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PHYSIOLOGICAL EFFICIENCY GROWTH AND YIELD REGULATION OF UPLAND RICE UNDER RAINFED CONDITION

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ABSTRACT

A field study was conducted to assess the physiological efficiency growth and yield regulation of upland rice under rainfed condition. The experiment was laid out in Randomized Block Design with 65 advanced rice breeding lines. The physiological parameters (relative water content, membrane stability index, apparent translocation rate), yield determinants (number of panicles/plant, panicle length, panicle weight, number of grains/panicle, were taken at respective growth phases. Among the breeding lines R-RF-25, Mahamaya and IR-70225 performed relatively better in rainfed condition as for as physiological and yield traits are concerned. The regression analysis showed significant and positive relationship of grain yield with panicle harvest index and relative water content under upland rainfed condition.

Key Words : *Physiological efficiency, rice, upland rainfed condition, yield regulation.*

Rice is the most important staple food crop in the world and is grown under a broad range of environmental conditions (1). About 45% of global rice area is under rainfed ecosystems. In Asian countries, rice is the main staple crop covering about ninety per cent of rice grown in the world, with two countries, China and India, growing more than half of the total crop. The global production of rice has been estimated to be at the level of 680 million tonnes and the area of production is estimated as 150 million ha (2). It is grown globally on 153 million ha in a wide range of ecosystems under varying temperatures, altitudes and water regimes (3). India the second largest producer of rice after China. In India it is cultivated in area of 39.47 million ha with production of 87.10 million tonnes (4). Chhattisgarh which is central eastern state has been identified as “Rice Bowl of India”. Total area of rice in chhattisgarh is 3.70 million ha with the production of 6.16 million tonnes and productivity of 1751 kg per ha (5). A well defined research programme in crop stress physiology is needed for the improvement of rainfed rice because sustainable rice production from rainfed rice ecosystem is necessary to achieve the required target as the irrigation availability is becoming scarce and large areas are under rainfed cultivation. Low moisture in upland rainfed condition is the most important limiting factor for crop production and it is becoming severe problem in many regions of the world. Rainfed production level of the crop is dependent on adequate water received during monsoon (6). Under upland rainfed due to water deficit conditions, water uptake from the deep soil layers is a key trait for drought avoidance in upland rice. Plant production in water-limited environments is very often affected by consecutive plant traits that allow maintenance of a high water status (dehydration avoidance), Osmotic adjustment (OA) is a major cellular stress adoptive response in certain crop plants that enhances dehydration avoidance and supports yield under water deficit condition (7). Upland rice cultivars suffer from intermittent moisture stress during critical growth stages especially during germination, tillering, panicle initiation and grain filling period leading to yield loss to a great extent. It affects physiological processes both at whole plant and cellular levels (8). Development of drought tolerant varieties is one of the most important objectives of current breeding program. However breeding efforts are being hindered due to lack of understanding of inheritance of drought tolerance, poor understanding of the physiological basis of yield under water limited environment (9).

MATERIALS AND METHODS

The study was carried out at Research and Instructional farm, Department of Crop Physiology, Agricultural Biochemistry and Herbal Science, College of Agriculture, Indira Gandhi Agricultural University, Raipur (C.G.) during Kharif season 2011-12. The average annual rainfall ranges from 1200-1400 mm and temperature (max-min) ranged between 48°C. and 6°C. The experiment was conducted in upland rainfed

condition using RBD with two replications and sixty five treatments given in table-1. The nursery was sown in 30th June 2011 and transplanting was done in 20 cm row-row and plant to plant spacing on 27th July 2011. Standard cultural and management practices were carried throughout the crop growth period. Relative water content (RWC) of leaves was measured after flowering under water deficit condition. It was measured on the basis of oven dry weight. The fresh leaves were taken from plant between 12:00-1:00 pm and placed in the pre-weighed air tight vial to reduce the evaporation losses the vial along with the leaves were weighed for its fresh weight. After recording fresh weight leaf pieces were dipped in 30 ml distilled water for four hours. After four hour leaf pieces were removed from the vial and water drop present on leaf surface were soaked with the help of blotting paper. The leaf pieces were weighed for its turgid weight and then the pieces were kept in oven for drying till constant weight. Relative water content was calculated as follows :

$$\text{REC (W)} = \frac{\text{Fresh weight} - \text{Oven dry weight}}{\text{Turgid weight} - \text{Oven dry weight}} \times 100$$

Membrane stability index (MSI) was determined at terminal stage drought according to the method given by (10). Leaf disks (0.1g) were thoroughly washed in running tap water and double distilled water. After washing leaves were placed in double distilled water at 40°C for 30 minutes and then electrical conductivity (C_1) of the sample was recorded by Conductivity Bridge (Elico India, Model CM-180). Subsequently the samples were placed in boiling water bath (100°C) for 10 minutes and electrical conductivity was recorded as above (C_2). The membrane stability index (MSI) was calculated at flowering stage as :

$$\text{MSI} = [1\text{-}C1/C2] \times 100$$

Apparent translocation rate was estimated by applying the following formula :

$$\text{ATR} = \frac{\text{Stem dry matter at 50\% flowering} - \text{Stem dry matter at maturity}}{\text{Panicle dry matter at maturity} - \text{Panicle dry matter at 57\% flowering}}$$

Experimental data were analyzed statistically adopting the technique of analysis of variance (ANOVA) for Randomized Block Design (RBD). The level of significance was observed at 5 percent probability (11). Functional relationships among different parameters were established through regression analysis.

RESULTS AND DISCUSSION

Relative Water Content : The results related to relative water content have been presented in Table-2. The mean data from the experiment was statistically analyzed and result depicted it was significant under upland rainfed condition. In rice genotypes it ranges from 32.60 to 59.59 % under upland rainfed condition. In medium duration genotypes it ranges from 32.60 (Bandhi banku x R-979-1528) to 59.47 % (MTU 1010), while in late duration genotypes it ranges from 41.61 %(213 cross line) to 64.35 % (GP-145-51). Among the breeding lines highest percentage was recorded in GP-145-51 (64.35 %) followed by GP-145-74 (63.49 %), while lowest in Bandhi banku X R-979-1528 (32.60 %) under upland rainfed condition. Under water deficit condition the maintenance of plant water status after flowering is a essential key to maintain leaf water potential. In medium and late duration genotypes RWC play an important role. The RWC content of leaves of almost all the cultivars of rice reduced significantly when subjected to water deficit condition at tillering, flowering and grain filling stages. The ability of the rice genotypes to maintain high leaf water potential under water deficit conditions is considered as a possible drought resistance mechanisms in rice (8). Moderate value of RWC helped the plants to perform the physiological processes like stomatal conductance, photosynthesis, transpiration and biochemical metabolism to continue more efficiently even under low soil moisture condition (11).

Membrane stability index : The results related to membrane stability index have been presented in Table-2. The mean data from the experiment was statistically analyzed and result clearly showed that it was significant under upland rainfed condition. In rice genotypes it ranges from 47.965 to 87.715 % under upland rainfed condition. In medium duration genotypes it ranges from 47.965 (Danteshwari x Desi lal dhan) to 85.865 % (R-RF-44), while in late duration genotypes it ranges from 50.925 (213 cross line) to 87.715% (Gp-145-130). Among the breeding lines highest percentage was observed in Gp-145-130 (87.715 %) followed by R-RF-44 (85.865 %), while lowest in Danteshwari x Desi lal dhan (47.965 %) The mean percentage of membrane stability index was 70.165 under upland rainfed condition.

Table-1 : Experimental materials used for the study.

S. No.	Genotypes	S. No.	Genotypes	S. No.	Genotypes	S. No.	Genotypes
1.	R-RF-25	18.	ARB-6-11	35.	Lalmati X Swarna	52.	Gp-145-40
2.	R-1836	19.	Dagaddesi	36.	113 (Cross line)	53.	Gp-145-41
3.	R-RF-44	20.	Moroboican	37.	123 (Cross line)	54.	Gp-145-49
4.	R-1838	21.	Danteshwari	38.	150 (Cross line)	55.	Gp-145-51
5.	R-RF-26	22.	Swarna	39.	308 (Cross line)	56.	Gp-145-55
6.	R-1839-RF-42	23.	Karma masuri	40.	168 (Cross line)	57.	Gp-145-63
7.	R-RF-31	24.	Mahamaya x Dagaddeshi	41.	217 (Cross line)	58.	Gp-145-73
8.	SL-62	25.	IRD TN	42.	330 (Cross line)	59.	Gp-145-74
9.	R-RF-36	26.	Danteshwari x Desi lal dhan	43.	359 (Cross line)	60.	Gp-145-79
10.	R-RF-69	27.	Danteshwari x Dagaddesi	44.	213 (Cross line)	61.	Gp-145-91
11.	IR-70225	28.	Mahamaya x IR-6226-6	45.	318 (Cross line)	62.	Gp-145-99
12.	Annada	29.	BR-240 x Danteshwari	46.	387 (Cross line)	63.	Gp-145-103
13.	MTU 1010	30.	Abhaya x IR-42253	47.	40 (Cross line)	64.	Gp-145-130
14.	IR-64	31.	Bandhi banku X R-979-1528	48.	Nagina	65.	Gp-145-134
15.	Mahamaya	32.	Laloo-14 x IR-64	49.	Cure 10		
16.	Poornima	33.	Triguna x IR-42253	50.	IR-36		
17.	Samleshwari	34.	Abhaya x Dagaddesi	51.	Gp-145-5		

(12) also reported that membrane stability can be used as selection criteria to screen the germplasm for drought tolerance in rice. The ability of cells to continue metabolism at low leaf water status is termed as dehydration tolerance. Membrane disorder is often measured as leakage of solutes from the cell (13).

Apparent translocation rate : The results related to apparent translocation rate has been presented in Table-2. The mean data from the experiment was statistically analyzed and result clearly showed that apparent translocation rate varied significantly. In rice genotypes it ranges from 0.009 to 1.728 under upland rainfed condition. In medium duration genotypes it ranges from 0.009 (IR-70225) to 0.774 (Annada), while in late duration genotypes it ranges from 0.092 (Moroboican) to 1.728 (Gp-145-74). Among the breeding lines maximum apparent translocation rate was recorded in Gp-145-74 (1.728) followed by Gp-145-41 (1.681), while minimum in IR-70225 (0.009) under upland rainfed condition.

The higher apparent translocation rate could be associated with yield stability. Biomass production of rice is function of water use. The shortage of water in soil suppresses the leaf expansion, tillering and photosynthetic rate as well as leaf area. Due to senescence all these factors are responsible for reduction in dry matter accumulation as is suggested by (14). Higher current photosynthesis and post flowering dry matter production under water deficit compensate the low translocation of stem reserves to panicle and exhibited yield stability to some extent. An increase in stem apparent translocation rate under water deficit was related with yield stability particularly under reproductive stage (15). The higher photosynthetic stability by maintaining the higher leaf water status along with higher apparent translocation rate was found to be responsible for better performance of specific genotypes. (16)

Number of panicle/plant of rice breeding lines under upland rainfed condition : The results related to number of panicles/plant have been presented in Table-3. The mean data from the experiment was statistically analyzed and result showed that it varied significantly. In rice genotypes it ranges from 4.00 to 17.50/plant under upland rainfed condition. In medium duration genotypes it ranges from 4.25 (Dagaddesi) to 17.50/plant (Denteshwari x Desi lal dhan), while in late duration genotypes it ranges from 4.00 (Moroboican) to 10.75/plant (Mahamaya x Dagaddesi). Among the breeding lines maximum number of panicles/plant was recorded in Denteshwari x Desi lal dhan (17.50) followed by R-RF-25 (13.75), while minimum in Moroboican (4.00) under upland rainfed condition.

Genotypic differences in rice were observed in number of panicles. Reduction in panicle number under water deficits in upland rice was reported by (17).

Panicle length (cm) of rice breeding lines under upland rainfed condition : The results related to

Table-2 : Physiological parameters of rice breeding line under upland rainfed condition.

S.No.	Rice breeding lines	RWC (%)	MSI (%)	ATR	S.No.	Rice breeding lines	RWC (%)	MSI (%)	ATR
1	R-RF-25	41.81	64.980	0.030	35	Lalmati X Swarna	43.49	65.835	0.072
2	R-1836	43.27	75.550	0.035	36	113 (Cross line)	40.88	73.800	0.377
3	R-RF-44	46.33	85.865	0.113	37	123 (Cross line)	42.66	56.205	0.252
4	R-1838	43.50	70.955	0.346	38	150 (Cross line)	44.46	76.320	0.242
5	R-RF-26	44.77	68.310	0.542	39	308 (Cross line)	42.84	74.995	0.544
6	R-1839-RF-42	49.48	51.510	0.402	40	168 (Cross line)	42.66	71.725	0.132
7	R-RF-31	43.77	66.035	0.010	41	217 (Cross line)	45.72	60.790	0.276
8	SL-62	52.17	79.940	0.063	42	330 (Cross line)	42.69	60.750	0.306
9	R-RF-36	45.73	55.000	0.509	43	359 (Cross line)	39.82	61.855	0.582
10	R-RF-69	45.50	51.015	0.163	44	213 (Cross line)	41.61	50.925	0.775
11	IR-70225	39.18	49.400	0.009	45	318 (Cross line)	43.84	53.905	0.028
12	Annada	51.80	51.025	0.774	46	387 (Cross line)	43.72	69.890	0.307
13	MTU1010	59.47	57.970	0.310	47	40 (Cross line)	44.45	76.860	0.020
14	IR-64	44.75	72.100	0.428	48	Nagina	48.71	77.310	0.382
15	Mahamaya	50.28	76.400	0.219	49	Cure 10	46.65	83.655	0.283
16	Poornima	49.33	63.515	0.405	50	IR-36	47.84	76.715	0.251
17	Samleshwari	47.89	68.730	1.078	51	Gp-145-5	60.70	79.780	0.633
18	ARB-6-11	48.67	64.930	0.772	52	Gp-145-40	58.27	70.920	0.730
19	Dagaddesi	57.49	69.955	0.065	53	Gp-145-41	61.23	76.110	1.681
20	Moroboican	59.59	61.555	0.092	54	Gp-145-49	62.26	80.875	0.449
21	Danteshwari	48.05	68.465	0.439	55	Gp-145-51	64.35	84.260	1.285
22	Swarna	52.66	64.915	0.124	56	Gp-145-55	63.34	82.265	0.718
23	Karma masuri	51.61	73.740	0.364	57	Gp-145-63	57.15	77.380	0.520
24	Mahamaya x Dagaddesi	49.77	72.290	0.606	58	Gp-145-73	58.36	77.185	0.163
25	IRD TN	45.89	74.985	0.867	59	Gp-145-74	63.49	70.200	1.728
26	Danteshwari x Desi lal dhan	47.71	47.965	0.062	60	Gp-145-79	55.00	83.545	0.809
27	Danteshwari x Dagaddesi	44.77	62.750	0.027	61	Gp-145-91	59.16	80.610	0.734
28	Mahamaya x IR-6226-6	40.93	76.580	0.020	62	Gp-145-99	62.02	76.330	0.318
29	BR-240 x Danteshwari	45.73	77.360	0.136	63	Gp-145-103	60.46	81.335	1.337
30	Abhaya x IR-42253	41.62	69.900	0.283	64	Gp-145-130	60.96	87.715	0.182
31	Bandhi banku X R-979-1528	32.60	72.755	0.142	65	Gp-145-134	59.89	85.215	0.626
32	Laloo-14 x IR-64	44.51	63.880	0.035		Mean	49.376	70.1647	0.408
33	Triguna x IR-42253	51.75	74.410	0.241		SEm±	2.218	0.6081	0.012
34	Abhaya x Dagaddesi	38.57	70.710	0.240		CD at 5%	6.266	1.72	0.033

panicle length (cm) have been presented in Table 3. The mean data from the experiment was statistically analyzed and result clearly showed that it varied significantly. In rice genotypes it ranges from 19.75 to 33.10 cm under upland rainfed condition. In medium duration genotypes it ranges from 19.75 (R-1839-RF-42, Denteshwari x Desi lal dhan) to 28.20 cm (Dagaddesi), while in late duration genotypes it ranges from 19.95 (308 cross line) to 33.10 cm (Gp-145-79). Among the breeding lines maximum panicle length was recorded in Gp-145-79 (33.10 cm) followed by Gp-145-74 (33.05), while minimum in R-1839-RF-42, Danteshwari x Desi lal dhan (19.75) under upland rainfed condition.

Genotypes were found to differ in panicle length. Reduction in panicle length under water deficit has been reported by many workers such as (18). Panicle length had positive correlation with plant height. Similar results were reported by (19).

Panicle weight (g/panicle) of rice breeding lines under upland rainfed condition : The results related to panicle weight (g/panicle) have been presented in Table-3. The mean data from the experiment was statistically analyzed and result depicted that it varied significantly under upland rainfed condition. In rice genotypes it ranges from 0.50 to 3.70 g/panicle under upland rainfed condition. In medium duration genotypes it ranges from 1.20 (Abhaya x IR-42253) to

Table-3 : Yield attributes of rice breeding lines under upland rainfed condition.

S. No.	Rice breeding lines	No.of panicles/ plant	Panicle length (cm)	Paniclewe ight (g/ panicle)	No.of grains/ panicle	S. No.	Rice breeding lines	No.of panicles/ plant	Panicle length (cm)	Panicle weight (g/panicle)	No.of grains/ panicle
1	R-RF-25	13.75	22.55	2.25	116.83	35	Lalmati X Swarna	6.50	23.35	2.00	119.67
2	R-1836	11.00	27.05	2.75	171.50	36	113 (Cross line)	10.00	21.75	1.35	143.50
3	R-RF-44	8.50	24.95	2.40	190.83	37	123 (Cross line)	10.25	24.15	2.45	181.00
4	R-1838	11.50	25.05	1.60	93.67	38	150 (Cross line)	12.00	23.70	1.65	141.83
5	R-RF-26	9.00	23.45	2.70	133.67	39	308 (Cross line)	8.50	19.95	1.80	134.50
6	R-1839-RF-42	7.75	19.75	1.85	101.50	40	168 (Cross line)	10.50	25.40	2.10	130.17
7	R-RF-31	7.75	22.05	2.40	164.33	41	217 (Cross line)	8.00	21.10	1.80	168.17
8	SL-62	11.25	21.70	2.00	131.00	42	330 (Cross line)	7.25	22.20	2.15	158.83
9	R-RF-36	11.00	22.65	1.85	136.67	43	359 (Cross line)	11.50	22.65	1.45	106.33
10	R-RF-69	9.25	20.40	2.05	123.17	44	213 (Cross line)	7.00	25.95	2.70	225.83
11	IR-70225	9.00	20.15	2.35	153.00	45	318 (Cross line)	6.25	20.15	1.45	119.50
12	Annada	9.75	22.95	1.60	110.67	46	387 (Cross line)	9.00	26.25	2.50	195.50
13	MTU1010	8.75	21.70	1.95	129.67	47	40 (Cross line)	9.75	24.10	1.45	118.67
14	IR-64	8.00	22.75	1.90	132.17	48	Nagina	12.25	23.05	1.45	112.00
15	Mahamaya	8.00	25.35	2.85	152.67	49	Cure 10	8.75	23.35	1.85	117.00
16	Poornima	9.00	21.45	1.80	117.17	50	IR-36	9.75	22.95	1.10	95.50
17	Samleshwari	8.50	21.15	2.05	178.33	51	Gp-145-5	5.50	23.15	1.90	183.67
18	ARB-6-11	10.25	24.95	1.70	106.00	52	Gp-145-40	6.00	27.05	0.55	105.17
19	Dagaddesi	4.25	28.20	3.70	196.33	53	Gp-145-41	5.75	22.05	1.55	167.17
20	Moroboican	4.00	25.00	3.15	157.00	54	Gp-145-49	5.50	27.35	2.25	138.67
21	Danteshwari	11.00	21.45	1.50	108.17	55	Gp-145-51	6.00	21.75	0.50	125.50
22	Swarna	9.50	23.00	1.35	178.50	56	Gp-145-55	6.50	27.05	0.55	215.83
23	Karma masuri	8.00	22.25	1.90	231.83	57	Gp-145-63	9.75	24.15	0.65	102.17
24	Mahamaya x Dagaddesi	10.75	21.05	1.75	107.17	58	Gp-145-73	5.75	27.80	1.50	140.00
25	IRD TN	6.50	25.60	2.00	114.17	59	Gp-145-74	8.75	33.05	0.90	95.17
26	Danteshwari x Desi lal dhan	17.50	19.75	1.45	104.33	60	Gp-145-79	8.25	33.10	0.65	212.00
27	Danteshwari x Dagaddesi	7.25	20.70	2.20	135.17	61	Gp-145-91	6.00	25.60	0.90	182.67
28	Mahamaya x IR-6226-6	10.00	21.30	1.75	118.17	62	Gp-145-99	9.00	28.55	0.60	108.33
29	BR-240 x Danteshwari	8.25	23.25	2.00	106.17	63	Gp-145-103	8.50	24.45	1.55	152.67
30	Abhaya x IR-42253	12.25	21.25	1.20	78.67	64	Gp-145-130	6.00	26.15	0.70	249.17
31	Bandhi banku x R-979-1528	9.25	20.05	1.95	149.17	65	Gp-145-134	9.50	24.55	0.50	138.33
32	Laloo-14 x IR-64	10.75	24.40	1.95	124.83		**Mean**	**8.84**	**23.68**	**1.76**	**141.48**
33	Triguna x IR-42253	9.00	22.70	1.90	104.50		**SEm±**	**0.94**	**0.28**	**0.25**	**23.78**
34	Abhaya x Dagaddesi	10.25	23.15	2.00	154.67		**CD at 5%**	**2.66**	**1.65**	**0.70**	**67.17**

3.70 g/panicle (Dagaddesi), while in late duration genotypes it ranges from 0.50 (Gp-145-51, Gp-145-134) to 3.15 g/panicle (Moroboican). Among the breeding lines maximum panicle weight was recorded in Dagaddesi (3.70 g/panicle) followed by Moroboican (3.15 g/panicle), while minimum in Gp-145-51, Gp-145-134 (0.50 g/panicle) under upland rainfed condition.

Panicle weight is a desirable character for the cultivar performing better under water limiting condition as an index of their genetic potential expression (20).

Number of grains/panicle of rice breeding lines under upland rainfed condition : The results related to number of grains/panicle have been presented in Table-3. The mean data from the experiment was

statistically analyzed and result showed that it varied significantly under upland rainfed condition. In rice genotypes it ranges from 78.668 to 249.165 under upland rainfed condition. In medium duration genotypes it ranges from 78.668 (Abhaya x IR-42253) to 196.335 (Dagaddesi), while in late duration genotypes it ranges from 95.168 (Gp-145-74) to 249.165 (Gp-145-130). Among the breeding lines maximum number of grains/panicle was recorded in Gp-145-130 (249.165) followed by Karma masuri (231.832), while minimum in Abhaya x IR-42253 (78.668) under upland rainfed condition.

Genotypic differences regarding grains/panicle was noticed in rainfed condition. (8) found that the number of grains/panicle and chlorophyll stability index were the major yield contributing traits under water deficit conditions and have to be given importance in selection process for improvement in yield under water deficit situations. (21) reported that number of filled grains was observed as a major attributes affected yield drastically under rainfed condition.

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