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Characterization of rice (*Oryza sativa* L.) genotypes on the basis of morpho-physiological and biochemical traits grown under aerobic situation in rainfed ecosystem

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Abstract

The objective of the present study was to examine the effect of aerobic situation on yield, physiological and biochemical traits of advanced breeding lines of rice. Experiment was conducted with two set of rice genotypes under two water regimes (aerobic and irrigated), during three consecutive wet seasons 2010-2012. Significant decrease in yield was observed in rice genotypes grown under aerobic situation as compared to the irrigated ones. Promising rice genotypes having the ability to maintain high plant biomass, harvest index, early vegetative vigour, improved physiological and biochemical traits in terms of relative water content (RWC), leaf area index (LAI), total soluble sugar, starch, protien and proline content help to sustain higher grain yield under aerobic situation. The yield gap between aerobic and irrigated rice ranged between 24% to 68 %. Grain yield showed positive correlation with harvest index (0.434), test weight (0.647), plant biomass (0.411) and effective tiller numbers (0.473), whereas spikelet sterility was negative associated (-0.380). The current study suggested that promising genotypes viz., IR77298-14-1-2-130-2, IR84899-B-182-3-1-1-2, IR84887-B-157-38-1-1-3 and IR 84899-B-179-1-1-1-2 for aerobic situation, showing yield advantage due to better performance of physiological and biochemical traits, might be adopted in large area of rainfed ecosystem as well as in irrigated areas where water scarcity was a major problem.

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Introduction

Rice (*Oryza sativa* L.) is the staple food of more than three billion people in the world, most of them living in Asia. Rice production consumes about 30% of all the freshwater used worldwide. Flood-irrigated rice uses two to three times more water than other cereal crops such as wheat and maize. In Asia, flood-irrigated rice consumes more than 45% of total freshwater used (Barker *et al.,* 1999). The increasing water crisis is threatening the sustainability of the irrigated rice system and food security in Asia (Lal *et al.*, 2013). Almost 28% of the world's rice is grown under rainfed lowland and is frequently affected by un-even rainfall distribution pattern. Another 13% of the rice area is under upland cultivation, which is always subjected to water stress during the growing season. Water scarcity is an important yield constraint of rice in rainfed lowland areas. By 2025, 15 out of 75 million ha of Asia's flood-irrigated rice crop will experience water shortage (Tuong and Bouman, 2002). Being an extravagant consumer of water, rice requires approximately 3000-5000 lt of water to grow one kilogram of rice traditionally (Joshi *et al.*, 2009). There is a need to develop alternative system that requires less water for rice crop production.

Aerobic rice is a new type of rice that is aerobic-soil-adapted and input-responsive. It grows well in non-puddled and non-saturated soils with 70% to 100% water-holding capacity throughout the growing season (Parthasarathi *et al.,* 2012). In this paper, aerobic rice refers to rice crop grown in non-irrigated and non-puddled aerobic soil with supplemented irrigation and high external inputs. Aerobic rice is a new concept of growing rice in non-puddled and non-flooded aerobic soil (Mall *et al.*, 2015) and promises substantial water savings by minimizing loss of water by seepage and percolation and greatly reducing evaporation (Bouman, 2002). Aerobic rice cultivars with high yield potential and moderate tolerance of drought stress have been developed by crossing traditional upland cultivars with improved irrigated cultivars. Aerobic rice cultivars should combine the drought-tolerance characteristics of upland cultivars with high-yielding characteristics of lowland cultivars (Lafitte *et al.,* 2002). Currently in India, particularly in the eastern region, aerobic rice cultivation practice is in the initial phase (Kumar *et al.,* 2013). There is a need to identify promising rice genotypes for aerobic (water scarcity) condition with suitable morpho-physiological and biochemical traits, so that these genotypes can perform better under such situation. In this context, a field experiment was conducted for three consecutive wet seasons 2010-2012 at ICAR RCER, Patna with the objective to examine the effect of aerobic situation on yield and yield attributing physiological and biochemical trait responses of rice genotypes and to identify promising genotypes for aerobic condition.

Materials and Methods

Experimental site : A field experiment was carried out at the experimental farm of ICAR Research Complex for Eastern Region, Patna, India during three consecutive wet seasons 2010, 2011 and 2012. The experimental site was typical rainfed having clay loam soil with pH 7.5, organic carbon 0.67 %, bulk density 1.47 g cm^{-3}, electrical conductivity 0.26 dS m^{-1}, available nitrogen 227 kg ha^{-1}, available phosphorous 28.4 kg ha^{-1} and exchangeable potassium 218 kg ha^{-1}.

Plant materials : Seventy two rice genotypes comprising of advanced breeding lines, popular high yielding cultivars of rainfed lowland (Swarna, Sambha Mahsuri, RajendraSweta, Rajendra Shubhasani, IR36, Sahbhagi, Susk Samrat,) and check varieties (IR 64, Rajendra Bhagwati and MAS 946) of eastern region were used for evaluation. Rice genotypes used for study were collected from the International Rice Research Institute (IRRI), Philippines and Central Rice Research Institute (CRRI), Cuttack.

Design and layout of experiments : Field experiments were conducted in an alpha lattice design under aerobic and irrigated (control) situation. Aerobic fields were dry ploughed, harrowed and levelled with laser leveller machine and two to three rice seeds were drilled by hand in shallow furrows spaced 15 cm apart and covered with 2-3 cm soil. Non-flooding helps in maintaining aerobic situation of experimental field. Inter-cultural operations were carried out from time to time, whenever required. In aerobic field, surface irrigation was given once a week, at vegetative stage and at 2-3 day interval at the reproductive stage. Surface Irrigation was given when soil moisture tension at 15 cm depth reached -30 kPa. At the time of flowering, the threshold for irrigation was reduced to -10 kPa to prevent spikelet sterility. During growing season, groundwater table depth was measured within aerobic rice plots. In aerobic field, weeds were controlled by a pre-emergence application of pendimethelin 30 EC (3.0 ml in per litre of water), followed by two hand weeding at approximately three and five weeks after emergence. In control (irrigated) field, twenty one days old seedling from wet bed nurseries were transplanted. Control plot was kept continuously wet with 5 cm water after transplanting until 25 days before harvest. In each plot, a uniform plant stand was maintained and standard agronomic practices were followed for raising and maintenance of plants. Both aerobic and control field were fertilized @ 100-60-40 kg NPK ha^{-1}. Nitrogen was applied in spilit dose (1/3each at basal, maximum tillering and panicle initiation stage) while P_2O_5 and K_2O were applied as a basal application. The observations of yield and yield attributes such as plant biomass, effective tillers per m^2, test weight, harvest index and percent spikelet sterility under both control and aerobic condition were recorded.

Physiological and biochemical parameters : Ten promising genotypes viz., IR77298-14-1-2-130-2, IR84899-B-182-3-1-1-2, IR84887-B-157-38-1-1-3, IR84887-B-156-17-1-1, IR 84899-B-179-1-1-1-2, IR 83927-B-B-278-5-1-1-1, IR 84887-B-158-7-1-1-4, IR 84882-B-B-123-46-1-1, IR 84895-B-125-12-1-1 and IR 84894-B-140-16-1-1-1, along with three check varieties viz., IR64, Rajendra Bhagwati and MAS 946, were selected out of seventy two genotypes on the basis of yield and yield attributes for further study of physiological and biochemical parameters (relative water content (RWC), leaf area index (LAI), total soluble sugar, starch concentration, total soluble protein and proline content) at the reproductive stage. RWC was estimated by recording turgid weight of 0.5 g fresh leaf sample by keeping in water for 4 hr, followed by drying in hot air oven till constant weight was achieved (Weatherly, 1950). TSS and starch concentration of shoot was measured following the procedure of anthrone reagent method (Sadasivam and Manickam, 1992). Soluble protein (Lowry *et al*., 1951) and proline content (Bates *et al*., 1973) was also recorded.

Statistical analysis : Agro-morphological data were analyzed by using CropStat 7.2 programme at IRRI. Physiological and biochemical data was analyzed using OPSTAT software of Hisar Agricultural University, Hisar.

Results and Discussion

Observations of yield and yield contributing traits were recorded under both aerobic and irrigated conditions (Table 1). Aerobic rice produced significantly lower grain yield than irrigated rice throughout the experiment and season. The mean grain yield was 2.19 t ha^{-1}, 0.96-3.92 t ha^{-1}, 4.21 t ha^{-1} and 2.96-6.07 t ha^{-1} observed under aerobic and irrigated condition, respectively (Table 2). Similarly, the mean sterility percentage was 11.6, 6.29-23.55, 29.7 and 13.81-61.82% as observed under aerobic and irrigated conditions, respectively.

Table1 : Yield and yield attributes response of top ten promising rice genotypes and check varieties to aerobic and irrigatedcondition

Promising genotypes	Plant height (cm)		Grain yield (t ha^{-1})		Number of effective tiller m^{-2}		Spikelets panicle^{-1}		Harvest index	
	AC	IC	AC	IC	AC	IC	AC	IC	AC	IC
IR77298-14-1-2-130-2	116	124	3.92	5.68	351	469	194	216	0.42	0.48
IR84899-B-182-3-1-1-2	119	126	3.69	5.97	364	478	176	203	0.41	0.51
IR84887-B-157-38-1-1-3	109	114	3.53	5.16	338	433	191	224	0.41	0.46
IR84887-B-156-17-1-1	121	126	3.47	5.38	329	408	177	194	0.42	0.48
IR 84899-B-179-1-1-1-2	117	126	3.41	4.91	335	421	182	211	0.43	0.45
IR 83927-B-B-278-5-1-1-1	115	132	3.34	5.19	358	442	175	197	0.39	0.45
IR 84887-B-158-7-1-1-4	113	124	3.27	4.83	327	415	192	231	0.39	0.43
IR 84882-B-B-123-46-1-1	125	128	3.20	5.45	336	452	170	202	0.41	0.47
IR 84895-B-125-12-1-1	120	127	3.19	4.62	321	434	183	214	0.40	0.42
IR 84894-B-140-16-1-1-1	117	125	3.05	5.23	345	441	179	195	0.41	0.44
RajendraBhagwati (check)	108	119	1.97	4.68	267	424	148	209	0.34	0.45
MAS 946 (check)	103	111	2.32	4.53	289	437	156	197	0.36	0.44
IR 64 (check)	113	116	1.81	4.81	253	429	145	211	0.32	0.46
Mean	105.4	117.2	2.19	4.21	248	369	166	207	0.31	0.43
CV (%)	3.68	4.11	11.96	6.38	8.33	5.64	8.27	6.59	5.49	6.76
LSD (5%)	4.95	6.53	0.27	0.45	16.91	25.63	6.94	7.45	0.03	0.04

AC (Aerobic condition) and IC (Irrigated condition)

Performance of promising genotypes and check varieties under aerobic situation in terms of grain yield and its contributing physiological and biochemical traits is presented in Table 3. Higher grain yield of 3.92 t ha^{-1}was observed in IR77298-14-1-2-130-2, followed by 3.69 t ha^{-1} in IR84899-B-182-3-1-1-2 and 3.53 tha^{-1} in IR84887-B-157-38-1-1-3, under aerobic condition. Grain yield of check varieties Rajendra Bhagwati, MAS 946 and IR 64 in under aerobic condition was 1.97, 2.32 and1.81t ha^{-1}respectively (Table1). Mean grain yield of rice genotypes was 2.62 tha^{-1} , 2.07 tha^{-1} and 1.99 tha^{-1} under aerobic condition whereas, 4.28 tha^{-1} , 4.22 tha^{-1} and 4.15 tha^{-1} under irrigated condition was observed during 2010, 2011 and 2012 crop season. As compared to irrigated conditions, a reduction in grain yield was observed in advanced breeding lines and high yielding check varieties under aerobic condition. However, as expected, reduction was low in promising tolerant lines and high in susceptible lines. Difference in grain yield between aerobic and irrigated rice was 30.98 % in IR77298-14-1-2-130-2, 30.19% in IR84899-B-182-3-1-1-2 and 31.58 % in IR84887-B-157-38-1-1-3 whereas it was 57.90, 43.20 and 62.37 % in Rajendra Bhagwati, MAS 946 and IR 64, respectively. The promising genotypes showed lesser spikelet per panicle in aerobic situation as compared to irrigated condition. Rice genotypes IR84899-B-182-3-1-1-2 showed highest effective tillers m^{-2}(364) followed by IR83927-B-B-278-5-1-1-1 (358) and IR77298-14-1-2-130-2 (351) under aerobic condition. In direct seeded aerobic rice, earlier studies have reported the association of early vegetative growth with more tiller production, height and plant biomass. Irrigated rice produced significantly more number of tillers m^{-2} than aerobic rice all through the three years. In general, flooded rice produced more panicles with more spikelet per panicles than aerobic rice. Under aerobic condition, high yield of promising genotypes comes from high harvest index, test weight, plant biomass and spikelet per panicles as compared to the check varieties. The results indicated the existence of variation for grain yield and yield components among the genotypes and showed different level of adaptation to aerobic environment. George *et al.* (2002) reported decreased yield under mono-cropping of aerobic rice in Philippines. Grain yield decreased by 73% in third season as compared to second season under mono-cropping of aerobic rice for the variety UPLRi-5

Table 2 : Mean and range of yield and yield contributing traits of rice genotypes

Traits	Mean	
	AC	IC
Days to fifty % flowering (DFF)	88.7(84-107)	85.9(81-105)
Plant height (cm)	105.4(103-125)	117.2(111-132)
Grain yield (t ha^{-1})	2.19(0.96-3.92)	4.21(2.94-5.97)
Harvest index (%)	0.31(0.14-0.43)	0.43(0.32 - 0.51)
Biomass (g plant^{-1})	15.7(7.38 -22.5)	23.4(14.32-31.57)
Sterility (%)	29.7(13.81-61.82)	11.6(6.29-23.55)
Tiller number (No. m^{-2})	248(176-364)	369(287-478)
Panicle length (cm)	24.5(19.8-27.2)	25.7(21.6–28.4)
Test weight (gm)	22.6(16.34 – 25.92)	24.2(20.9 - 27.2)
LAI	2.31(1.74-2.76)	3.52(3.32-3.87)
RWC (%)	63.10 (47.2-72.1)	85.06(81.5-89.3)
TSS (mg g^{-1})	26.99(12.7-33.4)	37.60(34.9-41.7)
Starch concentration (mg g^{-1})	20.62(7.7-27.2)	39.43(35.5-43.9)
Soluble protein content (mg g^{-1})	11.24(5.8-14.2)	25.68(22.7-29.8)
Proline content (mg g^{-1})	0.90(0.42-1.16)	0.38(0.32-0.46)

AC: Aerobic condition, IC: Irrigated condition

Table 3 : Plant biomass, leaf area index, test weight and grain sterility of top ten promising rice genotypes and check varieties to aerobic and irrigated (control) condition

Promising Genotypes	Plant biomass ($g\ plant^{-1}$)		Leaf area index		Test weight (g)		Sterility (%)	
	AC	IC	AC	IC	AC	IC	AC	IC
IR77298-14-1-2-130-2	20.7	28.4	2.59	3.37	25.6	26.6	14.5	7.8
IR84899-B-182-3-1-1-2	18.3	26.9	2.71	3.55	25.3	27.2	16.9	11.5
IR84887-B-157-38-1-1-3	19.8	27.8	2.38	3.32	24.5	26.1	13.8	14.2
IR84887-B-156-17-1-1	21.8	26.4	2.76	3.87	25.9	26.9	16.5	9.4
IR 84899-B-179-1-1-1-2	22.5	30.7	2.18	3.56	24.8	25.6	22.4	10.7
IR 83927-B-B-278-5-1-1-1	17.9	25.6	2.15	3.43	23.7	24.3	16.7	7.3
IR 84887-B-158-7-1-1-4	19.2	26.9	2.47	3.61	24.5	25.1	19.5	11.2
IR 84882-B-B-123-46-1-1	20.7	29.3	2.21	3.49	23.8	24.9	25.1	8.3
IR 84895-B-125-12-1-1	16.8	24.8	2.55	3.58	23.6	24.7	24.6	12.5
IR 84894-B-140-16-1-1-1	18.7	27.5	2.43	3.63	24.3	25.1	22.4	13.7
Rajendra Bhagwati	15.3	26.1	1.86	3.74	17.8	23.7	36.9	15.1
MAS 946 (check)	16.7	25.3	2.04	3.51	19.2	24.8	33.7	12.5
IR 64 (check)	13.6	26.9	1.74	3.55	16.3	25.2	41.8	12.8
Mean	15.7	23.4	2.31	3.52	22.6	24.2	29.7	11.6
CV(%)	5.88	7.29	5.92	4.66	6.71	5.48	8.79	6.14
LSD (5%)	0.53	0.74	0.19	0.34	1.37	1.59	2.06	1.48

AC (Aerobic condition); IC (Irrigated condition)

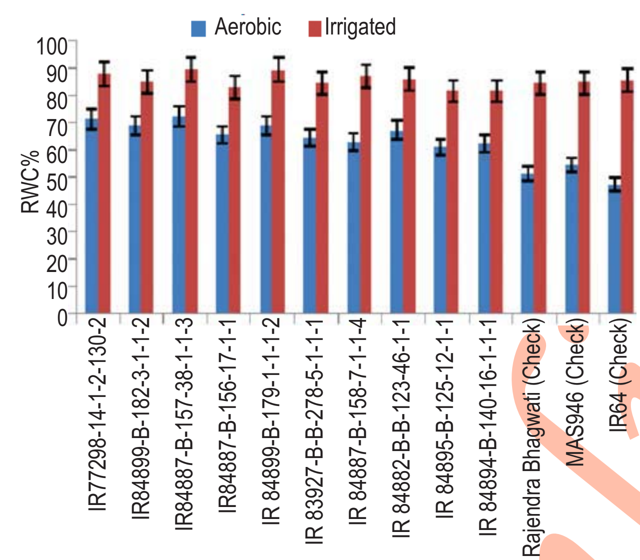

Fig. 1 : Effect of aerobic situation on relative water content (%) in rice genotypes

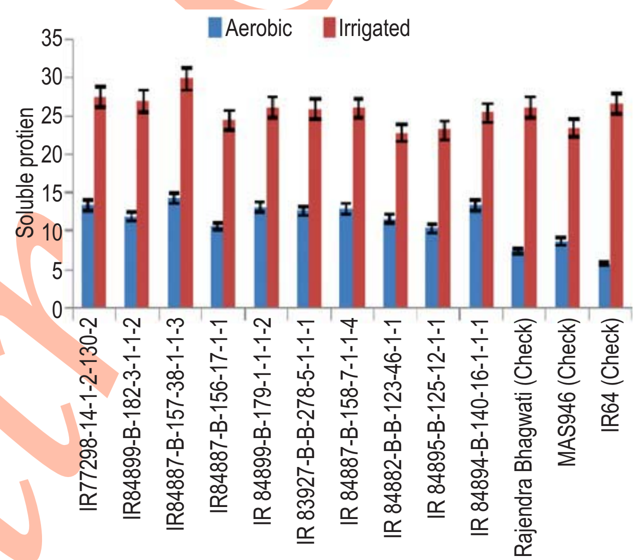

Fig. 2 : Effect of aerobic situation on soluble protein content ($mg\ g^{-1}$d.wt.) in rice genotypes

(George *et al.,* 2002). Mahmood *et al.* (2014) observed significant grain yield reduction in rice under non-flooded condition as compared to continuous flooding. Peng *et al.* (2006) also observed 8 to 69 % yield difference between aerobic and flooded rice during eight season experiment (2001 to 2004) in the tropical environment.. Spikelet number per panicle, plant biomass and grain filling percentage which were greater in flooded rice than in aerobic rice was noted aerobic condition causes reduction in grain yield, plant height, number of tillers, spikelet per panicle, harvest index, test weight, grain filling percentage, leaf area, relative water content and plant biomass. Liu *et al.* (2015) also observed differences on yield components (panicles per m^2 and spikelets per panicles) between dry direct seeded aerobic rice and transplanted flooded rice.

Aerobic rice produced significantly less total plant biomass than irrigated rice during all three years experiment. The mean plant biomass was 15.7 g $plant^{-1}$ and 23.4 g $plant^{-1}$ under

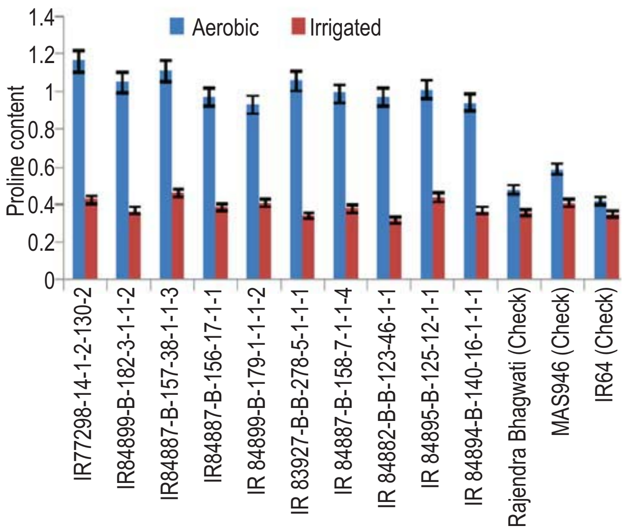

Fig. 3 : Effect of aerobic situation on proline content (mg g^{-1} f.wt.) in rice genotypes

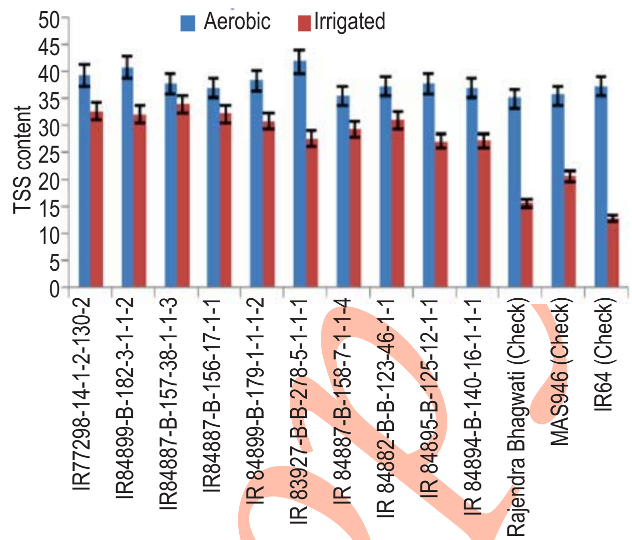

Fig. 4 : Effect of aerobic situation on TSS (mg g^{-1} d.wt.) content

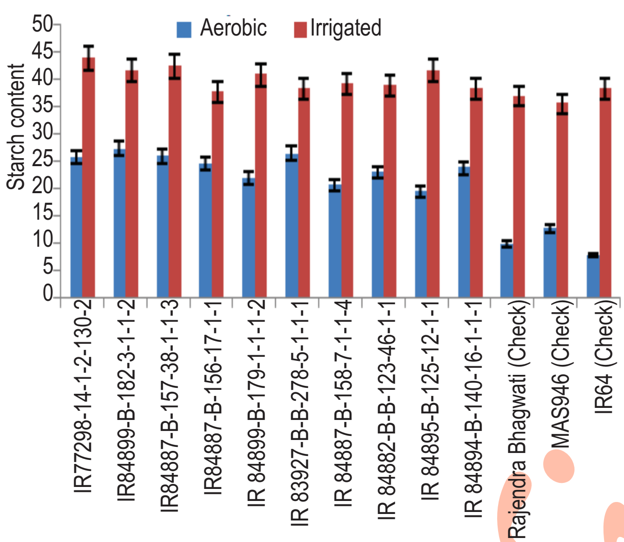

Fig. 5 : Effect of aerobic situation on starch (mg g^{-1} d.wt.) content in rice genotypes

aerobic and irrigated conditions, respectively (Table 2). Maximum plant biomass was observed in IR84899-B-179-1-1-1-2 (22.5) followed by IR77298-14-1-2-130-2 (20.7) and IR84887-B-156-17-1-1 under aerobic condition (Table 3). Mean plant biomass of rice genotypes observed during 2010, 2011 and 2012 crop season was 15.9 g $plant^{-1}$, 16.7 g $plant^{-1}$ and 14.4 g $plant^{-1}$ under aerobic condition whereas 22.4 g $plant^{-1}$, 24.8 g $plant^{-1}$ and 22.9 g $plant^{-1}$ under irrgated condition. Difference between aerobic and irrigated rice above ground in terms of total plant biomass gradually widened as the number of cropping seasons increased. Similar trends were also observed for effective tiller number, harvest index and test weight. Early vegetative vigour determines rapid, uniform emergence and development of seedlings under direct seeded aerobic condition. It has been considered as one of the important characteristics that determines successful crop establishment. Under aerobic condition, rapid early growth reduces water loss through reduced evapotranspiration loss by early canopy closure, thereby allowing greater soil water reservoir available for plant growth. All promising genotypes in the present study showed high early vegetative vigour, whereas check varieties showed average to low vegetative vigour under aerobic situation. In the present study, plants with high vegetative vigour yielded significantly higher than plants with low vigor under aerobic condition. Plants with high early vigor produced more tillers m^{-2} and spikelet per panicle than those with low early vigour. Aerobic rice had lower test weight (22.6) and grain filling percentage (70.3%) than irrigated rice (24.2, 88.4%). Irrigated rice showed more consistent 1000-grain weight in all the three seasons than aerobic rice. Promising genotypes viz., IR84887-B-157-38-1-1-3 (13.8%), IR77298-14-1-2-130-2 (14.5%), IR84887-B-156-17-1-1 (16.5%) IR84899-B-182-3-1-1-2 (16.9%) maintained lesser grain sterility percentage as compared to susceptible and check varieties under aerobic situation. Peng *et al.* (2006) also observed low test weight in aerobic rice than flooded rice.

Relative water content showed significant and positive correlation with plant biomass. Soil moisture stress significantly reduced relative water content. A significant difference in RWC was observed among genotypes between aerobic and irrigated situation. Under aerobic condition, high value of relative water content was recorded in water deficit stress tolerant rice genotypes as compared to the susceptible one at reproductive stage. Highest value of relative water content was observed in IR84887-B-157-38-1-1-3(72.2%) followed by IR77298-14-1-2-130-2 (71.4%) and IR 84889-B-179-1-1-1-2 (69.1%) (Fig.1). Study revealed that relative water content of all genotypes reduced significantly under aerobic (water scarcity) condition as

Table 4 : Estimates of correlation coefficients between different characters in rice genotypes under irrigated condition (IC) and aerobic condition (AC)

Characters	Environments	pH	Biomass	PL	TW	TN	ST	HI	SY	GY
DFF	IC	-0.21	-0.198	-0.214	0.0274	-0.115	-0.178	0.174	0.095	-0.085
	AC	0.035	-0.213	-0.159	0.0588	0.065	-0.091	0.283*	0.078	-0.103
pH	IC		0.295*	0.336*	-0.341	0.037	-0.043	0.071	0.159	0.137
	AC		0.312*	0.529*	-0.244	-0.027	0.077	0.023	0.193	0.082
Biomass	IC			0.311	0.152	0.456**	-0.054	-0.117	0.348	0.362*
	AC			0.247	0.177	0.405**	0.184	-0.205	0.293	0.411*
PL	IC				0.418*	0.095	0.112	0.349*	0.103	0.341*
	AC				0.337*	0.134	0.103	0.451*	0.074	0.425
TW	IC					0.142	0.055	0.413*	-0.072	0.524**
	AC					0.068	-0.038	0.375*	-0.066	0.647**
TN/m^2	IC						0.141	0.355*	-0.162	0.429**
	AC						0.172	0.402*	-0.084	0.473**
ST	IC							-0.087	0.185	-0.242*
	AC							-0.052	0.204	-0.380**
HI	IC								-0.383*	0.377**
	AC								-0.349*	0.434**
SY	IC									-0.418**
	AC									-0.562**

DFF: Days to 50 per cent flowering (days); PH: Plant Height (cm); TN/P: Tiller number per plant; PL: panicle length (cm); TW: Test Weight (g); ST: Sterility (%); HI= Harvest index; SY: Straw weight (t ha^{-1}); GY= Grain Yield (t ha^{-1}); *- significant at 5% ; **- significant at 1%

compared to normal irrigated condition. Gupta *et al*. (2011) also observed significant reduction of relative water content in 20 rice genotypes grown under water scarce condition as compared to the flooded situation. The results of the present study is in consistency with the finding of Jongdee *et al*. (1998) and indicate reduction of relative water content in rice under water scarce condition as compared to irrigated condition. A decrease in relative water content in response to water stress has been documented in a wide variety of plants by Nayyar and Gupta (2006). Leaf area index was recorded at the reproductive stage under both aerobic and irrigated conditions. The mean of leaf area index was 2.31 and 3.52 under aerobic and irrigated (control) conditions. Significant decrease in leaf area index was observed in rice genotypes grown under aerobic condition as compared to irrigated situation. Gupta *et al*. (2011) observed 1.1% to 8.83% reduction in leaf area in rice grown under water stress condition as compared to flooded rice. He reported that water deficit in rice caused high reduction in leaf area than shoot dry matter demonstrating greater sensitivity of leaf enlargement to water stress than dry matter accumulation.

Under aerobic condition, IR84887-B-156-17-1-1, IR77298-14-1-2-130-2 and IR84887-B-157-38-1-1-3 genotypes showed less reduction in protein content as compared to other genotypes and check varieties (Fig. 2). This was in agreement with the results of Jha and Singh (1997) that water scarcity stress tolerant rice genotypes had comparatively higher protein content than susceptible lines under stress condition. Aerobic condition led to increase in proline content (130 %) across genotypes as compared to the irrigated ones. Highest value of proline content was observed in IR77298-14-1-2-130-2 followed by IR84887-B-157-38-1-1-3 and IR84887-B-156-17-1-1 genotypes (Fig. 3). Non-structural carbohydrate level (total soluble sugar and starch) in shoot has long been associated with genotypic differences in their ability to water scarcity stress tolerance in rice. The concentration of sugar and starch in shoots was investigated and changes in their pattern under control and aerobic condition was noticed. In general, starch concentration was observed highest in control condition than aerobic. Under aerobic condition, IR77298-14-1-2-130-2 and IR 84899-B-179-1-1-1-2 genotypes showed higher TSS and starch concentration as compared to other genotypes and check varieties (Fig. 4, 5). Study suggested that water scarcity tolerant genotypes consistently maintained higher concentration of starch and total soluble sugar under both water regimes. Result revealed that the best performing rice genotypes under aerobic situation showed superior physiological and biochemical traits as compared to check varieties. However, rice genotypes under controlled (irrigated) situation exhibited high relative water content, soluble protein and starch content while the level of water stress marker (proline content) and TSS was more under aerobic condition.

Inter- relationship between grain yield and its contributing traits were determined by correlation matrix. Grain yield was significantly and positively correlated with harvest index, biomass, tiller number and test weight under both irrigated and aerobic condition (Table 4). Grain yield showed positive correlation with harvest index (0.434), test weight (0.647), plant biomass (0.411) and effective tiller numbers (0.473), whereas spikelet sterility had negative association (-0.380). Kumar *et al.* (2013) observed significant positive correlation between grain yield and yield attributing traits plant biomass, harvest index, tiller number and test weight. These results is in agreement with those of Girish *et al.* (2006) and Murthy *et al.* (2011), who reported significant and positive correlation between grain yield and panicle number, test weight and effective tiller number under aerobic situation. Grain yield was found to be significant and negatively correlated with spikelet sterility. Rice is especially sensitive to limited water availability during flowering period as this greatly affects spikelet sterility.

The present study suggested significant variations among rice genotypes for various physio-morphological and biochemical traits under aerobic condition. These traits can be used as indirect selection criteria to improve grain yield under aerobic situation. Moreover, promising rice genotypes IR77298-14-1-2-130-2, IR84899-B-182-3-1-1-2, IR84887-B-156-17-1-1, IR84887-B-157-38-1-1-3, IR 84899-B-179-1-1-1-2 and IR 83927-B-B-278-5-1-1-1 for aerobic situation, may be adopted in rainfed lowland ecosystem as well as in irrigated area where water is too scarce.

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