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Effect of aerobic cultivation on yield, biochemical and physiological characters of selected rice genotypes

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ABSTRACT

A field experiment was conducted during wet seasons of 2004 and 2005 to find out the suitability of rice genotypes for higher evaluating zinc and iron content under aerobic cultivation. The maximum photosynthetic efficiency (Fv/Fm) was in Kasturi at flowering stage and BPT-5204 at grain filling stage. Most of the genotypes had higher zinc content under irrigated condition as compared to aerobic rice cultivation. Amongst the genotypes studied BPT-5204 had higher zinc content in shoots and DRRH-1 in grains under irrigated condition. Under aerobic cultivation Jaya had higher zinc content in shoots and Kasturi in grains. IR72176-307-4-2-2-3, DRRH-1 and BPT-5204 had higher iron content (794.30-992.60) in shoots under aerobic condition while Jaya, Pant Dhan 4 and Kasturi under irrigated condition. Most of the genotypes showed higher iron contents in grains under normal condition as compared to alternate wetting and drying. In general zinc content increased while iron content decreased under aerobic cultivation. The total chlorophyll content decreased 6% in DRRH1 and 24.4% in BPT5204 under aerobic cultivation. Higher chlorophyll stability index was found in Pant Dhan 4 at vegetative and flowering stages and Jaya at grain filling stage.

Key words: *aerobic rice, zinc effect, chlorophyll, iron, grain,shoot*

Water is one of the most vital natural resources of the world. According to United Nations Organization (UNO), water crisis is the major threat for mankind in the 21stcenturay. Among 1400 million cubic km of water in the world 97% is salty sea water, 2% is frozen in glaciers only 1% is available as fresh water (Kirloskar,2003). From the total available water 75% is used for rice cultivation. Irrigated rice requires lot of water about 3000-5000 liters is used to produce 1 kg of grain (IRRI,2001). This high requirement of water for rice cultivation is because rice is generally grown under lowland conditions. In lowland rice fields, seepage and percolation accounts for 50-80% of the total water outflow from the field (Sharma, 1989). Evaporation makes up about 30% of evapo-transpiration and only 13-33% of total water is consumptive water use by transpiration. Thus it is necessary to develop a better way of growing rice that uses less water, while maintaining high yields (Wang *et al*., 2002). Aerobic rice is a way of growing rice in aerobic soils with intermittent irrigation. It is a system of growing high yielding rice in non puddle and non- flooded aerobic soil (Bouman and Toung, 2001). Rice cultivation in aerobic conditions may lead to unknown challenges with respect to productivity, weed infestation, availability of nitrogen, micronutrients and pest and disease incidence (Singh *et al*., 2002). Iron stress is the second most important micronutrient disorders after zinc in India. It occurs in high pH calcareous soils having low water availability and limits the yield of upland rice (Singh *et al*. 2003). Zinc deficiency is the most widespread micronutrient disorders in rice. About 10 million ha land in India is under Zn deficiency (Singh *et al*. 2005). The major reason for the widespread occurrence of zinc deficiency in soils is low availability of zinc to plant roots and water deficit, responsible for translocation of nutrients. The other factors which are predominantly responsible for low availability of zinc to plant roots are high pH and high levels of $CaCO_3$, and low levels of organic matters and soil moisture etc (Kalayci *et al.* 1999; Cakmak, 2008).

Thus, there is a tremendous need for

micronutrient increase with rise in productivity. Selection of zinc and iron efficient genotypes under aerobic cultivation is the most logical and sustainable approach to solve zinc and iron deficiency problem in plants and humans. The main aim of the present study was to find out the cultivars that are efficient for iron and zinc content under aerobic cultivation.

MATERIALS AND METHODS

Field experiments were conducted during wet seasons of 2004 and 2005 with six rice genotypes viz. IR-72176-307-4-2-2-3 (New plant type) DRRH-1 (hybrid), Kasturi (aromatic), BPT-5204 (high yielding variety), Jaya and Pant Dhan 4. Field experiment was setup in two separate plots with three replicates in randomized design at the Crop Research Center, Pantnagar. Normal irrigation (control) block was laid in one plot and aerobic in another cultivation plot. Aerobic plot was laid out with double channels around all the experimental plots to prevent sub soil lateral water flow. In the aerobic setup, mid season drainage was given with effect from 15 days after transplanting (DAT). After first cycle of drainage for 10 days, irrigation was given once and second cycle of drainage commenced on the 7^{th} day after this irrigation. This periodicity of cyclic drainage cum irrigation was continued until maturity with 7 days and 10 days alternate wetting and drying (AWD) respectively. In normal irrigated plots, water depth of 2-3cm was maintained during the initial stage up to seedling establishment, thereafter, the water level was gradually raised to 3-5 cm up to the flowering stage. Physiological parameters such as plant height at vegetative and flowering stages, grain yield, thousand grain weight, percentage of fully filled, partially filled and chaffy grains were recorded after harvesting. Biochemical parameters such as chlorophyll content according to (Hiscox and Israelstam, 1979), chlorophyll stability index, chlorophyll fluorescence variable (Fv/Fm) was recorded by handy plant efficiency analyzer were estimated just before flooding. Chlorophyll stability index was calculated by using the formula given by Yogameenakshi *et al.* (2004).

The straw and grain were dried in an oven at 80^{o}C and grinded in a mechanical shaker. The ground samples were used for digestion according to Jackson (1958). One gram of plant samples were transferred in a beaker and 10 ml of nitric acid was added kept overnight. Thereafter it was kept on hot plate for 10 min. The samples were cooled and 10 ml of di-acid mixture (Nitric acid: Perchloric acid; 9:4, v/v) was added to each sample and kept on hot plate till the completion of digestion, leaving a trace of white residue at the bottom. After cooling, 5 ml of 6N HCl was added and then volume of the digests was made to 50 ml with distilled water. The digests were filtered with Whatman No.1 filter paper and transferred to storage vials. Iron and zinc were determined from these samples with the help of double beam atomic absorption spectrophotometer. All the data related to three growth stages such as vegetative (maximum tillering stage), flowering and grain filling stages were statistically analyzed.

RESULTS AND DISCUSSION

The rice genotypes had considerable variation in marginally growth, grain yield performance and water relations under periodic water stress. Plant height increased (0.022%) in IR-72176-307-4-2-2-3 and 5.7% in DRRH1 at vegetative stage under aerobic as compared to flooded but at flowering stage the plant height decreased by 0.022% in DRRH1 and 7.3% in Jaya and BPT 5204 under aerobic as compared to flooded condition (Table1). The decrease in plant height might be due to sensitivity of reproductive phase to water status (Biswas and Chaudhary, 1984). A similar result has also been reported by Pirdasthi *et al.* (2004).

All the genotypes produced significantly higher grain yield in control than aerobic cultivation (Table 1). DRRH1 (6.75 t ha^{-1}) showed higher grain yield under stressed as well as under normal irrigation which might be due to the maximum number of panicles m^{-2} i.e., 341 under aerobic cultivation and 389 was under flooded condition. However, there was no significant difference amongst the genotypes for panicle numbers under both the conditions (Table1). Genotypic differences for grain yield have also been reported by Baughman and Toung (2001). The panicle number was not influenced by the water stress. However, the reduction in panicle number m^{-2} under aerobic cultivation compared to flooded could be due to coincidence of water stress period during panicle development (Pirdasthi *et al.* 2004).

Harvest index under aerobic condition decreased slightly as compared to control condition in almost all the genotypes. DRRH 1 had higher panicle

Table 1. Effect of periodic water stress on plant height, panicle number m^{-2}; grain yield (t ha^{-1}) and harvest index in different rice genotypes

Genotypes	Plant height at vegetative stage		Plant height at flowering stage		Panicle number m^{-2}		Grain yield (t ha^{-1})		Harvest Index (%)	
	AWD (A)	Flooded condition (B)	AWD (A)	Flooded condition (B)	AWD (A)	Flooded condition (B)	AWD (A)	Flooded condition (B)	AWD (A)	Flooded condition (B)
IR-72176-307 -4-2-2-3	63.20	63.06	106.10	105.86	306.00	330.00	5.250	5.58	38.33	40.66
DRRH-1	71.86	67.96	111.06	111.20	341.00	389.60	6.750	6.83	42.35	41.40
Kasturi	73.06	70.6	131.86	135.53	297.00	299.00	4.416	5.25	30.71	32.08
BPT –5204	57.06	60.26	91.30	98.50	340.60	297.33	5.416	6.08	33.26	34.21
Jaya	58.73	58.20	104.40	112.63	276.30	377.66	5.250	6.50	42.19	44.32
Pant Dhan 4	66.96	69.40	103.86	105.53	327.60	278.66	5.500	6.58	38.75	41.21
Mean	65.14	64.92	108.10	111.54	314.66	328.72	5.430	6.13	37.69	38.98
	SEM±	CD at1%	SEM±	CD at1%	SEM±	CD at 1%	SEM±	CD at1%	SEM±	CD at 1%
AWD	0.97	3.86	0.85	3.40	14.84	NS	0.296	1.18	0.99	3.97
Flooded	0.56	NS	0.49	1.96	8.57	NS	0.171	0.68	0.57	NS
AWDxFlooded	1.37	NS	1.20	4.81	20.90	NS	0.419	NS	1.41	NS

AWD - Alternate weting and drying

number m^{-2}and the maximum grain yield might be due to higher harvest index and faster mobilization of dry matter towards grain. Under aerobic cultivation Jaya, which had comparable harvest index (42.019) to that of DRRH1 (42.35) had reduced grain yield because of lower panicle number m^{-2} (Table 1). Fully filled grains decreased under aerobic cultivation i.e., BPT-5204 (82.82%) had the highest filled grains and Pant Dhan 4 had the lowest (59.60%). In all the genotypes partially filled and chaffy grains increased under aerobic cultivation except in BPT-5204 (Table 2).

The thousand grain weight decreased under aerobic condition as compared to flooded condition in BPT-5204, Jaya and Pant Dhan 4. Jaya (24.92g) showed highest and BPT-5204 (13.21g) lowest grain weight per thousand seeds in comparison to others under aerobic cultivation. In control Jaya (26.44g) also showed highest and BPT-5204 lowest grain weight (13.81g) per thousand seeds (Table 2). Similarly higher thousand grain weight under normal as compared to alternate wetting and drying was also reported by Saxena *et al.*(1996).

The role of chlorophyll in photosynthesis is well established, an alternation in chlorophyll content could bring changes in photosynthetic rates of the plant. The maximum chlorophyll content under aerobic cultivation at flowering stage was in IR-72176-307-4-2-3 (1.57 mg g^{-1} fr-wt) and the minimum was in Jaya (1.35 mg g^{-1} fr.wt). At grain filling stage the maximum (1.31 mg g^{-1} fr.wt) chlorophyll content was found in Jaya and the minimum (0.97 mg g^{-1} fr.wt) in Pant Dhan 4 under aerobic condition. There was a general decrease in chlorophyll content from flowering to grain filling stage. Under aerobic conditions, the maximum decreased in chlorophyll content was from 1.56 mg g^{-1}fr-wt at flowering stage to 0.97mg g^{-1}fr-wt at grain filling stage in Pant Dhan 4 (Table 3). The decrease in chlorophyll content due to water stress in rice has been reported by several workers (Baruah *et al*. 1998; Deka and Baruah, 2000). The chlorophyll stability index (CSI) was low at flowering stage compared to grain filling stage. The highest CSI was observed in Pant Dhan 4 at vegetative (1.003) and flowering (1.146), whereas at grain filling stage the highest CSI was observed in Jaya (1.210) indicating that the water stress did not have much effect on chlorophyll content (Table3). A higher CSI help plants to withstand stress through better availability of chlorophyll. This leads to increased photosynthetic rate, more dry matter production and higher productivity (Mohan *et al*. 2000).

Chlorophyll florescence (Fv/Fm) indicates the photosynthetic efficiency of plants, is a valuable

Table 2. Effect of periodic water stress (AWD) on thousand-grain weight (g), Fully filled grain (%), partially filled (%) chaffy grains (%) in different genotypes of rice.

Genotypes	Thousand grain weight (g)		Fully filled grain (%),		Partially filled (%)		Chaffy grains (%)	
	AWD (A)	Flooded condition (B)	AWD (A)	Flooded condition (B)	AWD (A)	Flooded condition (B)	AWD (A)	Flooded condition (B)
IR-72176-307-4-2-2-3	22.19	24.53	72.75	83.56	4.39	5.29	22.83	10.22
DRRH-1	18.44	18.07	67.52	71.44	2.57	2.17	29.89	25.79
Kasturi	18.43	17.60	63.37	67.46	6.09	5.88	30.59	26.85
BPT –5204	13.21	13.81	82.82	73.89	3.71	4.78	13.45	19.71
Jaya	24.92	26.44	70.23	80.36	8.80	6.70	20.95	15.00
Pant Dhan 4	19.34	26.44	59.60	75.84	8.72	6.40	36.72	20.06
Mean	19.42	20.81	69.38	75.42	5.71	5.20	25.74	19.60
	SEM±	CD at %	SEM±	CD at 1%	SEM±	CD at 1%	SEM±	CD at 1%
(A)	0.564	2.250	4.166	NS	1.347	NS	3.554	NS
(B)	0.325	1.299	2.405	NS	0.777	NS	2.052	NS
Ax B	0.798	3.182	5.892	NS	1.905	NS	5.026	NS

Table 3. Effect of periodic water stress (AWD) on total chlorophyll content (mg g^{-1} fr.wt.), chlorophyll Florescence (Fv/Fm) and chlorophyll stability index (CSI) in different genotypes of rice at flowering and grain filling stages.

Genotypes	Flowering stage					Grain filling stage				
	Total chl. content AWD (A)	Total chl. content Flooded condition (B)	Fv/FmA WD (A)	Fv/Fm Flooded condition (B)	CSI	Total chl. content AWD (A)	TotalChl. content Flooded condition (B)	Fv/FmA WD (A)	Fv/Fm Flooded condition (B)	CSI
IR-72176-307 -4-2-2-3	1.57	1.52	0.650	0.711	1.030	1.12	1.32	0.694	0.748	0.836
DRRH-1	1.55	1.43	0.692	0.780	1.080	1.16	1.23	0.671	0.777	0.936
Kasturi	1.49	1.77	0.704	0.814	0.840	1.21	1.33	0.692	0.760	0.899
BPT –5204	1.41	1.52	0.645	0.807	0.923	1.27	1.68	0.758	0.770	0.750
Jaya	1.35	1.55	0.712	0.792	0.870	1.31	1.07	0.637	0.747	1.210
Pant Dhan 4	1.56	1.35	0.700	0.738	1.146	0.97	1.04	0.656	0.719	0.930
Mean	1.49	1.52	0.684	0.773	0.98	1.17	1.28	0.685	0.753	0.927
	SEM±	CD at 1%	SEM±	CD at 1%	CD at 1%	SEM±	CD at 1%	SEM±	CD at 1%	CD at 1%
(A)	0.016	0.06	0.029	NS	0.0845	0.006	0.027	0.017	NS	0.0549
(B)	0.009	NS	0.017	0.068		0.003	0.015	0.009	0.039	
AxB	0.023	0.09	0.041	NS		0.009	0.038	0.024	NS	

indicator of water stress (Maxwell and Johnson, 2000). The Fv/Fm values decreased under aerobic cultivation compared to flooded in almost all the six genotypes. This decrease in Fv/Fm values could be due to the effect of water stress on partial breakdown of the photosynthetic apparatus (Tambursi *et al*. 2000). The Fv/Fm values under control condition showed significant variation, however, under water stress condition it was non significant. This might be because of similar decrease in PSII efficiency due to water stress. The maximum Fv/Fm value at flowering stage of aerobic cultivation was observed in Kasturi (0.704) and at grain filling stage in BPT-5204 (Table3). Although Kasturi had higher photosynthetic efficiency, it had low grain yield which might be due to poor translocation of the photosynthates as indicated by low thousand-grain weight.

In all the genotypes zinc content in shoots were decreased due to aerobic as compared to flooded conditions, where as in grains there was slightly increase in zinc content under aerobic rice cultivation compared to flooded conditions. The highest zinc content in shoots under aerobic cultivation was found in Jaya (32.86 ppm) and in grains it was observed in Kasturi (22.85 ppm) (Table4). The percent translocation of zinc from shoots to grains under aerobic and flooded conditions, respectively were in the following order: Jaya<DRRH-1< IR72176-307-4-2-2-3 <BPT-5204<Pant Dhan–4<Kasturi and Kasturi< Jaya<Pant Dhan-4< IR72176-307-4-2-2-3 <BPT-5204<DRRH-1 (Fig.1). A marked variation in zinc content and its translocation from shoots into grains in rice genotypes was observed in the present investigation. Similarly genotypic variation of zinc uptake and its translocation has been reported by earlier workers(Gregoria *et al.* 2000; Shankhdhar *et al.* 2000, Fageria, 2001). The variation in zinc efficiency might be related to differences in biochemical zinc utilization and zinc re-translocation from older into younger tissues in shoots suggested as one possible mechanism affecting zinc efficiency (Hascialihoglu and Kochian, 2003).

Table 4. Effect of periodic water stress (AWD) on Zinc and Iron content in shoots and grains of different genotypes of rice at grain filling stage.

Genotypes	Shoots (ppm)				Grains (ppm)			
	Zinc		Iron		Zinc		Iron	
	AWD (A)	Flooded condition(B)	AWD (A)	Flooded condition(B)	AWD (A) condition (B)	Flooded	AWD (A)	Flooded condition(B)
IR-72176-307-4-2-2-3	28.33	35.59	892.30	860.30	18.61	21.76	431.00	178.00
DRRH-1	31.78	29.27	992.60	815.60	16.05	23.22	222.00	244.66
Kasturi	26.96	33.76	634.60	910.30	22.85	13.4	186.60	242.66
BPT –5204	32.50	36.88	794.30	573.30	21.50	23.11	345.30	584.33
Jaya	32.86	28.75	726.30	921.30	14.96	13.23	356.60	582.33
Pant Dhan 4	32.07	34.47	902.0	971.60	21.41	20.06	359.60	664.33
Mean	30.75	33.12	823.72	842.11	19.23	19.13	316.94	416.05
	SEM ±	CD at 1%	SEM ±	CD at 1%	SEM ±	CD at 1%	SEM ±	CD at 1%
(A)	4.38	NS	12.736	50.78	0.79	3.17	16.28	64.91
(B)	2.53	NS	7.35	29.31	0.45	NS	9.40	37.47
AxB	6.20	1.55	18.01	71.85	1.12	4.481	23.02	91.80

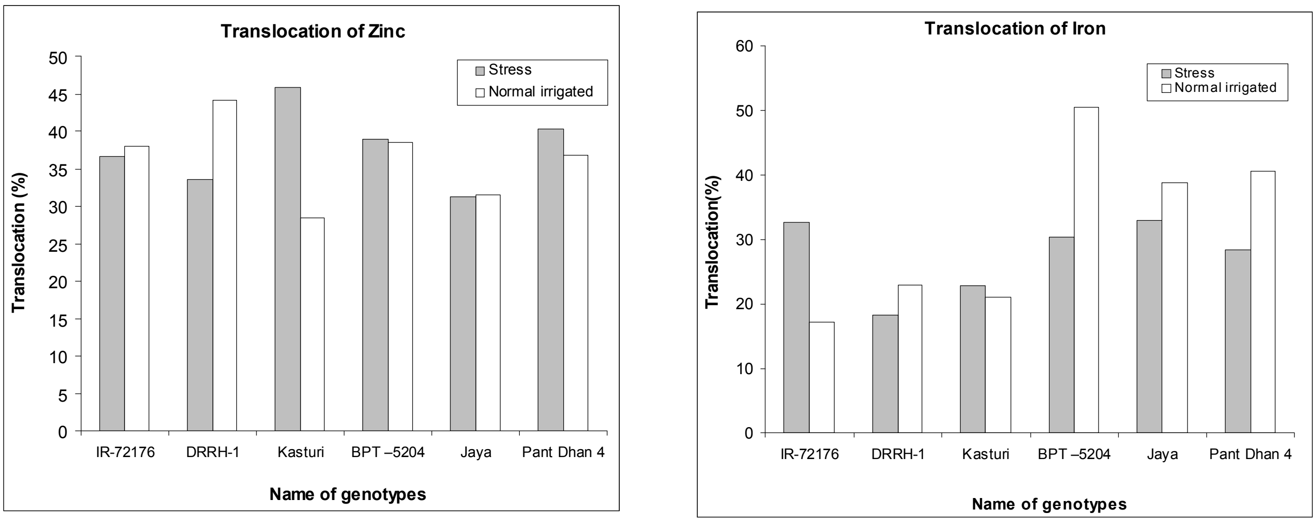

Fig. 1. Percent translocation of zinc and iron from shoots into grains at grain filling stage in different genotypes of rice.

All the genotypes showed significant variation for iron content in shoot and grain. DRRH-1 had the highest (992.60ppm) iron content in shoots while IR-72176-307-4-2-2-3 (431ppm) in grains under aerobic cultivation (Table 4). The translocation of iron from shoots into grains was maximum in Jaya and minimum in DRRH-1 under aerobic cultivation (Fig 1). These results indicated that genotypes vary for iron uptake and its translocation from shoot into grains. Some genotypes had better translocation of iron than others and amongst all the genotypes iron content decreased in shoots in comparison to grains under aerobic cultivation which could be due to reduced solubility of iron in aerobic conditions. The percent translocation of iron from shoots to grains under aerobic and flooded conditions, respectively were as follows:DRRH-1<Kasturi<Pant Dhan-4<BPT-5204< IR72176-307-4-2-2-3 < Jaya and IR72176-307-4-2-2-3< Kasturi <DRRH-1 <Jaya<Pant Dhan-4<BPT-5204 (Fig1). Similarly genotypic variation of iron content and its translocation has also been reported by earlier workers (Fageria *et al*.,1990;Ramirez *et al*.,2002; Shimizu *et al*.,2005).

Our results indicated that amongst the six genotypes of rice studied Kasturi and Jaya are efficient in higher zinc and iron content, respectively under aerobic cultivation, whereas, DRRH-1 and BPT-5204 were better genotypes for higher zinc and iron content, respectively under normal irrigation.

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