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Effect of Water Stress on Morphological Traits and Yield in Rice Genotypes

Parveen Fatima[1], Pooran Chand[2], S. K. Singh[3], Purushottam[3], Anurag Mishra[1] and Pushpendra Kumar[1*]

[1]Department of Agricultural Biotechnology, Sardar Vallabhbhai Patel University of Agriculture and Technology, Meerut 250110, India.
[2]Department of Genetics and Plant Breeding, Sardar Vallabhbhai Patel University of Agriculture and Technology, Meerut 250110, India.
[3]College of Biotechnology, Sardar Vallabhbhai Patel University of Agriculture and Technology, Meerut 250110, India.

Authors' contributions

This work was carried out in collaboration between all authors. All authors read and approved the final manuscript.

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ABSTRACT

Water stress is a major factor limiting rice production and cause a severe threat to rice production. Study of relationships of morphological traits and analysis of relationships between grain yield is a useful way to finding out genetic basis of drought tolerance. Six rice varieties Pusa Basmati1, Pusa1121, Type3 and Vallabh basmati (Basmati type) and two non-basmati rice varieties Nagina 22 and Susk Samrat were imposed on water stress. All the selected varieties were monitored to evaluate the performance of different morphological and yield-related traits under water stress condition. The experiment was laid out in a complete randomised design (CRD) in control condition with three replications. In the experiment, susceptible check Pusa Basmati1 and resistance check Nagina 22 were studied along with the rice genotypes namely; Pusa 1121, Type 3 Basmati, Vallabh Basmati 21 and Susk Samrat. Water stress tolerant variety Nagina 22 showed a minimum reduction in filled grain per panicle whereas PB1 showed a maximum reduction after water stress. The experiment was conducted in two different conditions irrigated and water stress. The result showed that all the morphological characters are decreased under water stress condition. The studied traits indicate as ideal for improvement through selection or molecular breeding and that they may provide a high response to water stress.

**Corresponding author: E-mail: drpkdhaka@gmail.com;*
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Keywords: Water stress; grain yield; tolerance; drought susceptible.

1. INTRODUCTION

Rice is the staple food for its large population, and this crop is cultivated in almost all the Indian states under a remarkably wide range of agro-climatic conditions and ecological situations. Conventional flooded rice cultivation in Asian provides more than 75% of the world rice supply for the half the earth main staple food (Qin et al., 2006). Rice (*Oryza sativa* L.) is a significant and staple food crop in many parts of the world [1], feeding more than three billion people and providing 50-80 % of their daily calories intake (Khush, 2005). It is a drought susceptible crop exhibiting serious deleterious effects when exposed to water stress at critical growth stages especially at reproductive stage (Suriyanet al., 2010).

Rice (*Oryza sativa* L.) is an important cereal crop that requires a relatively higher amount of water for its normal growth in comparison with other crops (Pandey and Shukla, 2015). Therefore, water stress is a major factor limiting rice production that causes a great threat to rice production [2]. Hence, due to diminishing quantities of water supplies worldwide, screening of rice genotypes for drought tolerance is becoming increasingly a useful approach [3]. Approximately 27million hectares of rice are grown is subject to drought stress [4]. Developing new rice cultivars with improved drought tolerance is a useful approach to conferring this issue [4]. In spite of many studies on drought tolerance of crops for many years [5], the improvement of drought-tolerant crops is hindered greatly due to largely unknown mechanisms used by different crops respond to drought stress [4]. Drought is the most important limiting factor for crop production in many regions of the world [6,7]. It is a worldwide problem that seriously influences grain production and quality. It is often unpredictable and does not occur in all years in a target environment [8]. The drought problem is becoming more severe as the human population increases and global climate changes.

A definition of drought generally accepted by plant breeders is: “a shortfall of water availability sufficient to cause a loss in yield" [9] or “a period of no rainfall or irrigation that affects crop growth". Drought stress is multidimensional stress that affects plants at different growth stages. The impact of drought stress on the total green plant surface and plant response to drought stress are very intricate because it reflects a combination of stress impacts and plant response in all essential levels of the plant over time and place [10].

Drought is a major abiotic stress that limits rice productivity in the rain fed and upland ecosystems and worldwide. Drought stress is not only limited to arid or semiarid areas but also sometimes, due to the irregular distribution of rain, causes a significant decrease in plant yield. Stress in the tillering stage happened to have some opposite effect on the number of effective tillers, flag leaf length and area and there are some lines which are capable to withstand the stress when water availability becomes almost normal [11,12]. Grain yield under stress environment is the primary trait for selection in breeding for drought tolerance. Drought effect on seed yield is due to the relation with the duration of watering from flowering until physiological maturity [13].

Drought stress during the vegetative growth, flowering, and terminal stages of rice cultivation can cause spikelet sterility and unfilled grains [14]. Usually, drought during the grain-filling process induces early senescence and shortens the grain-filling period, but increases remobilisation of assimilates from the straw to the grains [15]. Thus, the manner in which drought influences grain yield is not straightforward, and it is necessary to understand the mechanism of plant responses to drought conditions, with the ultimate goal of improving crop performance for the vast rice cultivation areas of the world where rainfall is unreliable. Plant responses to drought are complex and different mechanisms are adopted by plants when they encounter drought [16]; furthermore, drought itself is a complicated physical process [7,17].

Less reduction in grain yield during water stress is an important trait that plays an important role in tolerance against drought. Thus, yield constancy under water stress conditions and increased crop water productivity should be the target of all the approaches involved in water stress tolerance [18]. The main objective of the present study is the identification of drought tolerance attributes traits in important Basmati type scented rice varieties.

2. MATERIALS AND METHODS

2.1 Experiment Site

The experiment was conducted under rainout shelter at field laboratory of Agriculture Biotechnology. Department of Ag. Biotechnology, S. V. P. U. A. & T., Modipuram, Meerut, U.P. India, which is situated at 26.47^0N (latitude), 82.12^0E (longitude) and at 113 m above mean sea level. The total four basmati rice germplasm PusaBasmati1, Pusa1121, Type3 and Vallabh basmati 21was taken as water stress-susceptible and non- basmati Nagina 22 and Susk Samrat rice germplasm which was tolerant for water stress, were collected from BEDF Meerut, India and Zonal research station Nagina, Bijnor, India.

The experiment was laid out in a complete randomised design (CRD) in control condition with three replications. In all three screening conditions, the susceptible check Pusa Basmati1, Pusa 1121, Type 3 Basmati, and Vallabh Basmati 21 and resistance check Nagina22 and Susk Samrat were transplanted in a line each block (replication). The experiment was conducted in two different conditions irrigated and water stress. The genotypes were planted in a plot size of 1m x 1m with a spacing of 25 x 20 cm. The recommended agronomic practices were followed up to the tillering stage. After tillering stage irrigation was withheld for 10 days in one set of experiment to impose artificial drought. Fourteen morphological characters such as Days to 50% flowering, Days to maturity, Plant height(cm), Panicle length(cm), Panicle bearing tillers per plants, spikelet's per panicle, Filled Grain per panicle, Unfilled Grain per panicle, Spikelet fertility, Test weight (g), Biological yield (g), Leaf Area(cm), Grain yield (g), Harvest index (%) were considered in the present investigation.

The collected data were analysed using the general linear models' procedure. The correlation coefficient between the component of each method and between different methods was determined (Gomez and Gomez, 1984) by the correlation procedure in SAS (version 6.12). Data collected from the field.

3. RESULTS AND DISCUSSION

Morphological characters such as days to 50% flowering, days to maturity, plant height(cm), panicle length(cm), panicle bearing tillers per plants, spikelet's per panicle, filled grain per panicle, unfilled grain per panicle, spikelet fertility, test weight (g), biological yield (g), leaf area(cm), grain yield (g), and harvest index (%) under the water stress as well as in control condition showed wide range of variation in different rice genotypes. Days to fifty percent flowering ranged between 66.33 days (Nagina 22) to 111.67 days (Type3) with an average mean of 93.55 in control, while under water stress condition, days to fifty percent flowering ranged from 80.67 days (Nagina 22) to 121.33 days (Pusa 1121) with an average mean of 109.38 days (Table 1). Days to maturity was also varied among the different rice varieties and ranged between 84.67 days (Nagina 22) to 153.67 days (PB1121) with an average mean of 126.22 in control, while under water stress condition date of maturity ranged from 91.33 days (Nagina 22) to 162.67 days (PB1121) with an average mean of 137.72 days (Table 1).

Several leaf related traits severely affected by water deficit, which include reduction in number of leaves per plant [19] Cerqueira et al. 2013; Singh et al. [20]; Sokoto and Muhammad [21] leaf area and leaf area index [22]. The reduction in plant height might be due to a rapid decline in cell division and leaf elongation under water stress. Thus, leaf characters comprising of a number of leaves, leaf area, leaf angle and plasticity in leaf rolling and unrolling can be used as selection criteria in selecting drought-resistant rice varieties.

The delay in flowering under drought is a consequence of a reduction in plant dry-matter production and a delay in panicle exertion [23]. Novero et al. [24] reported that the delay in flowering depends on the intensity, time, and period of drought. Wopereis et al. [25] observed longer flowering delay when drought occurred during early tillering than when it happened in the mid-tillering stage. Pantuwan et al. [26] made similar observations and concluded that under prolonged drought, flowering time is an important determinant of rice grain yield.

Plant height ranged between 94.33 cm (PB1) to 111.0 cm (Type3) with an average mean of 101.74cm in control, while under stress condition Plant height ranged from 83.93cm (VB21) to 100.47 cm (Type3) with an average mean of 91.08 cm (Table 1). Bhattacharjee et al. [27] and De Datta [28] found that significant reductions in tillers and panicles numbers, as well as plant height and grain yield were found when water stress was imposed at tillering stage. Water

Table 1. Analysis of variance (ANOVA) for five different characters of rice genotypes

S. No.	Genotype	DF		DM		PH		PL		PBT	
		Control	Treatment	Control	Treatment	Control	Treatment	Control	Treatment	Control	Treatment
1	PB1	109.00	117.00	124.00	141.00	94.33	86.13	23.10	19.10	9.67	6.00
2	PB1121	100.67	121.33	153.67	162.67	106.17	94.20	31.13	24.90	12.00	7.33
3	Type3	111.67	130.00	148.67	158.00	111.00	100.47	33.13	27.23	13.00	8.00
4	VB21	96.67	117.00	139.00	150.00	103.43	83.93	26.20	20.83	7.67	5.67
5	Nagina22	66.33	80.67	84.67	91.33	99.73	93.20	22.43	19.20	9.67	8.00
6	Susk Samrat	77.00	90.33	107.33	123.33	95.77	88.53	24.43	20.63	9.33	6.67
Mean		93.55	109.38	126.22	137.72	101.74	91.08	26.74	21.98	10.22	6.94
S. Em.±		0.724	1.255	0.590	1.022	0.889	1.541	0.390	0.676	0.272	0.471
C.D. @ 5%		1.496	2.591	1.218	2.109	1.836	3.181	0.806	1.396	0.561	0.972
C.V. (%)		9.33		5.84		12.06		20.95		41.42	

DF: Days to 50% flowering, DM: Days to maturity, PH: Plant height(cm), PL: Panicle length(cm), PBT: Panicle bearing tillers per plants

Table 2. Analysis of variance (ANOVA) for five different characters of rice genotypes

S. No.	Genotype	SPP		FGP		UGP		SFP		BY	
		Control	Treatment	Control	Treatment	Control	Treatment	Control	Treatment	Control	Treatment
1	PB1	159.00	152.67	148.67	81.00	10.33	71.67	93.50	53.03	46.40	39.10
2	PB1121	151.67	138.67	137.33	64.67	14.33	74.00	90.62	46.70	36.13	29.97
3	Type3	150.67	142.00	140.00	71.67	10.67	70.33	92.95	50.45	45.03	35.63
4	VB21	153.00	151.33	124.67	71.67	28.33	79.67	81.68	47.31	43.30	35.83
5	Nagina22	148.00	141.00	135.33	119.67	12.67	21.33	91.56	84.96	39.20	33.50
6	Susk Samrat	149.33	131.00	118.00	101.00	31.33	30.00	78.98	77.40	36.50	30.17
Mean		151.94	142.78	134.00	84.94	17.94	57.83	88.22	59.97	41.09	34.03
S. Em. ±		1.326	2.298	1.129	1.957	2.097	3.633	1.418	2.457	0.583	1.011
C.D. @ 5%		2.738	4.743	2.331	4.039	4.329	7.498	2.927	5.071	1.204	2.086
C.V. (%)		11.76		13.48		72.32		25.01		20.29	

SPP: spikelet's per panicle, FGP: Filled grain per panicle, UGP: Unfilled grain per panicle, SFP: Spikelet fertility, Biological yield (g)

Table 3. Analysis of variance (ANOVA) for four different characters of rice genotypes

S. No.	S. No.	S. No.		S. No.		S. No.		S. No.	
		Control	**Treatment**	**Control**	**Treatment**	**Control**	**Treatment**	**Control**	**Treatment**
1	PB1	17.47	12.87	17.20	14.43	37.14	36.94	53.80	25.83
2	PB1121	21.63	16.63	16.63	14.00	46.16	33.33	52.70	36.03
3	Type3	23.03	17.13	17.23	13.53	38.40	31.81	47.46	38.20
4	VB21	22.97	16.57	17.23	14.73	39.95	32.63	39.60	32.03
5	Nagina22	22.03	18.13	14.17	12.10	36.32	32.03	55.23	43.20
6	Susk Samrat	19.27	16.00	15.20	13.50	41.75	38.00	46.55	42.33
Mean		21.07	16.22	16.28	13.72	39.95	34.13	49.22	35.72
S. Em.±		0.232	0.402	0.172	0.298	0.588	1.020	0.981	1.699
C.D. @ 5%		0.479	0.831	0.35	0.616	1.215	2.105	2.025	3.508
C.V. (%)		16.29		15.01		19.08		29.99	

TW: Test weight (g), GYP: Grain yield/plant (g), HI: Harvest index (%) and LA: Leaf Area(cm) stress reduces the metabolic activities due to deficiency of water. Such condition reduces turgor pressure and affects the cell division and cell elongation activities of the plant and ultimately plant height reduces. Similar results were reported under water deficit condition which showed reduced yield in rice genotypes [29,30].

Panicle length ranged from 22.43 (Nagina 22) to 33.13 cm (Type3) with an average mean of 26.74 cm in control condition, while under water stress condition panicle length ranged from 19.10 cm (PB1) to 27.23 cm (Type3) with an average mean of 21.98 cm (Table 1). Panicle bearing tillers ranged from 7.67 (VB21) to 13 (Type3) with an average mean of 10.22 in control condition, while under water stress condition panicle bearing tillers ranged from 5.67 (VB21) to 8.0 (Type3 and Nagina22) with an average mean of 6.94 (Table1). Water stress decreased panicle bearing tillers in the present experiment, this reduction is mainly due to drought stress is responsible for causing spikelets sterility probably due to pollen sterility and also hampered pollen fertilisation [31,14].

Spikelet per panicles ranged from 7.67 (VB21) to 13 (Type3) with an average mean of 10.22 in control condition, while under water stress condition spikelet per panicles ranged from 5.67 (VB21) to 8.0 (Nagina 22 and Type3) with an average mean of 6.94. The data of spikelet per panicles was given in the Table 2. Filled grain per panicle ranged from 118.0 (Susk S amrat) to 148.67 (Pusa Basmati1) with an average mean of 134.0 in control condition, while under water stress condition filled grain per panicle ranged from 64.67 (Pusa1121) to 119.67 (Nagina 22) with an average mean of 84.94 (Table 2). Unfilled grain per panicle ranged from 10.67 (Type3) to 31.33 (Susk Samrat) with an average mean of 17.94 in the control condition, while under water stress condition unfilled grain per panicle ranged from 21.33 (Nagina 22) to 79.67 (VB 21) with an average mean of 57.83 days (Table 2). Spikelet fertility percentage ranged from 78.98 (Susk Samrat) to 93.50 (PB1) with an average mean of 88.22 in control condition, while under water stress condition spikelet fertility percentage ranged from 46.70 (PB 1121) to 77.40 (Susk Samrat) with an average mean of 59.97 (Table 2). Similar results were reported by Manickavelu et al. [32] and Yadav et al. (2011).

Biological yield ranged 36.13 (PB1121) to 46.40 (PB1) with an average mean of 41.09 in control condition, while under water stress condition biological yield ranged from 29.97 (PB1121) to 39.10 (PB1) with an average mean of 34.03 (Table 2). Test weight ranged from 17.47 (PB1) to 23.03 (Type3) with an average mean of 21.07 in control condition, while under water stress condition test weight ranged from 16.00 (Susk Samrat) to 18.13 (Nagina 22) with an average mean of 16.22. Test weight was given in the Table 3. Grain yield per plant ranged from 14.17 (Nagina 22) to 17.23 (Type3) with an average mean of 16.28 in control condition, while under water stress condition grain yield per plant ranged from 12.10 (Nagina 22) to 14.73 (VB21) with an average mean of 13.72 days (Table 3). Bhattacharjee et al. [27] and De Datta [28] Found the lowest amount of this trait with 7.66 % was recorded from that significant reduction in tillers and panicles numbers I irrigation level. The similar result was obtained as well as plant height and grain yield was found when Pirmoradian et al. (2002). Although the irrigation effect water stress was imposed at the tillering stage. Harvest index ranged from 36.32 (Nagina 22) to 46.16 (PB1121) with an average mean of 39.95 in control condition, while under water stress condition harvest index ranged from 31.81 (Type3) to 38.00 (Susk Samrat) with an average mean of 34.13 (Table 3). Biomass per plant declined significantly under drought stress in all varieties might be due to reduced photosynthetic rate and altered morphological, physiological and biochemical processes [33]. Decreased grain yield under drought stress in rice varieties is mainly due to a reduction in grain filling period, leaf gas exchange assets, limiting the size of the source and sink tissues, weakening in phloem loading and assimilate translocation [34]. The other possible reasons of decreased seed yield in rice might be due to a reduction in limiting photosynthesis due to decline in RuBISCO activity, an enzyme involved in carbon fixation in C3 crops [35,36].

4. CONCLUSION

Water stress highly reduced yield and yield components of rice genotypes. Nagina 22 and Susk Samrat showed less reduction under water stress over PusaBasmati1, Pusa1121, Type3 and Vallabh basmati 21 was highly susceptible to water stress. It is concluded from the present study that Nagina 22 and Susk Samrat both perform well in drought stress among the six varieties. The varietal differences in grain yield as evident in the present experiment are dependent on genotypic ability to resist drought. Nagina 22 and Shushk Samrat were promising genotypes might be due to its better morphological, physiological and biochemical attributes to have a higher yield than others scented rice genotypes Pusa Basmati 1, Pusa 1121, Type 3 Basmati and Vallabh Basmati 21.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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