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Effect of Zinc and Iron Fortification on Growth and Developmental Stages of Upland Irrigated Rice (*Oryza sativa* L.) Cultivars

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Field studies were carried out during the growing season 2015-16 and 2016-17 at Research Farm, Department of Agronomy, Dr. Panjabrao Deshmukh Krishi Vidyapeeth, Akola (Maharashtra) to study "Effect of zinc and iron fortification on growth and developmental stages of upland irrigated rice (*Oryza sativa* L.) cultivars". 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 growth and developmental stages whereas combine application of $ZnSO_4$ + $FeSO_4$ with RDF treatment recorded maximum growth and yield attributing characters respectively.

Introduction

Rice (*Oryza sativa* L.) being the staple food for almost two thirds of the population plays a pivotal role in Indian economy. Over 2 billion people in Asia alone derive 80% of their energy needs from rice, which contains 80% carbohydrates, 7–8% protein, 3% fat, and 3% fiber. India ranks first in the world in area of rice cultivation with 43.97 million ha and second in production with 104.32 million tons (Anonymous, 2013). In Maharashtra, the area under rice cultivation is 14.99 lakh ha, with annual rough rice production of 32.37 lakh tones, and productivity 2.01 t ha$^{-1.}$ Maharashtra ranks 13th place in rice production in country and in case of Vidarbha region, area under upland rice is 7800 ha with production of 5600 tons and yield is about 718 kg ha^{-1}.

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 + $ZnSO_4$ (25 kg ha^{-1}), N_3-RDF + $FeSO_4$ (30 kg ha^{-1}), N_4-RDF+ Foliar spray of $ZnSO_4$ @ 0.5% at flowering and dough stage, N_5 -RDF+ Foliar spray of $FeSO_4$ @ 1.0% at flowering and dough stage,

N_6 -RDF + $ZnSO_4$ + $FeSO_4$ (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.

Growth characters

Plant height (cm)

Effect of varieties

Data pertaining to varieties revealed that maximum plant height (35.28 and 42.25 cm) was recorded by variety PBNR-03-02 which was statistically superior over SYE-1 and SYE-2001 during both years of experimentation. However, lowest plant height (29.87 and 34.48 cm) was observed in SYE-2001. The maximum height of variety PBNR-03-02 was mostly due to its genetic potential which was reflected in the plant height of all the varieties in second year mainly because of most favorable climate prevailed. Similar results were enclosed by Mannan *et al.*, (2012)

Effect of nutrients

Data presented in the Table 1 showed that during first year and second year of investigation the combine application of zinc and iron along with RDF had a significant effect on the plant height during harvest stage. The comparison of treatment means revealed that soil application of zinc and iron together with RDF (N_6) consistently maintained tallest plant height. Combination of soil application of Zn and Fe shows best results because applying nutrients viz. Zn and Fe to the soil is efficient because in soil solution they are present as positively charged metal ions and will readily react with oxygen or negatively charged hydroxide ions (OH^-). Iron has structural role in chlorophyll, energy transfer within the plant and enters in root cells also zinc increased plant height via increasing internodes distance. Similar result was obtained by Ananda and Patil (2005).

Interaction effect

The interaction effect of varieties and nutrients on plant height was found to be non significant during the course of investigation.

No. of functional leaves

Plants growing in good condition develop leaves in faster rate than those leaves growing in non conductive environment Data pertaining to the number of functional leaves per plant as affected by various treatments are presented in Table 1.

The difference in number of functional leaves $plant^{-1}$ due to genotypic character of varieties was found to be significant except during both the year. Variety PBNR-03-02 was found significantly superior over SYE-1 and SYE-2001 during both the year of trial, however variety SYE-1 at harvest during 2015-16 and 2016-17 was at par with the PBNR-03-02. Variety SYE-2001 exhibited less number of functional leaves.

During the year 2016-17 maximum growth of leaves occurred as compared to previous year due to vegetative growth by favorable weather condition. The variations in number of leaves per plant attributed to the differences in the genetic makeup of the varieties and their differences in the utilization ability of the different rates of fertilizer applied. These observations are in consonance with that of Dixit and Patro (1994)

Effect of nutrients

During 15-16 combined application of $ZnSO_4$ and $FeSO_4$ along with RDF (N_6) produced significantly maximum functional leaves which were on par with $ZnSO_4$ with RDF and significantly superior to rest of treatments. Maximum functional leaves were observed at combined application of Zn and Fe with RDF (N_6) which was on par with RDF + $FeSO_4$ and found significantly superior at rest of the treatments. Supplemented Zn and Fe along with RDF, exhibited significantly more functional leaves during 16-17.

Combination of $ZnSO_4$ and $FeSO_4$ with RDF (N_6) enhanced the leaf production significantly during both the years. Micronutrients may be responsible for prolific leaf production combine with RDF, as nitrogen, being the main constituent of chlorophyll, increased the photosynthetic efficiency of crop which resulted in higher leaf counts. Production of greater number of leaves in these treatments might be attributed to availability of Zn, Fe and RDF Similar results were also observed by Dahiphale (2002) at VNMKV, Parbhani.

Interaction effect

Interaction effect between the varying varieties and nutrients over number of functional leaves was found to be non-significant in both years.

No. of tillers m^{-2}

Effect of varieties

Data in Table 1 show that variety PBNR-03-02 (V_3) has recorded highest number of tillers plant^{-1} which was significantly more than rest of varieties, however variety SYE-1 (V_1) and SYE-2001(V_2) were statistically at par with each other to produce tillers during 2016 and 2017. As the tillers of the plant are controlled by the genetic factors the differences in tiller were observed as reported. Bangladesh Rice Research Institute (2000).

Effect of nutrients

During both the years of trial a significant variation in number of tillers plant^{-1} was recorded due to various treatments as shown in Table 1. At harvest stage significantly highest production of tillers per plant was explored by the application of RDF with $ZnSO_4$ (25 kg ha^{-1}) + $FeSO_4$ (30 kg ha^{-1}) (N_6) than rest of the treatments, consecutively for two years, it may ascribed higher amount of macro and micronutrient availability and uptake. Alone application of nutrient $FeSO_4$ (30 kg ha^{-1}) recorded marginally higher number of tiller which was at with the with RDF+ $ZnSO_4$ (25 kg ha^{-1}) over Recommended dose of fertilizer followed by Foliar application of Fe SO_4 (N_5) and Foliar application of $ZnSO_4$ (N_4) was compare with each other the pattern was similar for both the years of experimentation.

Interaction effect

Interaction effect of different varieties and RDF with micronutrients was found non-significant.

Total dry matter (gm)

Effect of varieties

During first year of experimentation maximum dry matter accumulation (g plant^{-1}) was recorded by the variety PBNR-03-02 (V_3) which was significantly superior over rest of two varieties.

Table.1 Growth characters of upland irrigated rice cultivars as influenced by different treatments during 2015-16 and 2016-17

Treatments	2015-16				2016-17			
	Days				Days			
	Plant Height (cm)	No. of functional leaves	No. of tillers m^{-2}	Total dry matter (gm)	Plant Height (cm)	No. of functional leaves	No. of tillers m^{-2}	Total dry matter (gm)
A) Varieties (V)								
V_1 - Sindewahi -1 (SYE-1)	31.66	36.01	8.37	6.86	35.53	40.38	10.91	7.94
V_2 - Sindewahi-2001 (SYE-2001)	29.87	35.76	8.19	5.61	34.48	38.50	10.45	7.09
V_3 - PBNR-03-02	35.28	39.42	9.31	7.76	42.25	41.85	12.91	8.69
SE (m)±	0.75	0.79	0.09	0.28	0.75	0.69	0.18	0.09
CD (P=0.05)	2.08	2.21	0.26	0.78	2.10	1.91	0.51	0.27
B) Nutrients (N)								
N_1 - RDF (100: 50:50 NPK kg ha^{-1})	30.12	35.07	8.42	5.38	35.36	36.10	10.52	7.08
N_2 - RDF + $ZnSO_4$ (25 kg ha^{-1})	32.22	37.33	8.60	7.27	37.37	40.20	11.60	7.99
N_3 - RDF + $FeSO_4$ (30 kg ha^{-1})	32.80	38.02	8.62	7.40	37.87	42.87	11.80	8.30
N_4- RDF+ Foliar spray of $ZnSO_4$ @ 0.5 % at flowering and dough stage	31.18	35.42	8.47	5.66	36.41	39.16	10.73	7.50
N_5 - RDF+ Foliar spray of $FeSO_4$ @ 1.0 % at flowering and dough stage	31.22	36.51	8.58	6.22	36.51	39.33	10.83	7.69
N_6 - RDF +$ZnSO_4$ + $FeSO_4$ (25+30 kg ha^{-1})	36.07	40.02	9.06	8.50	41.02	43.80	13.04	8.91
SE (m)±	1.06	1.13	0.13	0.39	1.07	0.97	0.26	0.13
CD (P=0.05)	2.94	3.13	0.36	1.10	2.97	2.71	0.72	0.38
C) Interactions (V x N)								
SE (m)±	1.84	1.95	0.23	0.68	1.85	1.69	0.45	0.24
CD (P=0.05)	NS	NS	NS	NS	NS	NS	NS	NS
General Mean	32.27	37.06	8.62	6.75	37.42	40.24	11.42	7.91

Table.2 Developmental stages of upland irrigated rice cultivars as influenced by different treatments during 2015-16 and 2016-17

Treatments	2015-16				2016-17			
	Days				Days			
	Panicle initiation	50 % heading	50% flowering	Grain maturation	Panicle initiation	50 % heading	50% flowering	Grain maturation
A) Varieties (V)								
V_1 - Sindewahi -1 (SYE-1)	33	60	74	91	36	62	81	94
V_2 - Sindewahi-2001 (SYE-2001)	40	67	85	98	43	70	91	102
V_3 - PBNR-03-02	32	52	68	87	36	55	72	91
SE (m)$\pm$	0.60	0.66	0.44	0.66	0.62	0.99	0.52	1.13
CD (P=0.05)	1.66	1.85	1.23	1.84	1.72	2.75	1.44	3.13
B) Nutrients (N)								
N_1 - RDF (100: 50:50 NPK kg ha^{-1})	33	59	76	94	38	62	81	91
N_2 - RDF + $ZnSO_4$ (25 kg ha^{-1})	34	61	77	94	37	64	82	96
N_3 - RDF + $FeSO_4$ (30 kg ha^{-1})	35	60	77	93	38	62	81	96
N_4- RDF+ Foliar spray of $ZnSO_4$ @ 0.5 % at flowering and dough stage	36	57	76	90	39	60	83	97
N_5 - RDF+ Foliar spray of $FeSO_4$ @ 1.0 % at flowering and dough stage	36	57	75	88	38	60	81	97
N_6 - RDF + $ZnSO_4$ + $FeSO_4$ (25+30 kg ha^{-1})	37	63	72	93	39	66	80	97
SE (m)$\pm$	0.85	0.94	0.62	0.94	0.87	1.40	0.73	1.59
CD (P=0.05)	2.35	2.62	1.74	2.61	N.S	N.S	N.S	N.S
C) Interactions (V x N)								
SE (m)$\pm$	1.47	1.63	1.08	163	1.52	2.43	1.27	2.76
CD (P=0.05)	NS	NS	NS	NS	NS	NS	NS	NS
General Mean	35	59	75	92	38	62	81	96

However variety SYE-1 was at par with the variety SYE-2001 (V_2). but in next year variety V_3-(PBNR-03-02) yielded significantly higher dry matter at all the stages. However Sindewahi-1 was significantly superior to Sindewahi-2001 at harvest. This observed because of the natural endowments of crop cultivars to optimally utilize available nutrients and subsequently partition its photosynthates for dry matter accumulation and/or conversion to economic yield vary (Ndon and Ndaeyo, 2001).

Effect of nutrients

Maximum dry matter production was observed with combination of $ZnSO_4$ + $FeSO_4$ (25+30 kg ha^{-1}) with RDF which was significantly superior over rest of the nutrient management. The application of $FeSO_4$ was found comparable with $ZnSO_4$ along with RDF and found significantly superior over RDF alone. Foliar spray of $ZnSO_4$ and $FeSO_4$ were comparable to produce more or less equal dry matter production but found significantly superior over soil application of RDF during 2016.

During 2017 maximum dry matter was noticed with $ZnSO_4$ and $FeSO_4$ which was found significantly higher than rest of the treatments. Addition of $ZnSO_4$ and $FeSO_4$ produced significantly higher dry matter over the RDF alone foliar spray of $FeSO_4$ and $ZnSO_4$ were comparable but found significantly superior over RDF alone.

The apparent and significantly higher dry matter accumulation in wheat plant obtained with RDF with $ZnSO_4$ + $FeSO_4$ compared to the values obtained in other treatments in this study, might be due to better nourishment derived from the soil as a result of balanced fertilization which improves soil nutrient status. Moreover, the initiation and development of tillers is very much dependent on the concentration of N, P and K in the mother stem at tillering stage of crop. Another reason is when Zn and Fe provided in combination with RDF as soil application distribution of Zn and Fe within rice plant occurs through xylem and retranslocation in phloem which increases vegetative tissue formation resulted in improved photosynthetic activity which shows boosted growth of plant parts and increment in dry matter. These results are supported by Nadim *et al.,* (2012)

Interaction effect

The different factors under study did not interact significantly in respect of dry matter accumulation at all growth stages of crop.

Development stage of rice

As the tillering stage comes to complete, they would develop flowers. These flowers are more commonly called as panicles. After the panicle initiation further phenotyping of rice crop starts.

Effect of varieties

The data depicted in the Table 2 revealed that the rice requires 52 and 70 days for 50% flowering and 78 and 91 days for grain maturation in 2015-16 and 2016-17 respectively.

In 2015-16, Variety PBNR-03-02 shows earlier Panicle initiation (32^{nd} DAS), 50% heading (52^{nd} DAS), 50% flowering (68^{th} DAS) and grain maturation (87^{th} DAS) as compared to 2016-17 and maturity was delayed in case of variety Sindewahi-2001.

During 2016-17, Panicle initiation of Sindewahi-1 and PBNR-03-02 was on same day, but PBNR-03-02 shows early 50% heading, 50% flowering and grain maturation over Sindewahi-1 and late phenological stages occurred in variety Sindewahi-2001.

This variation might be due to genetic makeup of cultivars. This Variations in crop growth period among different cultivars under different climatic condition is also reported by Khalifa *et al.,* (2014)

Effect of nutrients

Alone application of RDF i.e. (100:50:50) recorded earlier panicle initiation (33^{rd} DAS) during 2015-16, 50% heading occurred due to combination of Foliar spray of $FeSO_4$ @1.0 % and $ZnSO_4$ @ 0.5% at flowering and dough stage with RDF (57^{th} DAS) and rice reached to its50% flowering by the combine application of N_6 - RDF + $ZnSO_4$ + $FeSO_4$ (25+30 kg ha^{-1}) 72^{th} day in the same year. However in year 2016-17 panicle initiation, 50% initiation and grain maturation was earlier due to the foliar application of $FeSO_4$ @ 1.0 % on 88^{th} day.

During next year all the developmental stages of upland irrigated rice was not differ significantly due to various nutrient treatments.

In the present investigation, induction of early ear head emergence due to optimum supply of required essential plant nutrient, which have an influence on early ear head emergence in rice.

The results are in line with the findings of Sharma (2009) who had reported that days to flowering in wheat occurred significantly late in control plots, while it was earlier in 100 % NPK applied to wheat.

Interaction effect

The Interaction effect between variety and nutrients was found non-significant at all developmental stages. On the basis of the results obtained, the following conclusions of significant and utility can be drawn

Variety PBNR-03-2 recorded significantly higher growth and developmental characters vary according to stages.

Soil application of RDF (100:50:50 kg ha^{-1}) + $ZnSO_4$ (25 kg ha^{-1}) + $FeSO_4$ (30 kg ha^{-1}) recorded significantly highest growth and developmental studies.

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