



Effect of natural safe rock minerals on growth, yield and quality of rice (*Oryza sativa*) in rice-wheat cropping system

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ABSTRACT

A field experiment was conducted during two *Kharif* seasons of 2016 and 2017 at the research farm of ICAR-Indian Agricultural Research Institute, New Delhi to study the effect of Safe Rock Mineral (SRM) on productivity and quality of rice in rice-wheat cropping system. The experiment was carried out in randomized block design with three replications involving two rice (*Oryza sativa*) establishment methods (aerobic rice and transplanted rice) and six crop nutrition levels on rice-wheat sequence. The results indicate that, in general transplanted rice performed comparatively better in terms of growth, yield and quality parameters compared to aerobic rice. Different nutritional level improved the productivity of rice and succeeding wheat crop in both the years significantly. Among nutrient management practices, highest plant growth, yield attributes and yield of rice were obtained with the application of SRM application @ 250 kg/ha + 100% RDF and it was followed by No SRM application + 100% RDF, SRM application @ 250 kg/ha + 50% RDF (Chemical) + 25% RDF (Organic-FYM) and SRM application @ 250 kg/ha + 50% RDF (Organic-FYM). Integrated nutrient management with SRM application @ 250 kg/ha + 100% RDF increased grain protein content significantly over only SRM application @ 250 kg/ha. An increase of 16.42% and 18.07% in grain protein was recorded under aerobic and transplanted method of rice, respectively. It was concluded that integrated application of SRM @ 250 kg/ha + 100% RDF gave the highest growth and productivity of rice and with this treatment grain yield was 32.2% and 32.9% higher than only SRM application at @ 250 kg/ha under aerobic and transplanted conditions respectively.

Key words: Aerobic rice, Farmyard manure, Rice quality, Safe Rock Mineral, Transplanted rice

Rice is grown globally on an area of about 163.2 million ha with a production of about of 751.9 million tonnes and average productivity of 4.61 t/ha (FAO 2017). In India, rice ranks first among all the crops occupying around 44 million ha and production of 110.2 million tonnes of rice with average productivity of 2.51 t/ha (DAC&FW 2018). It has been estimated that approximately half the global population subsists wholly or partially on rice whereas nearly 90% of the world's rice is grown and consumed in Asia (Bana 2009). In South Asia, around 13.5 million hectares area, including 10.5 million hectares in India, rice is grown in rotation with wheat (Bana *et al.* 2015). Rice-wheat (R-W) rotation is the largest agriculture production

system in South Asia and is fundamental to employment and income (Singh and Kaur 2012). The R-W system is source of livelihoods for millions of people and is kingpin of food security of the region (Bana *et al.* 2013).

During past decades, the R-W system is showing the sign of fatigue because of continuous use of traditional practices and imbalance and indiscriminate use of synthetic fertilizer which resulted in yield stagnation and declining factor productivity (Ladha *et al.* 2003; Bhatt *et al.* 2016). Such emerging challenges have put a big question mark on the sustainability of rice and wheat. The productivity and quality of rice depend on agronomic management practices mainly nutrient management (Singh 1998). Utilization of indigenous sources of organic nutrient source as alternatives and/or supplements to chemical fertilizers is not only a strategy to achieve economic and ecological sustainability but also help in increasing the productivity (Bana *et al.* 2012; Bana *et al.* 2016). But availability of organic sources for effective nutrient management is not sufficient in India. Therefore, natural rocks and minerals can be a suitable alternative for efficient organic nutrient management.

Safe Rock Minerals (SRM) may be one of the option for crop nutrition which is reported as one of the natural

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mineral resource. SRM has been recently discovered from sedimentary rocks in the United Kingdom and is unique blend of minerals originated from the ocean floor south of the equator millions of years ago. The resource, when crushed to a powder, provides a unique blend of minerals and nutrients that are 100% recoverable with no additives being used or waste being created. They aim to use SRM to provide a natural holistic solution to help mitigate the global crisis of soil degradation and water scarcity. SRM attracts and retains ammonium, potassium, calcium and magnesium as well as many trace elements (SRM 2019). It has the greatest affinity for ammonium and potassium but when a plant is taking up the ammonium or potassium off the SRM, it attracts calcium from the phosphorus mineral apatite, such as rock phosphate, or locked up phosphorus in soil to balance the SRM negative charge (SRM 2019). This reaction releases a free phosphorus, effectively unlocking trapped phosphorus within the soil and making it available for plant use. The SRM prevents free nutrients from leaching. SRM is a mineral soil conditioner and has been certified for use in organic agriculture. It is a natural mineral resource which can be used to reduce our dependence on chemical fertilizers, as it contains many of the minerals and trace elements essential for healthy crops and livestock. This is achieved through its unique balance of nutrients and clay minerals, which also increases microbial and earthworm activity and builds long term soil fertility (Ranva *et al.* 2018). So far no scientific information is available on this on the effects of natural SRM on rice crop, so the present study was conducted to find out the effect of SRM on growth, yield attributes, productivity and quality of rice in R-W cropping system.

MATERIALS AND METHODS

The field and laboratory experiments were conducted during *kharif* seasons of 2016-17 and 2017-18 at ICAR-Indian Agricultural Research Institute, New Delhi, India. The institute farm is located at a latitude of 28°40' N and longitude of 77°12' E with an altitude of 228.6 meters above the mean sea level (Arabian Sea). Before beginning of experiments composite soil sample of same field was taken and analysed. The soil of the experimental field had 144.6 kg/ha alkaline permanganate oxidizable N (Subbiah and Asija, 1956), 14.7 kg/ha available P (Olsen *et al.* 1954), 261.5 kg/ha 1N ammonium acetate exchangeable K. The pH of soil was 7.8 (1: 2.5 soil: water ratio).

Experimental details: The experiment was laid out in randomized block design (RBD) with six treatment combinations which was statistically analyzed using the F-test as per the procedure given by Gomez and Gomez (1984). LSD values at $P = 0.05$ were used to determine the significance of difference between treatment means. The treatment included: T_1 : No Safe Rock Minerals (SRM) application +100 % recommended dose of fertilizer (RDF) ($N_{120}P_{60}K_{60}$)- control; T_2 : Only SRM application @ 250 kg/ha; T_3 : SRM application @ 250 kg/ha + 50 % RDF; T_4 : SRM application @ 250 kg/ha + 100 % RDF; T_5 : SRM

application @ 250 kg/ha + 50 % RDF (Chemical)+ 25 % RDF (Organic-FYM) and T_6 : SRM application @ 250 kg/ha + 50 % RDF (Organic-FYM)

Basmati rice variety 'Pusa Basmati 1509' was taken in aerobic and transplanted condition. Twenty one days old seedlings were transplanted after land preparation through puddling. Two seedlings were transplanted per hill. The field was kept ponded as per the general irrigation recommendations of transplanted rice. For aerobic rice, the direct seeding was done through seed drill using a seed rate of 20 kg/ha. The field was kept wet (not flooded). The RDF (N, P, K) were applied through urea, single super phosphate and potassium chloride (muriate of potash). SRM contained 0.05, 5.5, 1.3, 0.0026 and 1.2% P, K, Mg, S and Ca, respectively (SRM 2019). The SRM was broadcasted at basal one day before seeding and transplanting. Weeds were managed with a pre-emergence spray of pretilachlor @ 0.75 kg/ha followed by post-emergence application of bispyribac-sodium @ 20 g/ha. General recommendations for the crop were followed for performing all other agronomic practices excluding the treatments. Observations on plant growth parameters (plant height, no. of tillers, dry matter accumulation, leaf area index), yield attributes (no. of panicles/m², no. of grains/panicle, 1000-grain weight), grain and straw yield, harvest index, hulling % and protein content were taken as per standard procedures.

RESULTS AND DISCUSSION

Growth parameters: Data pertaining to growth parameters of rice are presented in Table 1 and 2. The plant height was not affected significantly by different nutrient application sources. However, application of SRM @ 250 kg/ha + 100% RDF produced significantly higher growth attributes of transplanted and aerobic rice viz., tillers/m², dry matter accumulation, root dry matter and LAI as compared to only SRM application @ 250 kg/ha during 2016 and 2017, respectively. Although tillers/m² remained statistically on par with all treatment except only SRM 250 kg/ha during both the year, while same trend was observed with dry matter accumulation also in transplanted as well as aerobic rice. Next to that, application of SRM @ 250 kg/ha + 100% RDF produced significantly higher root dry matter and mean LAI (31.01 to 36.14%), which was on par with application of SRM + 50% RDF and only SRM 250 kg/ha. Moreover, lowest growth attributes were measured in only SRM 250 kg/ha during both the years of experimentation. The higher values of growth attributes might be associated with increased availability of all essential nutrient due to application SRM and chemical fertilizers. Balanced crop nutrition plays an important role in rapid cell division and elongation in meristematic plant tissues, growth, photosynthesis, and protein synthesis responsible for quantitative increase in plant growth (Panwar, 2008 and Manasa *et al.* 2015).

Yield attributes: Different levels of plant nutrition applied in rice affected all these parameters significantly in both the years (Table 3 and 4). Application of SRM @

Table 1 Effect of Safe rock minerals application on growth parameters of rice in rice-wheat cropping system

Treatment	Plant height (cm)				Tillers/m ²				Dry matter (g)			
	Aerobic rice		Transplanted rice		Aerobic rice		Transplanted rice		Aerobic rice		Transplanted rice	
	2016	2017	2016	2017	2016	2017	2016	2017	2016	2017	2016	2017
No SRM + 100% RDF	111.3	111.7	112.1	113.7	331.6	333.1	336.78	338.5	35.2	35.9	36.1	37.1
Only SRM 250 kg/ha	105.1	106.4	108.3	109.4	314.7	315.8	319.0	320.1	27.1	28.1	28.3	28.5
SRM + 50% RDF	109.1	110.5	110.6	111.9	326.5	327.9	330.6	332.5	32.5	32.8	33.1	34.2
SRM + 100% RDF	112.7	113.6	113.6	114.6	348.3	350.7	351.9	355.8	37.0	37.1	37.3	38.1
SRM + 50% RDF (chemical) + 25%RDF (organic)	110.3	110.9	111.9	112.5	330.0	330.2	334.7	336.6	35.0	35.0	35.1	36.2
SRM + 50% RDF (organic)	109.3	110.0	110.9	111.7	327.7	328.9	333.5	335.3	32.16	33.11	34.0	34.1
SEm±	3.85	3.88	3.92	3.96	8.12	8.22	8.87	8.94	2.78	2.84	2.97	3.12
LSD (P=0.05)	NS	NS	NS	NS	28.55	29.55	28.88	29.67	8.45	8.64	8.87	9.21

RDF: Recommended dose of fertilizer; SRM: Safe rock mineral; DAS: Day after sowing; DAT: Day after transplanting

Table 2 Effect of Safe rock minerals application on growth parameters of rice in rice-wheat cropping system

Treatment	Root dry matter (g/plant)				Leaf area index (LAI)			
	Aerobic rice		Transplanted rice		Aerobic rice		Transplanted rice	
	2016	2017	2016	2017	2016	2017	2016	2017
No SRM + 100% RDF	7.84	8.12	8.21	8.43	4.35	4.45	4.51	4.87
Only SRM 250 kg/ha	5.40	5.78	5.17	5.32	3.11	3.21	3.12	3.18
SRM + 50% RDF	6.21	6.67	6.85	6.93	3.94	4.12	3.85	3.92
SRM + 100% RDF	8.23	8.56	8.65	8.78	4.53	4.63	4.89	4.98
SRM + 50% RDF (chemical) + 25%RDF (organic)	7.71	7.98	8.00	8.35	4.32	4.42	4.43	4.78
SRM + 50% RDF (organic)	7.64	7.85	7.90	8.12	4.26	4.32	4.20	4.43
SEm±	0.42	0.45	0.50	0.44	0.11	0.13	0.25	0.20
LSD (P=0.05)	1.10	1.30	1.40	1.32	0.30	0.36	0.72	0.60

RDF: Recommended dose of fertilizer; SRM: Safe rock mineral; DAS: Day after sowing; DAT: Day after transplanting

250 kg/ha + 100% RDF produced significantly higher yield attributes of transplanted and aerobic rice viz., number of panicle/m², panicle length, panicle weight, grains/panicle and test weight during 2016 and 2017, respectively. However, number of panicle/m², panicle length and test weight remained on par to No SRM + 100% RDF, SRM + 50% RDF (chemical) + 25%RDF (organic) and SRM + 50% RDF (organic) only, whereas panicle weight and grains/panicle to all treatments except only SRM 250 kg/ha and significantly superior to rest of the level. The lowest yield attributes were measured only in SRM 250 kg/ha during both the year of study. It might be due to better effect of integrated application of inorganic and organic sources on the adequate nutrients supply for longer period, which will affects crop growth and photosynthetic activity. Similar results were reported by other researchers (Sharma et al. 2013, Kokani et al. 2014).

Yield and harvest index: Integrated use of organic manures and inorganic fertilizers sources are effective in

arresting the deterioration in productivity. In the present study, generally grain and straw yields were higher during the second year as compared to the first year. Yields and harvest index also varied significantly due to increment of fertility level and reached maximum in SRM @ 250 kg/ha + 100% RDF during both the year of study (Table 5 and 6). Although grain yield, biological yield and harvest index remained statistically on par with No SRM + 100% RDF, SRM + 50 % RDF (chemical) + 25 % RDF (organic) and SRM + 50 % RDF (organic) during both the years. Next to that, straw yield was on par with all treatment except only SRM 250 kg/ha. The minimum yields and harvest index were recorded in SRM 250 kg/ha during both the years of investigation. This may be attributed to better utilization of applied nutrients through the activities of soil micro-organisms which involved in nutrient transformation and fixation (Powar and Mehta, 1997) and also the transport of nutrients from organic sources influences the nutrient availability to the crop plants as well as the potential for

Table 3 Effect of safe rock minerals application on yield attributes of transplanted rice in rice-wheat cropping system

Treatment	2016					2017				
	No. of panicle/ m ²	Panicle length (cm)	Panicle weight (g)	Grains/ panicle	Test weight (g)	No. of panicle/ m ²	Panicle length (cm)	Panicle weight (g)	Grains/ panicle	Test weight (g)
No SRM + 100% RDF	307.7	32.2	2.50	75.4	29.0	310.3	33.8	2.76	84.7	30.1
Only SRM 250 kg/ha	279.7	27.0	2.22	65.7	26.3	283.7	28.6	2.34	71.3	27.1
SRM + 50% RDF	293.2	29.3	2.31	71.8	27.6	297.9	30.8	2.47	76.4	28.1
SRM + 100% RDF	319.7	33.3	2.74	77.3	29.4	327.6	34.2	2.81	86.1	30.9
SRM + 50% RDF (chemical) + 25%RDF (organic)	303.6	32.0	2.41	74.2	28.7	308.8	32.6	2.67	80.3	30.0
SRM + 50% RDF (organic)	298.3	31.2	2.32	72.4	27.2	305.3	31.8	2.58	79.0	29.1
SEm±	7.12	1.02	0.16	2.85	0.68	7.58	1.16	0.17	2.92	0.77
LSD (P=0.05)	22.06	3.12	0.47	7.41	1.91	22.52	3.45	0.49	9.87	1.98

RDF: Recommended dose of fertilizer; SRM: Safe rock mineral; DAT: Day after transplanting; DAS: Day after sowing

Table 4 Effect of safe rock minerals application on yield attributes of aerobic rice in rice-wheat cropping system

Treatment	2016					2017				
	No. of panicle/ m ²	Panicle length (cm)	Panicle weight (g)	Grains/ panicle	Test weight (g)	No. of panicle/ m ²	Panicle length (cm)	Panicle weight (g)	Grains/ panicle	Test weight (g)
No SRM + 100% RDF	295	33.0	2.80	85.2	29.2	300	34.1	2.70	82.4	29.2
Only SRM 250 kg/ha	266	27.5	2.16	67.1	25.4	276	28.3	2.23	67.1	25.3
SRM + 50% RDF	281	30.1	2.39	78.3	28.7	285	31.4	2.42	75.8	27.7
SRM + 100% RDF	300	34.3	3.01	87.5	30.4	311	35.6	2.78	84.4	30.4
SRM + 50% RDF (chemical) + 25%RDF (organic)	291	32.6	2.71	84.6	28.4	306	33.7	2.62	79.3	28.5
SRM + 50% RDF (organic)	288	31.1	2.44	81.2	27.7	293	32.1	2.54	76.2	28.0
SEm±	7.4	1.33	0.22	2.92	0.94	7.7	1.46	0.02	2.96	0.98
LSD (P=0.05)	17.6	3.32	0.65	8.25	2.91	24.4	3.57	0.40	8.57	3.04

higher production (Singh et al. 1997). Moreover, organic manures, viz. SRM has the essential plant nutrients and other growth promoting substances like enzymes and hormones, while no synthetic fertilizer can supply all together. Yield enhancement in cereal crops due to integrated plant nutrient supply and balance nutrition was also reported by Bana et al. 2012; Kandeshwari et al. 2012 and Bana et al. 2016. Hence, integrated use of organic and inorganic fertilizers can make important contribution to increasing and sustaining rice production.

Quality parameters: The effect of different nutrient levels applied to rice was non-significant with respect to milling and hulling % in transplanted and aerobic rice during the both years (Table 7). However, during both the years of investigation, significantly higher protein content was recorded with application of SRM @ 250 kg/ha + 100% RDF, which remained statistically on par with all treatment except only SRM 250 kg/ha during 2016. But in 2017, it was on par with No SRM + 100% RDF, SRM + 50 % RDF (chemical) + 25 % RDF (organic) and SRM + 50 % RDF (organic). Moreover, lowest protein content was observed under the only SRM 250 kg/ha. This may be ascribed to

intense protein synthesis in plant and its efficient storage in the presence of abundant supply of available nutrients through SRM and inorganic (Bana et al. 2016). The easy availability of nutrients leads to balanced C: N ratio which enhanced the vegetative growth of plant resulting in high photosynthetic activity. Which finally out yielded better protein content in plant and higher grain yield which in turn improved the protein yield. The results of present investigation corroborate with the findings of Pathak et al. 2002 and Sharma et al. 2013.

Nutrient content and uptake: Higher N, P and K concentrations and uptakes were recorded in transplanted rice comparison to aerobic rice (Fig 1 and 2). In both the years, nutrient concentration in rice grain was significantly higher with SRM @ 250 kg/ha + 100% RDF over only SRM 250 kg/ha. Nutrient uptake in rice grain was influenced significantly by various nutrient concentration of RDF with SRM during both the years. Higher uptake was recorded with application of SRM @ 250 kg/ha + 100% RDF, which remained statistically on par with all treatment except only SRM 250 kg/ha. Moreover, nutrient content was observed under the only SRM 250 kg/ha. This may be because of the

Table 5 Effect of safe rock minerals application on yield and harvest index of transplanted rice in rice-wheat cropping system

Treatment	2016				2017			
	Grain yield (t/ha)	Straw yield (t/ha)	Biological yield (t/ha)	Harvest index (%)	Grain yield (t/ha)	Straw yield (t/ha)	Biological yield (t/ha)	Harvest index (%)
No SRM + 100% RDF	5.14	17.12	22.26	23.09	5.21	17.22	22.43	23.22
Only SRM 250 kg/ha	3.57	15.21	19.01	18.04	3.65	15.36	19.01	19.20
SRM + 50% RDF	4.19	16.29	20.48	20.46	4.34	16.61	20.95	20.71
SRM + 100% RDF	5.35	17.41	22.76	23.50	5.44	17.65	23.09	23.55
SRM + 50% RDF (chemical) + 25% RDF (organic)	4.87	17.02	21.89	22.24	5.18	17.18	22.36	23.16
SRM + 50% RDF (organic)	4.44	17.01	21.55	20.60	5.11	17.06	22.17	23.04
SEm±	0.34	0.59	0.74	0.99	0.15	0.62	0.75	0.77
LSD (P=0.05)	0.96	1.61	2.13	2.97	0.44	1.87	2.10	2.41

RDF: Recommended dose of fertilizer; SRM: Safe rock mineral; DAT: Day after transplanting; DAS: Day after sowing

Table 6 Effect of safe rock minerals application on yield and harvest index of aerobic rice in rice-wheat cropping system

Treatment	2016				2017			
	Grain yield (t/ha)	Straw yield (t/ha)	Biological yield (t/ha)	Harvest index (%)	Grain yield (t/ha)	Straw yield (t/ha)	Biological yield (t/ha)	Harvest index (%)
No SRM + 100% RDF	4.62	15.88	20.5	22.53	4.87	16.43	21.3	22.86
Only SRM 250 kg/ha	3.36	14.24	17.6	19.09	3.43	15.21	18.64	18.40
SRM + 50% RDF	3.82	15.15	18.97	20.13	3.97	15.65	19.62	20.23
SRM + 100% RDF	4.84	15.95	20.79	23.28	5.06	16.98	22.04	22.95
SRM + 50% RDF (chemical) + 25% RDF (organic)	4.59	15.74	20.33	22.57	4.76	16.32	21.08	22.58
SRM + 50% RDF (organic)	4.15	15.50	19.65	21.11	4.62	16.11	20.73	22.28
SEm±	0.27	0.46	0.59	0.75	0.18	0.49	0.74	0.83
LSD (P=0.05)	0.79	1.42	1.73	2.28	0.51	1.21	2.21	2.34

Table 7 Effect of safe rock minerals application on different quality parameters of rice in rice-wheat cropping system

Treatment	Aerobic rice						Transplanted rice					
	2016			2017			2016			2017		
	Milling %	Hulling %	Protein content (%)	Milling %	Hulling %	Protein content (%)	Milling %	Hulling %	Protein content (%)	Milling %	Hulling %	Protein content (%)
No SRM + 100% RDF	53.1	64.7	7.79	54.2	64.9	8.21	54.3	66.1	8.21	54.5	66.4	8.64
Only SRM 250 kg/ha	51.6	61.7	6.66	52.1	62.3	6.90	52.7	63.1	7.02	52.8	63.5	7.19
SRM + 50% RDF	52.0	62.1	7.14	52.7	63.1	7.49	53.1	64.1	7.79	53.5	64.7	7.85
SRM + 100% RDF	54.6	65.0	7.85	54.9	65.1	8.38	55.7	67.1	8.46	55.8	66.9	8.89
SRM + 50% RDF (chemical) + 25% RDF (organic)	53.0	64.3	7.61	54.1	64.7	8.03	53.7	65.6	7.97	54.3	66.1	8.44
SRM + 50% RDF (organic)	52.6	63.7	7.43	53.9	64.6	7.79	53.1	64.7	7.87	54.0	65.3	8.21
SEm±	1.41	1.93	0.25	1.52	2.12	0.26	1.46	2.1	0.26	1.56	2.23	0.28
LSD (P=0.05)	NS	NS	0.76	NS	NS	0.78	NS	NS	0.78	NS	NS	0.79

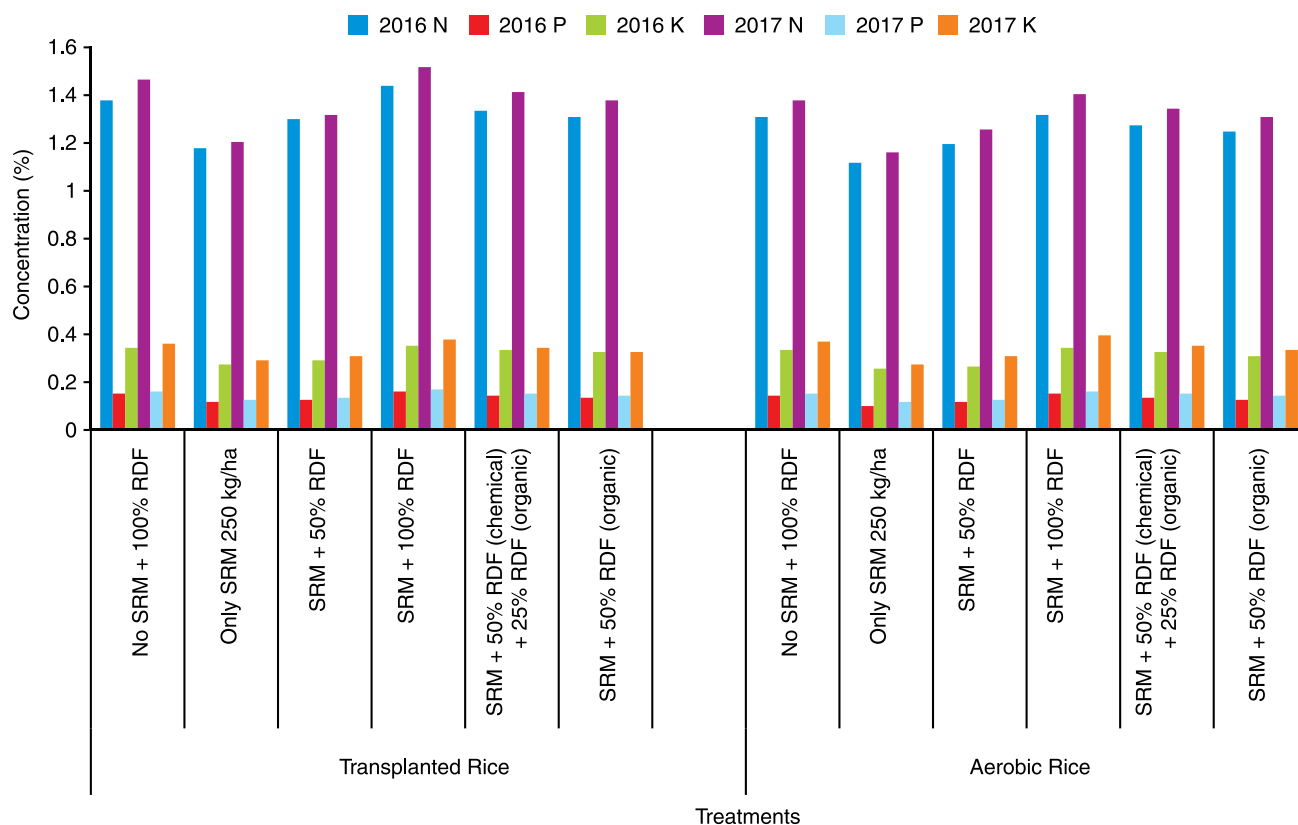


Fig 1 Effect of SRM application on N, P, K concentration in grain of transplanted and aerobic rice.

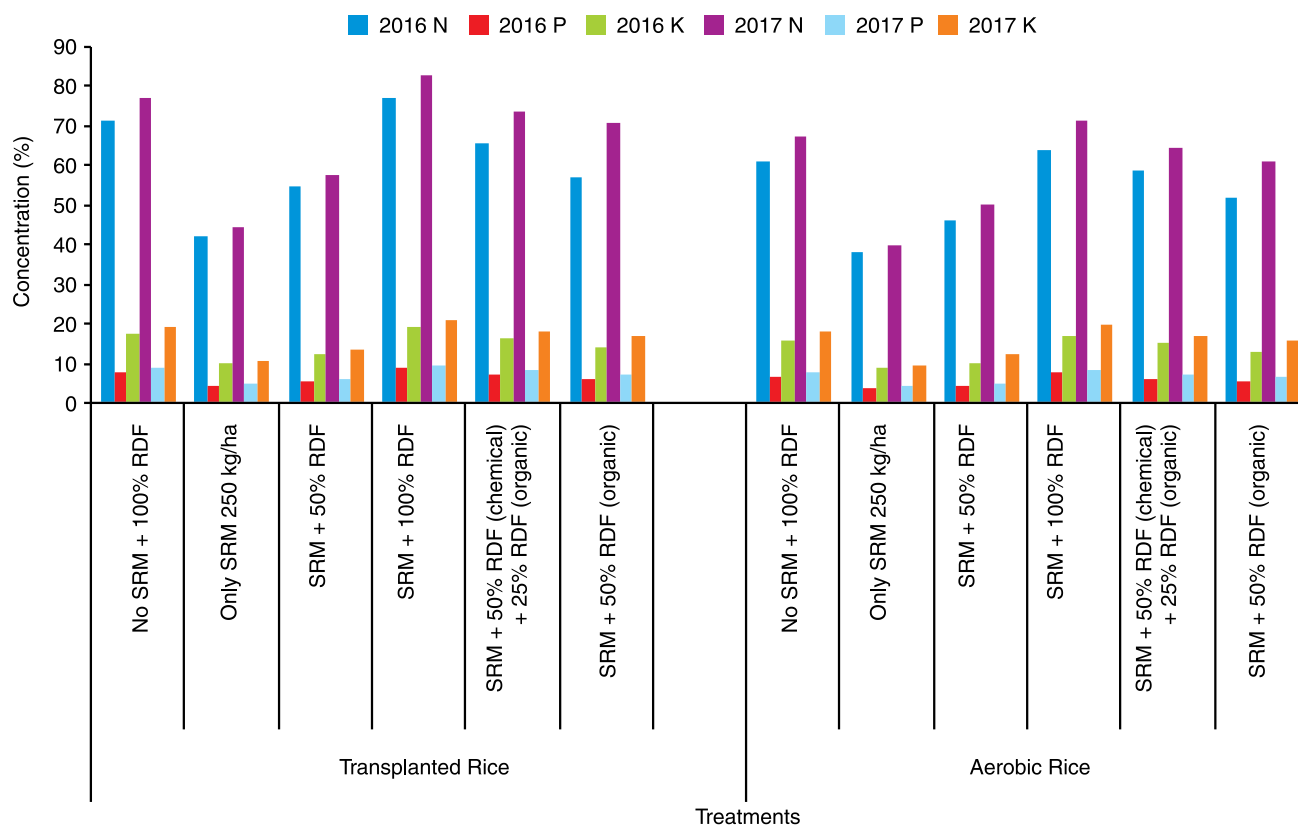


Fig 2 Effect of SRM application on N, P, K uptake in grain of transplanted and aerobic rice.

fact that increased availability of all essential nutrient due to application SRM and chemical fertilizers. Results have shown that the nutrient efficiency of the soil has improved, which is responsible for the high nutrient uptake in grain (Manasa et al. 2015).

In the present study, it was concluded that integrated nutrient management using appropriate combination of natural minerals and chemical fertilizers may be a suitable option to enhance the growth and yield of transplanted as well as direct seeded rice. Considering all the parameters, it was proved that the integrated application of 250 kg SRM + 50% organic-FYM was an excellent source for plant growth and crop productivity of rice, however the highest yield was observed in 250 kg SRM + 100% RDF. Therefore, 250 kg SRM + 50% organic-FYM may be recommended for rice in rice-wheat cropping system of Indo-Gangetic plains.

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