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Effect of zinc and iron biofortification on nutrient availability, uptake and yield of dry direct seeded rice under aerobic condition

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Abstract
A field experiments were conducted at Agricultural Research Station, Gangavathi, University of Agricultural Sciences, Raichur, Karnataka during *kharif* seasons for two consecutive years (2019 and 2020) to conduct the effect of zinc and iron biofortification on nutrient availability, uptake and yield of dry direct seeded rice under aerobic condition. The experiment was laid out in split plot design and comprised of two factors for the study *viz*., main plots and sub plot treatments. Pooled data of two years showed that, among the rice genotypes, G_3: GNV-10-89 recorded significantly higher grain yield (5719 kg ha^{-1}), straw yield (6825 kg ha^{-1}), number of panicles (390.03 m^{-2}), panicle weight (6.42 g), total nitrogen, (121.54 kg ha^{-1}), phosphorus (42.36 kg ha^{-1}), potassium (131.75 kg ha^{-1}), zinc (584.63 g ha^{-1}) and iron (2485.2 g ha^{-1}) uptake by the plant. The rice genotype, G_1: RP Bio-226 resulted in significantly higher available nitrogen (249.82 kg ha^{-1}), phosphorus, (25.10 kg ha^{-1}), potassium (287.17 kg ha^{-1}), zinc (0.63 g ha^{-1}) and iron (4.67 g ha^{-1}) in the soil as compared to other genotype. With respect to micronutrient application, M_6: Soil application of $ZnSO_4$ @ 15 kg ha^{-1} and $FeSO_4$ @ 10 kg ha^{-1} + foliar application of $ZnSO_4$ @ 0.5 % and $FeSO_4$ @ 0.5 % at 30 and 45 DAS recorded significantly higher grain yield (5774 kg ha^{-1}), straw yield (6792 kg ha^{-1}), number of panicles (391.25 m^{-2}), panicle weight (6.64 g), total nitrogen (132.68 kg ha^{-1}), phosphorus (47.03 kg ha^{-1}), potassium (145.21 kg ha^{-1}), zinc (692.30 g ha^{-1}) and iron (2797.5 g ha^{-1}) uptake by the plant. The micronutrient application, M_6: Control resulted in significantly higher available nitrogen, phosphorus, potassium in soil (249.82, 25.10 and 287.17 kg ha^{-1}), available zinc and iron in the soil (0.66 and 4.68 ppm) as compared to other micronutrient application. Similar trend was observed during 2019 and 2020.

Keywords: Rice, yield, uptake, genotypes, micronutrient, biofortification

Introduction
Rice is the world's most important cereal crop and is a staple food for more than half of the world's population. Asia accounts for 60 per cent of the global population and stands first in world's rice production and as well as consumption (92 and 90 %, respectively) (FAO, 2018) [3]. Rice plays a vital role related with the diet and human health and is rich in various nutrient components like carbohydrates, proteins, certain fatty acids and micronutrients. In India, rice is grown in an area of 46.2 m ha and production of 117.32 m t with an average productivity of 2585 kg ha^{-1} (Anon., 2019) [1]. In Karnataka, rice is cultivated in command areas of Cauvery, Tungabhadra and Upper Krishna. The total area under rice cultivation in Karnataka is 9.93 lakh ha, with an annual production of 29.07 lakh tonnes and productivity of 3082 kg ha^{-1} (Anon., 2019a) [2]. Here, rice crop is not subjected to transplanting stress. Direct seeding can be done in two ways depending on the land preparation method used such as dry seeding and wet seeding. Dry seeding is done for rainfed crop in which sowing is done in dry soil surface. In case of wet seeding, sowing is done either through broadcasting or drilling seeds into the mud with drum seeders in wet fields. In this method sole crop competition from weeds, deficiency of micronutrients (iron and zinc) and nematodes are the major limitation for successful DSR production. However, DSR could be an alternative to transplanted puddled rice (TPR) as it consumes less irrigation water without any significant yield reduction, requires less labour, as puddling and transplanting is completely avoided and can be highly mechanised.

Zinc and iron deficiencies are well documented in public health issue and as an important soil constraint to crop production. Generally, there is a close geographical overlap between soil deficiency and human deficiency of Zn and Fe, indicating a high requirement for increasing concentrations of these nutrients in food crops. Generally Zn and Fe deficiencies are very common in black soils of North Karnataka due to their low solubility in this soil. In this regard, a fertilizer strategy (agronomic biofortification) represents an effective way for biofortification of food crops including rice.

Materials and Methods

The field experiment was conducted at Agricultural Research Station, Gangavathi, which is situated between 15º 35' 07'' latitude 76º 15' 47'' longitude with an altitude of 419 meters above mean sea level and is located in Northern Dry Zone (Zone-3) of Karnataka. The experiment was laid out in split plot design with three genotypes i.e., G_1: RP Bio-226, G_2: GGV-05-01 and G_3: GNV 10-89 as main plot treatments and seven micronutrient application i.e., M_1: Seed treatment with $ZnSO_4$ @ 1% and $FeSO_4$ @ 1%, M_2: Soil application of $ZnSO_4$ @ 15 kg ha^{-1} and $FeSO_4$ @ 10 kg ha^{-1}, M_3: Foliar application of $ZnSO_4$ @ 0.5 % and $FeSO_4$ @ 0.5 % at 30 and 45 DAS, M_4: Seed treatment + soil application (M_1 + M_2), M_5: Seed treatment + foliar application (M_1 + M_3), M_6: Soil application + foliar application (M_2 + M_3) and M_7: Control as sub plot treatments and replicated thrice. The plot size for each plot was 4.5 m length × 3.6 m width. The soil of the experimental site was medium black with clay loam texture with soil organic carbon 0.65 %, pH 8.35, EC 0.58 dS m^{-1}, available nitrogen 233.8 kg ha^{-1} (low), available phosphorus 31.4 kg ha^{-1} (medium) and available potassium 332.2 kg ha^{-1} (high), DTPA extractable zinc (0.68 ppm) and iron (4.77 ppm). During the cropping period, total rainfall was 570.1 mm in 2019 and 603.4 mm in 2020. September and October months of 2019 received higher rainfall (251.4 and 160.9 mm, respectively) whereas, July and September months of 2020 received higher rainfall in second year (140.1 and 141.4 mm, respectively). Temperature ranged between 28.7 °C to 39.2 °C in 2019 and 29.5°C to 36.7 °C in 2020. The mean monthly minimum temperature was noticed during December and January months of both the years (17.6 °C and 13.7 °C during 2019 and 15.7 °C and 18.0 °C during 2020, respectively). The highest relative humidity of 58.32 % and 41.25 % was noticed during September of both the cropped years.

Results and Discussion

Nutrient availability

The pooled data showed that available nitrogen, phosphorus, potassium in the soil was significantly higher in G_1: RP Bio-226 (249.82, 25.10 and 287.17 kg ha^{-1}, respectively) over G_3: GNV 10-89 (244.40, 22.24 and 280.93 kg ha^{-1}, respectively) but was on par with G_2: GGV-05-01 (247.49, 23.64 and 284.22 kg ha^{-1}, respectively) and is presented in table 1. Similarly control (M_7) resulted in significantly higher available nitrogen, phosphorus and potassium in soil (255.98, 30.68 and 295.21 kg ha^{-1}, respectively) over M_6: Soil application + foliar application (238.92, 22.81 and 276.33 kg ha^{-1}, respectively). However, it was found to be on par with soil application (M_2) (252.86, 29.26, 293.19 kg ha^{-1}, respectively). Similar observations were noticed during 2019 and 2020. It was due to availability of NPK nutrients is one of the major issues due to their fixation in soil or unavailability to the plant after application of chemical fertilizers. The lower availability of major nutrients was due to promoted to harness the naturally available biological system of nutrient mobilization and thereby better crop growth resulting in higher utilization (uptake) of the major nutrients. Higher major nutrients removal especially that of nitrogen, phosphorous and potassium due to NPK application could be attributed to the priming effect causing higher crop growth to increase nutrients demand and thereby better nutrient uptake due to balance fertilization. The results were in accordance with the finding of Rathod *et al.* (2012) [6].

Among the rice genotypes, significantly higher available zinc and iron in soil was recorded with G_1: RP Bio-226 (0.63 and 4.67 ppm) over G_3: GNV 10-89 (0.58 and 4.58 ppm) but was on par with that of G_2: GGV-05-01 (0.62 and 4.65 ppm). Similarly control (Without micronutrient application) resulted in significantly higher available zinc and iron in soil (0.66 and 4.68 ppm) over M_6: Soil application + foliar application (0.55 and 4.45 ppm). However, it was on par with M_2: Soil application (0.59 and 4.67 ppm). Similar observations were noticed during 2019 and 2020. It might be due to removal of more amounts of nutrients by rice (cereals are highly exhaustive crops. This could be evidenced from increased plant height, number of leaves per plant, leaf area, leaf area index and dry matter production with increased yield and yield attributes of rice. Available nutrient status in soil helps to detect the efficiency of fertilizers applied and used by the crop. The soil and foliar application of $ZnSO_4$ and $FeSO_4$ along with recommended chemical fertilizer and FYM may increase the utilization of nutrients mainly due to its beneficial effect in mobilizing the native nutrients to increase their availability. These might be the reason for more available N, P and K in the soil at harvest (Latha *et al*., 2002) [5].

Nutrient uptake

Pooled data of two years showed that total nitrogen, phosphorus and potassium uptake by the plant was significantly higher in case of genotype G_3: GNV-10-89 (121.54, 42.36 and 131.75 kg ha^{-1}, respectively) when compared to G_1: RP Bio-226 (113.88, 36.16 and 120.59 kg ha^{-1}, respectively) but was found to be on par with G_2: GGV-05-01 (117.88, 39.44 and 126.41 kg ha^{-1}, respectively) and is presented in table 2. Similarly soil application + foliar application (M_6) resulted in significantly higher total nitrogen, phosphorus and potassium uptake by the plant (132.68, 47.03 and 145.21 kg ha^{-1}, respectively) over control (108.02, 33.51 and 111.30 kg ha^{-1}, respectively). But it was found to be on par with M_4: Seed treatment + soil application (128.90, 44.10 and 138.32 kg ha^{-1}, respectively). Data of two individual years revealed the similar trend.

Among the rice genotypes, significantly higher zinc and iron uptake by plant was recorded with G_3: GNV-10-89 (584.63 and 2485.0 g ha^{-1}, respectively) when compared with genotype G_1: RP Bio-226 (512.25 and 2300.3 g ha^{-1}, respectively) but was found to be on par with G_2: GGV-05-01 (560.89 and 2400.6 g ha^{-1}, respectively) on pooled basis.

With respect to micronutrient application, significant influence on the zinc and iron uptake by plant was observed during both the years. During pooled data of two years showed that, significantly higher zinc and iron uptake by plant (692.30 and 2797.5 g ha^{-1}, respectively) was recorded with M_6: Soil application + foliar application as compared to other micronutrient application. Whereas, the lowest zinc and iron uptake by plant (389.61 and 1869.6 g ha^{-1}, respectively) were observed with control (Without micronutrient application). Similar trend was noticed for the pooled data of two years. Higher uptake was due to increased concentration in the grain and straw coupled with more grain and straw yield is mainly due to uptake of micronutrient which is associated with metabolic activities of plants with concentration and distribution of ions in the external media. It has been proved that zinc and iron enhanced the zinc availability in soil by preventing fixation and precipitation thereby enhanced the use efficiency in rice (Latha *et al*., 2002) [5].

Yield and yield attributes

Pooled data of two years showed that, the number of panicles and panicle weight was significantly higher in G_3: GNV 10-89 (390.03 m^{-2} and 6.42 g, respectively) which was found to be on par with G_2: GGV-05-01 (379.67 m^{-2} and 5.74 g, respectively). Significantly lower number of panicles was noticed in G_1: RP Bio-226 (369.94 m^{-2} and 4.69 g, respectively) and is depicted in table 3.

With respect to micronutrient application, M_6: Soil application + foliar application recorded significantly higher number of panicles and panicle weight on pooled basis (391.25 m^{-2} and 6.64 g, respectively). However, it was found to be on par with M_4: Seed treatment + soil application (385.85 m^{-2} and 6.58 g, respectively). The lowest number of panicles and panicle weight was recorded under control treatment (368.62 m^{-2} and 4.90 g, respectively). Similar trend of observations were noticed during 2019 and 2020. The variation in the yield was due to the variation in the yield components *viz*., number of panicles (m^{-2}) and panicle weight (g). The difference in the yield attributing characters in rice genotypes may be due to inheritance of genetic characters of the genotype and wider adaptability under different environmental conditions. GNV-10-89 as early maturing genotype, medium fine rice cultivar with kernels little bolder, harvest early by 10-15 days, could be preferred under moisture constraint situations to make best use of the scarce moisture and efficient transport of assimilates from leaves and stems (source) into panicles (sinks) which help in the increased yield parameters of rice. These results are in consonance with Kuldeep *et al.* (2017) [4].

Pooled data of two years showed that, among the rice genotypes, G_3: GNV-10-89 recorded significantly higher grain yield and straw yield (5719 and 6825 kg ha^{-1}, respectively) over G_1: RP Bio-226 (5171 and 6416 kg ha^{-1}, respectively) but was found to be on par with that of G_2: GGV-05-01 (5420 and 6644 kg ha^{-1}, respectively). Similar trend of observations were noticed during 2019 and 2020. The micronutrient application influenced the grain yield and straw yield significantly during both the years as well as in pooled data. In pooled data, the treatment M_6: Soil application + foliar application recorded significantly higher grain yield and straw yield (5774 and 6792 kg ha^{-1}, respectively) which in turn was found to be on par with M_4: Seed treatment + soil application (5628 and 6777 kg ha^{-1}, respectively). Significantly lowest grain yield and straw yield (5058 and 6287 kg ha^{-1}, respectively) was noticed in control. The trend was similar in 2019 and 2020. The increased yield due to zinc and iron foliar application was attributed to better performance of crop growth and yield parameters through adequate availability of major and micronutrient in soil, which in turn, favourably influenced physiological processes and buildup of photosynthates (Tabassum *et al*., 2013) [7].

Table 1: Available macro and micronutrient status in soil after harvest of crop as influenced by genotypes and agronomic biofortification

Treatments	Available nitrogen (kg ha^{-1})			Available phosphorus (kg ha^{-1})			Available potassium (kg ha^{-1})			Zn (ppm)			Fe (ppm)		
	2019	2020	Pooled	2019	2020	Pooled	2019	2020	Pooled	2019	2020	Pooled	2019	2020	Pooled
Main plot: Genotypes (G)															
G_1	248.19	251.46	249.82	24.07	26.13	25.10	285.99	288.36	287.17	0.62	0.64	0.63	4.64	4.71	4.67
G_2	245.86	249.13	247.49	22.54	24.74	23.64	282.67	285.77	284.22	0.61	0.63	0.62	4.62	4.69	4.65
G_3	241.94	246.86	244.40	21.29	23.19	22.24	279.55	282.31	280.93	0.57	0.59	0.58	4.58	4.59	4.58
S.Em±	1.48	1.70	1.09	0.47	0.50	0.44	1.23	2.13	1.64	0.01	0.01	0.01	0.02	0.03	0.02
C. D. (P=0.05)	5.43	2.38	2.99	1.59	1.97	1.48	3.75	5.86	4.36	0.04	0.03	0.04	0.05	0.08	0.05
Sub plot: Micronutrient application (M)															
M_1	240.75	242.86	241.80	22.74	25.58	24.16	275.28	281.18	278.23	0.62	0.63	0.62	4.52	4.66	4.59
M_2	251.95	253.77	252.86	27.88	30.64	29.26	291.58	294.81	293.19	0.59	0.60	0.59	4.63	4.71	4.67
M_3	242.84	244.59	243.72	24.18	27.18	25.68	279.08	283.57	281.32	0.63	0.64	0.63	4.61	4.67	4.64
M_4	249.32	251.80	250.56	26.84	29.11	27.97	287.48	290.48	288.98	0.57	0.58	0.57	4.63	4.69	4.66
M_5	246.96	248.59	247.77	25.74	28.14	26.94	282.11	285.81	283.96	0.61	0.62	0.61	4.62	4.68	4.65
M_6	237.79	240.04	238.92	21.32	24.31	22.81	273.85	278.82	276.33	0.55	0.56	0.55	4.40	4.51	4.45
M_7	254.71	257.26	255.98	29.16	32.21	30.68	293.31	297.11	295.21	0.65	0.67	0.66	4.65	4.72	4.68
S.Em±	0.93	1.17	1.04	0.54	0.62	0.49	1.42	0.82	0.71	0.01	0.03	0.01	0.01	0.03	0.02
C. D. (P=0.05)	2.78	3.52	3.14	1.54	1.77	1.53	4.21	2.48	2.10	0.03	0.09	0.03	0.03	0.09	0.06
Interaction (G × M)															
S.Em±	9.97	11.46	6.65	0.93	1.07	0.68	13.34	13.90	9.01	0.03	0.04	0.04	0.07	0.09	0.08
C. D. (P=0.05)	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS

Note: NS-Non significant

G_1: RP Bio-226	M_1: Seed treatment with $ZnSO_4$ @ 1 % and $FeSO_4$ @ 1 %
G_2: GGV-05-01	M_2: Soil application of $ZnSO_4$ @ 15 kg ha^{-1} and $FeSO_4$ @ 10 kg ha^{-1}
G_3: GNV 10-89	M_3: Foliar application of $ZnSO_4$ @ 0.5 % and $FeSO_4$ @ 0.5 % at 30 and 45 DAS
	M_4: Seed treatment + soil application (M_1 + M_2)
	M_5: Seed treatment + foliar application (M_1 + M_3)
	M_6: Soil application + foliar application (M_2 + M_3)
	M_7: Control

Table 2: Total macro and micronutrient uptake by plant as influenced by genotypes and agronomic biofortification

Treatments	Total N uptake (kg ha^{-1})			Total P uptake (kg ha^{-1})			Total K uptake (kg ha^{-1})			Total Zn uptake (g ha^{-1})			Total Fe uptake (g ha^{-1})		
	2019	2020	Pooled	2019	2020	Pooled	2019	2020	Pooled	2019	2020	Pooled	2019	2020	Pooled
Main plot: Genotypes (G)															
G_1	109.80	117.96	113.88	33.39	38.93	36.16	119.53	121.65	120.59	491.30	533.21	512.25	2200.8	2399.7	2300.3
G_2	113.98	121.78	117.88	36.77	42.11	39.44	124.64	128.18	126.41	537.09	584.69	560.89	2297.8	2503.4	2400.6
G_3	117.73	125.36	121.54	39.56	45.17	42.36	129.79	133.72	131.75	558.51	610.75	584.63	2378.1	2591.9	2485.0
S.Em±	1.31	1.26	1.37	0.81	0.98	0.88	1.32	1.51	1.89	6.07	5.41	5.67	26.12	27.54	26.64
C. D. (P=0.05)	4.06	3.84	5.37	2.85	3.16	2.98	5.19	5.84	5.67	21.58	26.42	27.23	82.32	89.65	86.21
Sub plot: Micronutrient application (M)															
M_1	108.40	115.80	112.10	31.70	37.99	34.84	116.72	119.02	117.87	435.32	479.99	457.65	1989.7	2196.1	2092.9
M_2	121.73	128.26	124.99	38.53	44.82	41.67	131.27	135.60	133.43	589.49	640.80	615.14	2466.1	2675.3	2570.7
M_3	112.69	120.14	116.41	33.95	40.70	37.32	120.26	124.12	122.19	485.64	535.99	510.81	2124.9	2342.3	2233.6
M_4	125.60	132.20	128.90	41.06	47.15	44.10	136.15	140.50	138.32	627.19	681.77	654.48	2578.4	2801.1	2689.7
M_5	117.22	124.21	120.71	35.96	43.10	39.53	126.09	130.75	128.42	524.92	571.30	548.11	2280.1	2476.1	2378.1
M_6	129.83	135.53	132.68	44.03	50.03	47.03	143.21	147.22	145.21	664.57	720.04	692.30	2688.3	2906.7	2797.5
M_7	103.95	112.10	108.02	31.14	35.89	33.51	109.59	113.01	111.30	375.59	403.64	389.61	1792.9	1946.4	1869.6
S.Em±	2.44	2.64	1.66	1.33	1.29	1.40	3.58	3.04	2.51	12.85	13.09	12.93	45.51	49.20	47.07
C. D. (P=0.05)	7.33	7.93	4.96	3.98	3.89	4.20	10.73	9.12	7.53	38.54	39.27	38.81	136.54	147.62	141.21
Interaction (G × M)															
S.Em±	4.43	4.79	3.00	1.08	0.84	0.73	6.48	5.51	4.55	7.23	7.15	5.64	29.78	28.54	29.47
C. D. (P=0.05)	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS

Note: NS-Non significant

G_1: RP Bio-226	M_1: Seed treatment with $ZnSO_4$ @ 1 % and $FeSO_4$ @ 1 %
G_2: GGV-05-01	M_2: Soil application of $ZnSO_4$ @ 15 kg ha^{-1} and $FeSO_4$ @ 10 kg ha^{-1}
G_3: GNV 10-89	M_3: Foliar application of $ZnSO_4$ @ 0.5 % and $FeSO_4$ @ 0.5 % at 30 and 45 DAS
	M_4: Seed treatment + soil application (M_1 + M_2)
	M_5: Seed treatment + foliar application (M_1 + M_3)
	M_6: Soil application + foliar application (M_2 + M_3)
	M_7: Control

Table 3: Yield and yield parameters of direct seeded rice as influenced by genotypes and agronomic biofortification

Treatments	Number of panicles (m^{-2})			Panicle weight (g)			Grain yield (kg ha^{-1})			Straw yield (kg ha^{-1})		
	2019	2020	Pooled	2019	2020	Pooled	2019	2020	Pooled	2019	2020	Pooled
Main plot: Genotypes (G)												
G_1	366.47	373.42	369.94	4.54	4.85	4.69	5138	5204	5171	6315	6518	6416
G_2	375.71	383.63	379.67	5.68	5.80	5.74	5394	5446	5420	6592	6696	6644
G_3	386.92	393.14	390.03	6.20	6.64	6.42	5647	5792	5719	6771	6879	6825
S.Em±	4.56	3.50	3.11	0.38	0.29	0.20	40	37	38	24	23	23
C. D. (P=0.05)	12.25	11.24	10.54	1.18	0.95	0.88	157	147	149	94	90	92
Sub plot: Micronutrient application (M)												
M_1	368.93	376.04	372.48	5.33	5.60	5.46	5209	5254	5231	6429	6538	6483
M_2	377.84	386.79	382.31	6.11	6.31	6.21	5485	5540	5513	6651	6760	6706
M_3	370.94	379.97	375.45	5.49	5.65	5.57	5223	5312	5268	6533	6641	6587
M_4	381.89	389.81	385.85	6.48	6.69	6.58	5603	5656	5628	6728	6825	6777
M_5	375.11	383.20	379.15	5.99	6.12	6.05	5326	5411	5368	6603	6711	6657
M_6	387.74	394.76	391.25	6.49	6.79	6.64	5763	5785	5774	6738	6847	6792
M_7	364.71	372.54	368.62	4.82	4.98	4.90	5042	5075	5058	6233	6342	6287
S.Em±	1.96	1.65	1.83	0.09	0.10	0.08	59	46	49	28	27	29
C. D. (P=0.05)	5.89	4.97	5.48	0.28	0.31	0.26	176	137	147	82	78	92
Interaction (G × M)												
S.Em±	4.00	2.91	9.04	0.13	0.19	0.12	107	83	90	49	47	48
C. D. (P=0.05)	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS

Note: NS-Non significant

G_1: RP Bio-226	M_1: Seed treatment with $ZnSO_4$ @ 1 % and $FeSO_4$ @ 1 %
G_2: GGV-05-01	M_2: Soil application of $ZnSO_4$ @ 15 kg ha^{-1} and $FeSO_4$ @ 10 kg ha^{-1}
G_3: GNV 10-89	M_3: Foliar application of $ZnSO_4$ @ 0.5 % and $FeSO_4$ @ 0.5 % at 30 and 45 DAS
	M_4: Seed treatment + soil application (M_1 + M_2)
	M_5: Seed treatment + foliar application (M_1 + M_3)
	M_6: Soil application + foliar application (M_2 + M_3)
	M_7: Control

Conclusion

The experimental findings indicated that there were marked variations in the productivity of varied genotypes and micronutrient application. Based on the present investigation, it can be concluded that the rice genotype, G_3: GNV-10-89 and G_2: GGV-05-01 was found better as compared to G_1: RP Bio-226 with respect to nutrient uptake, yield parameters and grain yield of rice. With respect to micronutrient application *i.e.* soil application + foliar application is a better option in dry direct seeded rice which was found to be most productive, economically viable and sustainable.

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