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Agronomic bio fortification to Improve Yield along with Iron Augmentation of Paddy

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ABSTRACT: Iron supplementation of paddy varieties had been carried out by the economical agronomical biofortification process. Impressive changes had been observed among varieties for yield and yield related traits along with increased iron contents in dehusked rice varieties. The increase in grain yield per plant was higher in HBC19, Pusa 1121 while lowest in Govind. Palman 579 showed maximum increase while Super had minimum increase of in thousands grain weight at higher augmentation level. Increase in numbers of seeds per panicle was also observed in all rice varieties while maximum by Pusa1121followed by Super. Fe content in roots and shoots increased with increase in Fe concentration. Roots of HBC19 and Palman579 and shoots of Pusa1121 contained higher iron. Highest iron in dehusked grains was recorded in Palman579 followed by HBC19, Pusa1121, HKR120, Super and Govind. Agro biofortification desired a balance of iron augmentation as its excess causes toxic affect on the physiological process of the plants.

Keywords: Iron fortification, rice genotypes, yield and contributing traits.

INTRODUCTION

Larger portion of resources poor people, lack to consume micronutrients-rich non staple food in daily diet to ensure good health (Bouis *et al.*, 2017). Rice has been established as a prime source of nutrition of country population. The fortification of paddy with Iron supplementation to overcome the problem of Anemia in children and lactating women would be very much appreciated (Bharadva *et al.*, 2019; Masuda *et al.*, 2020). Soil may be enriched with Iron availability either by fertilizer application or foliar application directly to the leaves of the crop (Garg *et al.*, 2018; Kumar *et al.*, 2019). Traditionally agronomic biofortification, being economical, has applied which involves micronutrient uptake from the surrounding soil and translocation into the edible parts of the plants (Giordano *et al.*, 2019; Hassan *et al.*, 2019). Iron (Fe) is an essential micronutrient that plays critical role in metabolic processes such as DNA synthesis, respiration and photosynthesis in all living organisms. Further, many metabolic pathways are activated by Fe, and it is a prosthetic group constituent of many enzymes. In nature, Fe occurs in abundance however, its availability to plants is reduced, once this element is in the form of hydrated oxides, which can limit plant productivity and biomass production. On the other hand, in high concentrations, this essential micronutrient for the plants can become a toxic agent, also increasing the environmental contamination. The balance of Fe should be strictly maintained, because its deficiency and as well as its toxicity affect the physiological process of plants (Prity *et al.*, 2021).

MATERIALS AND METHODS

Six rice varieties were evaluated under field trials during kharif in the net houses of the Department of Chemistry and Biochemistry, CCS HAU, Hisar during cropping seasons 2015-2016 and 2016-2017. Seeds of all rice varieties were sown directly in pots at 2-3 cm depth in light textured (loamy) soil with recommended agronomical practices (Sikirou *et al.*, 2006) and the pots were divided in three sets after 20 days of sowing for Iron augmentation as: One set was given Yoshida nutrient medium without Fe (0 mM EDTA-Fe(II)). Second set was given Yoshida nutrient medium with 0.1mM EDTA-Fe(II)) concentration. Third set was given Yoshida nutrient medium with high Fe concentration (0.5 mM EDTA-Fe (II)). The data obtained in the present investigation was subjected to analysis of variance (ANOVA) technique and further analyzed according to one/two factorial randomized designs. The critical difference value at 5% level was used for making comparison among various rice varieties grown under different iron treatments.

RESULTS AND DISCUSSION

Analysis of yield and contributing traits

ANOVA analysis had observed highly significant variations among the estimated values among genotypes as well as for doses of iron supplementation (Jalal *et al.*, 2020). Pair wise comparison expressed differences by superscripts on mean values (Shi *et al.*, 2016). The height of rice plants ranged significantly from 68.82 (Govind) to 108.76 cm (HBC19) under control conditions (Table 1). At 0.1 mM Fe treatment, plant height increased in all the six rice varieties by 3.25% (Super) to 13.51% (HBC19). Noticeably, at high Fe concentration (0.5 mM), fall in plant height was recorded in all six rice varieties. Maximum height had enhanced for HBC19 followed by Super & HKR120.

As depicted in Table 2, effective number of tillers per plant ranged from 10.00 (Pusa1121) to 19.17 (HBC19) under control conditions. In rice plants grown under 0.1 mM Fe treatment, number of tillers increased; HKR120 displayed a maximum increase of 18.33% followed by Govind (18.00%), Super (15.77%), Pusa1121 (14.47%), HBC19 (15.08%) (24.07%) and Palman579 (14.50%). At high (0.5 mM) Fe treatment, effective number of tillers per plant were less than that at 0.1 mM Fe and it ranged between 14.13 (Palman579) and 17.63 (HKR120). Overall mean values favoured the HBC19genotypes followed by Govind & Pusa1121 for more number of tillers.

Similar to plant height, the panicles' length of all the six rice varieties increased significantly at 0.1 mM Fe treatment, however, rice varieties showed reduction in panicles length at 0.5 mM Fe treatment in comparison to 0.1 mM Fe (Table 3). Under control (no additional iron in soil) conditions, the length of panicles ranged from 25.45 (Palman579) to 27.67 cm (HBC19). At 0.1 mM Fe treatment, maximum increase in panicle length was observed in HBC19 (11.75%) while least increase was recorded in Super (7.03%). At high (0.5 mM) Fe treatment, increase of 9.17%, 10.19%, 9.16%, 12.62% and 6.02% in panicle length was observed in Pusa1121, HBC19, HKR120, Palman579 and Super, respectively whereas increase of only 5.21% was observed in Govind. Genotype Super followed by Pusa1121 & HKR120 for mean values of panicle length.

Table 1: Plant height of genotypes vis-à-vis EDTA application.

Genotype	0mM EDTA-Fe(II)	0.1mM EDTA-Fe(II)	0.5mM EDTA-Fe(II)	Mean
Govind	68.82	72.73	71.30	70.94 ^{f}
Super	95.37	98.47	97.41	97.08 ^{b}
HKR120	89.24	96.19	94.09	93.17 ^{c}
Pusa1121	81.69	92.64	89.27	87.86 ^{d}
HBC19	108.76	123.45	117.38	116.53 ^{a}
Palman	70.82	76.09	75.96	74.28 ^{e}
Mean	85.78 ^{c}	93.26 ^{a}	90.90 ^{b}	
CD at 5% for Genotypes	1.18			
CD at 5% for EDTA	0.83			

Table 2: Effective number of tillers of genotypes vis-à-vis EDTA application.

Genotype	0mM EDTA-Fe(II)	0.1mM EDTA-Fe(II)	0.5mM EDTA-Fe(II)	Mean
Govind	18.00	20.58	16.25	18.27 ^{b}
Super	11.67	14.17	13.17	13.0 ^{d}
HKR120	12.75	16.33	14.42	14.5 ^{c}
Pusa1121	10.00	15.17	11.50	12.22 ^{e}
HBC19	19.17	23.08	20.42	20.88 ^{a}
Palman	10.25	13.50	11.92	11.88 ^{f}
Mean	13.63 ^{c}	17.13 ^{a}	14.61 ^{b}	
CD at 5% for Genotypes	1.00			
CD at 5% for EDTA	0.71			

Table 3: Panicle length (cm) of genotypes vis-à-vis EDTA application.

Genotype	0mM EDTA-Fe(II)	0.1mM EDTA-Fe(II)	0.5mM EDTA-Fe(II)	Mean
Govind	55.58	59.67	57.92	57.72 ^{d}
Super	67.08	72.92	71.08	70.36 ^{a}
HKR120	59.83	65.33	64.50	63.22 ^{c}
Pusa1121	62.08	69.75	67.67	66.5 ^{b}
HBC19	47.67	54.42	51.92	51.33 ^{e}
Palman	42.83	47.33	45.67	45.27 ^{f}
Mean	55.84 ^{c}	61.56 ^{a}	59.79 ^{b}	
CD at 5% for Genotypes	1.03			
CD at 5% for EDTA	0.73			

Thousands grain weight increased significantly in all the rice varieties both at 0.1 and 0.5 mM Fe treatments as compared to control application (Table 4). In control, 1000- grain weight (g) varied from 18.95 (Palman579) to 27.71 (HKR120). At 0.1 mM Fe, increase in 1000-grain weight was recorded in HBC19 (13.80%), Palman579 (13.04%), Pusa1121 (11.39%), HKR120 (8.21%), Govind (9.37%) and Super (8.63%). At 0.5 mM Fe, Palman579 showed maximum increase of 8.68% while Super had minimum increase of 2.44% in 1000 grain weight. Maximum overall average values pointed towards Govind followed by Pusa1121 & HKR120 for thousands grain weight (Yadav *et al.*, 2016).

Table 4: Thousands grain weight (g) of genotypes vis-à-vis EDTA application.

Genotype	0mM EDTA-Fe(II)	0.1mM EDTA-Fe(II)	0.5mM EDTA-Fe(II)	Mean
Govind	23.30	25.95	24.56	24.60 ^{a}
Super	19.38	21.43	20.89	20.56 ^{e}
HKR120	19.59	22.46	21.11	21.05 ^{d}
Pusa1121	19.81	24.70	23.01	22.50 ^{b}
HBC19	17.65	23.44	21.27	20.78 ^{c}
Palman	16.79	21.63	18.83	19.08 ^{f}
Mean	19.41 ^{c}	23.27 ^{a}	21.60 ^{b}	
CD at 5% for Genotypes	1.01			
CD at 5% for EDTA	0.71			

As shown in Table 5, the number of grains/panicle at 0.1 mM and 0.5 mM Fe treatments invariably increased in all the six rice varieties compared to control conditions (no additional Fe in soil). The number of grains/panicle varied from 54.00 (Palman579) to 66.62 (HKR120) under control conditions. At 0.1 mM Fe, increase in grains/panicle was higher in HKR120 (13.16%) and HBC19 (13.13%) compared to Govind (8.40%) and Super (7.88%). An increase in numbers of grains/panicle was also observed at 0.5 mM Fe treatment in all rice varieties which ranged between 5.42% (Super) and 9.86% (Pusa1121). Maximum increase observed in Govind followed by Palman579 & HKR120 for grains per panicle trait (Kabir *et al.*, 2016).

Grain yield (g) per plant of six rice varieties under control and 0.1 and 0.5 mM Fe treatment conditions is given in Table 6.More over the grain yield (g) per plant varied from 13.62 (Palman579) to 30.83g (HKR120) under control conditions. At 0.1 mM Fe-EDTA, grain yield per plant significantly increased in all the rice varieties [18.36 (Palman579) to 40.15 g (HKR120)]. The increase in grain yield per plant was higher in HBC19 (44.43%) and Pusa1121 (37.53%) while lowest in Govind (19.88%). The grain yield, however, declined at high (0.5 mM) Fe in all the rice varieties. Overall average values highlighted maximum increase in HKR120 followed by Super & HBC19 (Ramzan *et al.*, 2020).

Table 5: Grains per panicle of genotypes vis-à-vis EDTA application.

Genotype	0mM EDTA-Fe(II)	0.1mM EDTA-Fe(II)	0.5mM EDTA-Fe(II)	Mean
Govind	34.00	37.08	36.08	35.72 ^{a}
Super	25.08	27.92	26.58	26.52 ^{d}
HKR120	26.50	30.25	28.75	28.5 ^{c}
Pusa1121	17.17	23.17	19.23	19.85 ^{f}
HBC19	19.75	25.08	21.92	22.25 ^{e}
Palman	29.00	32.83	31.67	31.16 ^{b}
Mean	25.25 ^{c}	29.38 ^{a}	27.37 ^{b}	
CD at 5% for Genotypes	1.39			
CD at 5% for EDTA	0.98			

Table 6: Grain Yield per plant (g) of genotypes vis-à-vis EDTA application.

Genotype	0mM EDTA-Fe(II)	0.1mM EDTA-Fe(II)	0.5mM EDTA-Fe(II)	Mean
Govind	20.67	25.34	22.27	22.76 ^{d}
Super	27.34	33.34	29.97	30.21 ^{b}
HKR120	31.45	37.46	34.41	34.43 ^{a}
Pusa1121	18.28	25.41	20.70	21.46 ^{e}
HBC19	20.31	26.68	22.85	23.27 ^{c}
Palman	19.18	23.29	21.06	21.17 ^{f}
Mean	22.86 ^{c}	28.58 ^{a}	25.20 ^{b}	
CD at 5% for Genotypes	1.05			
CD at 5% for EDTA	0.74			

Iron content in dehusked rice grains varied significantly between 27.63 (Govind) to 235.37 µg/g (Palman579) under control conditions (Table 7). Grain iron content increased linearly with increasing iron treatments in all the six varieties. The maximum increase in iron content was observed in Palman579 (65.26% and 92.17%) followed by HBC19 (48.71% and 79.65%) while the lowest increase was noticed in Govind (13.39% and 26.06%) at 0.1mM and 0.5 mM Fe treatments respectively, as compared to the control treatment. At 0.5 mM Fe, grain iron content ranged from 34.83 (Govind) to 452.34 µg/g (Palman579). Irrespective of Fe augmentations, significantly higher iron in grain content were observed in Palman579 and HBC19 varieties.

Table 7: Iron contents (µg/g) per panicle of genotypes vis-à-vis EDTA application.

Genotype	0mM EDTA-Fe(II)	0.1mM EDTA-Fe(II)	0.5mM EDTA-Fe(II)	Mean
Govind	27.63	31.33	34.83	31.27^f
Super	29.70	34.24	37.70	33.88^e
HKR120	44.27	60.40	69.97	58.21^d
Pusa1121	68.17	83.57	94.72	82.15^c
HBC19	146.30	217.57	262.83	208.90^b
Palman579	235.37	388.98	452.30	358.88^a
Mean	91.91^c	136.01^b	158.73^a	
CD at 5% for Genotypes	0.912			
CD at 5% for EDTA	0.6448			

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Conflict of Interest. Nil.

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