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Research Article

SCREENING OF RICE GERMPLASM AGAINST DROUGHT STRESS USING MORPHOLOGICAL PARAMETERS

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Abstract

Oryza sativa L. is a staple diet for billions of people in the world. Different rice varieties' drought stress responses and their effects on both qualitative and quantitative variables. Rice is the second main exportable product of Pakistan and the agriculture sector has shown remarkable growth, with the crop sector posting a growth of 6.58% in Fiscal year 2022. Drought have a bad effect on the vegetative and reproductive stages of crops. Drought stress can reduce crop yield production. The RCBD design, two-way ANOVA factorial analysis, Tukey test, Genetic advance and Heritability were used for this experiment. This study specifically focuses on the response of rice genotypes to drought stress and its effect on morphological parameters such as plant height, panicle length, stem diameter, flag leaf length and width, number of panicles per plant, and 1000-grain weight. Drought tolerance genotypes were screened out and used to the standard Index of IRRI to identify morphological processing in Rice Research Institute Kala Shah Kaku, Pakistan. Total 35 rice genotypes were sown under drought stress with checked variety. Six varieties perform better production under drought stress conditions. These varieties like Pokkoli, Vehari, Nonabokra, Kalomonk, PK10683, and Basmati 375 show better perform under drought stress. The findings of this research can contribute to the development of drought-tolerant rice varieties and enhance food security in drought-prone areas. The importance of qualitative parameters, such as panicle curvature and awning, is also explored, with potential implications for the visual appearance and market preferences of rice grains. Overall, this research provides valuable insights into the genetic basis and potential breeding strategies for improving drought tolerance in rice.

Keywords: *Drought stress, qualitative parameters, 1000 grain weight, Oryza sativa L.*
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1. INTRODUCTION

Rice is the second main exportable product after cotton. According to the economic survey of Pakistan 2021-22, the agriculture sector recorded a remarkable growth of 4.40 percent and surpassed the target of 3.5 percent and last year's growth of 3.48 percent. The crop sector outperformed and posted a growth of 6.58 percent during the Fiscal Year in 2022 against 5.96 percent last year (Njau, Panchbhai, Musila, & Murori, 2022). The rice production increased from 8.4 million tons to 9.3 million tons during 2020-21. In the past few decades, due to drought conditions on a worldwide scale, about 21% decline in the yield of Triticum aestivum L. and 40% decline in the yield of Zea mays L. were observed (Aslam, Maqbool, & Cengiz, 2015). It has been reported that due to drought stress conditions, decreased germination potential, reduced growth of seedlings, root/shoot dry weight, undersized length of hypocotyl and poor vegetative growth in several crops like Oryza sativa L., Pisum sativum L. and

Medicago sativa L. was observed (M. Liu, Li, Liu, & Sui, 2015).

At present 124 countries in Asia, Africa, North America, South America, Europe, and Australia are cultivating rice (Kraehmer, Jabran, Mennan, & Chauhan, 2016). Because there is always a supply of water, irrigation areas produce more than rainfed areas, where crop faces a global population. Annually 748 million tons of paddy are produced, which is equal to 496.7 million tons of milled rice (Jha & Srinivasan, 2012). Although, wheat covers more land than rice humans consume more rice than wheat. People use 85% of the total produced rice, compared with 72% of wheat and 19% of maize. Rice provides 21% per capita energy and 15% of protein. Rice proteins have high nutritional value. Rice also offers minerals, vitamins, and fibers (Chaudhari, Tamrakar, Singh, Tandon, & Sharma, 2018). Worldwide annual rice consumption of rice stands at 478.4 million metric tons (Aminu, Adnan, Abdullahi, & Halliru, 2017). Asia consumes almost 90% of the rice.

Morphological evaluation of drought stress and rice germplasm may help identify genetically diverse drought-resistant plants (Serraj et al., 2009). It uses morphology to identify better genotypes as regards stress, for example, drought stress and at the same time functions optimally when water is limited (Yadav & Sharma, 2016). The goal of this study is to characterize drought-stressed rice germplasm from phenotypic approaches.The morphological characteristics to screen rice germplasm against drought stress were derived from research on one of agriculture's major concerns (Verma & Sarma, 2021). Rice farming is impacted by drought, which affects agriculture as a whole. Therefore, drought-resistant genotypes are crucial (Vinod, Krishnan, Thribhuvan, & Singh, 2019). The most important germplasm lines and phenotypic characters were established that might be useful in determining the possible effect of water stress on plant growth and development (Verma & Sarma, 2021). Information is essential for designing and implementing breeding programs to improve rice drought resistance. The genetic study emphasizes the benefits of utilizing morphological features as drought tolerance markers, offering more efficient and affordable screening.

Insufficient irrigation water affects all field crops. Water shortages are caused by a decreasing water supply, a growing population, water pollution, a rise in water use in cities and factories, global warming, changing rainfall patterns, and changing sunlight (Jury & Vaux Jr, 2007). Rice farming is also affected by irrigation water shortages. Water stress during the vegetative phase, especially booting (Lilley & Fukai, 1994), flowering and later stages can inhibit floret initiation, resulting in sterile spikelets, and grain filling, resulting in lower grain weight and lower paddy yield (Mohapatra, Panigrahi, & Turner, 2011).

Most rainfall occurs from the first week of July to the latter week of August, thus flowering begins when crops have enough time without rain from mid-September to mid-November. (Hachigonta, Reason, & Tadross, 2008; K. Liu et al., 2020).

Low moisture stress during flowering is the biggest difficulty in upland rice cultivation. The yield of upland rice yield is extremely variable due to low water stress mainly at the reproductive stage. Drought stress at the blossoming stage is highly overwhelming and yield losses of 70-80% occur.

Due to climate change temperature of the earth is increasing along with the shortage of water due to low precipitation. Global warming is causing pressure on water availability along with pollution, world population growth, and changes in land use other problems (Arfanuzzaman & Dahiya, 2019; Smith et al., 2016). Drought stress is as lethal as temperature stress for sustainable rice production by decreasing the quality and stability of rice when applied at critical growth stages (Shah, Chaturvedi, & Gupta, 2019).

Water shortage affects various morphological traits of rice. It slows down or stops the plant growth, in this situation rice plant uses energy for survival rather than proliferation (Begna, 2023; Bhattacharya & Bhattacharya, 2021). Drought results in poor root growth and reduced leaf-surface traits including leaf colour, pubescence, shape, and composition of cuticular wax (Laoué et al., 2023).

Drought stress is a major abiotic stress that affects rice production worldwide. It can lead to reduced crop yields, increased susceptibility to pests and diseases, and even crop failure. A study by Sahoo et al. (2019) found that around 23 million hectares of rain-fed rice farming had been affected by drought stress. It is supposed that climate change will rigorously affect the water resources that would resulting in expectedly increased frequencies of drought in the near future. A study by Hussain et al. (2020) found that climate change could cause droughts to happen more often in rice-growing regions. The study found that the frequency of droughts could increase by up to 50% by the end of the 21st century. This could lead to a decrease in rice production of up to 10%. Upland and low-land rice ecosystems generally suffer low water stress at the flowering stage.

Genetic diversity in rice is of great interest as there are more than 140,000 known varieties of the crop. (Bhattarai & Subudhi, 2019) reported that the gene bank at the International Rice Research Institute (IRRI) held approximately 100,000 genotypes that contained numerous desired traits. Those traits can be further utilized to engineer more resistant varieties through breeding. Drought-tolerant varieties can be developed by identifying genotypes that produce a substantial yield even in the absence of adequate precipitation. To discern the differences between genotypes, phenotypic traits should be examined through principal component analysis and cluster analysis (Prasad, Patil, Geeta, & Matiwade, 2023).

1.1. Objectives of this Study:

- To screen the rice germplasm against drought stress on morphological basis.

2. Materials and Methods

2.1. Experimental Site

The experiment was conducted in the field of Rice Research Institute, Kala Shah Kaku Lahore Pakistan (31.72140 N, 74.27020E). The Randomization Complete Block Design (RCBD) was used to conduct this experiment. Three replications were used in this experiment. The environmental conditions during that time were high temperature and low humidity. The seeds of 35 varieties were sown under drought stress condition to check their productivity. After 34 days, one set of plants was relocated to a field with normal environmental conditions, while the other was transferred to a controlled environment with limited water availability and shelter against precipitation. Two sets of lines were sown in parallel with each other. After 34 days, one set of plants was relocated to a field with normal environmental conditions, while the other was transferred to a controlled environment with limited water availability and shelter against precipitation. This provided the opportunity to evaluate the effect of the varying environmental conditions on the growth of the plants.

The experiment was conducted under a rain-out shelter for 14 days during panicle initiation to avoid drought stress by precipitation. This followed the International Rice Research Institute's Rice Evaluation System protocol. Drought stress affected rice yield optimization in this experiment.

The experiment includes 35 genotypes with 3 replications. A control group received 100% water, while stress conditions were applied after 14 days (1st irrigation after 14 days, 2nd irrigation after 28 days, 3rd irrigation after 42 days, and

4th irrigation after 56 days) with four times the usual water supply.

The seeds of 35 varieties were sown under drought stress condition to check their performance and select the best performing lines. These varieties are described below in Table 1.

2.1.1. Stress Application:

Following the adaptation of genotypes, fourteen days of drought stress were applied at the panicle initiation stage only under rain out shelter to avoid precipitations during the drought period, to assess its effect on yield optimization in a study conducted under the protocol of the Rice Evaluation System (IRRI). The soil of Kala Shah Kaku is clay loamy soil. The temperature of Kala Shah Kaku was 36 C, and rainfall was 220 mm. Precipitations were kept at bay by using a rain-out shelter during the duration of the experiment.

2.2. Data Recorded

The data were recorded at the maturity stage. Different parameters like Plant Height (cm), Panicle Length (cm), Number of panicles per plant, Stem diameter (mm), Flag leaf length (cm), Flag leaf width (cm), 1000 Grain weight (g), Panicle curvature of main axis, and Awnings were recorded from quantitative and qualitative parameters at the appropriate time.

2.3. Statistical Analysis

Recorded data were analyzed in the software Statista8.1. The mean results are highly significant at a p-value of 0.01, significant at a p-value 0.05 and non-significant at a p-value > 0.05 using Factorial Design, Tukey Test, Heritability and Genetic Advance The heritability was calculated by this formula

$$H2 = \frac{Vg}{Vp}$$

where the genetic variation is Vg, the phenotypic variation is Vp, and the heritability estimate is H. while genetic advance was calculated by this formula

$$GA\ \% = \left(\frac{\sqrt{PV * H2b}}{G.\ M} * 1.755\right) * 100$$

3. Results:

3.1. Plant Height

Table 2 shows the significance of the trait , drought stress application, and their interaction. The average plant height was 107.34±0.2312cm with a low coefficient of variation (5.08%), indicating reliable and consistent results. Table 2 a Nonabokra (153.50cm) and PK10683 (151.33cm) had the highest plant heights, while Kissan Basmati (86.17cm), KS282 (72.33cm), and PK10324 (58cm) had the lowest. Heritability and genetic advance values for plant height were 95.817% and 334.089%, respectively (Table 3).

3.2. Panicle Length

Table 2 shows the significance of the trait, drought stress and their interaction. The mean panicle length was 19.181±0.27cm with reliable results (CV 2.8%). Nonabokra (28.333cm) and Vehari (26.167cm) had the highest panicle length, while Alkhalid Basmati (14cm) and PK10436 (13.833cm) had the lowest (Table 2 a). Heritability was 95.128%, and genetic advance was 155.994% (Table 3).

3.3. Stem Diameter

Table 2 show the significance of the trait , drought stress application, and their interaction. Stem diameter mean was 3.091±0.049 and coefficient of variation was 6.16%, indicating reliable and consistent results under drought stress. Table 2a displayed the thickest stem diameter for Nonabokra (5.2200mm), followed by Vehari (4.5000mm), PK10324 (4.1833mm), and Basmati.515 Tol-19 (3.9000mm). The thinnest stem diameter was recorded for Chenab Tol-19 (2.4000mm), Punjab Basmati (2.1950mm), and CSR-13 (1.5167mm). The heritability and genetic advance values for stem diameter were 95.979% and 70.037%, respectively (Table 3).

3.4. Flag Leaf Length

Table 2 show the significance of the trait, drought stress application, and their interaction. The mean for Flag leaf length was 27.900±0.375 with a low coefficient of variation (6.33%), indicating reliable and consistent results. PK434 had the highest flag leaf length at 39.167 cm, followed by

GRAPH LEGENDS:

Graph 1: Out of 35 rice varieties, these varieties like Nonabokra (153.50cm) and PK10683 (151.33cm) had the highest plant heights, while Kissan Basmati (86.17cm), KS282 (72.33cm), and PK10324 (58cm) had the lowest plant height.

Graph 2: Out of 35 rice varieties, these varieties like Nonabokra (28.333cm) and Vehari (26.167cm) had the highest panicle length, while Alkhalid Basmati (14cm) and PK10436 (13.833cm) had the lowest panicle length.

Graph 3: Out of 35 rice varieties, these varieties like thickest stem diameter for Nonabokra (5.2200mm), followed by Vehari (4.5000mm), PK10324 (4.1833mm), and Basmati.515 Tol-19 (3.9000mm). Thinnest stem diameter was recorded for Chenab Tol-19 (2.4000mm), Punjab Basmati (2.1950mm), and CSR-13 (1.5167mm).

Graph 4: Out of 35 rice varieties, these varieties like PK434 had the highest flag leaf length at 39.167 cm, followed by PK10683 (38.333 cm), Basmati 385 (37.167 cm), and Basmati 515 Tol-19 (34.167 cm). The lowest flag leaf length was recorded for Hossooli (21.500 cm), Alkhalid Basmati (21.500 cm), and Nonabokra (16.000 cm).

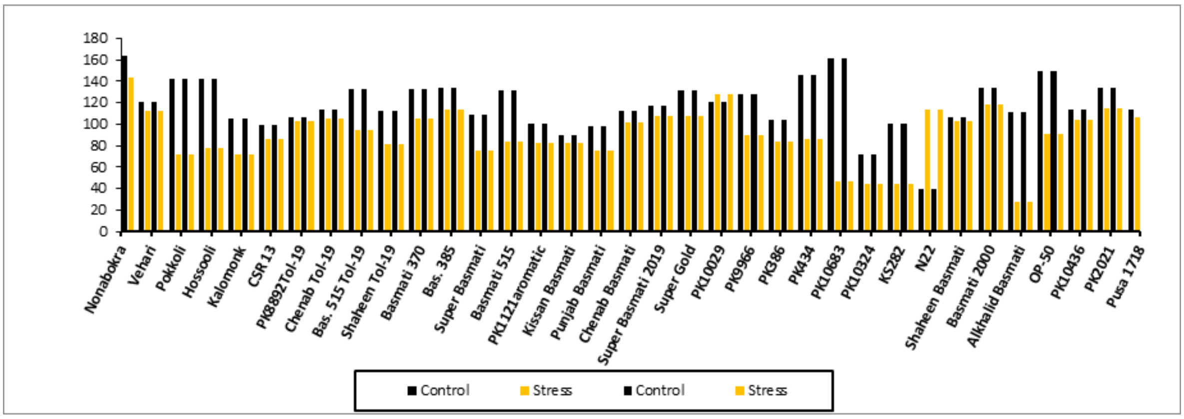
Graph 5: Out of 35 rice varieties, these varieties like Basmati375 had the highest width (45.784 cm) followed by Pusa 1718 (9.1667), PK386 (9.000), and Basmati 20 (8.8333). Vehari, Basmati 370, and PK8892 Tol-19 had the lowest flag leaf width

Graph 6: Out of 35 rice varieties, these varieties like Nonabokra, Vehari, Basmati 385, and Kalomonk had the highest number of panicles per plant, while Shaheen Basmati, PK 2021, and Pusa 1718 had the lowest panicles per plant.

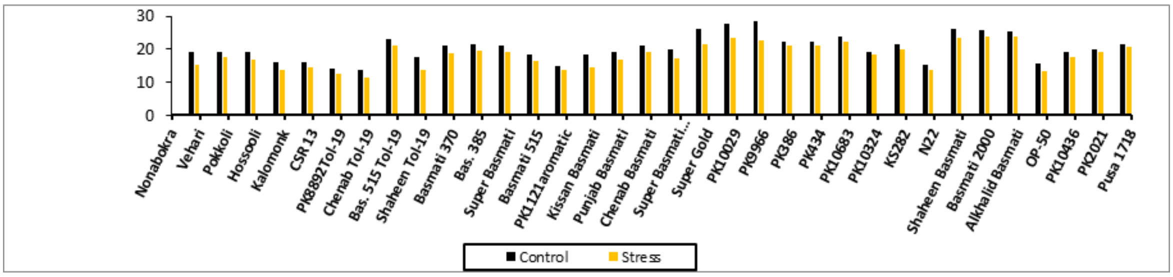
Graph 7: Out of 35 rice varieties, these varieties like showed Pokkoli, Vehari, Nonabokra, and Kalomonk as highest, while Pusa1718, PK10683, KS282 had lowest thousand paddy weight.

Graph 8: Out of 35 rice varieties, these varieties like 19 varieties showed upright panicle curvature (Vehari, Pokkoli, PK1121aromatic, Chenab Basmati, Super Gold, PK9966, Basmati 2000, PK10436, and Pusa 1718), 19 showed semi upright (Nonabokra, CSR 13, PK8892 Tol-19, Chenab Tol-19, Shaheen Tol-19, Basmati370, Super Basmati, Basmati 515, Kissan Basmati, Punjab Basmati, Super Basmati 2019, PK386, PK434, PK10683, PK10324, N22, Shaheen Basmati, Alkhalid Basmati, and OP-50), 4 showed slight dropping (Hossooli, Kalomonk, Basmati 515 Tol-19, and KS 282), and 2 showed dropping (PK10029, and PK2021).

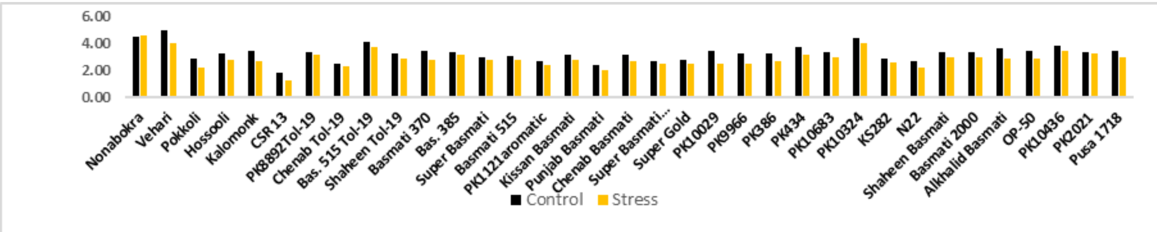
Graph 9: Out of 35 rice varieties, these varieties like 4 varieties (Nonabokra, Vehari, N22, and PK10436) show long and fully-awned, 5 varieties (Pokkoli, PK8892 Tol-19, Basmati 515 Tol-19, Basmati 385, and PK386) show long and partly-awned, 11 varieties show short and fully-awned (Hossooli, Chenab Tol-19, Shaheen Tol-19, Basmati 370, Super Basmati, PK1121aromatic, Chenab Basmati, PK10683, Shaheen Basmati, Basmati 2000, and Alkhalid Basmati), 7 varieties (Basmati 515, Kissan Basmati, Punjab Basmati, Super Basmati 2019, PK10029, PK2021, and Pusa 1718) show short and partly-awned, and 8 varieties (Kalomonk, CSR13, Super Gold, PK9966, PK434, PK10324, KS282, and OP-50) show zero-awned in drought stress.



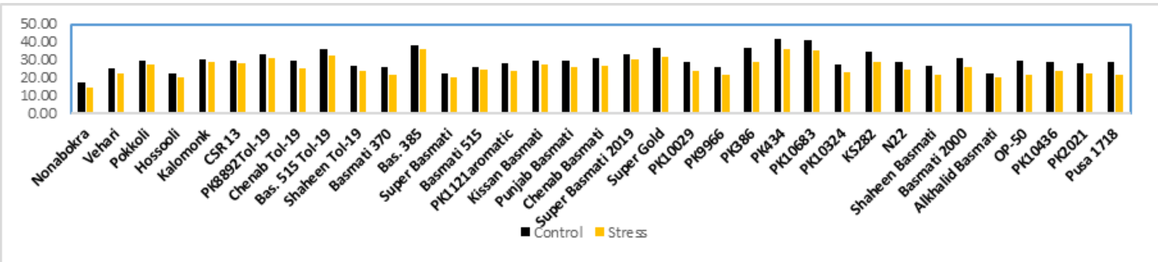
Graph 1 Plant Height: Nonabokra and PK10683 had the highest plant heights, while Kissan Basmati, KS282, and PK10324 had the lowest plant height**.**



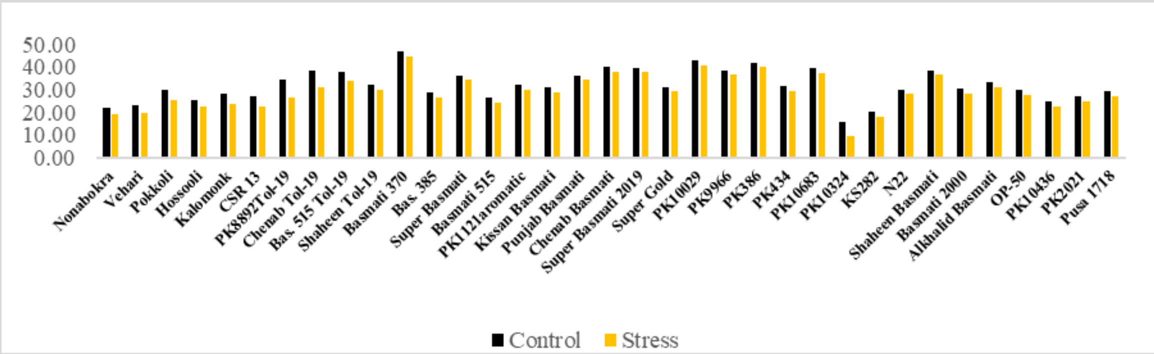
Graph 2 Panicle length: Nonabokra and Vehari had the highest panicle length, while Alkhalid Basmati and PK10436 had the lowest panicle length.



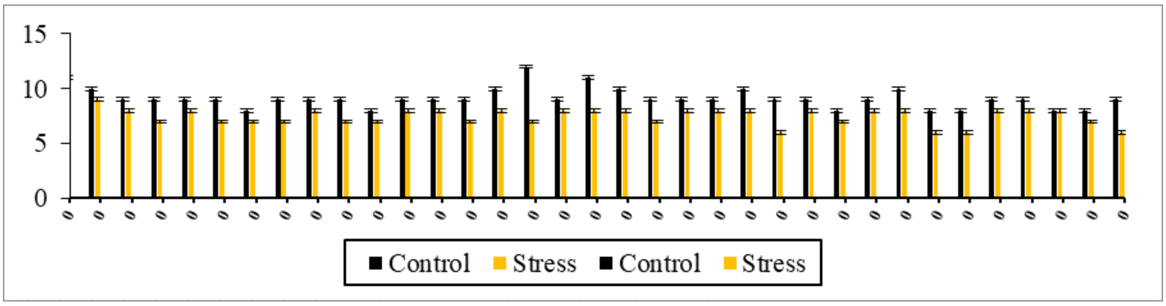
Graph 3 Stem diameter: Thickest stem diameter for Nonabokra, followed by Vehari, PK10324, and Basmati.515 Tol-19. Thinnest stem diameter was recorded for Chenab Tol-19, Punjab Basmati, and CSR-13**.**



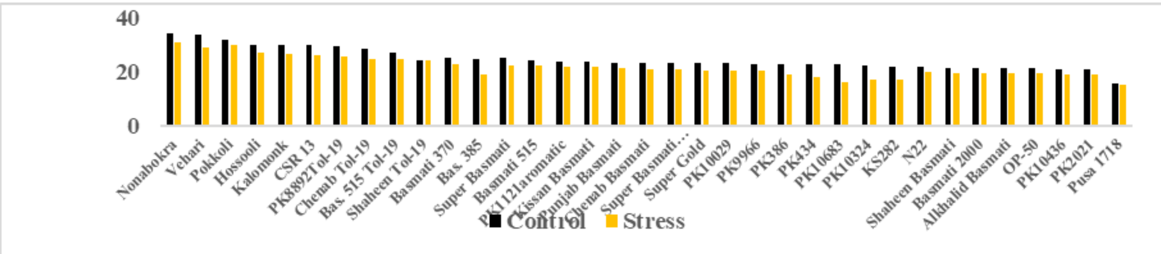
Graph 4 Flag Leaf Length: PK434 had the highest flag leaf length at 39.167 cm, followed by PK10683, Basmati 385, and Basmati 515 Tol-19. The lowest flag leaf length was recorded for Hossooli, Alkhalid Basmati, and Nonabokra.



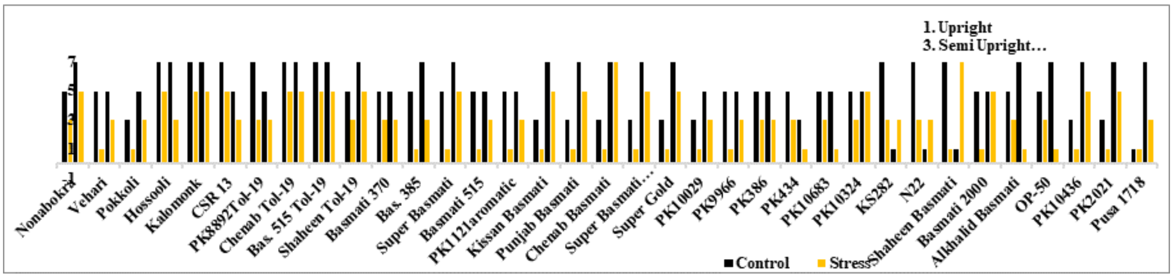
Graph 5 Flag Leaf width: Basmati375 had the highest width followed by Pusa 1718, PK386, and Basmati 20. Vehari, Basmati 370, and PK8892 Tol-19 had the lowest flag leaf width.



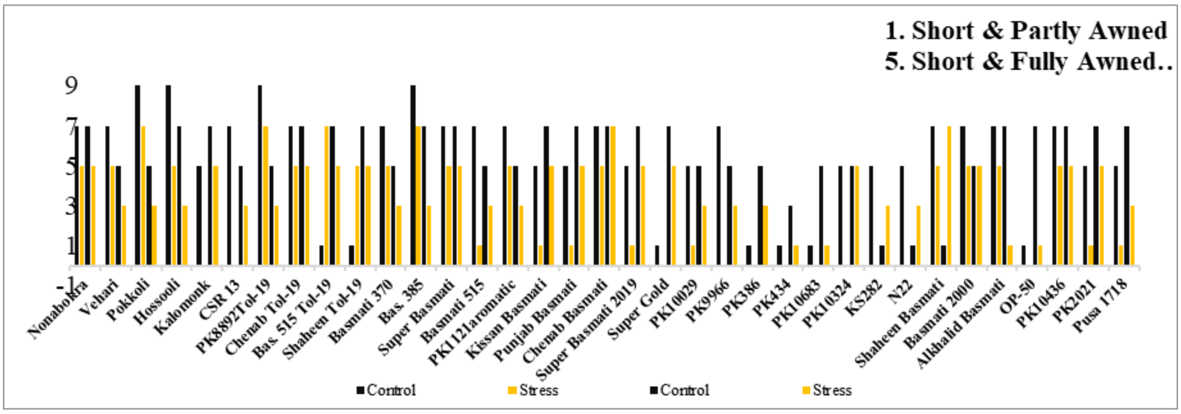
Graph 6 Number of Panicle per plant: Nonabokra, Vehari, Basmati 385, and Kalomonk had the highest number of panicles per plant, while Shaheen Basmati, PK 2021, and Pusa 1718 had the lowest panicles per plant.



Graph 7. 1000 Grain weight: Pokkoli, Vehari, Nonabokra, and Kalomonk as highest, while Pusa1718, PK10683, KS282 had lowest thousand paddy weight.



Graph 8 Panicle Curvature: 19 varieties showed upright panicle curvature (Vehari, Pokkoli, PK1121aromatic, Chenab Basmati, Super Gold, PK9966, Basmati 2000, PK10436, and Pusa 1718), 19 showed semi upright (Nonabokra, CSR 13, PK8892 Tol-19, Chenab Tol-19, Shaheen Tol-19, Basmati370, Super Basmati, Basmati 515, Kissan Basmati, Punjab Basmati, Super Basmati 2019, PK386, PK434, PK10683, PK10324, N22, Shaheen Basmati, Alkhalid Basmati, and OP-50), 4 showed slight dropping (Hossooli, Kalomonk, Basmati 515 Tol-19, and KS 282), and 2 showed dropping (PK10029, and PK2021).



Graph 9 Awning: 4 varieties (Nonabokra, Vehari, N22, and PK10436) show long and fully-awned, 5 varieties (Pokkoli, PK8892 Tol-19, Basmati 515 Tol-19, Basmati 385, and PK386) show long and partly-awned, 11 varieties show short and fully-awned (Hossooli, Chenab Tol-19, Shaheen Tol-19, Basmati 370, Super Basmati, PK1121aromatic, Chenab Basmati, PK10683, Shaheen Basmati, Basmati 2000, and Alkhalid Basmati), 7 varieties (Basmati 515, Kissan Basmati, Punjab Basmati, Super Basmati 2019, PK10029, PK2021, and Pusa 1718) show short and partly-awned, and 8 varieties (Kalomonk, CSR13, Super Gold, PK9966, PK434, PK10324, KS282, and OP-50) show zero-awned in drought stress.

Table 1. Detail of Genotypes, Origin, and Texan of Rice

Serial. No.	Genotype	Origin	Texan (taxonomy)	Fine/ Coarse
1	Nonabokra	KSK Pakistan	*ORYZA SATIVA L.*	Coarse
2	Vehari	KSK Pakistan	*ORYZA SATIVA L.*	Coarse
3	Pokkoli	KSK Pakistan	*ORYZA SATIVA L.*	Coarse
4	Hossooli	KSK Pakistan	*ORYZA SATIVA L.*	Coarse
5	Kalomonk	KSK Pakistan	*ORYZA SATIVA L.*	Coarse
6	CSR 13	KSK Pakistan	*ORYZA SATIVA L.*	Coarse
7	PK8892Tol-19	KSK Pakistan	*ORYZA SATIVA L.*	Fine
8	Chenab Tol-19	KSK Pakistan	*ORYZA SATIVA L.*	Fine
9	Basmati 515 Tol-19	KSK Pakistan	*ORYZA SATIVA L.*	Fine
10	Shaheen Tol-19	KSK Pakistan	*ORYZA SATIVA L.*	Fine
11	Basmati 370	KSK Pakistan	*ORYZA SATIVA L.*	Fine
12	Basmati 385	KSK Pakistan	*ORYZA SATIVA L.*	Fine
13	Super Basmati	KSK Pakistan	*ORYZA SATIVA L.*	Fine
14	Basmati 515	KSK Pakistan	*ORYZA SATIVA L.*	Fine
15	PK1121aromatic	KSK Pakistan	*ORYZA SATIVA L.*	Fine
16	Kissan Basmati	KSK Pakistan	*ORYZA SATIVA L.*	Fine
17	Punjab Basmati	KSK Pakistan	*ORYZA SATIVA L.*	Fine
18	Chenab Basmati	KSK Pakistan	*ORYZA SATIVA L.*	Fine
19	Super Basmati 2019	KSK Pakistan	*ORYZA SATIVA L.*	Fine
20	Super Gold	KSK Pakistan	*ORYZA SATIVA L.*	Fine
21	PK10029	KSK Pakistan	*ORYZA SATIVA L.*	Fine
22	PK9966	KSK Pakistan	*ORYZA SATIVA L.*	Fine
23	PK386	KSK Pakistan	*ORYZA SATIVA L.*	Fine
24	PK434	KSK Pakistan	*ORYZA SATIVA L.*	Coarse
25	PK10683	KSK Pakistan	*ORYZA SATIVA L.*	Fine
26	PK10324	KSK Pakistan	*ORYZA SATIVA L.*	Fine
27	KS282	KSK Pakistan	*ORYZA SATIVA L.*	Coarse
28	N22	KSK Pakistan	*ORYZA SATIVA L.*	Coarse
29	Shaheen Basmati	KSK Pakistan	*ORYZA SATIVA L.*	Coarse
30	Basmati 2000	KSK Pakistan	*ORYZA SATIVA L.*	Coarse
31	Alkhalid Basmati	KSK Pakistan	*ORYZA SATIVA L.*	Fine
32	OP-50	KSK Pakistan	*ORYZA SATIVA L.*	Fine
33	PK10436	KSK Pakistan	*ORYZA SATIVA L.*	Fine
34	PK2021	KSK Pakistan	*ORYZA SATIVA L.*	Fine
35	Pusa 1718	KSK Pakistan	*ORYZA SATIVA L.*	Fine

Table 2 Analysis of Variance (Anova)

Source	PH	STDM	FLL	FLW	THOUS	NPPP	1000 GRAIN W
RP	8.9	0.0337	3.205	81.383	0.6699	0.0619	0.5644
Genotype	**2077.8	**2.6281	*144.046	**312.111	**4.1665	**0.40299	**3.2615
Stress	**35467.2	**11.6281	*854.777	**429.532	**95.7344	**5.56335	**4.6334
Genotype* Stress	**491.5	**0.0987	*4.785	**3.639	**0.129	**0.08427	**0.139
Error	29.8	0.0362	3.117	1.099	0.064	0.03959	0.074

Table 2 A Tukey Test

Genotype	PH	NPPP	STD	FLL	FLW	1000 GRAIN W
Nonabokra	153.5 ^{A}	11.167 ^{A}	5.22 ^{A}	16 ^{L}	20.551 ^{RS}	30.62 ^{C}
Vehari	109 ^{EFGHIJ}	9.667 ^{B}	4.5 ^{B}	23.833 J^{K}	21.422 ^{QR}	31.297 ^{B}
Pokkoli	106.83 ^{GHIJK}	9 ^{C}	2.52 ^{KLM}	28.667 ^{EFGH}	27.802 ^{LMN}	32.992 ^{A}
Hossooli	110 ^{EFGHI}	9 ^{C}	3.0167 ^{GHI}	21.5 ^{K}	23.914 ^{OP}	29.751 ^{E}
Kalomonk	88.83 ^{N}	9 ^{C}	3.0533 ^{FGH}	29.5 ^{DEFG}	26.08 ^{MNO}	29.901 ^{D}
CSR 13	92.83 ^{MN}	9 ^{C}	1.5167 ^{N}	28.667 ^{EFGH}	25.071 ^{OP}	27.641 ^{F}
PK8892Tol-19	105 ^{GHIJKL}	9 ^{C}	3.2167 ^{EFG}	32.167 ^{CDE}	30.357 ^{IJK}	26.631 ^{G}
Chenab Tol-19	109.17 ^{EFGHIJ}	9 ^{C}	2.4 ^{LM}	27.833 ^{FGHI}	34.697 ^{GH}	25.944 ^{H}
Bas. 515 Tol-19	113.33 ^{CDEFGH}	9 ^{C}	3.9 ^{CD}	34.167 ^{BC}	35.939 ^{FG}	25.43 ^{HI}
Shaheen Tol-19	97 ^{KLMN}	9 ^{C}	3.05 ^{FGH}	25.5 ^{HIJ}	31.154 ^{IJ}	24.921 ^{IJ}
Basmati 370	119 ^{BCDEF}	9 ^{C}	3.1317 ^{FG}	24 ^{IJK}	45.784 ^{A}	24.424 ^{JK}
Bas. 385	123.5 ^{BCD}	9 ^{C}	3.215 ^{EFG}	37.167 ^{AB}	27.542 ^{LMN}	24.046 ^{KL}
Super Basmati	102.67 ^{IJKLM}	8.5 ^{D}	2.7075 ^{HIJKL}	26.75 ^{GHIJ}	37.073 ^{EF}	23.078 ^{MN}
Basmati 515	108.17 ^{FGHIJK}	9 ^{C}	2.8867 ^{GHIJK}	25.333 ^{HIJK}	25.535 ^{NOP}	23.49 ^{LM}
PK1121aromatic	91.33 ^{N}	8.833 ^{CD}	2.5517 ^{JKLM}	26 ^{GHIJ}	30.953 ^{IJ}	23.267 ^{M}
Kissan Basmati	86.17 ^{N}	8 ^{E}	2.98 ^{GHI}	28.833 DEFGH	29.749 ^{JKL}	23.061 ^{MN}
Punjab Basmati	87 ^{N}	8 ^{E}	2.195 ^{M}	27.667 ^{GHIJ}	35.367 ^{FG}	22.636 ^{NO}
Chenab Basmati	106.67 ^{GHIJK}	8 ^{E}	2.9 ^{GHIJK}	29 DEFGH	39.18 ^{CD}	22.496 ^{O}
Super Basmati 2019	103.56^{LMN}	8^{E}	2.9543^{IJKL}	26.33 ^{HIJK}	37.952 ^{EF}	22.568 ^{O}
Super Gold	119.33 ^{BCDEF}	8 ^{E}	2.625 ^{IJKL}	34.167 ^{BC}	30.15 ^{IJK}	22.166 ^{OP}
PK10029	111.83 ^{DEFGHI}	8 ^{E}	2.9567 ^{GHIJ}	26.5 ^{GHIJ}	41.789 ^{B}	21.866 ^{PQ}
PK9966	108.5 ^{EFGHIJK}	8 ^{E}	2.8933 ^{GHIJK}	24 ^{IJK}	37.575 DEF	21.589 ^{Q}
PK386	94 ^{LMN}	8 ^{E}	2.95 ^{GHIJ}	32.667 ^{CD}	40.986 ^{BC}	21.413 ^{QR}
PK434	116.5 ^{BCDEFG}	8 ^{E}	3.455 ^{EF}	39.167 ^{A}	30.351 ^{IJK}	21.313 ^{QRS}
PK10683	151.33 ^{A}	8 ^{E}	3.1717 ^{FG}	38.333 ^{A}	38.578 ^{DE}	18.357 ^{Z}
PK10324	58 ^{P}	8 ^{E}	4.1833 ^{BC}	25.333 ^{HIJK}	12.665 ^{T}	20.798 ^{STU}
KS282	72.33 ^{O}	8 ^{E}	2.6917 ^{HIJKL}	31.667 ^{CDEF}	19.114 ^{S}	19.139 ^{Y}
N22	116.5 ^{BCDEFG}	7.667 ^{E}	2.4317 ^{LM}	26.667 ^{GHIJ}	29.548 ^{JKL}	20.376 ^{UVW}
Shaheen Basmati	104.33 ^{HIJKLM}	7 ^{F}	3.15 ^{FG}	24.5 ^{IJK}	37.625 ^{DEF}	20.231 ^{VW}
Basmati 2000	126 ^{B}	7 ^{F}	3.15 ^{FG}	28.667 ^{EFGH}	29.548 ^{JKL}	20.018 ^{WX}
Alkhalid Basmati	97.5 ^{JKLMN}	7 ^{F}	3.25 ^{EFG}	21.5 ^{K}	32.408 ^{HI}	19.637 ^{XY}
OP-50	120.17 ^{BCDE}	7 ^{F}	3.16 ^{FG}	25.667 ^{GHIJ}	28.595 ^{KL}	19.318 ^{Y}
PK10436	108.83 ^{EFGHIJK}	7 ^{F}	3.6167 ^{DE}	26.333 ^{GHIJ}	23.578 ^{PQ}	20.587 ^{TUV}
PK2021	124.33 ^{BC}	7 ^{F}	3.2717 ^{EFG}	25.333 ^{HIJK}	25.786 ^{NOP}	20.973 ^{RST}
Pusa 1718	110 ^{EFGHI}	6.5 ^{G}	3.18 ^{FG}	25.5 ^{HIJ}	28.344 ^{KLM}	15.403 ^{a}

PK10683 (38.333 cm), Basmati 385 (37.167 cm), and Basmati 515 Tol-19 (34.167 cm). The lowest flag leaf length was recorded for Hossooli (21.500 cm), Alkhalid Basmati (21.500 cm), and Nonabokra (16.000 cm) (Table 2a). The heritability and genetic advance values for flag leaf length were 93.778% and 171.900%, respectively (Table 3).

3.5. Flag Leaf Width

Table 2 show the significance of the trait, drought stress application, and their interaction (Table 2). The mean width of the flag leaf was 30.436±0.504 and had a low coefficient of variation (3.44%), indicating reliable and consistent results. Basmati375 had the highest width (45.784 cm) followed by Pusa 1718 (9.1667), PK386 (9.000), and Basmati 20 (8.8333) Table 2a. Vehari, Basmati 370, and

PK8892 Tol-19 had the lowest number of tillers Table 2a. The heritability of flag leaf width was 98.951%, while the genetic advance was 244.497% (Table 3).

Graph 8.. 19 varieties showed upright panicle curvature (Vehari, Pokkoli, PK1121aromatic, Chenab Basmati, Super Gold, PK9966, Basmati 2000, PK10436, and Pusa 1718), 19 showed semi upright (Nonabokra, CSR 13, PK8892 Tol-19, Chenab Tol-19, Shaheen Tol-19, Basmati370, Super Basmati, Basmati 515, Kissan Basmati, Punjab Basmati, Super Basmati 2019, PK386, PK434, PK10683, PK10324, N22, Shaheen Basmati, Alkhalid Basmati, and OP-50), 4 showed slight dropping (Hossooli, Kalomonk, Basmati 515 Tol-19, and KS 282), and 2 showed dropping (PK10029, and PK2021).

Table 3. Genotypic variance, Genotypic coefficient variance%, Phenotypic variance, Phenotypic coefficient variance%, Error coefficient variance%, Heritability% and Genetic Advance%

Traits	M.S	G.M	GV	GCV %	PV	PCV %	EV	ECV %	h^2	GA%
PH	2077.8	107.34	682.6667	252.1875	712.4667	257.633	29.8	52.6899	0.9581735	334.089
PNL	88.07	19.262	28.75533	122.1824	30.55933	125.9567	1.804	30.60325	0.9409673	161.8628
SD	3.19862	3.0364	0.955037	56.08291	1.288547	65.14342	0.33351	33.14171	0.971135	74.29663
FLL	183.203	28.9	59.47233	143.4526	64.25833	149.1131	4.786	40.69466	0.9255194	190.0409
FLW	310.39	30.788	103.202	183.0852	103.986	183.7793	0.784	15.95759	0.99246050	242.5447
NPP	1.25	8.275	0.209	15.897	0.832	31.71	0.623	27.437	0.25132	21.059
EG	14.4699	13.65	3.017433	47.01674	8.435033	78.60987	5.4176	62.99951	0.3577263	62.28609
1000 GRAIN W	3.2615	23.502	1.0625	21.2624	1.1365	21.9904	0.074	5.6113	93.4888	28.1677

3.6. Number of Panicles per Plant

Table 2 shows the significance of the trait, drought stress application, and their interaction. The mean number of panicles per plant was 8.2745±0.07 with a coefficient of variation of 2.4%, indicating consistent and reliable results. Nonabokra, Vehari, Basmati 385, and Kalomonk had the highest number of panicles per plant, while Shaheen Basmati, PK 2021, and Pusa 1718 had the lowest (Table 2a). The heritability and genetic advance values for panicle per plant were 25.132% and 21.059%, respectively (Table 3).

3.7. 1000 Grain Weight

Table 2 show significance of the trait , drought stress application and their interactions, with a mean thousand grain weight of 23.347±0.27 and the lowest coefficient of variation of 1.08%, suggesting reliable data with highest consistency. Table 2a showed Pokkoli, Vehari, Nonabokra, and Kalomonk as highest, while Pusa1718, PK10683, KS282 had lowest thousand paddy weight. The heritability value of thousand-grain weight was 3741.134% (Table 3), with a genetic advance value of 142.473%.

3.8. Quality Parameters

3.8.1. Panicle Curvature Axis:

Panicle curvature for various rice genotypes under drought stress is shown in Graph 8.

3.8.2. Awning:

In Graph 9, 4 varieties (Nonabokra, Vehari, N22, and PK10436) show long and fully-awned, 5 varieties (Pokkoli, PK8892 Tol-19, Basmati 515 Tol-19, Basmati 385, and PK386) show long and partly-awned, 11 varieties show short and fully-awned (Hossooli, Chenab Tol-19, Shaheen Tol-19, Basmati 370, Super Basmati, PK1121aromatic, Chenab Basmati, PK10683, Shaheen Basmati, Basmati 2000, and Alkhalid Basmati), 7 varieties (Basmati 515, Kissan Basmati, Punjab Basmati, Super Basmati 2019, PK10029, PK2021, and Pusa 1718) show short and partly-awned, and 8 varieties (Kalomonk, CSR13, Super Gold, PK9966, PK434, PK10324, KS282, and OP-50) show zero-awned in drought stress.

4. Discussion

Plant height is one of most essential factors, which affects the rice growth under drought stress. With respect to plant height, sigificant differences were noted for resistance and genotypes with taller plants had higher tolerance and shorter plants were least resistant. Using moderate plant height genotypes we can utilize potential genetic variability for higher yield under drought stress in developing rice varieties. From this study it can therefore be deduced that selection for plant height is an efficient undertaking in breeding and cultivar improvement as it has above average heritability and genetic advance. The above postulates are also supported by previous research conducted in this regard (Ayele, 2011; Dhurai, Bhati, & Saroj, 2014).

As for the results of this work, it was established that panicle length as one of the characters which defines drought tolerance, plays an important role in studied genotypes of rice. The effects of panicle length on drought tolerance, as proven by the results above, can be further examined as possibly contributing to the creation of drought-tolerant rice strains. It is also evident from the high heritability and genetic advance values because, a given trait which is having high heritability can be easily selected in breeding programmes because it is a genetically controlled character. More studies have to be conducted to investigate the genetic link to this trait and to produce new rice lines with longer panicles and improved water deficit resistance. Therefore, the utilization of panicle length as a selection trait in breeding programs for rice could significantly help in the realization of food security to areas that experience dry spells most of the time (Ayele, 2011; Fahad et al., 2016; Jagadish et al., 2012).

The results revealed that rice plants' stem diameter results can be used as a reliable predictor of the level of drought stress tolerance. Phenotypes characterize by a big stem diameter are characterized by a better ability to develop a normal rate of growth even under the influence of a drought. This trait too revealed a high heritability and genetic advance which point towards the fact that it would be efficient to be included in breeding programmes for the development of drought resistant rice variety and hybrids. The information gathered from this research venture will go a long way in helping to advance a more precise knowledge about plant genetics, which in turn will help in the formulation of better practices in the breeding of crops to make them more enduring to environmental forces (Ghafoor et al., 2019; Jagadish et al., 2012).

It has been found that the length of the flag leaf is the best estimate among all the various morphological traits that are present in rice genotypes for drought tolerance. It was determined that genotypes with longer flag leaf lengths performed better and had better tolerance to drought attacks, and therefore, suitable for use in rice breeding. The high value of heritability indicates that the genetic factor is the major determinant of flag leaf length among the plants studied. Furthermore, the performance of genetic advance for flag leaf length shows that superior genotypes for this character could be harboured in advanced generations to select in future studies aimed at enhancing drought tolerance (Abarshahr, Rabiei, & Lahigi, 2011; Ayele, 2011; Dhurai et al., 2014; Jagadish et al., 2012). These findings can improve rice output and drought resilience.

Among the few helpful features that can help rice genotypes tolerate drought is flag leaf width. Its great genetic progress and strong heritability indicate that breeding stock can easily be selected for it. The genotypes with the wider flag leaf width are good sources for producing drought-resistant varieties and hybrid rice because they exhibit tolerance to the stress caused by water scarcity and, consequently, normal growth vigour. Regarding this aspect in particular, the flag leaf width, more study and breeding could help to increase grain yields in drought-stressed conditions and implement sustainable cultivation of rice (Abarshahr et al., 2011; Ayele, 2011; Biswal & Kohli, 2013; Dhurai et al., 2014).

The study conducted by A. Mishra et al. (2010) found that Since high-panicle plants were genotypically more resistant to drought stress than low panicle plants, it would be beneficial to include the former characteristics in high yielding rice varieties or hybrids for both dry like and irrigated conditions. Strong heritability values and components of genetic and phenotypic variance suggest that selection may be used effectively to improve this characteristic. Furthermore, researchers Dhurai et al. (2014) and Jagadish et al. (2012)suggested that this variation in panicle number may therefore be attributed to genetic effect from the differences in the genotypes considered in this study, they may be of importance for breeding and genetic studies in the future.

Good performers in 1000 grain weight across the genotypes possessed normal or improved plant stature under drought stress (Fageria, Baligar, & Li, 2008; Singh, Babu, Kumar, & Mehandi, 2013). The plants with the highest 1000 grain weight that has been assessed, displayed resistance tolerance which can be used towards the enhancement of cereal yield in relation to drought stress (Abarshahr et al., 2011). The heritability value also proves that the dry weight of the grain is controlled genetically to the largest extent hence high genetic improvement potential exists for the germplasm used in this study which makes it more probable for drought-tolerant varieties to be developed through simple breeding (Ayele, 2011; Dhurai et al., 2014; Jagadish et al., 2012). Therefore, this work has helped make a prediction of the gene structure of the germplasm studied for drought stress.

As the qualitative metrics showed, the genotypes had distinct patterns in the panicle curvature and awning. Unlike quantitative genes, the qualitative criteria can only be examined by looking at the physical traits of the plants found in (RAHMAN, 2020)As such, these qualitative characteristics might influence how rice grains look and appeal to consumers. Further in-depth genetic research of these traits might clarify the processes underlying appearance and their application in breeding.

5. Conclusion

It is suggested that drought stress may significantly affect the morphological characteristics of plant height, panicle length, stem diameter, flag leaf length and width, number of panicles per plant, and 1000-grain weight of various rice genotypes. The result found that these varieties like Pokkoli, Vehari, Nonabokra, Kalomonk, PK10683, and Basmati 375 rice genotypes performed better under drought stress. The results are significant for producing drought-tolerant rice cultivars to improve food security in drought-prone areas of Pakistan. The study also examined the way qualitative features like panicle curvature and awning affect rice grain appearance and consumer tastes. Overall, this research shows these varieties can be grown in drought-stress areas of Pakistan.

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