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Influence of Zinc and Iron Fortification on Yield and Post-Harvest Studies of Different Rice Cultivars (*Oryza sativa* L.)

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ABSTRACT

Keywords

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Among the micronutrients, zinc deficiency is widespread throughout the world particularly in upland rice fields causing low yields and affecting nutritional quality of the produce. Iron is also another micronutrient which is lacking in soil as well as in human body. Field studies were carried out during the growing season 2015-16 and 2016-17 at Research Farm, Department of Agronomy, Dr. Panjabrao Deshmukh Krishi Vidhyapeeth, Akola (Maharashtra) to study "Influence of zinc and iron fortification on yield and Post-harvest studies of different rice cultivars (*Oryza sativa* L.)". The treatments were laid out in factorial randomized block design (FRBD) with three replications. Two years results shows that among varieties PBNR-03-02 explored highest yield and post-harvest studies whereas combine application of $ZnSO_4$ + $FeSO_4$ with RDF treatment recorded maximum yield as well as post-harvest characters respectively.

Introduction

Zn and Fe deficiencies are widespread health problems. Iron deficiency is the most common nutritional disorder not only in the world, and almost 1.6 billion people are suffering from iron deficiency (De Benoist *et al.*, 2008). Iron deficiency anemia is by far the most widespread micronutrient deficiency, and it results in impaired physical growth, mental development, and learning capacity (Bouis, 2003). Similarly, Zinc deficiency is equally serious and is ranked as the 5th leading risk factor for diseases in the developing world (Maret and Sandstead, 2006). Numerous health problems link zinc

deficiency to retarded growth, skeletal abnormalities, delayed wound healing, increased abortion risk, and diarrhea (Salgueiro *et al.*, 2000). Approximately one-third of the world's population is suffering from zinc deficiency (Hotz and Brown, 2004). The situation is even more adverse in developing countries where more than half of the children and pregnant women are suffering from iron and zinc deficiencies (Seshadri, 2001). This situation is largely attributed to the high consumption of cereal based foods viz., rice (*Oryza sativa* L.), wheat (*Triticum aestivum* L.), and maize (*Zea mays* L.), in these countries (Pfeiffer and McClafferty, 2007). Edible parts (endosperms) of modern

cereal cultivars are inherently poor in iron and zinc. The concentration of iron in the brown rice ranges from 6.3 to 24.4 mg kg⁻¹ and zinc concentration ranges from 15.3 to 58.4 mg kg⁻¹ (Gregorio *et al.*, 2000). However, polished rice, the principal form of rice consumed, on an average contains only 2 mg kg⁻¹ iron and 12 mg kg⁻¹ zinc (Barry, 2006).

The existence of a negative relationship between irrigation and iron and zinc uptake (Scagel *et al.*, 2012) and a similar negative relationship between phosphorus and iron and zinc uptake (Saha *et al.*, 2013) also lead to lower the accumulation of these micronutrients in the cereal grains. Since the edible parts of the cereals are poor in iron and zinc, thus heavy dependence of people from developing countries on these foods results in the development of large-scale iron and zinc malnutrition. To alleviate iron and zinc deficiency, it is required to increase iron and zinc concentration in the endosperm to 8 and 30 mg kg⁻¹, respectively. Currently, there is growing concern to address micronutrient malnutrition through different interventions.

Typically, these interventions are categorized into 4 major groups: pharmaceutical supplementation, industrial fortification, dietary diversification, and biofortification (Meenaski *et al.*, 2007).

In case of biofortification research efforts focused on development of high-yielding varieties and adoption of modern production technologies resulted in enhanced production leading to self-sufficiency in the country. Considering the all facts stated above, the present investigation entitled “Effect of zinc and iron fortification on growth and developmental stages of upland irrigated rice (*Oryza sativa* L.) cultivars” was planned with the objective to study the effect of Zinc and Iron on growth, yield and quality of upland rice cultivars.

Materials and Methods

Two field experiments were conducted at Research Farm, Department of Agronomy, Dr. Panjabrao Deshmukh Krishi Vidyapeeth, Akola (Maharashtra) during growing seasons 2015-16 and 2016-17. Texturally the soil was clay. It contained 8.6 pH, 0.28 EC, 0.52 (g kg⁻¹) organic carbon, 217.2 kg ha⁻¹ available N, 16.89 kg ha⁻¹ available P, 374.39 kg ha⁻¹ available K, 0.72 mg kg⁻¹ available Zn, 9.01 mg kg⁻¹ available Fe contents. The experiment was arranged in a factorial randomized block design with three replications, each plot being 3.6 m x 4 m. Sowing of upland irrigated rice was done on 31st July 2015 during first year and on 26th June 2017 during second year by drilling seeds per hill on 30X10cm.

Experiment consist of two factors namely varieties and nutrients. Varieties were consisted of three varieties viz., V1- Sindewahi-1 (SYE-1), V2- Sindewahi-2001 (SYE-2001), V3- PBNR-03-02 and treatments were N1-RDF, N2- RDF + ZnSO₄ (25 kg ha⁻¹), N₃ -RDF + FeSO₄ (30 kg ha⁻¹), N₄-RDF+ Foliar spray of ZnSO₄ @ 0.5% at flowering and dough stage, N₅ -RDF+ Foliar spray of FeSO₄ @ 1.0% at flowering and dough stage, N₆ -RDF + ZnSO₄ + FeSO₄ (25+30 kg ha⁻¹). Five plants were selected from each plot at random.

Each plant marked with a small plastic white coloured ring and with wooden peg nearby for demarkation. The same five plants were observed at various stages of crop growth up to harvest for biometric observations. These five plants were harvested separately for post-harvest observations.

Results and Discussion

The results obtained from the present investigation have been presented under following heads.

Yield characteristics

Grain yield (kg ha⁻¹)

Effect of varieties

The average of two years shows pooled results of yield during both consecutive years. PBNR-03-02 explored maximum yield and found significant over both the varieties whereas variety Sindewahi-1 has produced significantly more yield than Sindewahi-2001. Higher number of panicles m⁻², LAI, dry matter and grains panicle⁻¹ this was attributed mainly to major yield attributes mostly. Similar results were achieved by Kusutani *et al.*, (2000) and Dutta *et al.*, (2002) who reported that genotypes producing higher number of effective tillers produced more grain yields in rice. PBNR-03-2 was the most efficient variety for conversion of biomass towards economic parts. Higher yields can be obtained by physiological process involving high accumulation of photosynthates and their partitioning (Miah *et al.*, 1996).

Effect of nutrients

From pooled means of seed yield, Increase in yield it is apparent that application of ZnSO₄ + FeSO₄ with RDF posed a great increment in yield (3072 kg ha⁻¹) over rest of the treatments. The next best treatment obviously was that of alone application of FeSO₄ with RDF, which by recording 2867 kg ha⁻¹ yield over alone application of ZnSO₄ with RDF ranked second. While foliar application of FeSO₄ @ 1.0% with RDF registered marginally higher yield as compared to foliar application of ZnSO₄ @ 0.5% with RDF and RDF alone. The contribution of ZnSO₄ to increase yield was 12 % and FeSO₄ 6 %. Combine application of Zn + Fe resulted in 34 % over RDF indicating essentiality of these nutrients in the initial year and in next year ZnSO₄ increase yield 8% and FeSO₄ increases

by 6% and combination of Zn and Fe with RDF posed 28% increase in yield.

Increase in yield by combining micronutrients with RDF, N increases vegetative growth, more synthesis of carbohydrates and their chloroplast the results are substantiated by the findings of the study Mattas *et al.*, (2011) and Roshan *et al.*, (2011). Similarly, the increase in grain yield on zinc addition might be due to enhanced formation of growth hormones such as auxin. Further, it also promotes starch formation and seed maturation. Similar findings were reported by Keram *et al.*, (2012).

Interaction effect

Interaction effect of varieties and nutrients could not reach to the level of significance for Grain yield (kg ha⁻¹).

Straw yield (kg ha⁻¹)

Effect of varieties

Pooled means of straw yield omitted that maximum straw yield was explored by PBNR-03-02 by super sending rest of the two varieties. Sindewahi-2001 produced significantly more straw than Sindewahi-1. This may be due to genetic variability of varieties.

It may be attributed to higher dry matter accumulation. Variability among different rice varieties for straw was also noticed by Hari Om *et al.*, (1997); Singh *et al.*, (2000) and Suresh *et al.*, (2001).

Effect of nutrients

As far as pooled values of straw yield concerned, the influence of treatments more amplified. Significantly highest straw yield was noted by the ZnSO₄ + FeSO₄ with RDF

over all the other treatments. Alone soil application of FeSO₄ along with RDF shows slightly lesser straw yield but being par with the ZnSO₄ with RDF, least value of straw yield was observed in foliar application of FeSO₄ and ZnSO₄ with RDF and also with RDF alone.

Such an effects of micronutrients (Zn) application might be due to their critical role in crop growth, involving in photosynthesis process, respiration and biochemical and physiological activates and their importance in higher yield and biomass production, Zeidan *et al.*, (2010).

Interaction effect

During both the year Interaction effect of varieties and nutrients was found to be significant.

Biological yield (kg ha⁻¹)

Effect of varieties

The biological yield of rice was significantly affected by different varieties. Maximum biological yield (6012 kg ha⁻¹ and 7788 kg ha⁻¹) was obtained by variety PBNR-03-02 during 2015-16 and 2016-17 which was significantly superior over variety SYE-2001 (V₂) and statistically similar with the variety SYE-1 (V₁) (5549 and 7520 kg ha⁻¹). From the result it was observed that biological yield differed due to combined effect of grain yield and straw yield. Variability among different rice varieties for biological yield was also noticed by Laza *et al.*, (2004); Singh *et al.*, (2007); Lack *et al.*, (2012) and Khalifa *et al.*, (2014).

Effect of nutrients

When the production of the plant is supported by macro and micronutrient application, then

certainly the reproductive capacity of plant enhances as par excellence. Such is the case with soil application of ZnSO₄ + FeSO₄ with RDF, where there was no barrier in supplying adequate nutrient to the plant had achieved overwhelming growth rate reflecting in attaining the greatest biological yield, when compared with remaining treatments. The soil application of FeSO₄ 30 kg ha⁻¹ (6246 and 7912 kg ha⁻¹) was found at par with RDF + ZnSO₄ (5404 and 7785 kg ha⁻¹). As evident in other characters maximum biological yield was noticed with addition of Zn and FeSO₄ with RDF indicating the essentiality of these nutrients in this region.

Zn, Fe and NPK manipulate the growth of rice, resulting in beneficial changes in yield and yield components. The possible reason for such beneficial role is the increase in the activity of growth hormone or activity of photosynthetic system or might be due to the active role of these micronutrients in metabolic processes of plants and photosynthesis and thus, tended to increase leaves formation, vegetative growth and grain formation which ultimately increased the yield attributes. These results are in line with that reported by Ananda and Patil (2005).

Interaction effect

Biological yield of both the respective year was not found significant.

Harvest index (%)

Effect of varieties

The highest harvest index (46.13 and 45.97%) was noticed by variety Sindewahi-2001 as compared to the other varieties during 2015-16 and 2016-17 whereas lowest harvest index was recorded by the variety Sindewahi-1 was (33.76 and 43.94%). PBNR-03-02 and Sindewahi-1 produce lower harvest index

because of emergence of new shoots from nodes before harvesting which contributed only towards straw yield. Superiority of PBNR-03-02 over other varieties indicated that this variety have efficient partitioning for assimilates of photosynthesis from source to sink (panicle). Laza *et al.*, (2004), Singh *et al.*, (2007) and Lack *et al.*, (2012) also reported varieties differences for harvest index.

Effect of nutrients

Perusal of data in Table 1 indicated that harvest index is concerned, it have merely brought out the status of economic yield attained when compared with aggregate yield of grain and straw in case of rice. Among the treatments highest harvest index (43.24%) was recorded by RDF + ZnSO₄ + FeSO₄ (25+30 kg ha⁻¹) during 2016-17 ensures higher economic productivity from the respective treatment. Individual application of ZnSO₄ and FeSO₄ also produced higher HI indicating beneficial effect to converts photosynthates in to economic yield.

This might be occurred due to relative grain and straw yield of crop. On the contrary application of zinc increased harvest index, may be due to maximum dry matter partitioning towards grain, hence the grain yield was more by the application of zinc. Similarly, Ghaffari *et al.*, (2011) reported increase in the harvest index of maize due to application of zinc. Iron helps in utilization of nitrogen. All these physiological processes proved instrumental in increasing HI by increasing yield as well as biomass, Ram *et al.*, (2013).

Post-harvest studies

Number of panicles plant⁻¹

Number of panicles plant⁻¹ is an important character which directly influences grain yield

of the crop. Data on Number of panicles plant⁻¹ under various treatments are enumerated in Table 19 which indicated that panicles were affected significantly due to genotypic variation and varietal management.

Effect of varieties

Number of panicles plant⁻¹ indicated that among the varieties variety PBNR-03-02 has produced maximum number of panicles plant⁻¹ (5.23 and 6.28) which was statistically similar with the SYE-1 during both the years and found significantly higher than variety SYE-2001.

Whereas variety SYE-2001 was having lowest number of panicle (4.42 and 5.52) may be due to lowest numbers of tillers in both the years which supported by the research conducted by the Hossain *et al.*, (2008) who reported.

Similar results that number of panicles depends on number of tillers and proportion of effective tillers to that particular variety.

Effect of nutrients

Data regarding Number of panicles plant⁻¹ shows that the maximum number of panicle plant⁻¹ (5.47 and 6.62) were produced with an combine application of ZnSO₄ + FeSO₄ with RDF which were comparable with alone application ZnSO₄ and FeSO₄ applied either soil and foliar spray but found superior over RDF.

It was further observed that the number of panicles was increased due to addition of FeSO₄ and ZnSO₄.

The foliar application of these nutrients were also responsible to increase the number of panicles per plant indicating the role of zinc and ferrous. Similar results were observed during the second year of experimentation.

Table.1 Grain yield (kg ha⁻¹), Biological yield (kg ha⁻¹), straw yield (kg ha⁻¹) and harvest Index (%) of upland irrigated rice cultivars as influenced by different treatments during 2015-16 and 2016-17

Treatments	Grain yield (kg ha ⁻¹)			Straw yield (kg ha ⁻¹)			Biological yield (kg ha ⁻¹)		Harvest index %		
	15-16	16-17	Pooled	15-16	16-17	Pooled	15-16	16-17	15-16	16-17	Pooled
A) Varieties (V)											
V ₁ - Sindewahi -1 (SYE-1)	1771	3276	2523	3778	4175	3575	5549	7520	33.76	43.94	38.84
V ₂ - Sindewahi-2001 (SYE-2001)	1601	3140	2370	2105	3734	2630	3707	6873	46.13	45.97	46.21
V ₃ - PBNR-03-02	2233	3613	2923	4060	4342	3736	6293	7788	38.88	45.87	41.61
SE (m) _±	49	83	34	343	122	22	343	145	-	-	-
CD (P=0.05)	135	230	103	951	338	66	951	403	-	-	-
B) Nutrients (N)											
N ₁ - RDF (100: 50:50 NPK kg ha ⁻¹)	1494	2775	2134	2107	3395	2472	3601	6170	43.24	44.97	44.09
N ₂ - RDF + ZnSO ₄ (25 kg ha ⁻¹)	1985	3584	2784	3419	4201	3427	5404	7785	39.75	45.97	42.85
N ₃ - RDF + FeSO ₄ (30 kg ha ⁻¹)	2126	3609	2867	4120	4304	3788	6246	7912	38.28	45.87	42.07
N ₄ - RDF+ Foliar spray of ZnSO ₄ @ 0.5 % at flowering and dough stage	1593	2977	2284	2752	3846	2996	4344	6823	38.74	43.78	41.26
N ₅ - RDF+ Foliar spray of FeSO ₄ @ 1.0 % at flowering and dough stage	1748	3232	2490	3206	4191	3327	4955	7423	39.71	43.84	41.76
N ₆ - RDF + ZnSO ₄ + FeSO ₄ (25+30 kg ha ⁻¹)	2265	3880	3072	4282	4366	3900	6547	8246	37.80	47.14	42.47
SE (m) _±	69	117	49	485.3	173	38	485	205	-	-	-
CD (P=0.05)	192	325	146	1345.	479	93	1345	570	-	-	-
C) Interactions (V x N)											
SE (m) _±	120	203	85	840	299	54	840	356	-	-	-
CD (P=0.05)	NS	NS	NS	NS	NS	NS	NS	NS	-	-	-
General Mean	1868	3343	2605	3314	4119	3313	5183	7394	39.71	45.26	42.42

Table.2 Number of panicles plant⁻¹, panicle length, weight of panicle and seed yield plant⁻¹ of upland irrigated rice cultivars as influenced by different treatments during 2015-16 and 2016-17

Treatments	2015-16				2016-17			
	Number of panicles plant ⁻¹	Panicle length (cm)	Weight of panicle (g)	Seed yield plant ⁻¹ (g)	Number of panicles plant ⁻¹	Panicle length (cm)	Weight of panicle (g)	Seed yield plant ⁻¹ (g)
A) Varieties (V)								
V ₁ - Sindewahi -1 (SYE-1)	4.92	14.18	2.79	8.59	5.96	15.25	3.76	13.55
V ₂ - Sindewahi-2001 (SYE-2001)	4.42	12.02	2.32	8.24	5.52	13.23	3.34	12.93
V ₃ - PBNR-03-02	5.23	20.08	4.01	9.96	6.28	20.15	5.59	14.62
SE (m) ₊	0.16	0.49	0.29	0.18	0.20	0.23	0.11	0.35
CD (P=0.05)	0.45	1.37	0.82	0.51	0.57	0.79	0.32	0.98
B) Nutrients (N)								
N ₁ - RDF (100: 50:50 NPK kg ha ⁻¹)	4.43	13.84	2.26	6.76	5.58	15.19	3.76	10.33
N ₂ - RDF + ZnSO ₄ (25 kg ha ⁻¹)	4.86	15.58	2.87	7.67	5.92	16.51	4.32	13.37
N ₃ - RDF + FeSO ₄ (30 kg ha ⁻¹)	5.03	15.96	3.58	10.74	6.32	16.53	4.48	16.03
N ₄ - RDF+ Foliar spray of ZnSO ₄ @ 0.5 % at flowering and dough stage	4.51	14.36	2.45	7.08	5.46	15.92	4.00	11.20
N ₅ - RDF+ Foliar spray of FeSO ₄ @ 1.0 % at flowering and dough stage	4.84	15.56	2.82	7.50	5.63	16.01	4.18	12.35
N ₆ - RDF + ZnSO ₄ + FeSO ₄ (25+30 kg ha ⁻¹)	5.47	17.00	4.26	13.81	6.62	17.09	4.64	18.92
SE (m) ₊	0.23	0.70	0.41	0.26	0.29	0.40	0.16	0.50
CD (P=0.05)	0.64	1.94	1.16	0.72	0.80	1.18	0.45	1.39
C) Interactions (V x N)								
SE (m) ₊	0.40	1.21	0.72	0.45	0.50	0.69	0.28	0.87
CD (P=0.05)	1.12	NS	NS	NS	NS	NS	NS	NS
General Mean	4.86	15.43	3.04	8.93	5.92	16.21	4.23	13.70

More number of panicles m^{-1} row, with combine application of RDF and micronutrients increase the use efficiency of added nutrients and supply it continuously to the plant throughout the crop growth period and promoted various physiological activities in plant which are consider being indispensable for proper growth and development. These results are in conformity with those of Nagrajan (1995) and Atwal *et al.*, (1998).

Interaction effect

Effect of varieties and nutrient over panicles $plant^{-1}$ was found to be non-significant.

Panicle length (cm)

Length of Panicle is an important yield component, which affect the number of grains per spike. The data on length of panicle as influenced by various treatments have been presented in Table 2. Both varieties and levels of micronutrients had significant effect on panicle length during both the years of investigation.

Effect of varieties

Panicle length (cm) was significantly influenced by affected by different varieties and mean length of variety PBNR-03-02 was 20.08 and 19.98 cm in 2015-16 and 2016-17 respectively whereas short panicle (12.02 and 13.23 cm) length was recorded by the variety SYE-2001 (V_2).

The significantly more panicle length was observed in variety PBNR-03-02 than SYE-2001, lowest panicle length was observed in Sindewahi-1. Sharma (2002) reported significant difference in panicle length among fine grain rice genotypes due to different nature in genotypic character.

Effect of nutrients

During both alternate years maximum panicle length (17 and 17.09 cm) was recorded with

combination of $ZnSO_4$, $FeSO_4$ along with the RDF which was found significantly superior over rest of the treatments. Soil application of $FeSO_4$ along with RDF was found increasing panicle length than the RDF alone. $ZnSO_4$ with RDF also responsible for increasing the panicle length. Beneficial effect of foliar spray of zinc and ferrous was also noticed. Combined application of Zn, Fe and RDF increased the grains of panicle and length is depend upon the grain bearing capacity of panicle owing to better utilization of nutrients for grain production and length of panicle through metabolic activities. The present results are in agreement with the findings of Mehra and Shekhawat.

Interaction effect

Panicle length (cm) was found non-significant over both the factors.

Weight of panicle (g)

Effect of varieties

During first year of experiment variety PBNR-03-02 produce the maximum weight of panicle which was significantly higher than SYE-1 and SYE-2001. However the later varieties were on par with each other. During the second year of experimentation PBNR-03-02 produce maximum weight of panicle (5.59 g) which was significantly superior over SYE-1 also produce significantly more weight of panicle than the SYE-2001.

Cultivars with an extremely high number of tillers would have greater consumption of stored materials by excessively bigger sink size so, panicle weight automatically increased (Yoshida and Parao, 1976).

Effect of nutrients

During initial year maximum weight of panicle (4.26 and 4.64 g) was observed with the addition of $ZnSO_4$ 25 kg and $FeSO_4$ 30 kg ha^{-1} with RDF which was found significantly superior over rest of the treatments except soil

application of ZnSO₄ and highest weight of panicle (4.26 g) was recorded by the combine application of ZnSO₄ and FeSO₄ alone along with RDF.

Foliar application of ZnSO₄ and FeSO₄ along with RDF was responsible for increasing the weight of panicle indicating the essentiality of these nutrients in addition to RDF. Similar trend was observed during next year also.

The better effectiveness of mixed application of these micronutrients may be attributed to their synergism effect.

These findings are consistence with the previous researches that indicates combination of zinc with other elements improved the photosynthetic attributes and has a positive effect on reproductive organs to produce more grain Similar findings were reported by Patel (1999).

Interaction effect

Interaction effect of varieties and nutrients in respect to weight of panicle (g) of rice could not reach to the level of significance.

Seed yield plant⁻¹

Generally the grain yield per unit area and number of grains spike-1 are the most important determinants of the yield which are affected by various factors including balanced nutrition. As shown in Table 19, different varieties and micronutrients shows significant variation during 2015-16 and 2016-17.

Effect of varieties

Maximum seed yield plant⁻¹ was observed with variety PBNR-03-02 (9.96 gm) which was significantly higher than other two varieties. The variety SYE-1 produce more seed yield as compared to SYE-2001. Similar result was also observed during second year of experimentation.

The varietal character of the Variety PBNR-03-02 documented highest seed yield plant⁻¹ PBNR-03-02 variety well-adjusted to the conditions of Akola so they performed better while changing spikelets into grains as compared to other varieties.

Effect of nutrients

During 2015-16 application of ZnSO₄ and FeSO₄ with RDF recorded maximum seed yield plant⁻¹ which was significantly higher than the rest of the treatments alone application of FeSO₄ produce maximum seed yield which was significantly superior over alone soil applied ZnSO₄ along with RDF and also RDF alone. Foliar spray of either ZnSO₄ or FeSO₄ increase the seed yield compared with the recommended dose of fertilizer but not reached to the level of significance. Soil application of FeSO₄ along with RDF significantly increase the seed yield than the alone application of ZnSO₄ along with RDF this indicated that significance of FeSO₄ can increasing productivity of rice. While comparing the addition of either ZnSO₄ or FeSO₄ in soil are foliar spray, the significance of soil application was more compared to foliar spray it was further observed that there is need to apply zinc and ferrous in addition to the RDF.

These findings are consistence with the previous researches that indicates combination of zinc with iron improved the photosynthetic attributes and has a positive effect on reproductive organs to produce more grain yield (Zayed, 2011) also flag leaf plays an important role in grain yield similar findings given by Patel *et al.*, (1999).

Interaction effect

Effect of varieties and nutrients over seed yield plant⁻¹ was found to be non-significant. On the basis of the results obtained, the following conclusions of significant and utility can be drawn. Variety PBNR-03-2 recorded significantly higher yield and post-harvest characteristics.

Soil application of RDF (100:50:50 kg ha⁻¹) + ZnSO₄ (25 kg ha⁻¹) + FeSO₄ (30 kg ha⁻¹) recorded significantly highest yield and post-harvest characters.

Maximum GMR, NMR and B: C ratio was recorded with upland rice cultivar PBNR-03-02 in combination with fertilizer treatment of RDF (100:50:50 kg ha⁻¹) + ZnSO₄ (25 kg ha⁻¹) + FeSO₄ (30 kg ha⁻¹).

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