The Pharma Innovation Journal 2021; 10(12): 1989-1995

www.ThePharmaJournal.com

The Pharma Innovation

ISSN (E): 2277- 7695
ISSN (P): 2349-8242
NAAS Rating: 5.23
TPI 2021; 10(12): 1998-1995

www.thepharmajournal.com
Received: 19-09-2021
Accepted: 29-11-2021

BK Farkade
Ph.D., Student and Assistant Professor of Agronomy, Oilseeds Research Unit, Dr. PDKV, Akola, Maharashtra, India

Dr. VM Bhale
Hon'ble Vice-Chancellor, Dr. PDKV, Akola, Maharashtra, India

Dr. VK Kharche
Director of Research, Dr. PDKV, Akola, Maharashtra, India

Dr. BV Saoji
Associate Dean, LAE and Professor of Agronomy Dr. PDKV, Akola, Maharashtra, India

Dr. MR Deshmukh
Assistant Professor, Department of Agronomy, Dr. PDKV, Akola, Maharashtra, India

Corresponding Author:
BK Farkade
Ph.D., Student and Assistant Professor of Agronomy, Oilseeds Research Unit, Dr. PDKV, Akola, Maharashtra, India

Effect of soil and foliar application of Fe and Mn on yield, nutrient content and uptake by upland rice varieties

BK Farkade, Dr. VM Bhale, Dr. VK Kharche, Dr. BV Saoji and Dr. MR Deshmukh

Abstract
An investigation entitled "Effect of soil and foliar application of Fe and Mn on nutrient content and uptake by upland rice varieties" was carried out during *Kharif* 2017 and 2018 at Department of Agronomy, Dr. Panjabrao Deshmukh Krishi Vidyapeeth, Akola in *kharif* season. Three upland paddy varieties were tested with seven nutrients levels applied in soil as well as by foliar application of Fe and Mn at flowering and dough stage. The experiment was conducted in factorial randomized block design with three replications. Half dose of N with full dose of P & K along with 25kg Fe and 5 kg Mn was applied at the time of sowing in soil. The remaining quantity of N was applied one month after sowing. Foliar application of Fe and Mn was done at flowing and dough stage for upland rice. Result revealed that, maximum grain yield (3223kg ha^{-1} and 3520 kg ha^{-1}), straw yield (6858 kg ha^{-1} and 7037 kg ha^{-1}) and biological yield (10082 kg ha^{-1} and10556 kg ha^{-1}) were recorded by variety Avishkar and found significantly superior over other varieties. Among the treatments, the application of RDF with $FeSO_4$ + $MnSO_4$ (25+5 kg ha^{-1}) in soil recorded significantly higher grain yield (2880 kg ha^{-1} and 3469 kg ha^{-1}) of rice and straw yield, biological yield as well as harvest index. It was found at par with alone application of $FeSO_4$, $MnSO_4$ with RDF in soil as well as RDF + Foliar spray of $FeSO_4$ @ 1.0% and $MnSO_4$ @ 0.5% at flowering and dough stage during 2017 and at par with RDF + FeSO4 @ 25 Kg ha^{-1} (N_2) during 2018. Significantly increased the N, P, K, Fe and Mn contents in grain and straw were observed by combine application of Fe and Mn in soil with RDF. With respect to nutrient uptake, significantly higher uptake of N, P, K, Fe and Mn by grain and straw was registered in Variery Avishkar with combine application of Fe and Mn with RDF in soil. Several workers have reported that, the combine role of Fe and Mn in plant nutrition is much more important than their individual roles (Karim & Mohsin, 1964). Response to growth Fe and Mn in growth and nutrition of the rice plant has been reported (Chiu, 1967, Alam 1982).

Keywords: Upland rice, Fe, Mn, Micronutrients, nutrient content and uptake

Introduction
Rice (*Oryza sativa* L.), the staple food of more than three billion people in the world, is cultivated under diverse ecosystems ranging from irrigated to *rainfed upland* to *rainfed lowland* to deep water. In Eastern Vidarbha region of Maharashtra, rice is majorly grown by puddled transplanting method, which is laborious and costly method. Hence, the study has been undertaken to find out the effect of drilled rice with soil and foliar application of Fe and Mn on nutrient content and uptake by upland rice varieties. However increasing cost of fertilizers has necessitated improving the efficiency of applied nutrients, supplementation of micro-nutrients in different combinations with RDF. Beside, increasing productivity of rice supplementation of micronutrients overcome certain malnutrition problems in dietary system of human being. Therefore, it becomes essential to undertake an investigation on agronomic biofortification of rice with Fe and Mn as Vital elements and to undertake study to test its content and availability in both i.e. in plant and in soil so as to provide a new to grow fortified rice cultivars in clayey soil of this region under aerobic (upland) condition in drilled method of sowing.

Micronutrients are essential mineral elements required for both plant and human development. However, micronutrients are often lacking in soils, crop, and food. Rice however is a poor source of many essential minerals nutrients, especially iron (Fe) and Manganese (Mn). For human nutrition Fe help in production of hemoglobin in human blood, which carries oxygen around the body; moreover the immune system to needs Fe to work well. Manganese nutrition is crucial for human health as well. For instance, Mn is vital for neurotransmitter synthesis (Golub *et al.* 2005) [5], brain functioning and reproduction (Greger 1999) [6] in humans, even its mild deficiency may cause anorexia, weakness and apathy (Huang *et al*. 1989) [8]. Iron plays a vital role in the formation of chlorophyll and takes part in oxidation-reduction reactions involved in ribonucleic acid (RNA) metabolism of the chloroplast, It is a constituent of the enzyme ferridoxin and cytochromes and is involved in symbiotic nitrogen (N)-fixation in the synthesis of several metalloenzymes, carbohydrate metabolism and protein synthesis. Fe and manganese (Mn) have essential metabolic roles in plants. There are several potential approaches to increase the concentration of Fe and Mn in staple foods, which include food biofortification either by plant breeding (genetic bio fortification) or by the use of micronutrient fertilizers (agronomic biofortification). The deficiency of Mn has rarely been observed in flooded rice; nonetheless, it has been reported in direct seeded aerobic rice (DSAR) systems (Snyder *et al*. 1990) [24], owing to oxidation of $Mn^{2+,}$ which results in precipitation of the oxides of Mn^{3+} and Mn^{4+} which are unavailable to plants (Tao *et al*. 2006) [27], especially under high soil pH conditions. Manganese (Mn) and Iron (Fe) are essential micronutrients for almost all living organisms including plants. Mn is required as a cofactor or activator for enzymes belonging to different functional groups which perform diverse functions. The deficiencies may be ameliorated by both soil and foliar applications of inorganic salts or chelated forms of the elements. Keeping in view, an experiment was conducted to study the effect of soil and foliar application of Fe and Mn on nutrient content and uptake by upland rice varieties.

Material and Methods

Experimental site

A field experiment was carried out at Agronomy Farm, Department of Agronomy, Dr. Panjabrao Deshmukh Krishi Vidyapeeth, Akola during *kharif season* of 2017-18 and 2018-19 in neutral to slightly alkaline clayey soil (pH 7.81, Ec 0.37 dSm^{-1}), medium in organic matter (0.51%), low in available nitrogen, phosphorus, Fe and Mn (209.5, 16.5 kg ha^{-1} and 4.06, 8.46 mg Kg^{-1}). Akola is situated in subtropical region between 22.42ºN latitude and 77.02º E longitude at an altitude of 307.42 m above the mean sea level. The climate of Akola is semi-arid and characterized by three distinct seasons i.e. hot and dry summer from March to May, warm humid and rainy monsoon from June to October and mild cold winter from November to February.

Testing variables and experimental method

The testing variables consisted of three varieties i.e. Kamesh (CR Dhan 40), Avishkar (PBNR-93-1) and Sindewahi-1 (Sye-1) and seven combination of nutrient sources recommended dose of fertilizers (NPK) with Fe and Mn levels. The experiment was replicated trice and was laid out in factorial randomized block design. The doses of nutrients applied to rice were 100:50:50 kg N, P_2O_5 and K_2O kg ha^{-1}. Full does of phosphorus, potassium, ferrous and manganese were applied before sowing as basal and half does of nitrogen was applied at 30 DAS. Also the foliar spray of $FeSO_4$ @ 1.0% and $MnSO_4$ @ 0.5% was sprayed at flowering and dough stage. Five plants were selected randomly and tagged in each treatment at plot for recording non-destructive sampling parameters like plant height, leaf area etc. Similarly, at each sampling interval five plants were uprooted for destructive sampling *viz*, leaf area, and dry matter from two rows on either side. The grain quality parameter such as protein and carbohydrate content and micronutrient content were measured in the micronutrients and biochemistry section of Department of soil science and Agricultral Chemistry, Dr. PDKV, Akola. The iron and manganese content in grain sample was determined by using Atomic Absorption Spectrophotometer after keeping the samples on the hot plate (Lindsay and Norvell, 1978) [17]. The nitrogen (N), Phosphorus (P) and potassium (K) contents thus obtained were expressed in percentage. The uptake of N, P and K by rice was computed and expressed in kg ha^{-1} as follows.

Statistical analysis

The experiment was laid out in Factorial Randomized Block design (FRBD) with three replications. The data was analyzed statistically by following the procedure outlined by Panse and Sukhatme (1967) [19].

Results and Discussion

Results

Upland rice varieties

From the data of table 1, 2, 3, it was revealed that, amongst the varieties, cv. Avishkar found superior in respect of grain yield, straw yield, biological yield and harvest index. The protein content of rice grain was significantly affected by different rice varieties during 2017-18; however it was not significantly affected by the different varieties during 2018-19. Variety Avishkar recorded higher protein content (8.15 and 8.34%) than other two varieties. However, variety Kamesh and Sye-1 was found at par with each other in respect of protein content during 2017-18.

Protein content of rice varieties was influenced significantly during both the years. Maximum protein yield (262 and 295 kg ha^{-1}) was produced in the variety Avishkar (V_2) which was found significantly superior over rest of the varieties, whereas, variety Kamesh (V_1) and Sye-1 (V_3) was statistically comparable with each other during 2018-19. Similar result was achieve by Gritta Elizabeth Jolly *et al*., (2018), who reported that among the varieties, the variety Avishkar was found to perform the best in terms of yield attributes like number of panicle, weight of panicle, number of filled spikelet's and the test weight which resulted to high grain yield. Higher yields can be obtained by physiological process involving high accumulation of photosynthates and their partitioning.

Among the three varieties, variety Avishkar produced maximum carbohydrate content (68.48% and 66.81%) which found was significantly superior over Kamesh and Sindewahi-1 during both the year of experimentation. The lowest carbohydrate content was recorded in the variety Sindewahi-1 (61.71 and 61.57%) during both years of study.

During both the year of experiment NPK content of variety Avishkar was significantly superior over variety Kamesh and Sye-1. However, lowest N content was recorded by the variety Sye-1 and lowest PK recorded in variety Kamesh. This was due to the different nature in genotypic characters. During second year of experiment, Mn content of variety Avishkar was significantly superior over variety Sye-1. However, variety Kamesh was statistically at par with each other. During both year of experiment Iron content was not statistically differed. This was due to the genotypic make of varieties.

Effect of Nutrients

Among the nutrient level, combine application of Fe and Mn along with RDF in soil recorded significantly highest grain yield, straw yield, biological yield and harvest index. The higher protein content (8.37 and 8.96%) was obtained due to the application of RDF + $FeSO_4$ @ 25 Kg ha^{-1} and $MnSO_4$ @ 5 Kg ha^{-1}. Data clearly showed that application RDF + $FeSO_4$ @ 25 Kg ha^{-1} and $MnSO_4$ @ 5 Kg ha^{-1} in soil recorded highest protein yield (243 and 310 kg ha^{-1} during 2017 and 2019) of grain and it remained significantly superior to other doses. Maximum content of carbohyadrate (67.78 and 70.33%) was recorded by the combine application of $FeSO_4$@ 25 Kg ha^{-1} and $MnSO_4$ @ 5 Kg ha^{-1} with RDF in soil. The carbohydrate yield was also significantly influenced due to combine application of @ 25 Kg ha^{-1} and $MnSO_4$ @ 5 Kg ha^{-1} with RDF in soil and explored highest carbohydrate yield (1971 and 2444 kg ha^{-1}) was comparable with alone application of $FeSO_4$ with RDF than control (RDF), manganese application and foliar application of micronutrients Fe and Mn during 2017-18. Similar trend was observed during 2018-19. Data clearly revealed that combine application of Fe and Mn (25+5 kg ha^{-1}) with RDF registered the maximum N, P and K content in grain which remained significantly superior to other doses. Combine application of Fe and Mn (25+5 kg $ha^{-1)}$ with RDF registered the maximum Fe and Mn content in grain and straw which remained significantly superior to other doses which was followed by alone application of Fe @ 25 kg ha^{-1} with RDF.

Uptake of nitrogen, phosphorus, potassium, iron and manganese were recorded by variety Avishkar followed by the variety Kamesh and Sindewahi-1. However, Application of Fe + Mn + RDF recorded significantly highest uptake of NPK, Fe and Mn in both year of experiment. Combine application of $FeSO_4$ @ 25 Kg ha^{-1} and $MnSO_4$ @ 5 Kg ha^{-1} with RDF recorded significantly highest yield with variety Avishkar.

Interaction

The interactions were not significant in respect of all parameters during both the years of study due to diverse genotypes and nutrients.

Discussion

These results are substantiated by the findings of the study Ashok Kumar *et.al*., (2017), he reported that zinc @ 10 kg ha^{-1}, iron 15 kg ha^{-1} and manganese 5 kg ha^{-1} recorded the maximum yield of rice. Iron and manganese are needed for chlorophyll synthesis and activities of numerous enzymes in plant system (Evans and Sorger, 1966) [4], Karim and Alam (1967) [15] have reported that, combine role of Fe and Mn is much more important than their individual role in nutrition of rice plant. The application of Fe might have increased the vigour, photosynthate accumulation and better translocation of photosynthates to the sink (Kanda and Dixit, 1995) [13]. The higher protein content in grain due to Fe application might be attributed to the enhanced activity of nitrite and nitrate reductase enzyme as Fe is a constituent of these enzymes. Rice protein is the most nutritious among the cereal proteins, but its major limitation is its lower availability (7-8%) because of major loss in milling (Ahamed, Boura and Das, 1998) [1]. Hamideh Ghaffari and Jamshid Razmjoo (2013) [7] reported that, highest 1000 grain weight, harvest index, grain and grain carbohydrate yields of wheat were produced by application of iron sulphate followed by application of nano iron oxide. Somers and Shive (1942) [25] suggested that, the physiological availability of iron in plants is determined by the relative manganese supply.

The concentration of N, P, K, Fe and Zn in grain and straw increased significantly by the application of Fe (Singh *et al*. 2004). Combination of Fe and Mn with RDF might have increased the use efficiency of added nutrients and supply it continuously to the plant throughout the crop growth. In aerobic conditions, Fe is highly unavailable for the plant uptake and Fe deficiency can be severe in plants grown in calcareous soils. Iron has structural role in chlorophyll formation and photosynthesis (Rawashdeh and Sala, 2015) [20]. Lingle *et al*. (1963) [16] reported that Mn interfere with Fe uptake and transport when Fe and Mn were at equimolar concentrations. These finding are in accordance with S.M. Alam (1985) [22].

The increase in NPK, Fe and Mn uptake by the crop was associate with a corresponding increase in grain and straw yields of the crop (Meena and Bhaskaran, 2005, Ramaiah et. al., 1986) [18, 21]. The beneficial effect of micronutrient combination Zn+Fe+Mn could be attributed to the synergistic effect between these nutrients and the continuous and enhanced supply of nutrient in a balance proportion, which led to higher nutrient uptake (Shanmugam and Veeraputhran, 2000) [23].

Fig 1: General view of Trial 2018-19 and foliar spraying

Table 1: Grain yield (kg ha^{-1}), straw yield (kg ha^{-1}), biological yield (kg ha^{-1}) and harvest index (%) of upland irrigated rice as influenced by different treatments during 2017-18 and 2018-19

Treatments	Grain yield (kg ha^{-1})			Straw yield (kg ha^{-1})			Biological yield (kg ha^{-1})		Harvest Index (%)		
A) Varieties (V)	**17-18**	**18-19**	**Pooled**	**17-18**	**18-19**	**Pooled**	**17-18**	**18-19**	**17-18**	**18-19**	**Avg**
V_1 - Kamesh (CR Dhan 40)	2256	2872	2564	3941	4894	4382	6197	7766	36.40	36.98	36.69
V_2 - Avishkar (PBNR 93-1)	3223	3520	3371	6858	7037	6952	10082	10556	31.97	33.35	32.66
V_3 - Sindewahi-1 (Sye-1)	1736	2640	2188	3069	4933	3875	4805	7572	36.13	34.87	35.50
SE (m) ±	99	131	82	228	216	177	270	334	--	--	--
CD (P=0.05)	282	375	233	653	619	506	772	953	--	--	--
B) Nutrients (N)											
N_1 - RDF (100:50:50) NPK kg ha^{-1}	1925	2438	2181	3599	4533	4066	5523	6971	34.85	34.97	34.91
N_2 - RDF + $FeSO_4$ @ 25 Kg ha^{-1}	2607	3381	2994	5435	6413	5710	8042	9795	32.42	34.52	33.47
N_3 - RDF + $MnSO_4$ @ 5 Kg ha^{-1}	2558	3078	2818	4674	5754	5199	7107	8765	35.99	35.12	35.55
N_4 - RDF + Foliar spray of $FeSO_4$ @1.0% at flowering and dough stage	2284	2921	2602	4201	5233	4708	6649	8144	34.35	35.87	35.11
N_5 - RDF + Foliar spray of $MnSO_4$ @ 0.5% at flowering and dough stage	2093	2793	2443	3993	5196	4627	6088	7989	34.38	34.96	34.67
N_6 - RDF + Foliar spray of $FeSO_4$ @ 1.0% and $MnSO_4$ @ 0.5% at flowering and dough stage	2488	2993	2740	4518	5547	4864	6965	8606	35.72	34.78	35.25
N_7 - RDF + $FeSO_4$ @ 25 Kg ha-1and $MnSO_4$ @ 5 Kg ha-1 (Soil application)	2880	3469	3175	5941	6680	6311	8821	10149	32.65	34.18	33.42
SE (m) ±	150	200	125	349	331	271	412	510	--	--	--
CD (P=0.05)	430	573	356	997	946	774	1179	1456	--	--	--
C) Interactions (V x N)											
SE (m) ±	261	347	216	604	573	469	714	883	--	--	--
CD (P=0.05)	NS	NS	NS	NS	NS	NS	NS	NS	--	--	--
General Mean	2405	3010	2708	4422	5620	5069	7028	8631	34.22	34.87	34.55

Table 2: Protein content (%), protein yield (kg ha^{-1}), carbohydrate content (%) and carbohydrate yield (kg ha^{-1}) of upland irrigated rice cultivars as influenced by different treatments during 2017-18 and 2018-19

Treatments	2017-18				2018-19			
	Protein content (%)	**Protein yield (kg ha^{-1})**	**Carbohydrate content (%)**	**Carbohydrate yield (kg ha^{-1})**	**Protein content (%)**	**Protein yield (kg ha^{-1})**	**Carbohydrate content (%)**	**Carbohydrate yield (kg ha^{-1})**
A) Varieties (V)								
V_1 - Kamesh (CR Dhan 40)	7.82	177	62.95	1427	8.11	234	64.67	1870
V_2 - Avishkar	8.15	262	68.48	2213	8.34	295	66.81	2356
V_3 - Sindewahi-1 (Sye-1)	7.73	135	61.71	1075	8.20	218	61.57	1638
SE (m) ±	0.11	8.38	0.27	65.04	0.12	11.80	0.39	83.37
CD (P=0.05)	0.31	23.95	0.77	185.90	NS	33.75	1.11	238.30
B) Nutrients (N)								
N_1 - RDF (100:50:50) NPK kg ha^{-1}	7.49	145	61.33	1204	7.89	194	60.44	1492
N_2 - RDF + $FeSO_4$ @ 25 Kg ha^{-1}	8.20	214	66.33	1754	8.63	292	67.89	2302
N_3 - RDF + $MnSO_4$ @ 5 Kg ha^{-1}	7.85	192	65.11	1603	8.12	246	66.33	1993
N_4 - RDF + Foliar spray of $FeSO_4$ @1.0% at flowering and dough stage	7.70	189	63.11	1560	7.94	232	61.60	1811
N_5 - RDF + Foliar spray of $MnSO_4$ @ 0.5% at flowering and dough stage	7.94	170	63.12	1331	7.86	219	60.22	1693
N_6 - RDF + Foliar spray of $FeSO_4$ @ 1.0% and $MnSO_4$ @ 0.5% at flowering and dough stage	7.76	190	63.89	1580	8.11	249	63.56	1950
N_7 - RDF + $FeSO_4$ @ 25 Kg ha^{-1} and $MnSO_4$ @ 5 Kg ha^{-1} (Soil application)	8.37	243	67.78	1971	8.96	310	70.33	2444
SE (m) ±	0.16	22.80	0.41	99.35	0.19	18.04	0.59	127.35
CD (P=0.05)	0.47	36.58	1.18	283.97	0.53	51.56	1.69	364.01
C) Interactions (V x N)								
SE (m) ±	0.28	22.17	0.71	172.08	0.32	31.25	1.03	195.52
CD (P=0.05)	NS	NS	NS	NS	NS	NS	NS	NS
General Mean	7.89	191	64.38	1571	8.21	249	64.34	1954

Table 3: Nitrogen, Phosphorus, potassium, Iron and Manganese contents of rice grain as influence by various treatments during 2017-18 and 2018-19

Treatments	Nitrogen (%)		Phosphorus (%)		Potassium (%)		Iron (mg kg^{-1})		Manganese (mg kg^{-1})	
A) Varieties (V)	**2017**	**2018**	**2017**	**2018**	**2017**	**2018**	**2017**	**2018**	**2017**	**2018**
V_1 - Kamesh (CR Dhan 40)	1.25	1.30	0.25	0.26	0.34	0.35	232	243	64.13	65.77

V_2 - Avishkar	1.30	1.33	0.27	0.27	0.35	0.36	233	242	64.51	65.66
V_3 - Sindewahi-1 (Sye-1)	1.24	1.31	0.28	0.26	0.34	0.35	234	238	64.55	66.40
SE (m) ±	0.017	0.019	0.008	0.005	0.004	0.004	2.37	2.61	0.461	0.395
CD (P=0.05)	0.049	NS	0.022	NS	NS	NS	NS	NS	NS	NS
B) Nutrients (N)										
N_1 - RDF (100:50:50) NPK kg ha^{-1}	1.20	1.26	0.22	0.23	0.32	0.33	209	216	60.49	61.99
N_2 - RDF + $FeSO_4$ @ 25 Kg ha^{-1}	1.31	1.38	0.30	0.29	0.37	0.37	243	250	64.86	65.63
N_3 - RDF + $MnSO_4$ @ 5 Kg ha^{-1}	1.26	1.30	0.26	0.26	0.35	0.36	235	238	65.73	67.95
N_4 - RDF + Foliar spray of $FeSO_4$ @1.0% at flowering and dough stage	1.23	1.27	0.25	0.25	0.34	0.34	231	242	61.84	64.13
N_5 - RDF + Foliar spray of $MnSO_4$ @ 0.5% at flowering and dough stage	1.20	1.26	0.23	0.24	0.32	0.33	234	234	65.52	66.94
N_6 - RDF + Foliar spray of $FeSO_4$ @ 1.0% and $MnSO_4$ @ 0.5% at flowering and dough stage	1.24	1.30	0.28	0.26	0.35	0.35	233	252	64.08	65.72
N_7 - RDF + $FeSO_4$ @ 25 Kg ha^{-1} and $MnSO_4$ @ 5 Kg ha^{-1} (Soil application)	1.34	1.43	0.33	0.30	0.37	0.38	255	257	68.28	69.24
SE (m) ±	0.026	0.030	0.012	0.008	0.006	0.006	3.62	3.98	0.704	0.603
CD (P=0.05)	0.075	0.085	0.033	0.02	0.017	0.016	10.34	11.38	2.012	1.724
C) Interactions (V x N)										
SE (m) ±	0.046	0.051	0.020	0.013	0.010	0.010	6.27	6.89	1.219	1.045
CD (P=0.05)	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
General Mean	1.26	1.31	0.25	0.26	0.346	0.354	233.68	241.27	64.40	65.94

Table 4: Nitrogen, Phosphorus, potassium, Iron and Manganese contents of rice straw as influence by various treatments during 2017-18 and 2018-19

Treatments	**Nitrogen (%)**		**Phosphorus (%)**		**Potassium (%)**		**Iron (mg kg^{-1})**		**Manganese (mg kg^{-1})**	
A) Varieties (V)	**2017**	**2018**	**2017**	**2018**	**2017**	**2018**	**2017**	**2018**	**2017**	**2018**
V_1 - Kamesh (CR Dhan 40)	1.04	1.09	0.18	0.19	0.38	0.48	247	251	266	267
V_2 - Avishkar	1.10	1.10	0.20	0.22	0.48	0.54	247	252	266	270
V_3 - Sindewahi-1 (Sye-1)	1.01	1.07	0.18	0.20	0.43	0.45	243	252	259	263
SE (m) ±	0.01	0.01	0.003	0.004	0.01	0.02	1.82	1.80	1.95	1.93
CD (P=0.05)	0.03	0.04	0.009	0.013	0.04	0.05	NS	NS	5.57	5.52
B) Nutrients (N)										
N_1 - RDF (100:50:50) NPK kg ha^{-1}	1.02	1.04	0.19	0.19	0.43	0.49	232	239	250	250
N_2 - RDF + $FeSO_4$ @ 25 Kg ha^{-1}	1.02	1.11	0.19	0.22	0.43	0.49	252	256	264	264
N_3 - RDF + $MnSO_4$ @ 5 Kg ha^{-1}	1.05	1.06	0.18	0.21	0.39	0.45	240	248	268	271
N_4 - RDF + Foliar spray of $FeSO_4$ @1.0% at flowering and dough stage	1.05	1.08	0.18	0.21	0.41	0.47	244	249	260	263
N_5 - RDF + Foliar spray of $MnSO_4$ @ 0.5% at flowering and dough stage	1.06	1.09	0.18	0.20	0.41	0.46	244	246	269	273
N_6 - RDF + Foliar spray of $FeSO_4$ @ 1.0% and $MnSO_4$ @ 0.5% at flowering and dough stage	1.07	1.08	0.19	0.21	0.45	0.49	242	253	264	268
N_7 - RDF + $FeSO_4$ @ 25 Kg ha^{-1} and $MnSO_4$ @ 5 Kg ha-1 (Soil application)	1.06	1.15	0.21	0.23	0.50	0.46	264	268	270	274
SE (m) ±	0.02	0.02	0.005	0.007	0.02	0.03	2.79	2.75	2.98	2.95
CD (P=0.05)	NS	NS	NS	0.019	0.05	NS	7.96	7.86	8.51	8.43
C) Interactions (V x N)										
SE (m) ±	0.03	0.04	0.009	0.012	0.03	0.04	4.82	4.76	5.16	5.11
CD (P=0.05)	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
General Mean	1.05	1.09	0.19	0.21	0.43	0.49	246	251	264	266

Table 5: Iron uptake (g ha^{-1}) of upland irrigated rice cultivars as influenced by different treatments during 2017-18 and 2018-19

Treatments	**2017-18**			**2018-19**		
	Fe uptake in grain g ha-^{1})	**Fe uptake in straw (g ha-^{1})**	**Total uptake of Fe (g ha-^{1})**	**Fe uptake in grain (g ha-^{1})**	**Fe uptake in straw (g ha-^{1})**	**Total uptake of Fe (g ha-^{1})**
A) Varieties (V)						
V_1 - Kamesh (CR Dhan 40)	530.	981	1512	702	1230	1933
V_2 - Avishkar	756	1701	2456	855	1779	2634
V_3 - Sindewahi-1 (Sye-1)	408	751	1160	630	1242	1872
SE (m) ±	26	58	67	30	54	74
CD (P=0.05)	73	166	190	85	153	212
B) Nutrients (N)						
N_1 - RDF (100:50:50) NPK kg ha^{-1}	406	837	1243	527	1081	1608
N_2 - RDF + $FeSO_4$ @ 25 Kg ha^{-1}	632	1381	2013	847	1643	2489
N_3 - RDF + $MnSO_4$ @ 5 Kg ha^{-1}	601	1130	1731	733	1430	2163
N_4 - RDF + Foliar spray of $FeSO_4$ @1.0% at flowering and dough	526	1024	1550	706	1297	2003

stage						
N_5 - RDF + Foliar spray of $MnSO_4$ @ 0.5% at flowering and dough stage	468	970	1438	647	1273	1920
N_6 - RDF + Foliar spray of $FeSO_4$ @ 1.0% and $MnSO_4$ @ 0.5% at flowering and dough stage	579	1101	1680	751	1410	2160
N_7 - RDF + $FeSO_4$ @ 25 Kg ha^{-1} and $MnSO_4$ @ 5 Kg ha^{-1} (Soil application)	742	1569	2311	892	1787	2679
SE (m) ±	39	89	102	46	82	113
CD (P=0.05)	111	254	291	130	234	323
C) Interactions (V x N)						
SE (m) ±	68	154	176	79	142	196
CD (P=0.05)	NS	NS	NS	NS	NS	NS
General Mean	564.81	1144	1709	729	1417	2146

Table 6: Manganese uptake (g ha^{-1}) of upland irrigated rice cultivars as influenced by different treatments during 2017-18 and 2018-19

Treatments	**2017-18**			**2018-19**		
	Mn uptake in grain g ha^{-1})	**Mn uptake in straw (g ha^{-1})**	**Total Mn uptake (g ha^{-1})**	**Mn uptake in grain (g ha^{-1})**	**Mn uptake in straw (g ha^{-1})**	**Total Mn uptake (g ha^{-1})**
A) Varieties (V)						
V_1 - Kamesh (CR Dhan 40)	145	1050	1195	190	1306	1495
V_2 - Avishkar	208	1826	2035	232	1902	2133
V_3 - Sindewahi-1 (Sye-1)	113	796	909	176	1299	1475
SE (m) ±	6.38	59	61	8.86	60	65
CD (P=0.05)	18.23	170	174	25.32	170	186
B) Nutrients (N)						
N_1 - RDF (100:50:50) NPK kg ha^{-1}	117	900	1017	151	1138	1289
N_2 - RDF + $FeSO_4$ @ 25 Kg ha^{-1}	168	1440	1608	222	1698	1920
N_3 - RDF + $MnSO_4$ @ 5 Kg ha^{-1}	169	1254	1423	208	1561	1770
N_4 - RDF + Foliar spray of $FeSO_4$ @1.0% at flowering and dough stage	141	1096	1237	187	1381	1567
N_5 - RDF + Foliar spray of $MnSO_4$ @ 0.5% at flowering and dough stage	137	1076	1213	187	1418	1606
N_6 - RDF + Foliar spray of $FeSO_4$ @ 1.0% and $MnSO_4$ @ 0.5% at flowering and dough stage	159	1194	1353	197	1484	1681
N_7 - RDF + $FeSO_4$ @ 25 Kg ha^{-1} and $MnSO_4$ @ 5 Kg ha^{-1} (Soil application)	197	1609	1806	240	1834	2075
SE (m) ±	9.94	91	93	13.53	91	100
CD (P=0.05)	21.85	259	266	38.67	260	285
C) Interactions (V x N)						
SE (m) ±	16.87	157	161	23.44	158	173
CD (P=0.05)	NS	NS	NS	NS	NS	NS
General Mean	155	1224	1380	199	1502	1701

Conclusion

1. Variety Avishkar (PBNR 93-1) recorded higher, yield and quality attributes, uptake and NPKFe and Mn contens.
2. Iron @25 kg ha^{-1} + Manganese @ 5 kg ha^{-1} along with RDF (half dose of N and full dose of P, K, Fe and Mn) and remaining half dose of nitrogen one month after sowing be made for higher productivity and enriched rice quality of high nutritional value.
3. Significantly highest nutrient uptake and nutrient balance was observed in rice cultivar Parbhani Avishkar.

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