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Morpho-physiological study of rice (*Oryza sativa* L.) under moisture deficit conditions in Odisha

Rajkumari Bhola, Anita Mohapatra and Sushrismita Sahoo

Abstract
Two sets of experiments were conducted, one in the laboratory and the other infield during Rabi season 2011 & 2012-13 with five rice varieties *viz*. Mandakini, Sahabhagi Dhan, Parijat, Annada & Anjali in Chiplima farm to assess the efficiency and efficacy of moisture stress for their relative tolerance. Laboratory studies under simulated moisture stress conditions indicated that germination decreased with a decrease in water potential of the germinating medium irrespective of the varieties. There was a severe failure in germination beyond -0.6MPa. Anjali exhibited better performance and better germination parameters indicating tolerance to moisture stress. The field studies took 35 treatments laid out in split-plot design with three replications with seven combinations of drought stress comprising stress at three different stages of crop growth, i.e., tillering, panicle initiation, and flowering. It was observed that a significant reduction in plant height, tiller number/ hill, and leaf area responded to moisture stress. The tolerant variety Anjali exhibited a minor decrease due to the impact of moisture stress. Similarly, the accumulation of the biomass decrease in response to moisture stress. The decline was more pronounced in the case of Parijat compared to Anjali.

Keywords: Morphology, physiology, rice, moisture deficit condition

Introduction
Rice is one of the world's most important crops in terms of economic value, and 90% of the world's rice is grown and consumed in Asia. Rice is the dominant staple food of the country, and it holds the key to food security. It occupies 44million ha with 112 million tons in Eastern India comprising 26.8mha, of which 14.7Mha are under rain-fed lowlands. Rice, the mainstay of 50% of the global population, bears testimony to its importance while planning for food security of the ever-burgeoning population of the world. Since land area and other natural resources are becoming increasingly scarce, for increasing crop production, greater emphasis is being laid on increasing productivity per unit of land area, unit of input, and unit of time, which is also a fact for the rice crop. Out of the entire coverage under rice, nearly 13% is devoted to upland rice and 28% to rain-fed lowlands [14].

So in a way, almost half of the World's rice, about 45% [17], is grown in a rainfed ecosystem where production is dependent on a well and evenly distributed rainfall. Rice production in Asia needs to be increased to feed the growing population. Albeit a complete assessment of the level of water scarcity in Asian rice production is still lacking, some signs of declining quality and a declining availability of water resources are threatening so far as the sustainability of the irrigated rice-based production system is concerned. Drought stress is an example of the most prevalent form of environmental stress Drought caused to reduce the area by about 8 mha (20%) in 2009-10, causing yield reduction by around 6 million tonnes. India produces nearly one-fourth (22%) of the World's rice, only second to China, and exports 4.1 million tons (during 2002) only second to Thailand. However, the surplus production scenario has no room for complacency keeping in view the annual growth of population that hovers around 1.5% per capita consumption of 235 g/day and the vagaries of monsoon. The total area under rice production in Odisha is 44.5 lakh ha under irrigated and rainfed conditions.

It is estimated that rice demand for 2025 would be 140 million tons. This projected rice demand can only be met by maintaining steady productivity in the coming years. In the post-WTO era, adequate rice is to be produced for self-sufficiency and export purposes. This increase in production has come from increased productivity under depleting and diminishing resources, decreasing total factor productivity and demand of sustainability and preservation of environmental conditions irrespective of various production strategies being employed now- a-days the rice production is almost plateauing. The present study aims to ransack the response of rice plants to drought under agro-climatic conditions of Odisha by identification of relevant drought-tolerant traits with adaptive significance to improve productivity under water-limited conditions and by identifying measures for overcoming the innocuous effects of drought by improving the degree of resistance in the plants through drought mitigating chemicals.

Materials and Methods

Plant Materials

The morpho-physiological basis of drought tolerance in rice was studied using two sets of experiments, one in the laboratory and the other in the field conditions. Five varieties of rice, *viz*. Annada, Anjali, Mandakini, *Parijat*, *Sahabhagi Dhan we*re taken for the study. Required seeds were collected from NRRI, Cuttack, and Central farm OUAT for the above purpose.

Laboratory and field experiments

In the laboratory, germination studies were taken up under simulated water stress conditions using polyethylene glycol-6000 (PEG-6000) in a completely randomized design. Three replications were subjected to six different levels of water potentials *viz*. 0, -0.2, -0.4, and -0.6MPa.Osmotic solutions of 0, -0.2, -0.4, -0.6, MPa potentials were prepared by dissolving 0g, 11.8g, 18.5g, 21.8g, of PEG-6000 in 100ml of distilled water each, respectively. Healthy and uniform seeds of the five varieties were surface sterilized with Bavistin @2gm/liter of water for 60min. Then those were repeatedly washed with distilled water and surface dried using blotting papers. One hundred seeds were laid out uniformly in Petri dishes on Whatman no. 1 filter paper, which was made saturated with different osmotic solutions. The total number of seeds from each variety was divided into two parts. One part from each variety was kept overnight in 100ppm salicylic acid (0.1gm of Salicylic acid dissolved in 1litre of water). Then again, those were removed and surface dried using blotting paper. Three sets of such Petri dishes were used for each variety. Then they were kept in the germinator at 30°C with 100% RH. The temperature was maintained at 25± 1ºC with 12hr daylight in the germination chamber. The no. of seeds that germinated was counted daily from day two up to day fourteen. After the final count, germination parameters and other observations were recorded. Speed of germination (SG), germination percentage, was calculated by the standard methods [13, 10]. The Vigour index of the seedlings was also measured using standard protocol [1].

Field experiments were conducted during the Rabi season for two consecutive years, 2011-2012 and 2012-2013 were in Orissa University of Agriculture and Technology, Chiplima campus Sambalpur. The field experiment with 35 treatments was laid out in a split-plot design with three replications. Seven combinations of drought stress treatments comprising stress at three different crop growth stages, i.e., tillering, panicle initiation, and flowering with or without the use of Salicylic acid and control, were allotted to the main plots. Five rice varieties *viz*. Mandakini (V_1), Sahabhagi Dhan (V_2), Parijat (V_3), Annada (V_4), Anjali (V_5) were assigned to the subplots for a matter of convenience. The total number of treatments was abbreviated as T1-Control, T2-Water stress at tillering without salicylic acid, T3-Water stress at tillering with salicylic acid, T4-Water stress at panicle initiation without salicylic acid, T5-Water stress at panicle initiation with salicylic acid, T6-Water stress at flowering without salicylic acid and T7-Water stress at flowering with salicylic acid.

Results

Physiological parameters

The maximum average value of germination speed was found in Anjali (30.2%), followed by Mandakini (28.7%). In contrast, the lowest value was recorded from Parijat (26.45%). Data presented in Table 1 revealed that due to osmotic stress during germination, the speed of germination index (SGI) decreased as compared to control. In the case of moisture stress, the lowest value was observed at – 0.6 MPa (47.15) in non-treated seed, but when salicylic acid was treated, the same matter was enhanced irrespective of varieties. Among the varieties mean speed of germination index was maximum in Anjali (97.7) followed by Mandakini (93.75), whereas the lowest value of the same was recorded from Parijat (84.0).Imposition of moisture stress during germination with a decrease in water potential. Germination Resistance Index (GRI) decreased in all the varieties. The lowest value was recorded at – 0.6 MPa as (18.83) in non-treated seeds. Pre-treatment with salicylic acid increased the GRI of all the tested varieties to the tune of 6.7 to 27.1% over the counterpart of non-treated sources.

Morphological Parameters

Drought imposed at tillering, panicle initiation, and flowering stages, there was a reduction of plant height to a tune of 5.0, 6.0, and 2.5%, respectively (Table 2). Effect of moisture stress on tiller numbers per hill indicated a reduction of tiller number in all the varieties when drought was imposed at different growth stages (Table 3). The maximum decrease in tiller numbers per hill was recorded in plants exposed to stress at panicle initiation (10.52), followed by tillering stage 7.6%. In comparison, the impact of moisture stress at the flowering stage was 3.68% only. The average number of productive tillers was highest in Annada (10.22), followed by Anjali (8.82). The percentage of reduction of the productive tillers was maximum in Annada (4.7%), whereas the minimum reduction was recorded from Mandakini (1.1%). When the stress was imposed during the tillering stage, the leaf area decreased in all varieties to a tune of 28.4%.Spraying salicylic acid to the plants reduced the impact of stress a little, but the leaf area at the panicle initiation stage was 33%.The root dry weight (Table 4) was maximum in Annada (5.7gm/hill), whereas the minimum value of the same was reordered from Perinat (4.83g/hill).

The root dry weight decreased to 36.6% irrespective of varieties when stress was imposed at the panicle initiation stage compared to control. At a tillering location, the maximum mean Relative Water Content (RWC) (Table 5) was recorded in leaves of Anjali (89.15) followed by Mandakini (85.3).Similarly, when drought was imposed at the PI stage, the RWC was decreased in all the varieties. However, the maximum decrease was recorded from Annada (24.0) followed by Parijat (22.0). With the application of salicylic acid, the drop was minimized to 9% in Anjali and 7.3% in Annada. The RWC at flowering was also reduced compared to control in all the varieties, but the reduction was less compared to other growth stages. Moisture stress at tillering significantly impacted the Crop growth rate (CAGR) among the varieties. Spraying of salicylic acid resulted in an increase of GCR (Table 6) to a tune of 7.4% in Sahabhagi Dhan to 11.9% in Mandakini However, moisture stress at flowering reduced the CGRs maximum in Annada (29.8%) followed by Parijat(28,6%). Still, with salicylic acid application increased CGRs in Annada (5.8%), followed by Parijat (4.6%). The highest CGRs were recorded in tolerant varieties. The interaction between the treatment and genotypes was found significant. When stress was imposed at PI stage the reduction in filled grains was also much in Parijat (7.2%) followed by Annada (5.5%) The highest yield (Table 7) was recorded from Annada (31.4qha^{-1}) followed by Anjali (30.8qha^{-1}) and minimum value of the same being noticed in Parijata (27.9qha^{-1}).

Table 1: Speed of germination, SGI and GRI of rice in response to moisture stress

Treatment	Speed of germination			Speed of germination index(SGI)			Germination Resistance Index (GRI)		
	2011	2012	pooled	2011	2012	pooled	2011	2012	pooled
T1(Control)	34.4 (6.0)	35.8 (6.0)	35.1 (6.0)	95.6 (78.1)	96.2 (78.1)	95.9 (78.1)	34.2 (5.8)	35 (5.8)	34.6 (5.8)
T2 (-0.2MPa)	31.1 (5.6)	32.5 (5.6)	31.8 (5.6)	85.4 (70.2)	86.2 (70.2)	85.8 (70.2)	30.72 (5.5)	31.6 (5.5)	31.2 (5.5)
T3 (-0.2MPa+ S.A)	32.4 (5.7)	33.2 (5.7)	33.1 (5.7)	87.14 (71.2)	87.9 (71.2)	87.52 (71.2)	32.62 (5.7)	33.54 (5.7)	33.1 (5.7)
T4 (-0.4MPa)	23.8 (5.0)	24.8 (5.0)	24.3 (5.0)	66.5 (55.3)	67.0 (55.3)	67.75 (55.3)	25.4 (5.1)	26.2 (5.1)	25.8 (5.1)
T5 (-0.4MPa+ S.A)	28.4 (5.3)	29.5 (5.3)	28.95 (5.3)	85.5 (70.2)	86.1 (70.2)	85.8 (70.2)	32.58 (5.6)	33.42 (5.6)	33.0 (5.6)
T6 (-0.6MPa)	17.96 (4.2)	18.8 (4.2)	18.4 (4.2)	47.0 (44.5)	47.3 (44.5)	47.15 (44.5)	18.5 (4.3)	19.15 (4.3)	18.83 (4.3)
T7 (-0.6MPa+ S.A)	24.3 (4.9)	25.4 (4.9)	24.8 (4.9)	57.75 (48.4)	58.1 (48.4)	57.9 (48.4)	24.9 (5.0)	25.5 (5.0)	25.2 (5.0)
S.Em (±)	0.328	0.345	0.23	0.456	0.486	0.33	0.482	0.491	0.344
C.D (0.05)	0.928	1.01	0.71	1.28	1.31	0.99	1.36	1.42	1.03
Variety									
Mandakini (V1)	28.3 (5.3)	29.2 (5.3)	28.7 (5.3)	95.3 (78.1)	92.2 (78.1)	93.75 (78.1)	28.65 (5.4)	29.75 (5.4)	29.2 (5.4)
Sahabhagi Dhan (V2)	26.7 (5.2)	27.5 (5.2)	27.1 (5.2)	86.7 (70.1)	87.5 (70.1)	87.1 (70.1)	28.2 (5.3)	29.5 (5.3)	28.85 (5.3)
Parijata (V3)	26.1 (5.1)	26.8 (5.1)	26.45 (5.1)	83.1 (68.0)	84.8 (68.0)	84.0 (68.0)	27.0 (5.2)	28.3 (5.2)	27.75 (5.2)
Canada (V4)	26.3 (5.1)	27.2 (5.1)	26.75 (5.1)	86.3 (70.4)	87.2 (70.4)	86.7 (70.4)	28.0 (5.3)	29.2 (5.3)	28.6 (5.3)
Anjali (V5)	29.8 (5.5)	30.6 (5.5)	30.2 (5.5)	98.9 (84.1)	98.6 (84.1)	97.7 (84.1)	30.04 (5.5)	31.2 (5.5)	30.62 (5.5)
S.Em (±)	0.325	0.345	0.236	0.345	0.45	0.28	0.373	0.381	0.266
C.D (0.05)	1.09	1.1	0.71	1.1	1.7	0.84	1.21	1.26	0.79

Table 2: Effect of moisture stress on Plant height (cm) at different growth stages of rice cultivar

Treatment	Tillering			PI stage			Flowering		
	2011	2012	pooled	2011	2012	pooled	2011	2012	Pooled
T1	13.4	13.6	13.5	32.4	33.8	33.1	68.1	70.6	69.3
T2	12.5	13.1	12.8	30.7	31.1	31.0	66.4	66.9	66.7
T3	14.1	14.5	14.3	36.3	37.8	37.1	72.2	72.7	72.5
T4	13.5	13.5	13.5	30.4	31.8	31.1	66.7	66.7	66.7
T5	13.4	13.5	13.5	36.4	36.9	36.7	70.4	70.4	70.4
T6	13.6	13.6	13.6	32.9	33.4	33.1	68.5	66.6	67.6
T7	13.7	13.7	13.7	33.6	36.9	35.2	73.5	73.5	73.5
Mean	13.5	13.6	13.5	32.8	34.5	33.7	69.4	69.6	69.5
S.Em (±)	0.030	0.031	0.021	0.177	0.182	0.126	0.673	0.682	0.48
C.D (0.05)	0.085	0.087	0.064	0.502	0.530	0.38	1.903	2.01	1.43
Variety									
Mandakini (V1)	13.7	14.5	14.1	33.50	33.7	33.6	72.10	74.83	73.46
Sahabhagi Dhan (V2)	13.5	14.2	13.8	32.61	32.8	32.7	65.1	68.76	66.9
Parijata (V3)	13.6	14.3	14.0	32.3	32.5	32.4	67.6	68.3	68.0
Canada (V4)	14.4	14.8	14.6	34.0	34.8	34.4	74.2	76.0	75.1
Anjali (V5)	14.1	14.8	14.4	33.7	33.9	33.8	68.0	70.7	69.4
Mean	13.9	14.5	14.2	33.2	33.5	32.8	69.4	72.2	70.8
S.Em (±)	0.011	0.012	0.008	0.114	0.118	0.08	0.521	0.530	0.37
C.D (0.05)	0.035	0.037	0.024	0.373	0.390	0.246	1.699	1.750	1.11

Table 3: Effect of moisture stress on tiller numberhill^{-1} at different growth stages of rice cultivar

Treatment	Tillering			PI stage			Flowering stage		
	2011	2012	pooled	2011	2012	pooled	2011	2012	pooled
T1	8.7	8.0	8.4	9.9	10.2	10.0	8.5	8.3	8.4
T2	8.6	7.9	8.2	9.1	9.4	9.3	8.3	8.0	8.1
T3	8.7	8.2	8.4	9.7	9.5	9.6	8.5	8.4	8.4
T4	8.7	8.8	8.7	9.5	9.7	9.6	8.2	8.1	8.0
T5	8.6	8.1	8.3	9.7	9.8	9.7	8.3	8.1	8.2
T6	8.0	8.1	8.1	9.9	9.7	9.1	7.7	7.8	7.2
T7	8.4	8.5	8.4	9.8	9.6	9.1	8.0	8.1	8.2
Mean	8.5	8.2	8.3	9.7	9.6	9.2	8.2	8.1	8.0
S.Em (±)	0.035	0.031	0.023	0.063	0.065	0.045	0.042	0.036	0.027
C.D (0.05)	0.100	0.098	0.068	0.177	0.181	0.135	0.119	0.112	0.081
Variety									
Mandakini (V1)	9.4	9.8	9.6	8.8	9.0	8.9	8.7	8.9	8.8

Sahabhagi Dhan (V2)	8.8	9.1	8.9	7.2	7.4	7.3	8.5	8.7	8.6
Parijata (V3)	9.0	9.3	9.1	8.7	9.0	8.8	7.1	7.3	7.2
Canada (V4)	12.0	12.5	12.3	10.1	10.4	10.3	10.1	10.3	10.2
Anjali (V5)	10.0	10.3	10.2	8.5	8.8	8.7	8.6	8.8	8.7
Mean	9.8	10.2	10.5	8.6	8.9	8.5	10.1	10.3	10.22
S.Em (±)	0.032	0.041	0.02	0.17	0.018	0.066	0.025	0.027	0.018
C.D (0.05)	0.103	0.118	0.077	0.56	0.061	0.199	0.080	0.083	0.055

Table 4: Effect of moisture stress on root dry weight (g hill $^{-1}$) at different stages of growth

Treatment	Tillering			PI stage			flowering		
	2011	**2012**	**pooled**	**2011**	**2012**	**pooled**	**2011**	**2012**	**pooled**
T1	5.32	5.48	5.40	7.16	7.85	7.50	7.80	8.12	7.96
T2	3.84	3.95	3.89	5.78	6.32	6.05	6.42	6.67	6.54
T3	3.44	3.54	3.49	5.28	5.78	5.53	5.84	6.07	5.95
T4	5.34	5.49	5.41	4.26	4.65	4.45	5.30	5.50	5.40
T5	5.30	5.44	5.37	4.60	5.02	4.81	5.74	5.95	5.84
T6	5.34	5.48	5.41	7.22	7.87	7.54	5.46	5.65	5.55
T7	5.16	5.29	5.22	7.20	7.84	7.52	5.78	5.98	5.88
Mean	4.82	4.95	4.88	5.92	6.47	6.19	6.04	6.28	6.16
S.Em(±)	0.39	0.45	0.29	0.029	0.44	0.16	0.035	0.044	0.027
C.D (0.05)	0.109	0.12	0.89	0.083	0.09	0.49	0.099	1.2	0.083
Variety									
Mandakini (V1)	4.38	4.50	4.44	5.82	5.99	5.90	5.94	6.23	6.10
Sahabhagi Dhan (V2)	4.61	5.01	4.81	5.94	6.12	6.03	6.22	6.53	6.40
Parijata (V3)	4.45	4.83	4.64	5.51	5.68	5.60	5.48	5.76	5.62
Canada (V4)	5.47	5.94	5.71	6.18	6.38	6.28	6.45	6.78	6.61
Anjali (V5)	5.12	5.56	5.34	6.15	6.35	6.25	6.08	6.40	6.24
Mean	4.81	5.21	4.98	5.92	6.10	6.01	6.03	6.34	6.20
S.Em(±)	0.026	0.36	0.136	0.027	0.32	0.122	0.033	0.035	0.024
C.D(0.05)	0.084	0.086	0.41	0.088	0.089	0.36	0.108	021	0.072

Table 5: Effect of moisture stress on RWC (%) at different growth stages of rice cultivar

Treatment	Tillering			PI stage			Flowering stage		
	2011	**2012**	**pooled**	**2011**	**2012**	**pooled**	**2011**	**2012**	**Pooled**
T1	91.62	93.8	92.71	90.42	91.5	90.8	89.32	90.15	89.73
T2	76.96	78.7	77.83	86.4	87.36	86.88	88.64	89.48	89.08
T3	82.6	84.4	83.5	88.4	91.41	89.91	84.14	86.93	85.53
T4	83.4	85.4	84.4	73.7	76.37	75.05	88.98	89.79	89.38
T5	86.92	88.9	87.91	79.88	82.69	81.28	88.0	88.79	88.40
T6	85.72	86.0	85.86	87.0	86.0	86.5	73.52	74.20	73.86
T7	89.97	92.0	90.5	90.92	91.6	91.26	78.92	79.64	79.28
Mean	85.3	87.0	86.1	85.4	86.9	86.1	84.5	85.56	85.03
S.Em(±)	0.192	0.213	0.143	0.091	1.30	0.491	0.039	0.045	0.029
C.D (0.05)	0.542	0.561	0.43	0.258	0.26	1.47	1.045	1.048	0.089
Variety									
Mandakini (V1)	84.98	85.80	85.39	88.0	90.0	89.0	86.28	88.0	87.14
Sahabhagi Dhan (V2)	84.15	84.90	84.52	84.9	87.0	85.5	84.04	86.0	85.02
Parijata (V3)	82.7	83.60	83.15	80.5	84.5	82.2	82.8	84.7	83.75
Canada (V4)	84.78	85.62	85.2	84.68	86.7	85.6	85.57	87.6	86.58
Anjali (V5)	88.7	89.6	89.15	89.58	91.7	90.6	89.34	91.5	90.42
Mean	85.06	85.9	85.48	85.53	87.98	86.95	85.6	87.5	86.58
S.Em(±)	0.198	0.23	0.151	0.075	0.09	0.058	0.220	0.32	0.199
C.D(0.05)	0.646	0.67	0.45	0.243	0.25	0.175	0.718	0.73	0.57

Table 6: Effect of moisture stress on GCR (gcm^{-2}week-^{1}) at different growth stages of rice cultivar

Treatment	Tillering			PI stage			Flowering stage		
	2011	**2012**	**pooled**	**2011**	**2012**	**pooled**	**2011**	**2012**	**Pooled**
T1	33.7	34.5	34.1	130.6	135.9	133.2	100.2	103.6	101.9
T2	30.3	31.0	30.6	70.4	72.9	71.6	84.9	88.4	86.6
T3	32.4	33.4	32.9	84.0	87.8	85.9	93.3	97.6	95.5
T4	40.3	41.2	40.8	80.6	83.9	82.2	81.4	84.8	83.1
T5	44.3	45.6	45.0	93.3	97.1	95.2	92.7	96.3	94.5
T6	39.4	40.8	40.1	94.3	98.8	96.5	84.6	87.8	87.2
T7	41.9	43.0	42.4	97.7	101.8	99.7	92.5	96.3	94.4
Mean	37.4	38.5	37.95	93.0	96.88	95.0	90.0	93.5	91.8
S.Em (±)	0.592	0.67	0.26	0.659	0.72	0.48	0.78	0.79	0.56

C.D (0.05)	1.675	1.72	0.77	1.865	1.9	1.46	2.197	2.23	1.66
Variety									
Mandakini (V1)	37.8	38.9	38.3	94.6	97.4	96.0	92.1	94.8	93.4
Sahabhagi Dhan (V2)	36.3	37.4	36.8	89.7	92.8	91.2	87.1	90.7	88.9
Parijata (V3)	33.7	34.7	34.2	86.0	89.0	87.5	80.2	83.8	82.0
Canada (V4)	40.0	41.1	40.5	96.2	100.3	98.2	93.7	97.0	95.3
Anjali (V5)	40.2	41.4	40.8	98.4	101.8	100.1	96.5	100.3	98.4
Mean	37.6	38.7	38.12	93.0	96.3	94.6	90.0	93.3	91.6
S.Em (±)	0.516	0.67	0.42	0.410	0.46	0.31	0.401	0.411	0.28
C.D (0.05)	1.683	1.70	1.25	1.336	1.35	0.92	1.307	1.32	0.86

Table 7: Effect of moisture stress on yield and yield attributing characters

Treatment	Sterility percentage			1000 grain weight			Yield(Q/ha)		
	2011	2012	pooled	2011	2012	pooled	2011	2012	Pooled
T1	14.6	12.6	13.6	21.78	21.90	21.84	33.0	33.45	33.2
T2	16.0	14.2	15.1	21.48	21.33	21.4	28.48	28.87	28.6
T3	14.5	14.0	14.25	21.22	21.36	21.8	30.64	30.94	30.8
T4	16.4	15.7	16.05	21.4	20.53	21	27.66	27.22	27.4
T5	16.0	15.2	15.6	21.5	21.6	21.55	29.92	30.52	30.2
T6	17.1	17.06	17.08	19.04	19.0	19.02	28.92	28.96	28.94
T7	17.2	17.06	17.10	22.04	21.1	21.5	31.78	32.4	32.1
Mean	15.8	14.9	15.3	21.2	20.97	21.15	29.8	30.35	30.1
S.Em (±)	0.116	0.118	0.082	0.043	0.045	0.031	0.072	0.078	0.05
C.D (0.05)	0.329	0.356	0.248	0.121	0.123	0.093	0.204	0.23	0.16
Variety									
Mandakini (V1)	20.55	21.0	20.77	21.9	22.07	21.9	30.24	30.82	30.5
Sahabhagi Dhan (V2)	19.87	21.3	20.58	21.75	21.92	21.8	29.6	30.17	29.8
Parijata (V3)	20.02	19.42	19.72	20.25	20.41	20.3	27.71	28.25	27.9
Annada (V4)	21.07	22.5	21.78	22.21	22.39	22.3	31.1	31.71	31.4
Anjali (V5)	20.98	21.8	21.39	21.72	21.9	21.8	30.55	31.15	30.8
Mean	20.5	21.20	20.83	21.5	21.7	21.6	29.84	30.42	30.08
S.Em (±)	0.043	0.044	0.030	0.057	0.062	0.042	0.058	0.059	0.043
C.D (0.05)	0.141	0.142	0.092	0.186	0.187	0.12	0.191	0.194	0.13

Discussion

Pre-treatment with salicylic acid reduced the time taken for germination because the inhibition of water was faster than the stress condition, resulting in an MGT decrease compared to the stressed seed. These present findings agree with the results of previous workers [2]. The result found that with increasing water stress during germination, the speed of germination decreased. Still, the application of salicylic acid enhanced the speed of germination in all the tested varieties. Salicylic acid has got a hydroxyl group and regulates the transpiration rate and mobilization of food materials to the growing seedling. As a result, salicylic acid increased germination speed [9]. The plant height is more sensitive to water stress at the vegetative and reproductive stages and insensitive at the latter part of the growth. It is more sensitive during grain development [7]. This may be due to the osmotic effect, which is equivalent to a decrease in water activity through the specific toxic effect of ions and by disturbing the uptake of essential nutrients. Secondly, the plant height depends upon the quantity of moisture stress, which affects cell division, cell enlargement, and cell differentiation and develop moisture [3]. Application of salicylic acid enhanced the plant length to a tune of 8.8% to 15.2% over control. Annada was the tallest among other types among the varieties via the effect of hormones like auxin, gibberellin & cytokinin, and power in photosynthesis [8].

Results obtained from the experiment revealed that leaf area was decreased by increasing water restriction. Changes in plant water relations cause a reduction in meristematic activity and cell elongation and senescence of adult leaves, which resulted in a decrease in leaf area [5]. The present results strongly agree with Ali *et al.*, 2008 [4]. Closure of stomata prevents transpiration water loss, and salicylic acid is thought to increase the cell expansion enabling turgor pressure than the cell wall pressure [16]. Stress at PI and flowering stage resulted in a decrease in root dry weight compared to the control because more carbohydrate is diverted to the reproductive part [15] or is lost through root respiration to increase the metabolic efficiency of the plant [6]. It is a fact that the root is a significant sink of carbon fixed in photosynthesis.

According to Lambers, 1996 [11], during later stages of growth, for increasing tolerance to water stress conditions. About 60% of the photosynthesis fraction is utilized for respiration, for which the dry weight of the root decreased. It was implied that the suppression of leaf RWC due to water deficit reduces turgor, and the plant suffers from restricted water availability to the cells [12]. Application of salicylic acid increased the water status of the cell, for which the RWC improved with augmentation of proteins, nucleic acids (DNA& RNA), and lipids by decreasing the detrimental effect of stress. At the early stages of growth, GCR reduction was found less than the stress at the panicle initiation stage. The application of salicylic acid in the stressed plant enhanced the value, which was more prominent at the PI and flowering stage, and variety Anjali exhibited the highest GCR from transplanting to PI.

The yield reduction under water deficit stress over the control ranged from 17.4% to 12.8%. The percentage of reduction of panicle length at PI & tillering stage was 11% & 7.8% respectively as compared to control because water deficit affected the reduction division stage at the heading stage. Application Salicylic acid increased grains number might be due to decrease in the negative effect of drought stress and the percentage of increase varied from 5.1% to 1.8%. Water stress at flowering significantly interfere grain formation and fertilization and resulted in lower number of grain with higher grain weight/ spike. Among the varieties Anjali recorded the highest number (70.1 /panicle) of grains whereas the Parijat recorded the lowest number (63.3 grains /panicle). Water stress delayed the flowering and affected the various protocols linked to the grain development the reason for which grain weight (1000 seed weight) decreased. Application salicylic acid increased the 1000 seed weight which may be due to increase in photosynthetic pigment & photosynthetic rate.

Conclusion

The present study indicated that the response of moisture is different at vegetative and reproductive phases. Moisture stress imposed at the reproductive stage of the rice crop hastened senescence and other primary and secondary injuries. From the result of the present experiment, several physiological traits have been identified. The most important for the drought environment is the correct phenology and interaction between the genotypes and water stress. The physiological characteristics such as RWC, GCR have a positive correlation with grain yield, which can be used as selection criteria for rice variety selection through crop breeding programs. Notwithstanding the present achievement, further investigation is needed in various agro-climatic conditions of Odisha for continuation vis-a-vis recommendation of best suitable variety to primary stakeholders.

Conflict of Interest

The authors declare no conflict of interest.

References

1. Abdul- Baki AA, Anderson JD. Vigor determination in soybean seed by multiple criteria 1. Crop Science 1973;13(6):630-633.
2. Agarwal A, Nandipati KC, Sharma RK, Zippe CD, Raina R. Role of oxidative stress in pathophysiology of erectile dysfunction. J Androl 2005;27:335-47.
3. Aldesuquy H, Baka Z, Mickky B. Kinetin and spermine mediated induction of salt tolerance in wheat plants: Leaf area, photosynthesis and chloroplast ultrastructure of flag leaf at ear emergence. Egyptian Journal of basic and applied sciences 2014;1(2):77-87.
4. Ali B, Hasan SA, Hayat S, Hayat Q, Yadav S, Fariduddin Q *et al*. A role for brassinosteroids in the amelioration of aluminium stress through antioxidant system in mung bean (*Vigna radiata* L. Wilczek). Environmental and Experimental Botany 2008;62(2):153-159.
5. Bhatt RM, Rao NS. Influence of pod load on response of okra to water stress. Indian journal of plant physiology 2005;10(1):54.
6. Davidson EA, Keller M, Erickson HE, Verchot LV, Veldkamp E. Testing a conceptual model of soil emissions of nitrous and nitric oxides: using two functions based on soil nitrogen availability and soil water content, the hole-in-the-pipe model characterizes a large fraction of the observed variation of nitric oxide and nitrous oxide emissions from soils. Bioscience 2000;50(8):667-680.
7. Desclaux D, Roumet P. Impact of drought stress on the phenology of two soybean (*Glycine max* L. Merr) cultivars. Field Crops Research 1996;46(1-3):61-70.
8. Desclaux D, Roumet P. Impact of drought stress on the phenology of two soybean (*Glycine max* L. Merr) cultivars. Field Crops Research 1996;46(1-3):61-70.
9. Galetskiy D, Lohscheider JN, Kononikhin AS, Popov IA, Nikolaev EN, Adamska I. Mass spectrometric characterization of photooxidative protein modifications in Arabidopsis thaliana thylakoid membranes. Rapid Communications in Mass Spectrometry 2011;25(1):184-190.
10. Kabiri-Samani A, Javaheri A. Discharge coefficients for free and submerged flow over Piano Key weirs. Journal of Hydraulic Research 2012;50(1):114-120.
11. Khodarahmpour Z, Ifar M, Motamedi M. Effects of NaCl salinity on maize (*Zea mays* L.) at germination and early seedling stage. African Journal of Biotechnology 2012;11(2):298-304.
12. Lambers H, Atkin OK, Millenaar FF. Respiratory patterns in roots in relation to their functioning. Plant roots. The hidden half 1996;3:521-552.
13. Munns R. Comparative physiology of salt and water stress. Plant, cell & environment 2002;25(2):239-250.
14. Orenstein J, Kastner M. Photocurrent transient spectroscopy: measurement of the density of localized states in a-As 2 Se 3. Physical Review Letters 1981;46(21):1421.
15. Panda RK, Pandit E, Swain A, Mohanty DP, Baig MJ, Kar M *et al*. Response of physiological and biochemical parameters in deeper rooting rice genotypes under irrigated and water stress conditions. ORYZA-An International Journal on Rice 2016;53(4):422-427.
16. Sack L, Grubb PJ. The combined impacts of deep shade and drought on the growth and biomass allocation of shade-tolerant woody seedlings. Oecologia 2002;131(2):175-185.
17. Shao HB, Chu LY, Jaleel CA, Zhao CX. Water-deficit stress-induced anatomical changes in higher plants. Comptes rendus biologies 2008;331(3):215-225.
18. Wassmann R, Jagadish SVK, Heuer S, Ismail A, Redona E, Serraj R *et al*. Climate change affecting rice production: the physiological and agronomic basis for possible adaptation strategies. Advances in agronomy 2009;101:59-122.