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Effect of Rate and Sources of Nitrogen, Phosphorus and Zinc Fertilization on Potassium Nutrition of Rice in Different Cultivation Methods

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Abstract

A field study was conducted in 2013–14 and 2014–15 at Research Farm of ICAR-Indian Agricultural Research Institute, New Delhi, India with the objective to quantify variation in concentration and uptake of potassium (K) as influenced by rate and sources of nitrogen (N), phosphorus (P) and zinc (Zn) in rice. The rate of nutrient application (N and P) had strongly significant effect, followed by cultivation methods and least in case of Zn fertilization on concentration and uptake of K in rice. Among concentration and uptake, uptake was more affected due to applied treatments; while among growth stages, effect was significant at 70 and 100 days after sowing and in straw and milled rice. Application of recommended dose of N and P (RDN) increased total K uptake by 10–12 and 27–28 kg ha^{-1} over 75% RDN and control, respectively. Increase in total K uptake in puddled transplanted rice (PTR) and system of rice intensification (SRI) was 11–13 and 12–13 kg ha^{-1} over aerobic rice system (ARS). Similarly, increase in uptake due to application of microbial inoculations (MI) and Zn fertilization was 8–14 and 3–7 kg ha^{-1}. Soil available K showed negative balance which indicates that higher uptake than K applied through fertilizer and need of K fertilization in rice. Our study designates superiority of SRI and PTR among cultivation methods and RDN+Zn and 75% RDN+MI+Zn within nutrient management options in K nutrition of rice.

Keywords: Aerobic rice system, microbial inoculation, potassium, rice

1. Introduction

Rice is staple food of India consuming 29.3% of the total fertilizer consumption in India, out of which share of potassium (K) is 3.64% (0.9 mt) (FAI, 2016); while Prasad (2012) reported that share of rice in total fertilizer consumption in India was 37%. In India, K fertilization is not getting much attention which can be justified from wide nutrient application ratio (6.7: 2.7: 1, N: P_2O_5: K_2O) (Anonymous, 2017), disparity in K application rate and its total uptake in rice (30 kg K_2O t^{-1} grain produced), wheat (33 kg K_2O t^{-1} grain produced) or other cereals (32.8 kg K_2O t^{-1} maize grain produced) (Tandon, 2013) and share of K in total fertilizer used in India (9.6%) (Anonymous, 2017). The negative balance of K in soil was mentioned by Gurav et al. (2018) and Zhang et al. (2010), which also showed the need of K fertilization in rice. Singh et al. (2004) also emphasizes the importance of K nutrition in rice and wheat; while Yadav et al. (2000) reported the low rate of K application in rice–wheat cropping system in Indo-Gangetic plains. Growth and yield ability of rice is influenced more strongly by nitrogen (N) followed by phosphorus (P). The strong effect of these two nutrients may overshadow the influence of K on yielding ability. As both N and P have strong effect on growth, it may affect concentration and uptake of K in rice at different growth stages even after application of same rate of K application. At the same time, changes in cultivation method also had its own influence on soil K availability and plant K uptake. The increase in awareness among scientists, policy makers and stakeholders (farmers) about wastages of resource in puddled transplanted rice cultivation, new methods such as system of rice intensification (SRI) and aerobic rice system (ARS) getting more attention and importance. In such conditions, studying theses methods for their effect on K nutrition of rice and soil available K status generate valuable scientific information. The influence of zinc (Zn) fertilization on dry matter production and yield (Syed et al., 2016; Shivay et al., 2015; Singh and Shivay, 2014) of rice was highlighted in various studies. This response of Zn fertilization may affect K status of rice. With this background a field study was planned with objective to study the effect of three different rates of N and P fertilizer (0, 75% and 100% recommended dose of N and P (RDN)) (120 kg N ha^{-1} and 25.8 kg P ha^{-1}), two different sources on N and P (fertilizers and microbial inoculations (MI) and Zn fertilization on K content in rice plant and soil in three rice cultivation methods.

2. Materials and Methods

A field experiment was conducted in rainy seasons of 2013–14 and 2014–15 at the Research Farm of ICAR-Indian Agricultural Research Institute, New Delhi. This farm is situated at a latitude of 28°38' N, longitude of 77°10' E and altitude of 228.6 m above the mean sea level (Arabian Sea). The climate of Delhi is of sub-tropical and semi-arid type with hot and dry summer and cold winter and falls under the agro-climatic zone 'Trans-Gangetic plains'. Total rainfall received in first and second year during rice growing season was 1,349.8 mm and 451.4 mm; while evaporation losses during first and second rice growing seasons were 806 mm and 1075.1 mm, respectively. The soil of experimental field was sandy clay loam in texture having pH 7.6, organic carbon 0.54% (Walkley and Black, 1934) and available N (Subbiah and Asija, 1956), P (Olsen et al., 1954), K (Hanway and Heidel, 1952) and DTPA–extractable Zn (Lindsay and Norvell, 1978) of 257 kg ha^{-1}, 17 kg ha^{-1}, 327 kg ha^{-1} and 0.85 mg kg^{-1}, respectively.

The experiment involving rice variety *Pusa Sugandh 5* was conducted in split-plot design comprised of three main plots as methods of rice cultivation viz., puddled transplanted rice (PTR), system of rice intensification (SRI) and aerobic rice system (ARS) with nine nutrient management options as sub-plot treatments. Sub-plot treatments consisted of four treatments viz. RDN ($N_{120}P_{25.8}$), 75% RDN, 75% RDN+*Anabaena* sp. (CR1)+*Providencia* sp. (PR3) consortia (MI1) and 75% RDN+*Anabaena–Pseudomonas* biofilmed formulations (MI2) with and without Zn which making total eight treatments and another one treatment was absolute control ($N_0P_0Zn_0$). Potassium (K) was applied uniformly at the rate of 49.8 kg K ha^{-1} as basal dose. In case of Zn, soil application of 5 kg Zn ha^{-1} through Zn sulphate heptahydrate was applied in both rice crops at sowing/transplanting. Nitrogen was split applied in all treatments irrespective of dose at sowing, 30 days after sowing (DAS) and 60 DAS in ARS and 5 days after transplanting (DAT), 25 DAT and 55 DAT in both PTR and SRI. Sowing of rice in main field for ARS and sowing rice in nursery for transplanting in both PTR and SRI was done on same date. For ARS, direct sowing of seed (seed rate 60 kg ha^{-1}) was done with spacing of 20 cm between two rows using seed-drill. In SRI, 1 healthy seeding of 14 days old were transplanted hill^{-1} at a spacing of 20×20 cm^2, whereas in PTR, 2 healthy seeding of 25 days old, were transplanted per hill at a spacing of 20×15 cm^2. For application of microbial inoculants (MI), a thick paste of respective culture was made and applied to rice seedling in PTR and SRI method of rice cultivation by dipping roots in paste of respective culture for half an hour before transplanting. In ARS, pre-soaked seeds were treated with thick paste of culture made in carboxyl methyl cellulose. Standard recommended practices were followed for weed and water management in all three cultivation methods.

For measurement of above-ground shoot dry matter, representative plant sample were air dried and further dried in a hot air oven at 60°±2 °C till constant weight was obtained and expressed in g m^{-2}. After recording of dry matter accumulation, same samples were used to determine potassium concentration in plant; while for determination of K concentration in straw, milled rice, bran and hull, representative samples from each plot was taken at harvesting. The plant samples were digested in di-acid mixture (HNO_3 and $HClO_4$ in the ratio of 9:4). The potassium content was determined by using flame photometer method and expressed as percentage and mg kg^{-1} of dry matter. The potassium uptake was computed by multiplying the potassium concentration with plant biomass and was expressed as potassium uptake in kg ha^{-1}. For determination of available K in soil, flame photometric method was used. In this method, 1 N ammonium acetate solution was used to extract the K from soil. Reading was taken for soil extract and standard solutions. Standard curve was drawn with the readings for the standard solutions and read the concentrations of the extracts from the standard curve. The value of available K was expressed in terms of kg K ha^{-1}. All the data obtained from the experiment were statistically analyzed using the F-test as per the standard statistical procedure (Gomez and Gomez, 1984) and least significant difference (LSD) values (p = 0.05) were used to determine the significance of difference between treatment means.

3. Results and Discussion

3.1. Potassium concentration in rice at different growth stages

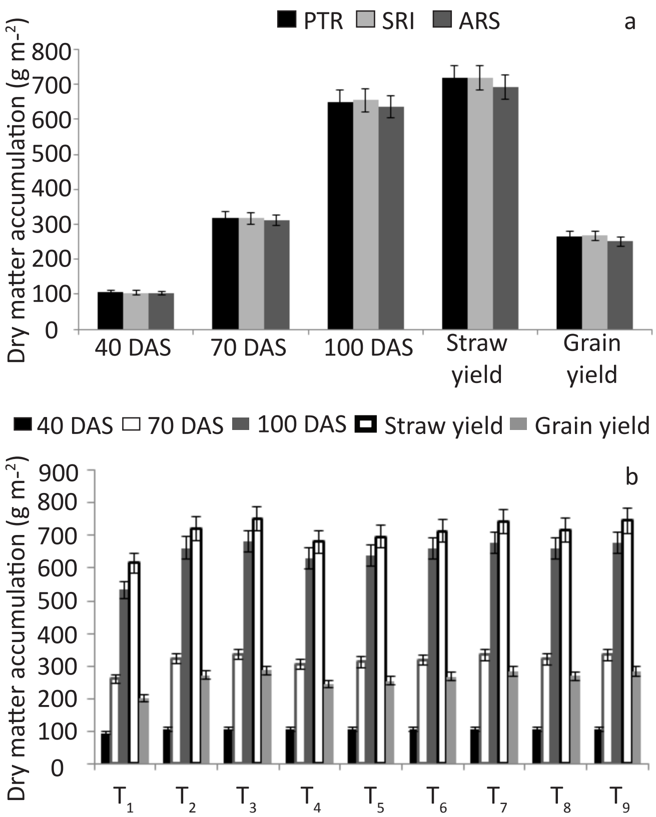
Concentration of K decreased as crop turns towards maturity with highest concentration at 40 DAS and the lowest in milled rice (Table 1). This decrease in concentration was attributed by dilution effect of increase in dry matter and decrease in K uptake towards crop maturity. Senapati et al. (2009) also mentioned the decrease in K concentration from maximum tillering stage to panicle initiation stage. Concentration in straw was 14 to 15 times higher than milled rice and 2.5 to 2.7 times higher than hull. Variation in K concentration among straw and rough rice was also mentioned by Sarkar et al. (2017). Decrease in K concentration was highest during 70 to 100 DAS and the lowest during 40 to 70 DAS. This variation was mainly due to variation in rate of increase in dry matter. Cultivation methods create significant variation in K concentration at all observations recorded and in all components of rough rice. Among cultivation methods, SRI and PTR remained statistically identical to each other and both found statistically superior to ARS at all observations. This variation might be due to change in the availability of K in soil due to various hydrological regimes among cultivation methods or due to different growth vigour of rice plant due

Table 1: Effect of cultivation methods and nutrient management options on potassium concentration and uptake in rice plant at different growth stages (data averaged over two years)

Treatment	Potassium concentration (%)							Potassium uptake (kg ha^{-1})						
	40 DAS	70 DAS	100 DAS	straw	Milled rice (mg kg^{-1})	Bran	Hull	40 DAS	70 DAS	100 DAS	straw	Milled rice	Bran	Hull
Crop cultivation methods														
Puddled transplanted rice	1.80	1.71	1.44	1.31	866.5	0.33	0.51	18.9	54.7	93.7	94.6	2.31	1.48	4.66
System of rice intensification	1.81	1.72	1.45	1.32	867.4	0.33	0.52	19.0	54.6	95.3	94.9	2.33	1.51	4.62
Aerobic rice system	1.69	1.60	1.31	1.20	854.3	0.27	0.44	17.5	49.9	83.7	83.2	2.14	1.17	4.07
SEm±	0.013	0.01	0.01	0.01	1.31	0.00	0.01	0.11	0.29	0.55	0.43	0.01	0.04	0.04
LSD (p= 0.05)	0.050	0.04	0.03	0.03	5.15	0.02	0.02	0.44	1.13	2.16	1.71	0.04	0.16	0.17
Nutrient management options														
Control ($N_0P_0Zn_0$)	1.57	1.46	1.24	1.13	842.5	0.20	0.35	14.7	38.1	65.9	69.9	1.70	0.73	2.86
RDN*	1.80	1.72	1.45	1.31	867.4	0.33	0.52	19.1	55.5	96.1	94.6	2.35	1.51	4.73
RDN+Zn**	1.83	1.78	1.47	1.33	871.9	0.34	0.53	19.5	59.6	100.4	99.6	2.49	1.57	4.92
75% RDN	1.75	1.60	1.33	1.24	854.9	0.29	0.46	18.3	49.0	83.5	84.3	2.09	1.30	4.16
75% RDN+ Zn	1.75	1.60	1.35	1.24	856.0	0.30	0.46	18.5	50.0	86.1	86.6	2.17	1.37	4.25
75% RDN+ MI1	1.78	1.71	1.43	1.30	866.3	0.33	0.51	18.7	54.6	94.2	92.8	2.32	1.46	4.67
75% RDN+ MI1+Zn	1.81	1.74	1.45	1.31	868.9	0.33	0.53	19.2	57.9	98.2	97.8	2.45	1.53	4.90
75% RDN+ MI2	1.79	1.71	1.43	1.30	866.8	0.32	0.52	18.9	54.8	94.7	93.6	2.33	1.47	4.65
75% RDN+ MI2+Zn	1.82	1.74	1.46	1.33	869.8	0.33	0.53	19.3	58.2	99.1	98.9	2.46	1.55	4.92
SEm±	0.033	0.03	0.02	0.02	2.68	0.01	0.01	0.30	0.75	1.23	1.00	0.02	0.06	0.12
LSD (p= 0.05)	0.094	0.08	0.06	0.04	7.62	0.02	0.03	0.86	2.13	3.49	2.84	0.05	0.16	0.34
Interaction	NS	NS	S	S	S	S	S	S	S	S	S	S	S	S

RDN*: Recommended dose of nutrients 120 kg N ha^{-1} and 25.8 kg P ha^{-1}; Zn**: Soil applied 5 kg Zn ha^{-1} through Zinc sulphate heptahydrate; MI1: (*Anabaena* sp. (CR1)+*Providencia* sp. (PR3) consortia; MI2: *Anabaena-Pseudomonas* biofilmed formulations; DAS: days after sowing; NS: non-significant; S: Significant

to applied main and sub-plot treatments which was clear from Figure 1 (a and b). Increase in dry matter production due to application of microbial inoculation (*Azospirillium* sp. and *Phosphotika* sp.) was also reported by Longkumer and Singh (2013); while increase in dry matter accumulation due to nitrogen was reported by Xie et al. (2007). Concentration remained unaffected due to sources of N and P nutrient and Zn fertilization at all growth stages and affected significantly due to rate of N and P fertilization at all growth stages except at 40 DAS. Application of 100% RDN stood statistically superior to 75% RDN and both had significantly higher concentration than control. Increase in concentration in straw due to application



T_1: Control ($N_0P_0Zn_0$), T_2: RDN*, T_3: RDN+Zn**, T_4: 75% RDN, T_5: 75% RDN+Zn, T_6: 75% RDN+MI1, T_7: 75% RDN+MI1+ Zn, T_8: 75% RDN+MI2 and T_9: 75% RDN+MI2 + Zn; RDN*: Recommended dose of nutrients 120 kg N ha^{-1} and 25.8 kg P ha^{-1}; Zn**: Soil applied 5 kg Zn ha^{-1} through Zinc sulphate heptahydrate; MI1: (*Anabaena* sp. (CR1)+*Providencia* sp. (PR3) consortia; MI2: *Anabaena-Pseudomonas* biofilmed formulations; DAS: days after sowing

Figure 1: Dry matter accumulation of rice at different growth stages as affected by crop cultivation methods (a) and nutrient management treatments (b) (data averaged over two years)

of 100% RDN was 0.07 and 0.18% over 75% RDN ad control, respectively; while same increase for milled rice was 13 and 25 mg kg^{-1} respectively, even though rate of K application and soil initial available K was same in all treatments. Concentration of K was positively correlated with N and P concentration in straw and milled rice (Figure 2 and 3) in our study which showed the positive effect of N application on K concentration. Interaction effect of cultivation methods and nutrient management treatments was significant at all observation (except 40 DAS) which indicates that, performance of sup-plot treatments varied in each method of rice cultivation.

3.2. Potassium uptake in rice at different growth stages

Uptake of K increased with growth and the highest K accumulated in straw and the lowest in bran. This variation was

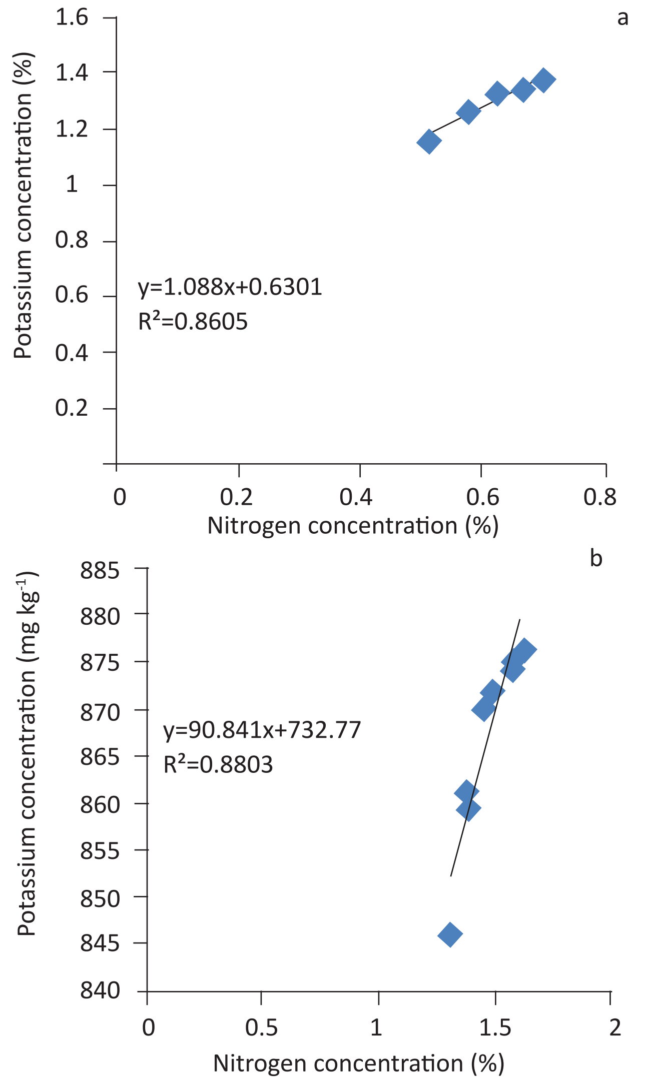
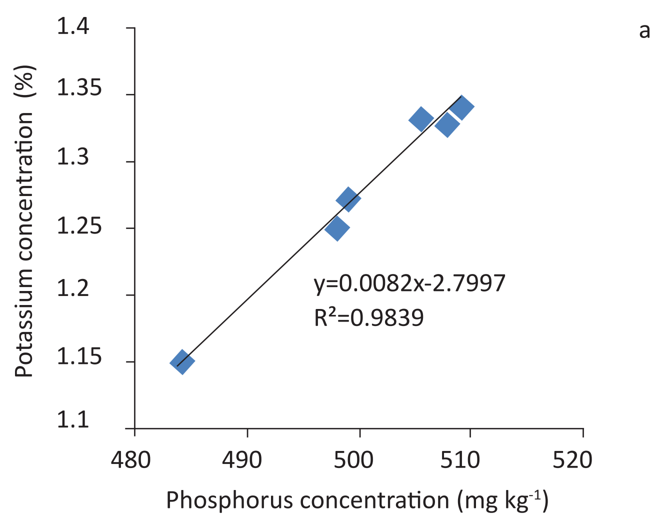


Figure 2: Correlation of potassium concentration and nitrogen concentration in straw (a) and milled rice (b) during first year of study



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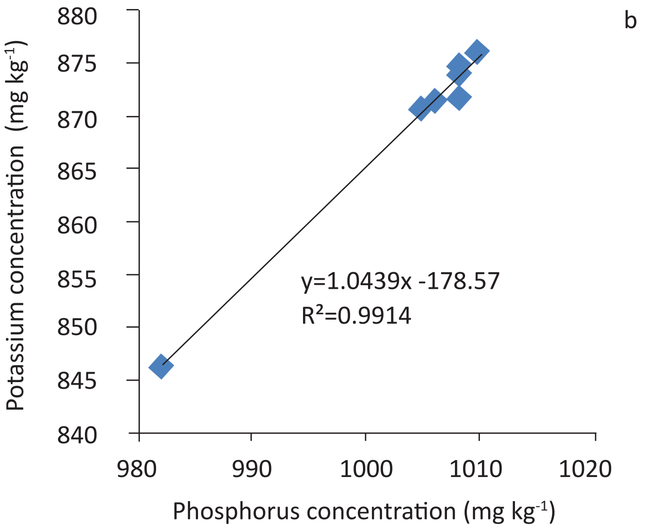

Figure 3: Correlation of potassium concentration and phosphorus concentration in straw (a) and milled rice (b) during first year of study

mainly due to higher concentration and dry matter production of straw than all components of rough rice. Chatterjee and Sanyal (2007) also observed such variation in K distribution among straw and grain of rice. Out of total uptake, 88 to 94% was accumulated in straw and remaining in rough rice grain (Table 1). As most of the K remained in straw, recycling of K is possible in arable land effectively by surface straw retention and incorporation (Sarkar et al., 2017). Uptake was remained on par in PTR and SRI and both methods found statistically superior to ARS at all observations during crop growth stages. Total uptake in PTR and SRI was higher by 11–13 and 12–13 kg ha^{-1} over ARS. Variation in dry matter production among cultivation methods was the major reason for differences in K uptake; while a difference in K concentration was secondary reason. Among nutrient management treatments, RDN + Zn recorded the highest uptake at all observations and remained on par with 75% RDN+MI1+Zn and 75% RDN+MI2+Zn. Variation in rate of nutrients (N and P) application showed significant difference in K uptake at all growth stages except at 40 DAS; while Zn fertilization creates significant difference in uptake at 70 DAS and in straw and milled rice. The application of RDN increased total K uptake by 10–12 and 27–28 kg ha^{-1} over 75% RDN and control; while increase in total K uptake due to Zn fertilization was 3.9, 3.2 and 5.5 kg ha^{-1} when Zn was applied with RDN, 75% RDN+MI1 and 75% RDN+MI2, respectively in first year and such increase was also occurred during second year too. Application of microbial inoculations increases total K uptake by 8 to 14 kg ha^{-1}. The significant variation in K uptake due to RDN, Zn fertilization and microbial inoculation (MI) even though application rate of K through this fertilizer and soil initial available K was same in all treatments. This showed the role of these components of nutrient management in K nutrition of rice. Improvement in K uptake due to application of optimum dose of nitrogen over suboptimal dose was also reported by El-Hamdi et al. (2010); while increase in K uptake due to application of recommended dose of N and P was reported by Tandon and Sekhon (1988). Interaction effect in case of K uptake followed similar trend as that of concentration with significance at all observations.

3.3. Soil available (NH_4OAC–extractable) K in soil at different growth stages and potassium balance

The variation in available soil K at different observations was mainly due to variation in K uptake by applied treatments. At 40 DAS, soil K level was increased by about 32 kg ha^{-1} in ARS and 34 kg ha^{-1} each in PTR and SRI (Table 2) over initial K in soil. Among cultivation methods, PTR and SRI remained on par to each other while ARS recorded significantly lower soil K both at 40 and 70 DAS. Nutrient management treatments did not affect the soil K level significantly at 40 DAS except control which had significantly higher soil K due to low uptake by rice in control; while at 70 DAS, 75% RDN (332.6 kg ha^{-1}) and 75% RDN+Zn (331.3 kg ha^{-1}) recorded significantly higher soil K content than all other treatments. Soil available K at 100 DAS and at harvest was lower than soil available K at 70 DAS by about 35–40 kg ha^{-1} and 38–45 kg ha^{-1}, respectively. At 100 DAS, ARS recorded the highest soil K which was significant over PTR, but remained on par with SRI; while at harvest, ARS recorded significantly higher soil K than both PTR and SRI. Among nutrient management treatments, 75% RDN, 75% RDN+Zn and control recorded significantly higher soil K at 100 DAS as compared to all other treatments. Lowest soil K was observed in RDN+Zn. Superiority of these three treatments was due to lower K uptake and this signifies the close relationship of soil available K with K uptake in rice. Mazumdar et al. (2014) also mentioned the close relation of soil available K and K uptake in rice.

The soil K at the start of second rice crop was lower than soil K present at start of first rice crop by 131 kg ha^{-1} in both PTR and SRI and 147 kg ha^{-1} in ARS. Soil K at 40 DAS was increased as compared to initial soil K due to application of K fertilizer as basal dose. At 40 and 70 DAS, both PTR and SRI recorded significantly higher soil K than ARS. Among nutrient management treatments, control recorded significantly higher soil K than 75% RDN and 75% RDN+Zn. These three treatments were statistically superior to all other treatments. Soil K at 100 DAS and at harvest was lower than soil K at 70 DAS by about 16–20 kg ha^{-1} and 28–35 kg ha^{-1}, respectively. The cultivation methods at 100 DAS and at harvest followed similar trend as that of 70 DAS with both PTR and SRI recorded significantly higher soil K than ARS. Among nutrient management treatments, control recorded the highest soil K which remained on par with 75% RDN. Both these two treatments recorded significantly higher soil K than all other treatments.

Table 2: Effect of cultivation methods and nutrient management options on soil available potassium (kg ha^{-1}) in rice at different growth stage during 2013 and 2014

Treatment	2013					2014				
	Initial	40 DAS	70 DAS	100 DAS	At harvest	Initial	40 DAS	70 DAS	100 DAS	At harvest
Crop cultivation methods										
Puddled transplanted rice	327	361.2	326.6	287.4	283.1	195.2	242.2	223.7	203.3	188.8
System of rice intensification	327	361.2	326.6	285.9	283.2	195.7	242.7	224.4	202.2	189.0
Aerobic rice system	327	359.9	326.1	289.2	287.7	179.1	226.1	209.3	192.7	180.4
SEm±	-	0.12	0.34	0.63	0.46	0.45	0.49	0.61	0.85	0.92
LSD (*p*=0.05)	-	0.47	1.33	2.47	1.79	1.76	1.93	2.41	3.34	3.61
Nutrient management options										
Control ($N_0P_0Zn_0$)	327	358.2	328.4	294.5	289.4	255.6	289.8	267.1	239.5	226.2
RDN*	327	360.9	325.7	283.5	282.2	176.6	224.6	206.5	186.8	173.9
RDN+Zn**	327	360.4	321.1	279.4	278.3	165.8	212.6	190.2	168.7	153.4
75% RDN	327	361.7	332.6	298.7	294.5	208.8	260.4	250.5	237.5	225.1
75% RDN+Zn	327	361.5	331.3	295.6	291.0	201.7	252.6	241.4	226.5	214.6
75% RDN+MI1	327	361.3	326.6	286.3	283.9	183.3	232.2	215.2	196.3	184.5
75% RDN+MI1+Zn	327	360.8	323.0	282.3	280.7	170.4	217.7	197.0	176.0	160.6
75% RDN+MI2	327	361.1	326.4	286.2	283.7	180.7	229.3	212.0	192.2	180.1
75% RDN+MI2+Zn	327	360.6	323.0	280.9	278.2	166.9	213.8	192.3	171.0	156.4
SEm±	-	0.36	0.86	1.41	1.29	2.59	2.81	3.21	3.62	3.57
LSD (*p*=0.05)	-	1.02	2.45	4.00	3.67	7.37	8.00	9.12	10.28	10.15
Interaction	-	S	S	NS	NS	NS	NS	NS	NS	NS

RDN*: Recommended dose of nutrients 120 kg N ha^{-1} and 25.8 kg P ha^{-1}; Zn**: Soil applied 5 kg Zn haha^{-1} through Zinc sulphate heptahydrate; MI1: (*Anabaena* sp. (CR1)+*Providencia* sp. (PR3) consortia; MI2: *Anabaena–Pseudomonas* biofilmed formulations; DAS: days after sowing; NS: non-significant; S: Significant

Lowest soil K was observed in RDN+Zn both at 100 DAS and at harvest and same treatment recorded the highest K uptake. The significant role of soil inherent available K over K applied through fertilizer in meeting K need of rice was justified from consistent decrease in soil available K status even after application of recommended dose of K. This consistent decreased in soil available K responsible for negative balance of K as reported by Sharma and Sharma (2002) and Panaullah et al. (2006) also mentioned the negative balance of soil available K. Singh et al. (2004) reported the depletion of soil K in rice–wheat cropping system even when optimum level of K was applied and on similar line, Tandon (2007) showed negative balance of K in most of the states in India.

The soil available and total K at initial stage present in soil did not differ among cultivation methods in the first year due to due to same rate of K application; while both were found significantly higher in both PTR and SRI than ARS in the second year (Table 3). In second year, K uptake in first season rice crop and wheat planted after first rice crop was main factor responsible for variation in available K status in soil. The balance and actual K present in soil at rice harvest was significantly higher in ARS than both PTR and SRI in the first year. One possible reason for this difference was significantly lower total K uptake in ARS than PTR and SRI. In second year, the balance and actual soil K was found significantly higher in both PTR and SRI over ARS. Variation between actual K present in the soil and calculated balance was 4–13 and 39–43 kg ha^{-1} in the first and the second year, respectively. The available and total K was found higher in control in both years which was found statistically superior to 75% RDN and 75% RDN+Zn. These three treatments were superior to all other treatments which were mainly due to lower uptake. Balance and actual K present in soil at harvest in both years also found higher in above-mentioned three treatments and this again showed the relationship of K uptake with available K (NH_4OAC–extractable) in soil.

Table 3: Effect of cultivation methods and nutrient management options on potassium (NH_4OAC–extractable) content in soil

Treatment	Available soil potassium (kg ha^{-1})		Potassium applied through fertilizer (kg ha^{-1})		Total potassium present in soil (kg ha^{-1})		Total uptake of potassium (kg ha^{-1})		Balance (kg ha^{-1})		Actual potassium present in soil after harvest (kg ha^{-1})	
	2013	2014	2013	2014	2013	2014	2013	2014	2013	2014	2013	2014
Crop cultivation methods												
Puddled transplanted rice	327	195.2	49.8	49.8	376.8	245.0	106.8	99.4	270.0	145.6	283.1	188.8
System of rice intensification	327	195.7	49.8	49.8	376.8	245.5	106.7	99.9	270.1	145.6	283.2	189.0
Aerobic rice system	327	179.1	49.8	49.8	376.8	228.9	93.5	87.7	283.3	141.2	287.7	180.4
SEm±	-	0.45	-	-	0.00	0.45	0.46	0.58	0.46	0.99	0.46	0.92
LSD (*p*=0.05)	-	1.76	-	-	0.00	1.76	1.79	2.29	1.79	3.89	1.79	3.61
Nutrient management options												
Control ($N_0P_0Zn_0$)	327	255.6	49.8	49.8	376.8	305.4	78.7	71.6	298.1	233.8	289.4	226.2
RDN*	327	176.6	49.8	49.8	376.8	226.4	107.1	99.3	269.7	127.1	282.2	173.9
RDN+Zn**	327	165.8	49.8	49.8	376.8	215.6	111.0	106.1	265.8	109.5	278.3	153.4
75% RDN	327	208.8	49.8	49.8	376.8	258.6	94.9	88.8	281.9	169.8	294.5	225.1
75% RDN+Zn	327	201.7	49.8	49.8	376.8	251.5	98.3	90.4	278.5	161.1	291.0	214.6
75% RDN+MI1	327	183.3	49.8	49.8	376.8	233.1	105.4	97.1	271.4	136.0	283.9	184.5
75% RDN+MI1+Zn	327	170.4	49.8	49.8	376.8	220.2	108.6	104.7	268.2	115.5	280.7	160.6
75% RDN+MI2	327	180.7	49.8	49.8	376.8	230.5	105.7	98.3	271.1	132.2	283.7	180.1
75% RDN+MI2+Zn	327	166.9	49.8	49.8	376.8	216.7	111.2	104.5	265.6	112.2	278.2	156.4
SEm±	-	2.59	-	-	0.00	2.59	1.29	1.12	1.29	3.31	1.29	3.57
LSD (*p*=0.05)	-	7.37	-	-	0.00	7.37	3.67	3.20	3.67	9.42	3.67	10.15
Interaction	-	NS	-	-	NS	S	S	S	S	NS	NS	NS

RDN*: Recommended dose of nutrients 120 kg N ha^{-1} and 25.8 kg P ha^{-1}; Zn**: Soil applied 5 kg Zn ha^{-1} through Zinc sulphate heptahydrate; MI1: (*Anabaena* sp. (CR1)+*Providencia* sp. (PR3) consortia; MI2: *Anabaena*–*Pseudomonas* biofilmed formulations; DAS: days after sowing; NS: non-significant; S: Significant

4. Conclusion

Potassium concentration and uptake by rice was not only depend on K fertilization but also on application rates and sources of N and P fertilizers; Zn fertilization and microbial inoculation had significant influence on concentration and uptake of K. The calculated balance as well as actual available K in soil showed negative trend over initial soil available K indicating need of K fertilization and consideration for revision of dose for K fertilization in rice.

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