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Effect of iron nutrition on plant growth and yield of aerobic rice

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Abstract
A Field experiments was carried out at the research farm of Indian Council of Agricultural Research - Indian Agricultural Research Institute (ICAR-IARI), New Delhi, India, during *Kharif* seasons (June–October) of 2011 and 2012 to study the "Effect of iron nutrition on plant growth and yield of aerobic rice". The experiment was laid out in factorial randomized block design and replicated thrice. Treatments comprised of two rice varieties (PRH-10 and PS-5) and eight sources and modes of iron fertilization-control (no iron), iron sulphate @ 50 kg ha^{-1} + one foliar spray of 2.0% iron sulphate, iron sulphate @ 50 kg ha^{-1} + one foliar spray of 0.5% iron chelate, iron sulphate @ 100 kg ha^{-1}, two foliar sprays of 2.0% iron sulphate, three foliar sprays of 2.0% iron sulphate, two foliar sprays of 0.5% iron chelate and three foliar sprays of 0.5% iron chelate. Results indicated that rice variety PRH-10 gave significantly better agronomic performance than PS-5 with respect to growth parameters (plant height, tillers, dry matter accumulation) and yield. Iron nutrition treatments significantly affected the plant height, tillers, dry matter accumulation and yield of aerobic rice. Three foliar sprays of 2.0% iron sulphate produced tallest plants, maximum number of tillers, accumulated highest dry matter and produced maximum yield across all the stages during both the years followed by three foliar sprays of 0.5% iron chelate.

Keywords: Iron nutrition, aerobic rice, varieties, growth, yield

Introduction
Rice (*Oryza sativa* L.) is the staple food for three-fourth of the Indian population. Similarly, it feeds roughly half the planet's population and approximately three-quarters of a billion of the world's poorest people depend on the staple to survive (Zeigler, 2007) [1]. India produced 275.68 million tonnes of food grains with major contribution from rice *i.e* 110.15 million tonnes (Anonymous, 2017) [2], but the productivity of milled rice is still much low *i.e.* 2,404 kg/ha (Anonymous, 2016) [3]. To safeguard the food security in India, it is quite important to raise the productivity levels of rice, particularly under the decreased water availability. Scarcity of water for agricultural production is becoming a major problem in many countries, particularly in the rice growing countries, China and India, where competing and growing demands for freshwater are coming from other sectors. Rice farmers need technologies to cope with water shortage and ways must be sought to grow rice with less water (Tuong and Bouman, 2002) [4]. Thus, there is a need to economize water use in irrigated rice production. The transplanted puddled rice production system is labour, water and energy-intensive which proved less profitable (Kumar and Ladha, 2011) [5]. The alarming rate of ground water depletion and increasing labour scarcity are major threats to future rice production in north-west India (Yadav *et al.,* 2012) [6]. Researchers are therefore trying to develop water saving technologies such as system of rice intensification (SRI) and aerobic rice system (ARS).
The aerobic rice system (ARS) is a new production system in which rice is grown under non-puddled, nonflooded and non-saturated soil conditions as other upland crops (Prasad, 2011; Bouman, 2001; Tuong and Bouman 2003) [7-9]. Thus, in ARS, soils are kept aerobic almost throughout the rice-growing season. But despite the usefulness of ARS, there are still many constraints that restrict its adoption by rice farmers. The major constraints in ARS are unavailability of varieties specifically bred for it, severe weed and nematode infestation and, of course, the iron deficiency. On the other hand, iron is an essential plant nutrient plays major role in photosynthesis. The increased cropping intensity and accompanying changes in the soil and fertilizer management options have changed the iron status and availability, especially in the Indo-Gangetic plains of India where on large areas rice-wheat cropping system is being practiced.

Cropping systems of 200–300% intensity deplete the soil iron more due to higher production. This Fe deficiency is aggravated further as farmers do not apply it externally and its mining occurs. However, application of iron fertilizers may overcome its deficiency in soil, increase crop yields which will subsequently increase crops productivity and income of the farmers. Furthermore, identification of efficient Fe-utilizing varieties would also help in coping with the iron deficiency. In view of the above facts, a field experiment was conducted to study the "Effect of iron nutrition on plant growth and yield of aerobic rice".

Materials and Methods

The field experiment entitled "Effect of iron nutrition on plant growth and yield of aerobic rice" was conducted at the Research Farm of ICAR-Indian Agricultural Research Institute, New Delhi during two consecutive years (2011-12 and 2012-13). The climate of Delhi is of sub-tropical and semi-arid type with hot and dry summer and cold winters and falls under the agro-climatic zone 'Trans-Gangetic plains'. During summer, May and June are the hottest with maximum temperature ranging between 41 and 46 °C, while there is a drop in temperature from September onwards. January is the coldest month of the year with a minimum temperature ranging from 5 to 7 °C. The mean annual rainfall is 650 mm, and July and August are the wettest months. The soil of experimental field was sandy clay loam in texture, *p*H-7.4 (1:2.5 soil: water) (Cyber scam 500 *p*H metre, Prasad *et al*., 2006) [10], low in available N (Subbiah and Asija, 1956) [11] and Fe (Prasad *et al*., 2006) [10] and medium in available P (Olsen *et al.*, 1954) [12], K (Flame photometer method, Jackson, 1958) [13] and organic carbon content (Walkley and Black, 1934) [14]. The experiment was laid out in factorial randomized block design and replicated three times. The treatments were randomly allotted to different plots, using random number table of Fisher and Yates (1963) [15]. The treatment combinations were 16 consisting of 2 rice varieties Pusa Sugandh-5 (PS-5) and Pusa Rice Hybrid-10 (PRH-10) and 8 sources and mode of application Control (no iron), Iron sulphate @ 50 kg/ha + one foliar spray of 2.0% iron sulphate, Iron sulphate @ 50 kg/ha + one foliar spray of 0.5% iron chelate, Iron sulphate @ 100 kg/ha, Two foliar sprays of 2.0% iron sulphate, Three foliar sprays of 2.0% iron sulphate, Two foliar sprays of 0.5% iron chelate, Three foliar sprays of 0.5% iron chelate.

The pre-sowing irrigation was given in experimental field before sowing of the seed of aerobic rice. The field was ploughed twice by disc harrow followed by one ploughing by cultivator. Rice crop was grown in *kharif* seasons of 2011 and 2012 followed by wheat in *rabi* seasons of 2011-12 and 2012-13. The experiment was conducted on a fixed site over two cropping cycles in order to study the residual effects of the treatments. Iron was applied as per treatment through various Fe sources. The amount of sulphur supplied to the field through iron fertilization was adjusted through elemental sulphur in all the plots. Recommended doses of N, P and K were applied to crop during both the years in all plots. Half dose of nitrogen and full doses of P and K was applied as basal at the time of sowing and remaining N was applied in two equal splits *i.e.*, at tillering and panicle initiation stages. Irrigations to the crops were provided as per the requirement. Other crop management practices were followed as per the recommendations. Ten plants were selected randomly from each plot, tagged permanently and used for measurement of plant height at 30, 60, 90 and at harvest. Plant height of the aerobic rice was measured from the base of the plant at ground surface to the tip of the tallest leaf. The number of tillers per metre row length was counted at periodical intervals from two different spots from each plot and the average was worked out. It was then converted to tillers m^{-2}. Plants of 50 cm row length were harvested at different stages of growth from the sampling rows. After recording the leaf area, these plants were sun-dried for 2-3 days and oven-dried at 60±2 ˚C for 24 hours and dry weight (g m^{-2}) was recorded at 30, 60, 90, and at harvest. The net plots (leaving 2 border rows on each side and 0.5 meter from each side of the length) were harvested and sun-dried for three days in the field and then the total biomass yield was recorded. After threshing, cleaning and drying the grain yield was recorded and reported at 14% moisture content. Yield was expressed in tonnes per hectare. All the data, under factorial randomized block design, were statistically analysed using the F-test as per the procedure given by Gomez and Gomez (1984) [16]. Least significant differences (LSD) values at $P = 0.05$ were used to determine the significance of differences between treatment means.

Results and Discussion

Plant Growth

The data pertaining to plant height of aerobic rice as affected by varieties and iron nutrition are presented in Table 1. Plant height increased with the advancement of the crop growth stages. Results indicate that the plant height was affected significantly by varieties and iron fertilization. Rice variety PRH-10 produced significantly taller plants than the variety PS-5 across all the growth stages of the crop during both the years of investigation. Iron fertilization of aerobic rice proved useful in enhancing the plant height. Three foliar sprays of 2.0% iron sulphate produced tallest plants at 30, 60 & 90 DAS and at harvest in both the years. Shortest plants were found with the control and plant height increased successively with iron sulphate @ 50 kg/ha + one foliar spray of 2.0% iron sulphate, iron sulphate @ 50 kg/ha + one foliar spray of 0.5% iron chelate and iron sulphate @ 100 kg/ha. All these former mentioned treatments produced significantly shorter plants over three foliar spray of 2.0% iron sulphate during both the years and across all the stages. Over all, three foliar sprays of either iron sulphate or iron chelate, in general, enhanced plant height substantially over other treatments.

The data related to the number of tillers are presented in Table 2. Tiller number increased progressively with the advancement of growth stages. Lowest number of tillers was found at 30 DAS whereas; it reached the maximum at 90 days of crop growth stage. Rice varieties differed significantly with respect to production of tillers. Variety PRH-10 produced 9.52% more tillers than PS-5 at harvest stage. Former variety produced significantly higher number of tillers than the later at all the growth stages during both the years. Iron nutrition of aerobic rice had a positive effect on tiller production. Among all the treatments maximum number of tillers was recorded with three foliar spray of 2.0% iron sulphate followed by three foliar spray of 0.5% iron chelate. These two treatments produced significantly higher tillers over control plot across all the stages. Control, iron sulphate @ 50 kg/ha + one foliar spray of 2.0% iron sulphate, iron sulphate @ 50 kg/ha + one foliar spray of 0.5% iron chelate and iron sulphate @ 100 kg/ha produced statistically similar number of tillers at 30, 60 and 90 DAS. It therefore, suggests that foliar feeding of iron through three sprays of iron sulphate (2.0%) or iron chelate (0.5%) helped the plants to produce more tillers.

In general, dry matter increased substantially and quadratically with the advancement of crop age (Table 3). The highest values of dry matter accumulation were recorded at harvest stage. However, the amount of dry matter accumulated by two varieties differed significantly. PRH-10 accumulated significantly higher dry matter across all the stages over PS-5 during both the years. Sources and mode of iron application also had a significant effect on dry matter production. Lowest dry matter accumulation was recorded with control plot which was significantly lower than two and three foliar sprays of 2.0% iron sulphate and 0.5% iron chelate at all the stages. However, application of iron sulphate @ 100 kg/ha, iron sulphate @ 50 kg/ha + one foliar spray of 2.0% iron sulphate and iron sulphate @ 50 kg/ha + one foliar spray of 0.5% iron chelate produced dry matter which was at par with the control.

It is thus evident from the preceding paragraphs that, in general, significantly higher values of growth parameters, viz. plant height, number of tillers per unit area and dry matter accumulation were recorded in PRH-10 than in PS-5. Overall, PRH-10 maintained its significant superiority over PS-5 with respect to growth parameters. PRH-10 is an aromatic hybrid and PS-5 an inbred aromatic variety. The differential growth behaviour of rice varieties could be attributed to the genetical characters of the variety (Adhikari *et al*., 2004) [17]. It is natural that growth of hybrids is generally more than inbred varieties, attributed mainly to the heterosis phenomenon in the former. The dry matter more than PS-5 due to more number of tillers hill^{-1}. Rice hybrids show heterobeltiosis for dry matter production due to higher tillers plant^{-1} (Lin and Liang, 1997) [18]. It can thus be inferred from the three preceding paragraphs that iron fertilization helped aerobic rice to attain better growth. However, the growth response varied significantly with respect to mode and source of iron fertilization. Over all, three foliar sprays of either iron sulphate (2.0%) or iron chelate (0.5%), in general, enhanced different plant growth parameters substantially over other treatments. Application of iron sulphate (2.0%) or iron chelate (0.5%) proved very effective in producing taller plants, more number of tillers and higher dry matter production. However, application of iron sulphate @ 100 kg/ha, iron sulphate @ 50 kg/ha + one foliar spray of 2.0% iron sulphate and iron sulphate @ 50 kg/ha + one foliar spray of 0.5% iron chelate, in general, was not much beneficial in enhancing the growth of aerobic rice. Most of the times these former treatments could not yield any additional growth, in general, even over the control. Hence, soil application of iron sulphate combined with one foliar spray of either iron sulphate or iron chelate could not bring much significant improvement in aerobic rice growth over the unfertilized control.

Xiaoyun *et al.* (2012) [19] also reported a significant increase in shoot dry weight by Fe application under both aerobic and flooded plots. Similarly, plant dry matter g/m^2 at various growth stages (active tillering, panicle initiation, flowering and at harvest) increased with iron application (Rakesh *et al*., 2012) [20]. Kulandaivel *et al*. (2004) [21] reported that the levels and mode of application of iron considerably increased the growth, yield attributes and yield of rice-wheat cropping system. Foliar application of $FeSO_4$ or Fe-chelate was shown to be more efficient than soil application because of the direct uptake of Fe by the plant through cuticular pores from the leaf surface (Fang *et al*., 2008) [22]. Yadav (2012) [23] reported that levels and methods of $FeSO_4$ significantly influenced the plant height of aerobically grown rice. The application of $FeSO_4$ @ 100 kg ha^{-1} recorded significantly higher plant height over control at 60 DAS. Xiaoyun *et al.* (2012) [19] conducted a field experiment to determine the effects of cultivation system (aerobic vs. flooded), genotype (five aerobic rice varieties and one lowland rice variety), and Fe fertilization [no Fe and 30 kg ha^{-1} ferrous sulphate ($FeSO_4$.7H2O] on rice grain yield and Fe nutrition. Plants were sampled at tillering and physiological maturity. In both aerobic and flooded plots, Fe application significantly increased shoot dry weight. In yet another study, Rakesh *et al*. (2012) [20] found that tillers m^{-2} and Plant dry matter g m^{-2} at various stages (active tillering, panicle initiation, flowering and at harvest) increased from the treatment $N_{180}P_{60}K_{40}$ (no iron application) to $N_{180}P_{60}K_{40}FeSO_{4\ 25}$ but the results were found non-significant.

Yield

The data on grain and biological yield of aerobic rice are given in Table 4. Grain and biological yield of aerobic rice was significantly influenced by varieties an iron nutrition. Rice variety PRH-10 produced significantly higher grain and biological yield over PS-5. On an average variety PRH-10 produced 8.3% higher grain yield and 4.64% higher biomass over PS-5 across two years. The grain yield of PRH-10 was 4.89 t/ha and 5.03 t/ha during 2011 and 2012, respectively. The corresponding values of grain yield for variety PS-5 were 4.52 t/ha and 4.63 t/ha, respectively. Whereas, the biological yield of PRH-10 was 12.74 t/ha and 12.95 t/ha and the values for variety PS-5 were 12.19 t/ha and 12.37 t/ha, during 2011 and 2012, respectively.

Iron nutrition of aerobic rice proved useful in enhancing the grain as well as biological yield. The grain yield rose from 4.20 in control to 5.21 t/ha in three foliar sprays of 2.0% iron sulphate during the first year. Corresponding values for second year were 4.44 t/ha in control and 5.26 t/ha in three foliar sprays of 2.0% iron sulphate. Highest grain yield was recorded from the three foliar sprays of 2.0% iron sulphate followed by three foliar sprays of 0.5% iron chelate, two foliar sprays of 2.0% iron sulphate and two foliar sprays of 0.5% iron chelate. All these former treatments produced statistically similar yields, which was significantly higher over control. Averaged across two years, treatments iron sulphate @ 50 kg/ha + one foliar spray of 2.0% iron sulphate, iron sulphate @ 50 kg/ha + one foliar spray of 0.5% iron chelate, iron sulphate @ 100 kg/ha, two foliar sprays of 2.0% iron sulphate, three foliar sprays of 2.0% iron sulphate, two foliar sprays of 0.5% iron chelate and three foliar sprays of iron chelate produced 6.25, 5.55, 2.78, 15.74, 21.30, 14.58 and 16.90% higher grain yield over control, respectively. As for as biological yield is concern, it was found highest with three foliar sprays of 2.0% iron sulphate which was closely followed by three foliar sprays of 0.5% iron chelate, two foliar sprays of 2.0% sulphate and two foliar sprays of 0.5% iron chelate. Lowest biological yield was recorded with control. The biological yield of aerobic rice due to iron fertilization ranged from 11.92 t/ha in the control to 13.17 t/ha in three foliar sprays of iron sulphate (2.0%). Three foliar sprays of 2.0% iron sulphate produced significantly higher biological yield over control, iron sulphate @ 50 kg/ha + one foliar spray of 2.0% iron sulphate, iron sulphate @ 50 kg/ha + one foliar spray of 0.5% iron chelate and iron sulphate @ 100 kg/ha.

It can thus be elucidated that variety PRH-10 gave significantly higher biomass and grain than PS-5. These increases in different yields may have been possible mainly due to increased production of tillers and dry matter in PRH-

10 than in PS-5. Further, the greater increase in grain yield of rice hybrid PRH-10 over inbred variety PS-5 was due to significantly higher values of yield attributing characters viz. number of panicles m^{-2}, number of filled grains $panicle^{-1}$, panicle weight and test weight. Duraisamy and Mani (2001) [24] have reported that iron application either alone or in combination with Mo increased the grain yield over control irrespective of the levels and modes of application and foliar application was found more effective than soil application. In general, application of iron in soil was less effective than sole foliar spray in the present study. It therefore suggests that foliar application of iron sulphate was superior to soil application alone. Foth and Ellis (1988) [25] have suggested that correcting iron deficiency is very difficult because it is caused by changes in soil's chemical conditions and not by low levels of iron. If soluble iron is added to soil, it is very quickly precipitated and becomes unavailable to plants (Fageria, 2014) [26]. Hence, we did not get any response to soil application of iron. In the present study two iron sources, viz. iron sulphate (2.0%) and iron chelate (0.5) were compared at two and three foliar sprays. Though the concentration of two iron sources differed for foliar spray, but their response was similar when used at same frequency, i.e. at 2 or 3 foliar spray. It indicates that either of the two sources could be used at their respective concentration for foliar spray. But now the economics would come into picture and decide which source needs to be used. Fageria (2014) [26] have also opined that important criterion in selecting a Fe source is its cost and solubility in water. He stated further that iron chelates are good sources and also soluble in water, but their cost is very high compared with other options.

In calcareous soils of Bihar, variable results have been reported. In one experiment, two foliar sprays of 1.0% $FeSO_4$ solution produced significantly higher grain yield of rice as compared to the soil application of 50 kg $FeSO_4$ ha^{-1} while in another experiment both the modes were equally efficient (Sakal *et al.*, 1996) [27]. Nayyar and Takkar (1989) [28] reported that since ferrous sulphate applied to soil is susceptible to transformations into unavailable forms, the rates of application to soils are very high and, therefore, uneconomical as compared to foliar application. Even the application of 200 kg $FeSO_4.7H_2O$ ha^{-1} was found to be inferior to three foliar applications with 2.0% unneutralized ferrous sulphate solution in mending the Fe deficiency in rice grown on coarse textured soils of Punjab. The results have shown that the combination of green manure and the foliar spray of 1.0% ferrous sulphate solution produced the highest grain yield followed by green manuring or foliar spray. Soil application of Fe proved significantly inferior to green manuring and foliar application (Nayyar and Takkar, 1989) [28].

Table 1: Plant height (cm) of aerobic rice (*Oryza sativa* L.) as affected by varieties and iron nutrition.

Treatment	30 DAS		60 DAS		90 DAS		At harvest	
	2011	2012	2011	2012	2011	2012	2011	2012
Variety								
PS-5	31.24	32.48	61.78	67.15	99.08	101.40	99.53	101.79
PRH-10	32.61	34.60	64.78	70.18	101.24	103.87	104.72	105.58
SEm±	0.42	0.35	0.38	1.03	0.64	0.58	0.85	0.56
LSD (*P*=0.05)	1.22	1.02	1.09	2.99	1.87	1.66	2.46	1.62
Sources and mode of iron application								
Control (no iron)	29.45	30.92	59.63	62.13	96.63	99.02	98.95	101.42
IS @ 50 kg/ha + 1 FS of 2.0% IS	31.27	32.42	61.43	66.47	99.50	101.65	100.82	103.32
IS @ 50 kg/ha + 1 FS of 0.5% IC	31.17	32.53	61.10	66.45	99.43	101.62	100.40	102.45
IS @ 100 kg/ha	30.88	32.32	61.03	65.35	99.33	101.48	99.82	102.77
2 FS of 2.0% IS	32.95	34.60	64.87	71.38	101.13	104.27	103.98	104.48
3 FS of 2.0% IS	34.22	35.77	67.13	73.87	102.27	106.22	105.75	106.12
2 FS of 0.5% IC	32.05	34.77	64.27	70.18	101.27	102.30	102.67	103.72
3 FS of 0.5% IC	33.42	34.98	66.77	73.47	101.73	104.53	104.62	105.22
SEm±	0.69	0.58	0.62	1.69	1.06	0.94	1.39	0.92
LSD (*P*=0.05)	1.99	1.67	1.78	4.88	3.05	2.72	4.02	2.64

Iron sulphate @ 50 kg/ha + one foliar spray of 2.0% iron sulphate, iron sulphate @ 50 kg/ha + one Foliar spray of 0.5% iron chelate, iron sulphate @ 100 kg/ha, two foliar sprays of 2.0% iron sulphate, three foliar sprays of 2.0% iron sulphate, two foliar sprays of 0.5% iron chelate, three foliar sprays of 0.5% iron chelate.

DAS-Days after sowing

Table 2: Tillers (m^{-2}) of aerobic rice (*Oryza sativa* L.) as affected by varieties and iron nutrition.

Treatment	30 DAS		60 DAS		90 DAS		At harvest	
	2011	2012	2011	2012	2011	2012	2011	2012
Variety								
PS-5	122.3	127.6	396.4	414.7	330.2	330.8	315.6	327.0
PRH-10	136.6	145.2	454.9	473.1	353.9	371.1	343.5	349.3
SEm±	3.6	2.6	8.2	12.1	7.7	7.3	4.2	6.0
LSD (*P*=0.05)	10.4	7.6	23.7	34.9	22.1	21.1	12.1	17.5
Sources and mode of iron application								
Control (no iron)	113.6	125.9	358.0	375.3	282.7	293.2	279.0	279.3
IS @ 50 kg/ha + 1 FS of 2.0% IS	126.6	136.4	419.3	427.3	322.0	327.2	310.3	320.0
IS @ 50 kg/ha + 1 FS of 0.5% IC	128.9	132.1	415.3	424.0	317.0	321.0	306.5	310.0
IS @ 100 kg/ha	121.4	129.1	399.3	407.3	303.3	298.7	297.0	280.7
2 FS of 2.0% IS	133.0	140.5	438.7	463.3	372.7	380.1	358.3	380.7
3 FS of 2.0% IS	140.7	142.8	472.7	507.3	386.8	407.3	373.7	388.7

2 FS of 0.5% IC	132.3	139.4	436.7	454.0	367.2	384.8	347.0	363.3
3 FS of 0.5% IC	139.1	145.1	465.3	492.3	384.2	395.0	364.7	382.3
SEm±	5.9	4.3	13.4	19.7	12.5	11.9	6.9	9.9
LSD (*P*=0.05)	17.0	12.4	38.7	57.0	36.2	34.4	19.8	28.5

Iron sulphate @ 50 kg/ha + one foliar spray of 2.0% iron sulphate, iron sulphate @ 50 kg/ha + one Foliar spray of 0.5% iron chelate, iron sulphate @ 100 kg/ha, two foliar sprays of 2.0% iron sulphate, three foliar sprays of 2.0% iron sulphate, two foliar sprays of 0.5% iron chelate, three foliar sprays of 0.5% iron chelate.
DAS-Days after sowing

Table 3: Dry matter production (g/m^2) of aerobic rice (*Oryza sativa* L.) as affected by varieties and iron nutrition.

Treatment	30 DAS		60 DAS		90 DAS		At harvest	
	2011	**2012**	**2011**	**2012**	**2011**	**2012**	**2011**	**2012**
Variety								
PS-5	52.1	58.0	287.5	297.8	801.7	845.0	1014.6	1048.2
PRH-10	61.7	66.9	342.2	358.1	862.3	904.8	1078.9	1106.8
SEm±	1.8	1.7	5.0	4.0	20.8	17.0	21.3	7.9
LSD (*P*=0.05)	5.2	4.8	14.4	11.5	60.0	49.0	61.4	22.9
Sources and mode of iron application								
Control (no iron)	46.9	54.6	257.5	276.2	760.4	780.7	875.5	948.4
IS @ 50 kg/ha + 1 FS of 2.0% IS	55.1	61.2	280.2	293.6	796.1	820.9	974.5	985.1
IS @ 50 kg/ha + 1 FS of 0.5% IC	55.2	61.1	280.6	292.7	777.2	799.0	975.4	982.4
IS @ 100 kg/ha	53.7	59.2	276.7	289.5	795.9	807.8	960.3	981.2
2 FS of 2.0% IS	59.7	64.5	348.7	351.6	867.9	890.3	1121.6	1153.6
3 FS of 2.0% IS	63.9	68.6	372.0	395.2	899.9	1009.2	1191.2	1229.8
2 FS of 0.5% IC	58.2	63.6	337.4	349.7	870.3	899.9	1087.9	1133.9
3 FS of 0.5% IC	62.3	67.0	365.7	374.8	888.1	991.3	1187.3	1205.9
SEm±	2.8	2.7	8.1	6.5	33.9	27.7	34.7	13.0
LSD (*P*=0.05)	8.5	7.8	23.5	18.7	97.9	79.9	100.2	37.4

Iron sulphate @ 50 kg/ha + one foliar spray of 2.0% iron sulphate, iron sulphate @ 50 kg/ha + one Foliar spray of 0.5% iron chelate, iron sulphate @ 100 kg/ha, two foliar sprays of 2.0% iron sulphate, three foliar sprays of 2.0% iron sulphate, two foliar sprays of 0.5% iron chelate, three foliar sprays of 0.5% iron chelate.
DAS-Days after sowing

Table 4: Yields of aerobic rice (*Oryza sativa* L.) as affected by varieties and iron nutrition.

Treatment	Grain yield (t/ha)		Biological yield (t/ha)	
	2011	**2012**	**2011**	**2012**
Variety				
PS-5	4.52	4.63	12.19	12.37
PRH-10	4.89	5.03	12.74	12.95
SEm±	0.10	0.05	0.13	0.07
LSD (*P*=0.05)	0.30	0.15	0.37	0.21
Sources and mode of iron application				
Control (no iron)	4.20	4.44	11.75	12.09
IS @ 50 kg/ha + 1 FS of 2.0% IS	4.53	4.64	12.24	12.35
IS @ 50 kg/ha + 1 FS of 0.5% IC	4.50	4.62	12.25	12.31
IS @ 100 kg/ha	4.35	4.53	12.02	12.20
2 FS of 2.0% IS	4.95	5.04	12.87	12.99
3 FS of 2.0% IS	5.21	5.26	13.07	13.26
2 FS of 0.5% IC	4.89	5.01	12.73	13.01
3 FS of 0.5% IC	4.99	5.10	12.84	13.08
SEm±	0.17	0.09	0.21	0.12
LSD (*P*=0.05)	0.49	0.25	0.61	0.35

Iron sulphate @ 50 kg/ha + one foliar spray of 2.0% iron sulphate, iron sulphate @ 50 kg/ha + one Foliar spray of 0.5% iron chelate, iron sulphate @ 100 kg/ha, two foliar sprays of 2.0% iron sulphate, three foliar sprays of 2.0% iron sulphate, two foliar sprays of 0.5% iron chelate, three foliar sprays of 0.5% iron chelate.

References

1. Zeigler RS. Rice and the millennium development goals: The International Rice Research Institute's strategic plan 2007–2015. Paddy Water Environment. 2007; 5: 67-71.
2. Anonymous. The 4th Advance Estimates 2016-17, Department of Agriculture, Cooperation and Farmers Welfare, Ministry of Agriculture & Farmers Welfare, Government of India, 2017.
3. Anonymous. The 4th Advance Estimates 2015-16, Agricultural statistics at a glance, Directorate of Economics and Statistics, Ministry of Agriculture & Farmers Welfare, Government of India, 2016.
4. Tuong TP, Bouman BAM. Rice production in water-scarce environments. (In:) Water productivity in agriculture: limits and opportunities for improvement. Kijne, J.W., Barker, R. and Molden, D. (Eds.), The

comprehensive assessment of water management in agriculture series, CABI Publishing, Wallingford, U.K. 2002; 1:13-42,
5. Kumar V, Ladha JK. Direct seeding of rice: recent developments and future research needs. Advances in Agronomy. 2011; 111:297-413.
6. Yadav S, Gill G, Humphreys E, Kukul SS, Walia US. Effect of water management on dry seeded and puddled transplanted rice. Part 1: Crop performance. Filed Crops Research. 2012; 120:112-22
7. Prasad R. Aerobic rice systems. Advances in Agronomy. 2011; 111:207-247.
8. Bouman BAM. Water efficient management strategies in rice production. International Rice Research institute notes. 2001; 16(20):17-22.
9. Tuong TP, Bouman BAM. Rice production in water-scarce environments. (In:) Water productivity in agriculture: limits and opportunities for improvements. Kijne, J.W., Barker, R. and Molden, D. (Eds.), CABI Publishing, UK, 2003, 53-67.
10. Prasad R, Shivay YS, Kumar D, Sharma SN. Learning by doing exercises in soil fertility (A practical manual for soil fertility). Division of Agronomy, Indian Agricultural Research Institute, New Delhi. 2006, 68.
11. Subbiah BV, Asija GL. A rapid procedure for assessment of available nitrogen in rice soils. Current Science. 1956; 25:259-260.
12. Olsen SR, Cole CV, Watanabe FS, Dean L. Estimation of available phosphorus in soil by extraction with sodium carbonate. U.S.D.A. Washington. Conc. 1954, 933.
13. Jackson ML. Soil chemical analysis, Asian publication house, New Delhi. 1958, 173-195.
14. Walkley AJ, Black IA. An examination of the Degtjareff method for determination of soil organic matter and a proposed modification of the chronic acid titration method. Soil Science. 1934; 37:29-38.
15. Fisher RA, Yates Y. Statistical tables. Oliver and Boyd, Edinburgh, 1963.
16. Gomez KA, Gomez AA. Statistical procedures for agricultural research. 2nd Edition. An International Rice Research Institute Book. A Wiley-Inter science Publication, John Wiley & Sons, New York, 1984.
17. Adhikari NP, Mishra BN, Dinesh Kumar, Mishra PK. Direct and residual effect of integrated nitrogen management on productivity and soil fertility in rice-wheat cropping system. In (ed. Singh *et al*.) Proc. of Symposium. Geoinformatics Applications for Sustainable Development, IARI, New Delhi, 2004, 292-297.
18. Lin WX, Liang YY. The heterotic effects of dry matter production and grain yield formation in hybrid rice. Chinese Rice Res. Newsletter. 1997; 5(2):10-11.
19. Xiaoyun Fan, Rezaul Karim MD, Xinping C, Yueqiang Z, Xiaopeng G, Fusuo Z *et al*. Growth and iron uptake of lowland and aerobic rice genotypes under flooded and aerobic cultivation. Communications in Soil Science and Plant Analysis. 2012; 43(13):1811-1822.
20. Rakesh D, Raghuramireddy P, Latheef PMD. Response of aerobic rice to varying fertility levels in relation to iron application The Journal of Research ANGRAU. 2012; 40(4):94-97.
21. Kulandaivel S, Mishra BN, Gangaiah B, Mishra PK. Effect of levels of zinc and iron and their chelation on yield and soil micronutrient status in hybrid rice (*Oryza sativa* L.) - wheat (*Triticum aestivum* L.) cropping system. Indian Journal of Agronomy. 2004; 49(2):80-83.
22. Fang Y, Wang L, Xin Z, Zhao L, An X, Hu Q. Effect of foliar application of zinc, selenium, and iron fertilizers on nutrients concentration and yield of rice grain in China. Journal of Agricultural and Food Chemistry. 2008; 56:2079–2084.
23. Yadav GS. Influence of mulching and iron nutrition on aerobic rice grown under aerobic rice-wheat cropping system. Ph.D. thesis submitted to Division of Agronomy Indian Agricultural Research Institute, New Delhi-12, 2012.
24. Duraisamy VP, Mani AK. Effects of zinc and iron on yield, content, uptake and soil fertility under samai in a red loamy sandy soil. Mysore Journal of Agricultural Sciences. 2001; 35(4):297-301.
25. Foth HD, Ellis BG. Soil Fertility. New York: John Wiley, 1988.
26. Fageria NK. Mineral nutrition of rice. CRC Press, Taylor & Francis Group ISBN-13: 978-1-4665-5807-6 (eBook - PDF), 2014.
27. Sakal R, Singh AP, Sinha RB, Bhogal NS. Twenty five years of research on micronutrients in soil sand crops of Bihar. Department of Soil Science, RAU, Pusa, Bihar, India, 1996, 1-207.
28. Nayyar VK, Takkar PN. Combating iron deficiency in rice-grown in sandy soils of Punjab. International symposium on managing sandy soils, CAZRI, Jodhpur, India. 1989; 1:379-384.