microbial pool with the changing microbial flush. The most soil conditions might have helped the mineralization of soil N and greater multiplication of soil microbes, which could convert organically bound nitrogen into readily available form leading to building up of higher available N. The inclusion of green manure (*Sesbania aculeate)* in rice based cropping sequence reduced the loss of native nitrate N accumulated during aerobic cycle of the rice based cropping sequence and also conserved nitrate nitrogen, which would be lost upon flooding (Alagappan and Venkitaswamy 2021).

Incorporation of organic manures in rice-maize system increased the nutrient pool and reduced the losses of nutrients. Green manuring, which are comparatively more succulent with narrow C: N ratio release nitrogen on decomposition steadily into the soil pool to meet the crop requirement. Significantly lower available N in soil was observed with application of 100% NPK. Urea which contains highest content of N when applied to rice is subjected to leaching, volatilization losses in addition to crop uptake resulted in lower availability after *kharif* rice. Similar results were observed in the findings of Chettri *et al*. (2017).

At tillering, Among the P levels, highest N content was recorded in P_5 (225.05 and 232.24, kg ha^{-1}) and this was on par with P_4 (222.50 and 229.61 kg ha^{-1}), P_3 (219.04 and 226.08 kg ha^{-1}) and P_2 (214.46 and 221.43 kg ha^{-1}) and significantly superior over P_1 (205.19 and 212.07 kg ha^{-1}) during 2017 and 2018, respectively.

Table 1. Effect of organic manures and inorganic P fertilizer on available nitrogen content (kg ha^{-1}) in soil at tillering stage of rice

P levels (kg P_2O_5 ha^{-1})	***Kharif* 2017**				**Mean**	***Kharif* 2018**				**Mean**
	Organic manures					**Organic manures**				
	M_0	M_1	M_2	M_3		M_0	M_1	M_2	M_3	
P_1– 0	186.79	201.57	214.83	217.57	**205.19**	191.01	207.83	223.17	226.26	**212.07**
P_2– 30	196.01	211.89	223.79	226.15	**214.46**	200.37	218.21	232.20	234.94	**221.43**
P_3– 60	200.69	216.28	228.54	230.66	**219.04**	205.11	222.66	237.03	239.51	**226.08**
P_4– 90	204.30	219.77	231.83	234.08	**222.50**	208.83	226.24	240.41	242.96	**229.61**
P_5– 120	207.06	221.94	234.41	236.79	**225.05**	211.67	228.50	243.06	245.70	**232.24**
Mean	**198.97**	**214.29**	**226.68**	**229.05**		**203.40**	**220.69**	**235.18**	**237.87**	
	SEm ±		**CD (p=0.05)**		**CV (%)**	**SEm ±**		**CD (p=0.05)**		**CV (%)**
M	3.34		12.23		7.7	3.61		14.27		8.0
P	3.25		12.25		6.8	3.18		12.05		6.5
M at P	7.51		NS			3.37		NS		
P at M	7.76		NS			3.79		NS		

M_0- No Organic manure

M_1- RDNK+FYM 5 t ha^{-1}

M_2- RDNK+Sunhemp 10 t ha^{-1}

M_3- RDNK+Dhaincha 10 t ha^{-1}

Table 2. Effect of organic manures and inorganic P fertilizer on available nitrogen content (kg ha^{-1}) in soil at panicle initiation stage of rice

P levels (kg P_2O_5 ha^{-1})	***Kharif* 2017**				**Mean**	***Kharif* 2018**				**Mean**
	Organic manures					**Organic manures**				
	M_0	M_1	M_2	M_3		M_0	M_1	M_2	M_3	
P_1– 0	163.54	175.98	188.64	194.76	**180.73**	167.09	181.57	196.32	202.78	**186.94**
P_2– 30	175.61	186.10	198.31	204.35	**191.09**	179.30	191.75	206.06	212.47	**197.40**
P_3– 60	180.52	195.11	207.98	210.96	**198.64**	184.27	200.82	215.80	217.48	**204.59**
P_4– 90	184.30	198.57	211.55	215.91	**202.58**	188.16	204.37	219.47	225.79	**209.45**
P_5– 120	187.23	200.99	214.60	217.16	**204.99**	191.17	206.89	222.58	225.41	**211.51**
Mean	**178.24**	**191.35**	**204.22**	**208.63**		**182.00**	**197.08**	**212.04**	**216.79**	
	SEm ±		**CD (p=0.05)**		**CV (%)**	**SEm ±**		**CD (p=0.05)**		**CV (%)**
M	3.41		11.81		6.8	3.63		12.57		7.0
P	3.46		9.97		6.1	3.82		11.01		6.6
M at P	6.92		NS			7.64		NS		
P at M	7.07		NS			7.74		NS		

M_0- No Organic manure

M_1- RDNK+FYM 5 t ha^{-1}

M_2- RDNK+Sunhemp 10 t ha^{-1}

M_3- RDNK+Dhaincha 10 t ha^{-1}

Table 3. Effect of organic manures and inorganic P fertilizer on available nitrogen content (kg ha^{-1}) in soil at harvest of rice

P levels (kg P_2O_5 ha^{-1})	***Kharif* 2017**				**Mean**	***Kharif* 2018**				**Mean**
	Organic manures					**Organic manures**				
	M_0	M_1	M_2	M_3		M_0	M_1	M_2	M_3	
P_1– 0	153.67	172.07	183.34	187.58	**174.17**	156.89	177.32	190.68	195.27	**180.04**
P_2– 30	163.09	181.83	192.51	196.69	**183.53**	166.44	187.14	199.91	204.47	**189.49**
P_3– 60	167.46	185.86	197.26	201.10	**187.92**	170.87	191.23	204.74	208.95	**193.95**
P_4– 90	171.29	189.31	200.82	204.63	**191.51**	174.80	194.76	208.40	212.51	**197.62**
P_5– 120	174.26	192.03	203.65	207.47	**194.35**	177.86	197.58	211.30	215.37	**200.53**
Mean	**165.95**	**184.22**	**195.52**	**199.49**		**169.37**	**189.61**	**203.01**	**207.32**	
	SEm ±		**CD (p=0.05)**		**CV (%)**	**SEm ±**		**CD (p=0.05)**		**CV (%)**
M	3.02		11.18		10.4	4.42		13.24		10.9
P	3.19		14.96		9.7	4.01		14.44		9.0
M at P	9.39		NS			9.02		NS		
P at M	9.56		NS			9.48		NS		

M_0- No Organic manure

M_1- RDNK+FYM 5 t ha^{-1}

M_2- RDNK+Sunhemp 10 t ha^{-1}

M_3- RDNK+Dhaincha 10 t ha^{-1}

However the lowest N content was observed in P_1 during both the years of study at all the growth stages of rice. Similar trend was observed at panicle initiation and harvest of rice also.

Phosphorus

Data pertaining to the soil available phosphorus (P) at all growth stages of rice are presented in the tables 4, 5 and 6 and the data revealed that available P in the soil differed significantly due to organic manure treatments and levels of phosphorus, but not by their interaction during both the years of study.

At all growth stages of rice, among the different sources of organic manures, the highest soil available P was recorded in RDNK+ *Dhaincha* 10 t ha^{-1} (M_3-64.95, 62.35, 61.30, 73.77, 69.56, and 69.12 kg ha^{-1}) which was on par with the application of RDNK+sunhemp 10 t ha^{-1} (M_2-64.59, 69.56, 60.03, 73.09, 61.73 and 67.52 kg ha^{-1}) and these two treatments were significantly superior over RDNK+FYM (M_1-59.99, 55.66, 53.55, 66.38, 61.39 and 58.94 kg ha^{-1}) and RDNK alone (M_0) during 2017 and 18 at tillering, panicle initiation and harvest, respectively. The significantly lower available phosphorus content was recorded in RDNK (M_0-48.79, 47.82, 42.23, 53.22, 51.58 and 45.65 kg ha^{-1}) alone. However, the soil available phosphorus was decreased with advancement of crop stage during both the years with the application of organic manures. This decrease in phosphorus might be attributed to absorption of P by the growing plants or due to refixation of solubilized phosphorus (Chikkaraju, 2022).

Increase in available P with FYM application and green manuring might be due to additional application of P and mobilization of P of the soil. This increase in P might also be attributed to the decomposition of organic manures accompanied by release of appreciable quantity of CO_2 and organic acids. Available P content of the soil increased with the incorporation of green manures and organic manures as compared to its initial status. These results were in conformity with the findings of Mallareddy and Devenderreddy (2020), who reported that the buildup of available P in soil was due to release of organic acids during microbial decomposition of green manures which, might have helped in the solubility of native P.

Table 4. Effect of organic manures and inorganic P fertilizer on available phosphorus content (kg P_2O_5 ha^{-1}) in soil at tillering stage of rice

P levels (kg P_2O_5 ha^{-1})	***Kharif* 2017**				**Mean**	***Kharif* 2018**				**Mean**
	Organic manures					**Organic manures**				
	M_0	M_1	M_2	M_3		M_0	M_1	M_2	M_3	
P_1– 0	45.40	56.94	60.71	61.57	**56.16**	49.62	63.20	69.06	70.26	**63.03**
P_2– 30	47.04	58.16	63.35	63.64	**58.05**	51.40	64.48	71.77	72.43	**65.02**
P_3– 60	48.36	60.88	65.53	65.31	**60.02**	52.78	67.26	74.02	74.16	**67.05**
P_4– 90	51.19	61.44	66.39	66.78	**61.45**	55.72	67.91	74.97	75.66	**68.56**
P_5– 120	51.95	62.52	66.96	67.43	**62.22**	56.56	69.09	75.62	76.34	**69.40**
Mean	**48.79**	**59.99**	**64.59**	**64.95**		**53.22**	**66.38**	**73.09**	**73.77**	
	SEm ±		**CD (p=0.05)**		**CV (%)**	**SEm ±**		**CD (p=0.05)**		**CV (%)**
M	0.63		2.18		10.1	0.70		2.42		10.1
P	0.52		1.51		9.0	0.61		1.77		9.2
M at P	1.05		NS			1.23		NS		
P at M	1.13		NS			1.30		NS		

M_0- No Organic manure

M_1- RDNK+FYM 5 t ha^{-1}

M_2- RDNK+Sunhemp 10 t ha^{-1}

M_3- RDNK+Dhaincha 10 t ha^{-1}

Table 5. Effect of organic manures and inorganic P fertilizer on available phosphorus content (kg P_2O_5 ha^{-1}) in soil at panicle initiation stage of rice

P levels (kg P_2O_5 ha^{-1})	***Kharif* 2017**				**Mean**	***Kharif* 2018**				**Mean**
	Organic manures					**Organic manures**				
	M_0	M_1	M_2	M_3		M_0	M_1	M_2	M_3	
P_1– 0	44.09	52.38	57.49	58.41	**53.09**	47.64	57.97	65.17	66.43	**59.30**
P_2– 30	45.26	53.98	60.34	60.37	**54.99**	48.95	59.63	68.09	68.49	**61.29**
P_3– 60	47.53	56.50	62.16	63.23	**57.36**	51.28	62.21	69.98	71.42	**63.72**
P_4– 90	50.74	56.70	63.86	64.43	**58.93**	54.61	62.50	71.78	72.64	**65.38**
P_5– 120	51.47	58.73	64.79	65.30	**60.07**	55.42	64.62	72.78	73.55	**66.59**
Mean	**47.82**	**55.66**	**61.73**	**62.35**		**51.58**	**61.39**	**69.56**	**70.51**	
	SEm ±		**CD (p=0.05)**		**CV (%)**	**SEm ±**		**CD (p=0.05)**		**CV (%)**
M	0.72		2.51		8.9	0.93		3.22		9.7
P	0.65		1.86		7.9	0.69		1.98		7.8
M at P	1.29		NS			1.37		NS		
P at M	1.36		NS			1.54		NS		

M_0- No Organic manure

M_1- RDNK+FYM 5 t ha^{-1}

M_2- RDNK+Sunhemp 10 t ha^{-1}

M_3- RDNK+Dhaincha 10 t ha^{-1}

Table 6. Effect of organic manures and inorganic P fertilizer on available phosphorus content (kg P_2O_5 ha^{-1}) in soil at harvest of rice

P levels (kg P_2O_5 ha^{-1})	***Kharif* 2017**				**Mean**	***Kharif* 2018**				**Mean**
	Organic manures					**Organic manures**				
	M_0	M_1	M_2	M_3		M_0	M_1	M_2	M_3	
P_1– 0	38.29	49.22	56.14	57.03	**50.17**	41.51	54.47	63.48	64.72	**56.04**
P_2– 30	39.63	50.45	58.38	59.18	**51.91**	42.98	55.76	65.79	66.97	**57.87**
P_3– 60	42.46	54.70	60.07	62.23	**54.86**	45.87	60.07	67.54	70.09	**60.89**
P_4– 90	44.60	55.91	61.98	63.38	**56.47**	48.12	61.36	69.56	71.26	**62.57**
P_5– 120	46.16	57.48	63.58	64.68	**57.98**	49.76	63.03	71.24	72.58	**64.15**
Mean	**42.23**	**53.55**	**60.03**	**61.30**		**45.65**	**58.94**	**67.52**	**69.12**	
	SEm ±		**CD (p=0.05)**		**CV (%)**	**SEm ±**		**CD (p=0.05)**		**CV (%)**
M	0.96		3.33		8.9	0.98		3.40		8.3
P	0.57		1.65		6.7	0.59		1.70		6.4
M at P	1.15		NS			1.18		NS		
P at M	1.41		NS			1.44		NS		

M_0- No Organic manure

M_1- RDNK+FYM 5 t ha^{-1}

M_2- RDNK+Sunhemp 10 t ha^{-1}

M_3- RDNK+Dhaincha 10 t ha^{-1}

The buildup in available P may be due to the influence of organic manures in increasing the labile P in soil though complexing of cations like Ca^{+2} and Mg^{+2} which are mainly responsible for fixation of P (Bajpai *et al.*, 2018). Tolanur and Badanur (2016) also reported that organic manures like FYM and green manuring with inorganic fertilizers had the beneficial effect on increasing the phosphate availability. These results are in general agreement with the findings of Verma *et al.*, 2020. The maximum available P recorded in treatments with green leaf manuring may be due to the mobilization of soil P by the acidification of soil and the release of enzymes such as phosphatases and phytases of carboxylates such as gluconates and oxalates (Jones and Oburger, 2017). Similar results were observed by Jemila *et al*. (2022).

At all growth stages of rice, among the P levels, the significantly higher soil available P content was observed with the P_5 (62.22, 60.07, 57.98, 69.40, 66.59 and 64.15 kg ha^{-1}) in 2017 and 2018, respectively and this treatment was significantly superior over P_2 and P_1. Significantly lower available phosphorus content was observed in P_1 (56.16, 53.09, 50.17, 63.03, 59.30 and 56.04 kg ha^{-1}). However, the treatment P_5 was on par with P_4, while P_4 was on par with P_3 during both the years of study. Among the P fertilizer treatments, available phosphorous content in soil increased with increased P levels. Verma *et al.* (2021) opined that the increase in available P with increase in levels of fertilizer might be due to the addition of P at higher rates.

Potassium

The data on soil available potassium (K) as influenced by different organic manures and P levels were presented in tables 7, 8 and 9. During both the years of study, significant differences in available potassium content were noticed due to different organic manures and P levels. However the interaction effect was not significant. At all growth stages of rice, among the different sources of organic manures, the highest soil available K was observed with RDNK+ *Dhaincha* @ 10 t ha^{-1} (M_3-529.20, 510.41, 487.91, 540.69, 521.23 and 498.40 kg ha^{-1}) which was at par with the application of RDNK+sunhemp 10 t ha^{-1} (M_2-522.72, 505.71, 483.21, 533.89, 516.21 and 493.37 kg ha^{-1}) in 2017 and 18 at tillering, panicle initiation and harvest, respectively. These two treatments were significantly superior over RDNK+FYM (M_1-478.59, 457.80, 487.65, 439.96, 466.20 and 448.02 kg ha^{-1}) and RDNK (M_0-

Table 7. Effect of organic manures and inorganic P fertilizer on available potassium status (kg K_2O ha^{-1}) in soil at tillering stage of rice

P levels (kg P_2O_5 ha^{-1})	***Kharif* 2017**				**Mean**	***Kharif* 2018**				**Mean**
	Organic manures					**Organic manures**				
	M_0	M_1	M_2	M_3		M_0	M_1	M_2	M_3	
P_1– 0	405.23	448.68	495.70	501.76	**462.84**	410.12	457.60	506.71	513.12	**471.89**
P_2– 30	426.26	470.67	514.69	520.74	**483.09**	431.29	479.65	525.77	532.20	**492.23**
P_3– 60	437.42	481.75	525.46	531.43	**494.02**	442.50	490.79	536.61	542.95	**503.22**
P_4– 90	447.55	490.58	534.07	541.14	**503.34**	452.75	499.71	545.32	552.68	**512.62**
P_5– 120	456.17	501.26	543.70	550.93	**513.01**	461.45	510.49	555.02	562.51	**522.37**
Mean	**434.53**	**478.59**	**522.72**	**529.20**		**439.62**	**487.65**	**533.89**	**540.69**	
	SEm ±		**CD (p=0.05)**		**CV (%)**	**SEm ±**		**CD (p=0.05)**		**CV (%)**
M	8.42		29.13		8.6	8.66		29.96		8.7
P	7.91		22.80		7.6	7.89		22.72		7.4
M at P	15.83		NS			15.77		NS		
P at M	16.47		NS			16.55		NS		

M_0- No Organic manure

M_1- RDNK+FYM 5 t ha^{-1}

M_2- RDNK+Sunhemp 10 t ha^{-1}

M_3- RDNK+Dhaincha 10 t ha^{-1}

Table 8. Effect of organic manures and inorganic P fertilizer on available potassium status (kg K_2O ha^{-1}) in soil at panicle initiation stage of rice

P levels (kg P_2O_5 ha^{-1})	***Kharif* 2017**				**Mean**	***Kharif* 2018**				**Mean**
	Organic manures					**Organic manures**				
	M_0	M_1	M_2	M_3		M_0	M_1	M_2	M_3	
P_1– 0	387.90	428.63	479.43	482.04	**444.50**	392.12	436.89	489.77	492.73	**452.88**
P_2– 30	409.88	449.65	497.45	502.01	**464.75**	414.24	457.97	507.86	512.80	**473.22**
P_3– 60	421.11	460.46	507.91	513.05	**475.63**	425.53	468.84	518.40	523.91	**484.17**
P_4– 90	430.07	470.35	517.36	522.81	**485.15**	434.60	478.82	527.94	533.69	**493.76**
P_5– 120	439.71	479.93	526.42	532.13	**494.55**	444.32	488.49	537.07	543.04	**503.23**
Mean	**417.73**	**457.80**	**505.71**	**510.41**		**422.16**	**466.20**	**516.21**	**521.23**	
	SEm ±		**CD (p=0.05)**		**CV (%)**	**SEm ±**		**CD (p=0.05)**		**CV (%)**
M	7.58		26.22		6.2	9.06		31.35		7.3
P	8.57		24.68		6.3	8.61		24.81		6.2
M at P	17.13		NS			17.23		NS		
P at M	17.09		NS			17.88		NS		

M_0- No Organic manure

M_1- RDNK+FYM 5 t ha^{-1}

M_2- RDNK+Sunhemp 10 t ha^{-1}

M_3- RDNK+Dhaincha 10 t ha^{-1}

Table 9. Effect of organic manures and inorganic P fertilizer on available potassium status (kg K_2O ha^{-1}) in soil at harvest of rice

P levels (kg P_2O_5 ha^{-1})	***Kharif* 2017**				**Mean**	***Kharif* 2018**				**Mean**
	Organic manures					**Organic manures**				
	M_0	M_1	M_2	M_3		M_0	M_1	M_2	M_3	
P_1– 0	374.34	410.07	457.25	459.61	**425.32**	378.22	417.99	467.25	469.97	**433.36**
P_2– 30	395.37	432.05	475.27	479.62	**445.58**	399.38	440.02	485.34	490.07	**453.70**
P_3– 60	405.56	443.14	485.33	490.24	**456.07**	409.64	451.18	495.47	500.76	**464.26**
P_4– 90	415.67	452.08	494.57	500.31	**465.66**	419.85	460.20	504.81	510.85	**473.93**
P_5– 120	425.23	462.47	503.65	509.76	**475.28**	429.50	470.69	513.97	520.33	**483.62**
Mean	**403.23**	**439.96**	**483.21**	**487.91**		**407.32**	**448.02**	**493.37**	**498.40**	
	SEm ±		**CD (p=0.05)**		**CV (%)**	**SEm ±**		**CD (p=0.05)**		**CV (%)**
M	6.99		24.19		7.0	7.55		26.11		7.3
P	7.57		21.79		6.8	7.23		20.83		6.4
M at P	15.13		NS			14.46		NS		
P at M	15.23		NS			14.97		NS		

M_0- No Organic manure

M_1- RDNK+FYM 5 t ha^{-1}

M_2- RDNK+Sunhemp 10 t ha^{-1}

M_3- RDNK+Dhaincha 10 t ha^{-1}

434.53, 417.73, 403.23, 439.62, 422.16 and 407.32 kg ha^{-1}) alone during both the years of study.

Among the P levels, the treatment P_5 (513.01, 494.55, 475.28, 522.37, 503.23 and 483.62 kg ha^{-1}) recorded significantly highest available potassium and this was on par with P_4 and P_3, while significantly superior over P_1 (462.84, 444.50, 425.32, 471.89, 452.88 and 433.36 kg ha^{-1}) at tillering, panicle initiation and harvest in 2017 and 2018, respectively. The lowest was recorded in P_1 during both the years of study at all growth stages of rice. However the available potassium status of the soil increased with increasing rates of phosphorus application might be due to release of potassium from decaying roots and the continuous replenishment of the potassium containing minerals in the soil. The green manures registered significantly higher K availability in soil due to its easy decomposition of mineral constituents and their effect on dislodging the exchangeable K into the soil solution. These results were in conformity with the Upadhyay *et al.* (2021).

When acid forming compounds are added in the form of compost to the soil, these acids affect potassium availability. The effect is positive resulting in more availability of K to the plants. The hydrogen ions released from organic materials are exchanged with K on exchange site or set free from the fixed site of the clay micelle. Thus, the overall status of soil regarding availability of potassium content was improved (Singh *et al.*, 2018). Verma *et al.* (2020) also reported that continuous use of FYM and green manures enhanced the potassium status in the soil. The beneficial effect of green leaf manuring and FYM on available potassium might be due to reduction of potassium fixation, solubilisation and release due to the interaction of organic matter with clay besides the direct potassium addition to the potassium pool of soil. Similar results were also observed by Chettri *et al.* (2017). On the other hand, the available potassium content was gradually decreased with advancement of crop stage i.e from tillering to harvest stage in both the years. These results were coincide with Subhalakshmi and Pratapkumarreddy (2023). This might be due to the continuous depletion of K by crop uptake and also due to potassium fixation in soils (Veeranagapapa *et al.*, 2022).

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