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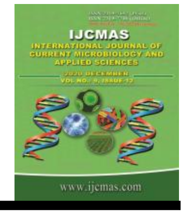

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Impact of Flowering Stage Drought Stress on Yield and Yield Related Attributes on Rice (*Oryza sativa* L) Genotypes

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Rice is a staple food crop in India as well as whole world. Plant growth and productivity of rice is adversely affected by various biotic and abiotic stress factors. Water deficit is one of the major abiotic stresses, which adversely affects crop growth and yield. Water stress is a limiting factor in agriculture production by preventing a crop from reaching the genetically determined theoretical maximum yield. In present study, a pot experiment was conducted with 20 rice (1 Non Basmati and 19 Basmati) genotypes during kharif season 2018-19 and 2019-20 at field laboratory, Department of Agricultural Biotechnology, S.V.P.U.A.&T., Modipuram, Meerut, U.P., India in Completely Randomized Design (CRD) with three replications. Drought treatment was given for 10 days at flowering stage. The screening of rice genotypes was done on the basis of plant height, panicle length, seed per panicle, yield per plant, test weight and flag leaf area. The rice genotypes Nagina22 followed by Pusa Basmati 1121 showed less percent reduction in yield and yield components comparatively all other varieties. The maximum reduction in yield and other parameters under drought stress condition was observed in Basmati 386 variety. Therefore, on the basis of yield and yield component Nagina 22 showed maximum tolerance in compare to other genotypes.

Introduction

Rice (*Oryza sativa* L.) is an important food crop in India and several parts of the globe. It is the second most cultivated cereal in the world and most widely consumed staple food for about 60% of the world's population (Pirdashti *et al.*, 2009) and occupied 197.59 million hectare area in the world with 996.07 million tones production (FAOSTAT, 2018-19). It shares maximum in grain production and occupies largest area under cultivation in India. India ranks second in rice production across the world and produced over 172.58 million tons during the crop year 2018-19 and occupies 44.5 million hectare area of harvesting (FAOSTAT, 2018-19). India is the largest rice growing country, while china is the largest producer of rice. In India, it accounts for more than 40% of food grain production, providing direct employment to 70% people in rural areas. Being the staple food for more than 65% of the people, our national food security hangs on the growth and stability of its production. The key goals of varietal development are yield, quality characteristics and biotic/abiotic stress tolerance (Nachimuthu *et al.,* 2015).

With the increasing population, the demand of rice will going to increase day by day. So, to meet the global rice demand, its production needs to be increase (Khush, 2005). Plants respond to various abiotic factors like drought, high salt, heavy metals, changes in temperature and light in the environment. Abiotic stresses affect the plant at morphological, physiological, biochemical and molecular level. Several abiotic stresses like Drought, high temperatures, salinity and oxidative stress are often interrelated, and may cause similar changes in plants (Szekeres *et al.,* 2003). The phenomenon of insufficient water supply to plants is known as Drought. It limits the crop production and is becoming a gradually more severe problem in many regions of the globe (Passioura, 1996, 2007). As rice is an aquatic plant hence it is very sensitive to drought stress for almost all growth phases which leads to drastic reduction in grain yield (O'Toole, 1982, Hsiao *et al.,* 1984, Venuprasad *et al.,* 2008, Bouman *et al.,* 2005).

Low moisture condition at flowering is most common and serious concern in upland rice ecosystem. The yield of upland rice is highly inconsistant because of drought especially at flowering stage. Drought at flowering stage is very destructive and sometimes it reduce the 70-80% yield. A lot of work had been already done on drought resistance in rice at vegetative stage (Yang *et al.,* 2014) but research work on impact of drought stress in rice at flowering stage is limited. Therefore, there is requirement to identify excellent donors of upland rice tolerant to drought at flowering stage (Chaturvedi and Ingram, 1988; Mishra, 2005). Like other abiotic stresses, Initially drought affects water relations on the cellular level as well as entire plant (Beck *et al.,* 2007). It impacts on several physiological, biochemical and molecular processes, like ion uptake, translocation, respiration, photosynthesis, carbohydrates, nutrient metabolism, harmonic balance and level of expression of several genes (Farooq *et al.*, 2009b). This results to the induced production of stress proteins and accumulation of compatible solutes by these diverse environmental stresses cause of cellular responses and cell signaling pathways of a plant. During changing environment scenario plants go through certain biochemical adaptations to sustain by evolution of new metabolic pathways which resulted to changes in biochemistry of the cell (Fujita *et al.*, 2006).

Several studies have shown that drought tolerance is a very complex feature, as it is a combined feature of a number of morphological, physiological and biochemical characteristics (Mishra, 2005, Pandey and Shukla, 2015).

To characterize the genotypic performance of rice under drought stress, plant height, panicle number, root volume, fertile spikelets, plant biomass, leaf area development, root/shoot ratio, grain yield, chlorophyll, starch, soluble sugar and proline contents were used in various drought stress experiments (Mishra, 2005; Maisura *et al.*, 2014). Hence, keeping above considerations in mind the present investigation was carried out to determine the impact of drought stress at flowering stage in rice varieties on morphological components.

Materials and Methods

Experiment location, plant materials, and observation of phenotypic trait

The present experiment was conducted during *kharif*-2018 and *kharif*-2019 consists of 20 (19 Basmati and 1 Non-Basmati) rice varieties, which were collected from BEDF Meerut, India and Zonal research station Nagina, Bijnor, India (Table 1). After 21 days of seedling emergence, the seedling were transplanted in pots (39× 33 cm^2 pot size containing 25 Kg of soil and 5 Kg of FYM) at Experimental plot, Department of Agricultural 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 in Completely Randomized Design (CRD) with three replications. The soil of experimental site was sandy loam with initial pH.-7.2 and EC_e of 1.39 dSm^{-1}. Recommended dose of fertilizer at the rate N: P: K 100:40:40 kg/ha on the pot area basis. After 30 days of planting, five plants were maintained in each pot by thinning process. Water deficit was created for 10 days at 50% flowering by withholding irrigation in pots. However, control pots were frequently irrigated to optimum field capacity level.

Weather conditions

The meteorological observations were recorded by an automatic weather station of Indian Institute of Farming System and Research (IIFSR), Modipuram, Meerut, India. Minimum and maximum temperature, percentage of relative humidity in morning and evening, average rainfall and bright sunshine were observed for the month from June- Nov 2018 and from June- Nov 2019 (Table 2 and Graph 1).

Observation of phenotypic trait

Morphological traits were recorded after stress treatment in drought stressed and control plants. The traits viz., plant height, number of tillers, panicle length, seed per panicle, yield per plant, 1000 seed weight and leaf area were recorded for three randomly selected plants for each replication for phenotypic trait analysis. Plant height was measured in cm from the base of the shoot to the tip of the main stem at ripening stage and averaged over three plants (O' Toole and Cruz, 1983). Whereas at the ripening point, the panicle length was measured in cm from the panicle neck to the tip and averaged over three plants and a healthy panicle was taken for counting the number of grains and counted at the time of harvesting in a per plant then averaged over three plants. For the grains of each randomly chosen plant, hand threshing was carried out then sun dried and weighed in grams. By weighing 1000 filled grains, the test weight was recorded in grams and averaged over three samples for each variety. Leaf areas were calculated by using index leaf method given by Sticker *et al.*, (1961). As, leaf area = L*W*F, where, L = Maximum length (cm), W= maximum width (cm), F= Factor (0.70).

Statistical analysis

Data presented are mean of three replicates. The data were subjected to ANOVA by OPSTAT software. The differences at ($p \leq 0.05$) were considered as significant.

Results and Discussion

Weather observations

The mean of meteorological variables data are presented (Table 2 and Graph 1) during the experimental period (June–Nov. 2018 and 2019). During the whole experimental period, weekly min and max temperature ranged from 11.78°C to 27.53°C with a general mean of 19.65 °C and 29.10 to 41.7 with average mean of 35.4°C. Total rainfall received was ranged from 0.0 mm to 323.10mm, relative humidity varies from 82.75% to 95.88% in morning whereas in evening time it varied from 45.75% to

72.10% and 121.99 h of bright sunshine (BSS) during entire experimental period.

Effect of drought stress at flowering stage on morphological traits

Plant height

Drought stress significantly affected mean plant height in all the twenty genotypes for year 2018-19 and 2019-20. In year 2018-19, the results showed that the plant height under irrigated condition varied from a lower value of 92.0 cm (Pusa Basmati 6) to higher value of 128.90 cm (Tarori basmati) while under simulated drought condition, it was reduced significantly and varied from a lower value of 87.60 cm (Punjab Basmati 4) to 118.33 cm (Taraori Basmati) (Table 3). The minimum reduction was observed in genotype Nagina 22 (2.71%) followed by genotype Pusa Basmati 1121 (3.33%) and the maximum difference was observed in genotype Basmati 386 (8.90%) (Graph 2).

In year 2019-20, the plant height under irrigated condition varied from a lower value of 92.5 cm (Pusa Basmati 6) to higher value of 129.5 cm (Tarori Basmati) while under simulated drought condition, it was reduced significantly and varied from a lower value of 92.10 cm (Vallabh Basmati 22) to 118.73 cm (Tarori Basmati) (Table 4). The minimum difference was observed in genotype Nagina 22 (2.31%) followed by genotype Pusa Basmati-1121 (3.47%) and maximum difference was observed in genotype Basmati 364 (9.31%) (Graph 3).

Panicle length

In year 2018-19, the results showed that the panicle length under irrigated condition varied from a lower value of 20.5 cm (N 22) to higher value of 33.13 (Pant Basmati 2). Under simulated drought condition, it was reduced significantly and varied from a lower value of 19.03 cm (Nagina 22) to 30.63 cm (Basmati 564) (Table 3). The minimum difference was observed in genotype Nagina 22 (7.16%) followed by genotype Pusa Basmati 1121 (7.23%) and the maximum difference was observed in genotype Basmati 386 (15.69%) (Graph 2).

In year 2019-20, the results showed that the panicle length under irrigated condition varied from a lower value of 20.3 cm (Nagina 22) to higher value of 34.73 cm (Basmati 564). Under simulated drought condition, the panicle length was reduced significantly and varied from a lower value of 18.86 cm (Nagina 22) to 30.1 (Basmati 564) (Table 4). The minimum difference was observed in genotype Nagina 22 (7.06%), followed by genotype Pusa Basmati 1121 (8.54%) and the maximum difference was observed in genotype Basmati 386 (13.51%).

Seed per panicle

In year 2018-19, the results showed that the seed per panicle under irrigated condition varied from a lower value of 97 (Pusa Basmati 1509) to higher value of 216.33 (Pant Basmati 2). Under simulated drought condition, the panicle length was reduced significantly and varied from a lower value of 57.70 (Basmati 386) to 129.33 (Pant Basmati 2) (Table 3). The minimum difference was observed in genotype Nagina 22 (14.74%) followed by genotype Pusa Basmati 1121 (22.83%) and the maximum difference was observed in genotype Basmati 386 (46.56%) (Graph 2).

In year 2019-20, the results showed that the seed per panicle under irrigated condition varied from a lower value of 95.33 (Pusa Basmati 1509) to higher value of 215.33 (Pant Basmati 2). Under simulated drought condition, the seed per panicle was reduced significantly and varied from a lower value of 57 (Basmati 386) to 128.66 (Pant Basmati 2)

(Table 4). The minimum difference was observed in N 22 (15.37%) followed by Pusa Basmati 1121 (22.26%) and the maximum difference was observed in genotype Basmati 386 (45.71%).

Grain yield per plant under irrigated and drought condition

Yield and yield characteristics are the ultimate manifestation of the ability of a plant to sustain growth and produce yield under water, regardless of the resistance processes involved. In year 2018-19, the values of grain yield ranges between 7.78 gm (Basmati 386) to 21.63 gm (Pant Basmati 1). Under drought condition, the grain yield range was decreased to 2.97 gm (Basmati-386) (lowest) and 14.13 gm (Pusa Basmati 1121) (highest) (Table 3). The minimum difference in yield was observed Nagina 22 (12.32%) followed Pusa Basmati 1121 (14.91%) and the maximum difference was observed in genotype Basmati 386 (61.83%) (Graph 2).

While in the year 2019-20, controlled plants of 20 genotypes showed a grain yield from 7.82 gm (Basmati 386) to 21.66 gm (Pant Basmati 1). However, grain yield under stressed condition varied from a lower value of 3.10 gm (Basmati 386) to a higher value of 13.8 gm in (Pusa Basmati 1121) (Table 4). The average difference in grain yield under irrigated and non-irrigated condition was observed minimum in genotype N-22 (12.03%), followed by Pusa Basmati-1121 (15.01%) and the maximum difference was observed in Basmati 386 (60.32%).

Test weight (1000 grain weight)

In year 2018-19, the results showed that the test weight under irrigated condition varied from a lower value of 19.93 gm in genotype (Vallabh Basmati 23) to higher value of 28.5 gm (Pusa Basmati 1609). Under simulated drought condition the test weight was reduced significantly and varied from a lower value of 14.68 gm (Vallabh Basmati 23) to 22.69 gm (Pusa Basmati 1121) (Table 3). The minimum difference was observed in genotype Nagina 22 (8.46%) followed by Pusa Basmati 1121 (15.21%) and the minimum difference was observed in genotype Basmati 386 (30.6%) (Graph 2).

In year 2019-20, the results showed that test weight under irrigated condition varied from a lower value of 20.21 gm (Vallabh Basmai 23) to higher value of 28.70 gm (Pusa Basmati 1609). Under simulated drought condition the test weight was reduced significantly and varied from a lower value of 14.80 gm (Vallabh Basmati 23) to 22.65 gm (Pusa Basmati 1121) (Table 4). The minimum difference was observed in genotype Nagina 22 (9.35%) followed by moderate in genotype Pusa Basmati 1121 (15.33%) and maximum difference was observed in genotype Basmati 386 (31.66%) (Graph 3).

Effect of drought on leaf area

Leaf area is directly related to increased photosynthesis and chlorophyll content. Therefore, this is a crucial factor for understanding the proper growth and development of plant. Drought stress significantly affected mean leaf area (cm^2) in all twenty rice genotypes.

In year 2018-19, the results showed that the leaf area under irrigated condition varied from a lower value of 25.2 cm^2 (Punjab Basmati 4) to higher value of 54.23 cm^2 (Pusa Basmati 1609). Under simulated drought condition, the leaf area was reduced significantly and varied from a lower value of 17.03 cm^2 (Basmati 386) to 40.8 cm^2 (Punjab Basmati 2) (Table 3). The minimum difference was observed in genotype N-22 (13.26%) followed by genotype Pusa Basmati

1121 (17.83%) and the maximum difference was observed in genotype Basmati 386 (35.24%) (Graph 2).

In year 2019-20, the results showed that the leaf area under irrigated condition varied from a lower value of 25.2 cm^2 (Tarori Basmati) to higher value of 54.5 cm^2 (Pusa Basmati 1609). Under simulated drought condition, the leaf area was reduced significantly and varied from a lower value of 16.63 cm^2 (Tarori Basmati) to 40.73 cm^2 (Pusa Basmati 1609) (Table 4). The minimum difference was observed in N-22 (14.79%) followed by Pusa Basmati 1121 (17.96%) and the maximum difference was observed in genotype Basmati 386 (34.68%) (Graph 3).

Table.1 Description of different rice genotypes used in present study

Genotype name	Origen	Pedigree	Releasing year
Nagina 22	Nagina, U P, India	-	1978
Panjab Basmati 04	PAU, India	-	2017
Panjab Basmati 02	PAU, India	-	2012
Pusa basmati 1609	IARI, New Delhi, India	Elite Basmati restorer line PRR78/C101A51	2015
Vallabh Basmati 23	SVBPUA &T, India	-	2015
Pusa Basmati 1 (IET 10364)	IARI, New Delhi, India	Pusa150/Karnal Local	1989
Pusa Basmati 1509 (IET 21960)	IARI, New Delhi, India	Pusa Basmati 1121/ Pusa 1301	2013
Tarori Basmati (HBC-19 or Karnal local)	HAU, Kaul, India	Selection from Basmati 370	1996
Basmati 564	SKUAST- Jammu, India	-	2015
Pusa Basmati 6	IARI, New Delhi, India	Pusa Basmati 1/1121	2010
Vallabh Basmati 21 (IET 19493)	SVBPUA &T, India	-	2013
Basmati CSR 30	CSSRI, Karnal, India	Buraratha 4-10/ Pakistani Basmati	2012
Vallabh Basmati 24	SVBPUA &T, India	-	2015
Type 3 or Dehradun Basmati	Nagina, U P, India	Selection from Basmati Deharadun	1978
Basmati 386	PAU, Punjab, India	Selection from Pakistani Basmati	1994
Pant Basmati 2 (IET 21953)	GBPUA&T,U.K,India	-	2016
Pusa Basmati 1121	IARI, New Delhi, India	Sister line of Pusa Basmati-1	2008
Pant Basmati 1 (IET 21665)	GBPUA&T,U.K,India	Pusa Basmati 1/ IET 12603	2016
Pusa sugandha 5	IARI, New Delhi, India	Pusa 3 A 9 Haryana Basmati	2005
Vallabh Basmati 22	SVBPUA &T, India	-	2009

Table.2 Standard meteorological variables during the months of June–Nov. 2018 and 2019

Week	Temp. max. (˚C)	Temp. min. (˚C)	RH morning(%)	RH evening(%)	WS (km/hr)	BSS (hrs)	Rainfall (mm)
25	**41.70**	26.90	82.75	45.75	1.95	7.71	0.00
26	39.25	**27.53**	83.31	56.80	3.70	6.40	6.75
27	38.90	25.88	89.15	51.95	2.44	6.67	41.63
28	34.92	26.73	90.28	72.10	2.41	2.90	73.18
29	36.07	27.19	88.59	57.25	1.83	5.08	16.30
30	33.40	26.05	93.28	70.73	1.60	3.56	323.10
31	36.52	27.20	91.43	55.61	1.69	4.06	16.48
32	36.00	26.76	94.00	55.37	1.79	4.20	45.30
33	37.04	26.78	92.86	59.50	1.64	5.53	46.05
34	35.73	24.80	92.25	57.28	1.50	5.53	17.55
35	35.25	24.00	89.55	54.20	1.75	3.23	166.15
36	36.80	22.63	92.50	57.70	1.53	3.10	63.40
37	34.80	22.98	88.73	58.13	2.30	5.73	7.28
38	34.70	22.23	89.28	57.45	7.25	4.90	10.33
39	32.28	22.90	94.20	74.85	11.18	5.85	31.35
40	34.73	20.68	95.88	59.35	7.00	8.45	5.73
41	33.55	18.75	88.63	55.50	11.43	7.10	2.55
42	33.80	15.88	91.18	53.50	3.63	7.00	1.05
43	32.05	14.03	91.50	49.55	4.95	7.13	0.00
44	31.23	12.95	91.75	47.48	6.80	4.95	0.00
45	30.13	11.83	93.68	49.48	5.55	6.78	0.00
46	**29.10**	**11.78**	94.78	53.50	8.00	6.18	0.00

Note- Temp.: temperature, RH: relative humidity, BSS: bright sun shine, WS: wind speed

Graph.1 Standard meteorological variables during the months of June–Nov. 2018 and 2019

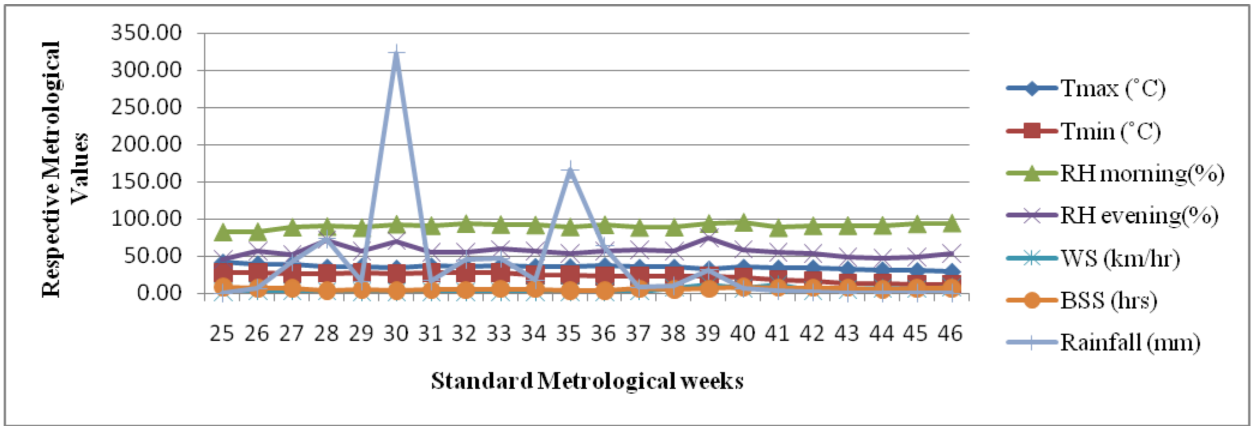


Table.3 Morphological performance of rice genotypes under drought stress (2018-19)

Name of variety	Plant height		Panicle length		Seed per panicle		Yield per plant		Test weight		Leaf area	
	C	DS	C	DS	C	DS	C	DS	C	DS	C	DS
N 22	98.46±0.72	95.8±0.37	20.5±0.28	19.03±0.63	147±0.57	125.33±0.66	14.12±0.29	12.38±0.27	22.01±0.38	20.14±0.52	29.66±0.57	25.73±0.57
Pnb Bas.4	92.58±0.71	87.6±0.37	23±0.28	20.73±0.28	119±1.0	85±0.57	16.44±0.34	9.083±0.33	26.23±0.13	20.02±0.11	25.2±0.52	19.46±0.57
Pnb Bas. 2	112.3±0.72	104.23±0.40	29.26±0.14	25.73±0.69	109.33±0.88	67.33±1.45	11.12±0.23	5.57±0.23	24.03±0.15	17.43±0.10	31.7±0.62	23.8±0.86
PB. 1609	104.66±0.88	97.96±0.38	29.9±0.20	25.8±0.55	214.33±0.88	126.33±0.33	17.36±0.36	11.83±0.26	28.5±0.45	21.30±0.12	54.23±0.57	40.8±0.60
VB. 23	106.73±0.88	100.03±0.41	26.33±0.16	23.9±0.25	115±0.577	83.66±0.33	12.4±0.26	8.39±0.23	19.93±0.41	14.68±0.14	31.23±0.50	24.1±0.63
PB. 1	115.5±0.41	106.83±0.46	30±0.11	26.63±0.40	179±1.15	108±0.57	16.89±0.35	10.76±0.22	22.79±0.42	18.09±0.10	30.4±0.60	21.96±0.54
PB. 1509	97.83±0.72	92.53±0.35	26.53±0.14	23.46±0.52	97±0.57	64±0.57	16.12±0.33	10.50±0.22	26.27±0.14	18.53±0.10	32.9±0.55	22.63±0.66
Tarori	128.9±0.29	118.33±0.50	28.66±0.14	25.06±0.54	118±1.15	74.33±0.88	14.61±0.30	8.66±0.23	24.66±0.43	18.35±0.11	25.56±0.98	17.13±0.98
Bas. 564	127.8±0.30	116.83±0.50	34.96±0.26	30.63±0.76	204.66±0.88	123.66±0.33	12.45±0.26	6.74±0.32	20.91±0.43	15.72±0.21	28.5±0.60	21.53±0.54
PB. 6	92±0.41	87.63±0.35	28.13±0.63	24.5±0.61	154±0.57	101.33±0.88	18.4±0.38	9.23±0.17	22.08±0.45	15.43±0.22	36.3±0.63	28.46±0.54
VB. 21	107±0.41	99.83±0.40	30.46±0.20	26.13±0.78	155±1.15	87.33±0.33	17.31±0.36	13.84±0.26	24.94±0.51	17.49±0.10	51.1±0.11	37.30±0.60
CSR 30	118.5±0.79	109.1±0.41	26.4±0.15	23.66±0.63	135±0.57	93.33±0.33	10.24±0.21	6.18±0.21	21.46±0.41	16.12±0.14	32.5±0.41	23.53±0.60
VB. 24	128.26±0.35	116.96±0.49	31.33±0.08	27.16±0.66	178.66±1.20	108±0.57	17.72±0.36	10.72±0.31	20.33±0.42	16.39±0.24	34.46±0.80	23.33±0.54
Type 3	126.9±0.30	117±0.47	27.46±0.14	24.1±0.66	168.66±0.88	108±0.57	17.05±0.35	8.26±0.38	21.7±0.45	17.04±0.18	40.93±0.98	28.2±0.05
Bas. 386	115.4±0.37	105.13±0.41	29.73±0.20	25.06±0.92	108±0.57	57.71±0.29	7.78±0.16	2.97±0.33	23.66±0.42	16.42±0.18	26.3±0.95	17.03±0.57
Pant Bas.-2	100.66±0.29	92.1±0.37	33.13±0.14	28.63±0.70	216.33±0.88	129.33±0.33	11.53±0.24	5.54±0.38	27.17±0.44	18.97±0.28	37.8±0.60	29.8±0.55
PB-1121	117.06±0.20	113.16±0.49	28.6±0.11	26.53±0.24	103.66±0.88	80±0.57	16.61±0.34	14.13±0.24	26.76±0.14	22.69±0.24	39.26±0.34	32.26±0.63
Pant Bas.-1	118.66±0.31	108.93±0.41	28.66±0.24	24.7±0.43	166.66±0.88	97±0.577	21.63±0.44	10.77±0.26	24.23±0.15	18.8±0.13	37.96±0.49	27.5±0.28
PS 5	107.5±0.41	100.4±0.41	32.96±0.63	28.46±0.33	128±0.57	75.33±0.33	14.93±0.31	5.96±0.25	24.71±0.14	19.88±0.29	42.2±0.5	29.3±0.47
VB. 22	98.16±0.44	92.46±0.32	28.63±0.24	25.2±0.75	153±0.57	98.66±0.66	14.3±0.29	8.63±0.27	21.3±0.18	16.08±0.28	33.63±0.61	23.2±0.26
C.D.	**1.56**	**1.21**	**0.78**	**1.72**	**2.44**	**2**	**0.91**	**0.8**	**1.05**	**0.63**	**1.82**	**1.69**
SE(m)	**0.54**	**0.42**	**0.27**	**0.6**	**0.85**	**0.69**	**0.31**	**0.28**	**0.37**	**0.22**	**0.63**	**0.59**
SE(d)	**0.77**	**0.60**	**0.38**	**0.85**	**1.2**	**0.98**	**0.45**	**0.39**	**0.52**	**0.31**	**0.9**	**0.83**
C.V.	**0.85**	**0.71**	**1.64**	**4.12**	**0.99**	**1.27**	**3.69**	**5.37**	**2.67**	**2.1**	**3.14**	**3.95**

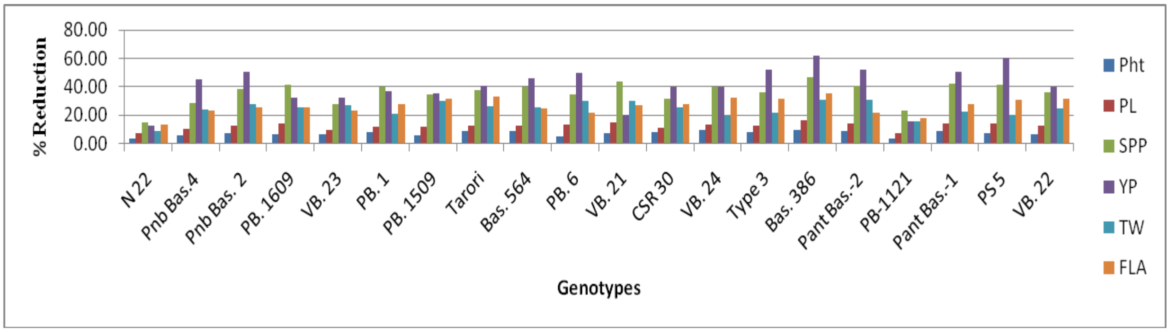
*C-Control, DS-Drought Stress

Table.4 Morphological performance of rice genotypes under drought stress (2019-20)

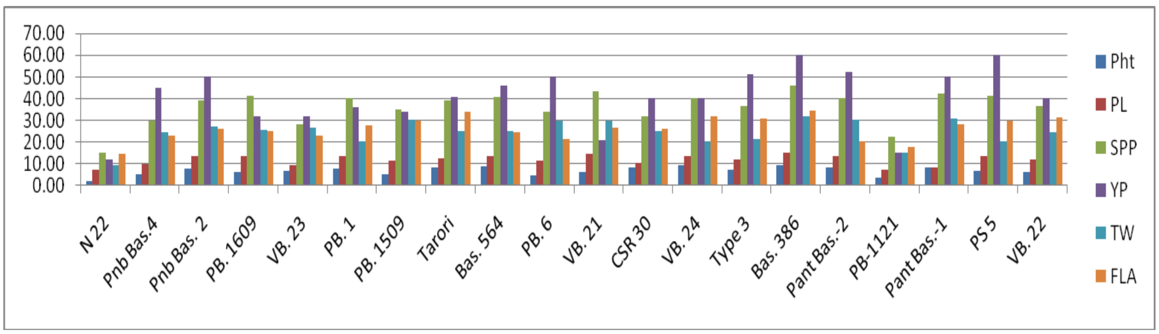
Name of variety	Plant height		Panicle length		Seed per panicle		Yield per plant		Test weight		Leaf area	
	C	DS	C	DS	C	DS	C	DS	C	DS	C	DS
Nagina-22	97.76±0.60	95.5±0.47	20.3±0.11	18.86±0.17	145.33±0.88	123±1.15	14.26±0.49	12.55±0.40	22.14±0.13	20.07±0.39	30.2±0.60	25.73±0.57
Panjab Bas.-04	92.73±0.49	87.83±0.43	23.3±0.15	21.03±0.14	120±0.57	84±0.57	15.85±0.15	8.72±0.22	26.43±0.14	20±0.34	25.3±1.12	19.53±0.34
Panjab Bas.-02	112.5±0.7	103.86±0.60	29.16±0.14	25.26±0.12	109.66±0.88	66.66±0.33	11.32±0.35	5.66±0.41	23.97±0.14	17.42±0.30	31.83±0.57	23.53±0.57
Pusa bas.-1609	104.33±0.66	97.73±0.61	30.16±0.23	26.06±0.14	214.33±0.88	125.66±0.33	16.83±0.32	11.44±0.28	28.70±0.15	21.38±0.30	54.5±0.60	40.73±0.37
VB-23	106.23±0.63	99.06±0.58	26.5±0.17	24.03±0.14	115.66±0.88	83±0.57	12.6±0.33	8.56±0.24	20.21±0.11	14.80±0.62	31.3±1.12	24.13±0.57
Pusa Bas.-1	115.73±0.69	106.86±0.55	30.16±0.20	26.1±0.17	181±0.57	108±0.57	16.66±0.53	10.66±0.28	22.96±0.12	18.29±0.51	30.5±0.60	22.03±0.57
Pusa Bas.-1509	97.5±0.47	92.3±0.64	26.6±0.11	23.56±0.12	95.33±0.88	62±0.57	16.28±0.57	10.74±0.23	25.89±0.17	17.99±0.11	33.1±1.18	23.23±1.09
Tarori Bas.	129.5±0.78	118.73±0.61	28.73±0.14	25.16±0.14	119.66±0.88	73±0.57	14.54±0.30	8.58±0.22	24.333±0.13	18.17±0.10	25.2±0.60	16.63±0.54
Bas.-564	127.5±0.72	116.33±0.63	34.73±0.26	30.1±0.17	207±0.57	122.33±0.33	12.42±0.37	6.71±0.35	21.21±0.11	15.88±0.38	25.5±0.26	19.26±0.53
Pusa Bas.-6	92.5±0.58	88.33±0.44	28.33±0.20	25.03±0.14	155±0.57	102.66±0.33	18.38±0.47	9.19±0.44	22.21±0.11	15.6±0.56	36.3±0.32	28.53±0.40
VB.-21	107.33±0.63	100.33±0.64	30.5±0.23	26±0.17	157±0.57	89.33±0.33	17.22±0.67	13.6±0.25	25.15±0.16	17.69±0.13	51±0.43	37.56±0.49
Bas. CSR 30	118.73±0.66	108.83±0.54	26.3±0.17	23.53±0.14	136.66±0.33	93.33±0.33	10.62±0.44	6.35±0.24	21.25±0.11	15.91±0.10	32.73±0.41	24.2±0.60
VB-24	128.16±0.77	116.2±0.58	31.5±0.23	27.16±0.17	182±0.57	108.66±0.66	17.65±0.63	10.59±0.30	20.66±0.12	16.46±0.50	34.53±0.52	23.53±0.61
Type-3	126.73±0.72	117.43±0.61	27.5±0.17	24.13±0.17	172.33±0.33	109±0.57	17.13±0.51	8.39±0.27	22.11±0.12	17.32±0.24	41±0.52	28.33±0.46
Bas.-386	115.63±0.76	104.86±0.51	29.5±0.17	24.96±0.21	105±0.57	57±0.57	7.82±0.55	3.10±0.42	23.75±0.13	16.23±0.30	26.33±0.69	17.20±0.60
Pant Bas.-2	100.5±0.60	92.2±0.58	31.33±0.20	27.1±0.17	215.33±0.33	128.66±0.66	11.61±0.61	5.57±0.41	26.66±0.15	18.57±0.31	37.5±0.60	29.93±0.46
PB-1121	117.3±0.64	113.23±0.56	28.76±0.17	26.6±0.11	107.33±0.33	83.33±0.33	16.24±0.28	13.8±0.20	26.75±0.15	22.65±0.27	39.53±0.63	32.43±0.54
Pant Bas.-1	118.5±0.75	108.63±0.54	28.5±0.17	26.06±0.17	167.66±0.33	97±0.57	21.66±0.65	10.81±0.33	24.33±0.14	16.85±0.35	38.3±0.60	27.53±0.80
PS-5	107.63±0.56	100.36±0.53	32.76±0.23	28.26±0.20	123±0.57	72±0.57	15.21±0.59	6.08±0.27	24.75±0.14	19.72±0.43	41.83±0.60	29.36±0.52
VB.-22	98.33±0.52	92.1±0.55	28.5±0.17	25.13±0.26	159±0.57	101±0.57	14.53±0.65	8.72±0.47	21.66±0.12	16.35±0.26	33.83±0.43	23.23±0.54
C.D.	**1.88**	**1.63**	**0.54**	**0.48**	**1.83**	**1.61**	**1.43**	**0.93**	**0.39**	**1.03**	**1.92**	**1.68**
SE(m)	**0.65**	**0.56**	**0.18**	**0.16**	**0.64**	**0.56**	**0.49**	**0.32**	**0.13**	**0.36**	**0.67**	**0.58**
SE(d)	**0.92**	**0.8**	**0.26**	**0.23**	**0.9**	**0.79**	**0.7**	**0.46**	**0.19**	**0.5**	**0.94**	**0.82**
C.V.	**1.02**	**0.95**	**1.13**	**1.16**	**0.74**	**1.03**	**5.78**	**6.28**	**1.01**	**3.49**	**3.32**	**3.93**

*C-Control, DS-Drought Stress

Graph.2 Percent reduction of traits under drought stress (2018-19)



Graph.3 Percent reduction of traits under drought stress (2019-20)



Water stress significantly affected the plant height at booting, flowering and grain filling stage in compare to control plants. In present study, the minimum difference was observed in genotype Nagina 22 (2.31%) and maximum difference was observed in genotype Basmati 364 (9.31%) for both years. This outcome agrees with Islam *et al.*, (1994), who found that below 20 percent soil saturation at booting and flowering phases, moisture stress decreased plant height. Similar findings have also been reported by Ahmadikhah and Marufinia (2016). The reduction in height might be either due to inhibition of cell length or cell division by water deficits. Rahman *et al.*, (2002) also reported that there were remarkable differences in plant height among the varieties under water stress. They observed with compare to control plants, the plant height decreases under soil moisture stress (30% of field capacity), ranges from 2.30 % to 9.41%.

In present study, the minimum difference was observed in genotype Nagina 22 (7.06%) and the maximum difference was observed in genotype Basmati 386 (15.69%) for both years. Due to water stress, the length of panicles was significantly reduced in all genotypes in relative to control plants (Rahman *et al.*, 2002). Ekanayake (1987) and Islam *et al.*, (1994) also founds the similar results. This might be due to the fact that moisture stress reduced the synthesis of carbohydrate and or weaken the sink at reproductive stages. Rahman *et al.*, (2002) reported that there were remarkable differences on panicle length among the varieties under stress at flowering time. With compare to control plants, the length of panicle decreases under soil moisture stress (30% of field capacity), ranges from 2.46% to 8.87%.

Water stress decreased the number and weight of grains at the reproductive and grain-filling stage. When drought stress occurred at flowering, the total grain number per panicle was significantly reduced (Sarvestani *et al.*, 2008). In present study, the minimum difference was observed in genotype Nagina 22 (14.74%) and the maximum difference was observed in genotype Basmati 386 (46.56%) for both years. This indicated the reduced crop growth at flowering time due to drought. Rahman *et al.*, (2002) and Islam *et al.*, (1994) also observed the number of filled grains per panicle decreased significantly compared to control with the moisture stress at booting, flowering and grain filling phases. They observed the lowest (71.24) number of filled grains per panicle during stress at flowering stage. Yang *et al.*, 2019, recorded that the number of spikelets per panicle (SPN) and filled grains (FG) yield components were significantly reduced by 18 percent and 19 percent for YLY6 and 21 percent and 19 percent for HY113, respectively, compared to the conventional flooding irrigation system on average over two seasons, leading to the significant decrease in GY in YLY6 and HY111 under stress condition.

Water stress at grain filling (anthesis to maturity) was more detrimental followed by panicle initiation stage regarding filled grains/panicle, effective tillers/hill, total spikelets/panicle, 1000-grain weight and grain yield/hill, irrespective of the genotypes (Moonmoon and Islam, 2017). The yield depends on dry matter accumulation and its partitioning (Baruah *et al.*, 2006). Rice grain yield can be restricted by the availability of grain-developing assimilates (source limitation) or by the reproductive organ's ability to accept assimilates (sink capacity). Yield losses from the usual level due to water deficit are helpful in assessing drought tolerance in as much as cultivar differs greatly in inherent yielding capacity (Pirdashti *et al.*, 2004). Pantuwan *et al.*, (2002) and Cattivelli *et al.*, (2008) have recorded decreased rice yield at critical growth stages due to drought stress. In present study, the minimum difference in yield was observed Nagina 22 (12.03%) and the maximum difference was observed in genotype Basmati 386 (61.83%) for both years. These findings are similar with some researchers who stated that if drought occurs during flowering time, grain yield could be dramatically decreased (about 60%) (Boonjung and Fukai 1996). Similarly, Rahman *et al.*, (2002) reported decreases in grain yield per hill under soil water stress (30 percent of field capacity), ranging from 16.07 percent to 41.21 percent. Yang *et al.*, (2019) also observed that the grain yield (GY) under drought stress was significantly reduced for YLY6 by 23.2 percent and for HY113 by 24.0 percent compared to traditional flooding.

The reduction in yield at the flowering stage under drought stress was mainly due to a decrease in the total number of grains per panicle (increase in unfilled grain and a greatly decreased proportion of filled grains) and 1000-grain weight, respectively. Islam (1999) and Islam *et al.*, (1994) have demonstrated similar findings on 1000-grain weight under water stress at booting and flowering stages. In present study, the minimum difference was observed in genotype Nagina 22 (8.46%) and maximum difference was observed in genotype Basmati 386 (31.66%) for both years. Sarvestani *et al.*, 2008 reported that the drought stress at grain filling stage reduced the 1000-grain weight by 17% than control. In terms of 1000 - grain weight, mentioned cultivars show a reduction under non-submerged treatment, however the reduction was higher in 829 cultivar (8.1%) (Mostajeran and Rahimi-Eichi, 2009). Similar results on 1000-grain weight under water stress had been reported by Venuprasad *et al.*, (2007) and Castillo *et al.*, (2006). Rahman *et al.*, (2002) reported that there were remarkable differences in 1000 grain weight among the varieties under stress at flowering time. With compare to control plants, the 1000 grain weight decreases under soil moisture stress (30% of field capacity), ranges from 1.07% to 7.80%. Stress could decrease translocation of assimilates to the grains during different growth stages, which decreased gram weight and increased the empty grains. The efficient translocation of assimilates towards sink can be indicated HI values. Lower HI values at booting and flowering stages under stress suggest that the translocation of assimilates to grains over grains filling stage was more detrimental (Rahman *et al.*, 2002). Under extreme drought stress, it was argued that when yıelds are decreased to below 50% of those wider favorable conditions the relationship between yield under favorable and stress conditions break down (Ceccarelli and Grando, 1991). The results of this experiment indicate that under these circumstances, genotypes were not able to convey their genetic yield potential.

Leaf area of rice genotypes significantly reduced irrespective of genotypes. In present study, the minimum difference was observed in genotype Nagina 22 (13.26%) and the maximum difference was observed in genotype Basmati 386 (35.24%) for both years. Similarly, the high reduction in leaf area was recorded in Swarna Sub 1 (49.08%) while low in Nagina 22(18.70%) Susk Samrat (28.22%), NDR 97 (22.40%) and NDR 102 (20.60%) (Singh *et al.,* 2018). Negative effects of water deficiency on mineral nutrition and metabolism reduce the leaf area and change the partitioning of plant organs (Zain *et al.*, 2014).

In conclusion, all the morphological parameters was found significantly reduced under drought stress condition at flowering stage and directly makes a negative impact on yield of rice genotypes .

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Conflicts of interest

Authors declare no conflicts of interest.

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