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Characterization of rice (*Oryza sativa* L.) genotypes for various Morpho-physiological and biochemical traits under moisture stress in Jammu

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Abstract
In rice, a major cereal, water stress is one of the major constraints for production and yield stability in rainfed ecosystems. In an effort to identify promising rice accessions having tolerance against water stress, fifteen rice genotypes were examined at the vegetative stage under both field and laboratory conditions during Kharif season at the Research Farm, Division of Plant Breeding and Genetics, FOA, SKUAST-Jammu, Main Campus-Chatha. A wide range of phenotypic variability was observed under moisture stress condition for most of the traits. It was high for plant height, days to 50% flowering, relative water content at 30 days after transplanting and relative water content at 60 days after transplanting. The traits, total sugars, grain yield, root length, relative water content at 60 days after transplanting showed high genotypic coefficients of variation as compared to others under moisture stress condition. Root length at 35 days after transplanting, total sugars, number of effective tillers, grain yield, plant height, days to 50% flowering, relative water content at 30 days after transplanting, relative water content at 60 days after transplanting, showed high heritability coupled with moderate to high genetic advance, indicating that these traits can be considered during selection for drought tolerance. Grain yield per plant was significant and positively correlated with days to 50% flowering and leaf area index at 60 days after transplanting. Further, it was also significant and negatively correlated with root length at 35 days after transplanting, leaf area index at 30 days after transplanting, total sugars and proline content under moisture stress condition.

Keywords: relative water content, total sugars, leaf area index, proline content

Introduction
Rice (*Oryza sativa* L.) is the staple food of more than three billion people in the world, most of who live in Asia. Presently, world's production of rice is 474 million tons per year with India alone producing about 107 million tons annually (International Grains Council: Grain Market Report, 2013). About 13% of the world's 147 million ha of rice is cultivated as rainfed rice under upland conditions (Crosson, 1995) [10] where moisture stress affects rice growth and reduces grain yield and quality (Carlos *et al.*, 2008) [8]. These areas frequently experience severe water deficit due to uncertain and uneven rainfall distribution patterns and yields are seriously affected by drought. Another 13 per cent of the rice is grown under upland conditions without any surface water accumulation and is always prone to water stress during a part of the growing season. Water is a major constituent of plant tissue as reagent for chemical reactions and solvent for translocation of metabolites and minerals as well as an essential component for cell enlargement through increasing turgor pressure (Carlos *et al.*, 2008) [8]. The occurrence of moisture stress affects many of the physiological processes such as photosynthesis and transpiration resulting in reduced growth and poor grain filling (Samonte *et al.*, 2001) [26]. Water stress parameters responsible for several metabolic processes of plants in rice have been studied by various workers (Nayyar and Gupta, 2006, Lawlor and Cornic, 2002; Yordanov *et al.*, 2003; Zhu, 2002) [23, 21, 31, 32]. Kramer (1983) [17] reported that in water stress condition the nitrogen metabolism is disturbed. A decrease in protein and increase in the concentration of amino-acids like proline, a disturbed carbon metabolism under the water stress has been reported. Due to this disturbance the starch levels generally decrease, whereas total sugar level increases. Breeding varieties for sustainable production under moisture stress conditions has always been difficult because selection becomes either impossible or inefficient in the absence of a representative drought period during the testing season (Blum, 1988) [4]. Genetic improvement of adaptation to drought is addressed through the conventional approach by selecting for yield and it's stability over locations and years. Keeping in view these facts,

the present study is being undertaken to characterize and screen the locally available/adapted rice germplasm/varieties under moisture stress conditions for various morpho-physiological and biochemical traits in Jammu.

Material and Methods

Fifteen genotypes of rice viz., Jaya, Ratna, RR-8585, Basmati-370, Saanwal Basmati, Ranbir Basmati, RR-564, Baggar Dhan, Dular, K-39, K-343, K-448, Giza, PC-19 and IET-1410 grown in pots under moisture stress condition. Fifteen genotypes of rice with three replications in a completely randomized design were grown in earthen pots of 25 cm diameter with a capacity of 7.5 kg of dry soil. The drought stress was created by restricting irrigations at different stages of plant growth *viz.*, (i) after initial establishment, at 7 days interval upto flowering, and (ii) after flowering at 14 days internal upto maturity. The soil of about 10cm depth was taken from a cultivated field for filling the pots. It was well homogenized with recommended dose of fertilizer added before filling the pots. Observations were recorded on the following traits *viz*., plant height, number of effective tillers, days to 50% flowering, relative water content, leaf rolling, leaf drying, root length at 35 days after transplanting, leaf area index, grain yield plant^{-1}, proline content according to (Bates *et al* 1973) [2], total sugars extracted by Phenol-sulphuric acid method and total proteins by micro-Kjeldhal method proposed by (Thimmaiah 1999) [27]. The data were subjected to analysis of variance by the procedures as described by Gomez and Gomez (1983) [14] and genetic parameters by the procedures described by Burton and Devane (1953) [7].

Table 1: Mean of various morpho-physiological and biochemical traits of rice (*Oryza sativa* l.) genotypes under moisture stress condition

Genotype	Plant height (cm)	Days to 50% flowering	No. of effective tillers	RWC at 30 DAT (%)	RWC at 60 DAT (%)	Root length at 35 DAT (cm)	LAI at 30 DAT	LAI at 60 DAT	*Leaf rolling	* Leaf drying	Total sugars (%)	Total Proteins (%)	Proline content (µ moles / g fresh wt.)	Grain yield per plant (gm)
Jaya	102.13	100.50	5.08	49.3	50.38	17.40	2.83	2.94	5.20	1.30	3.98	12.28	0.65	4.50
Ratna	102.20	99.70	5.29	76.33	72.17	15.60	3.78	4.85	3.20	1.30	3.64	11.23	0.67	3.30
RR-8585	89.40	103.87	7.88	74.07	73.82	19.10	2.40	3.50	5.20	1.20	1.69	12.26	0.83	2.80
Basmati 370	125.60	102.57	7.77	81.75	84.87	21.50	2.85	3.22	4.30	1.30	4.45	11.20	0.90	3.20
Saanwal Basmati	107.33	97.27	6.99	55.96	55.38	17.40	3.97	4.71	3.50	1.60	2.01	12.50	0.88	3.30
Ranbir Basmati	-	-	-	-	-	-	-	-	-	-	-	-	-	-
RR-564	116.13	92.93	4.60	65.83	58.56	13.70	4.54	5.48	3.50	1.80	2.37	11.01	0.82	6.30
Baggar Dhan	105.50	90.77	3.84	44.39	45.73	13.30	2.55	3.67	3.30	1.40	4.72	12.20	0.73	4.30
Dular	104.70	83.50	4.02	56.47	63.46	11.10	3.45	4.45	2.70	1.30	3.18	11.51	0.78	2.90
K-39	99.40	88.47	5.09	52.30	50.7	12.10	2.43	3.85	2.50	1.50	4.20	18.60	0.87	4.00
K-343	-	-	-	-	-	-	-	-	-	-	-	-	-	-
K-448	98.77	91.27	5.03	51.60	53.03	12.40	2.57	3.98	2.20	1.50	4.23	19.22	0.88	2.70
Giza	-	-	-	-	-	-	-	-	-	-	-	-	-	-
PC-19	86.93	90.93	7.07	83.06	83.43	12.90	4.34	4.96	1.20	1.30	2.21	12.17	0.67	5.00
IET-1410	85.93	92.23	5.10	90.6	81.56	9.20	2.57	4.45	1.50	1.30	0.87	12.40	0.69	4.70
C.D	3.97	2.07	0.60	3.85	4.86	1.18	0.32	0.28	-	-	0.12	0.31	0.06	0.44

Genotypes, Ranbir Basmati, K-343 and Giza were unable to survive 25 days after transplanting under moisture stress condition
* Scale of 0-9 according to standard evaluations system of IRRI, RWC = Relative Water Content, DAT = Days after transplanting, LAI = Leaf Area Index, C.D= Critical difference.

Table 2: Genetic parameters of various morpho-physiological and biochemical traits of rice (*Oryza sativa* L.) genotype under moisture stress condition

Source of variation	Plant height (cm)	Days to 50% flowering	No. of productive tillers	RWC at 30 DAT (%)	RWC at 60 DAT (%)	Root length at 35 DAT (cm)	LAI at 30 DAT	LAI at 60 DAT	Total sugars (%)	Total proteins (%)	Proline content (µ moles / g fresh wt.)	Grain yield per plant (gm)
G.M. ± S.E	102.00 ± 1.37	94.50 ±0.71	5.65 ± 0.21	65.14 ±1.33	51.54 ±1.69	11..71 ±0.41	2.55 ±0.11	4.17 ±0.09	2.5 ±0.04	12.07 ±0.02	0.78 ±0.02	3.14 ±0.15
Range Max. Min.	125.60 85.93	103.87 83.50	7.88 3.84	90.60 44.39	84.87 45.73	21.50 9.20	4.54 2.40	5.48 2.94	4.72 0.87	19.22 11.01	0.88 0.61	6.3 2.7
σ^2_g	1886.11	1560.79	6.98	914.16	866.13	46.74	2.22	3.44	2.93	35.33	0.11	3.53
σ^2_p	1891.73	1562.32	7.11	919.45	874.54	47.24	2.26	3.47	2.94	35.36	0.12	3.60
σ^2_e	5.62	1.53	0.13	5.29	8.41	0.50	0.04	0.03	0.01	0.03	0.01	0.07
h^2	0.99	0.99	0.98	0.99	0.99	0.98	0.98	0.99	0.99	0.99	0.92	0.98
GCV	42.58	41.81	46.76	46.41	57.10	58.37	58.34	44.48	68.47	49.23	42.30	59.89
PCV	42.64	41.83	47.19	46.55	57.38	58.68	58.87	44.67	68.58	49.25	44.87	60.48
GA	88.69	80.62	5.39	61.83	60.30	13.87	3.03	3.79	3.49	12.13	0.66	3.82

σ^2_g = variance due to genotype, σ^2_p = variance due to phenotype, σ^2_e = variance due to environment, h^2= heritability in broad sense, GCV = Genotypic Coefficient of Variation, PCV= Phenotypic Coefficient of Variation, GA = Genetic Advance, RWC = Relative Water Content, DAT= Days after transplanting, LAI = Leaf Area Index.

Results and Discussion

The analysis of variance (ANOVA) indicated highly significant differences for all the traits under moisture stress conditions. A wide array of traits are said to contribute towards drought tolerance in rice (Fukai and Cooper, 1995) [12]. It is suggested that selection on the basis of a single parameter may not provide true picture of genotypes response to stress and therefore atleast two or three parameters should be used for identifying drought tolerant genotypes (Tyagi and Sairam, 2002) [28]. There is a considerable range of variability among all the traits however; the range of variability for morpho-physiological traits was higher than that for biochemical traits. Similar patterns were also recorded by Khan *et al.* (2004) [16] in which highly significant genetic differences among genotypes were observed for days to flowering and yield. A wide range of variability has been observed for plant height, days to 50% flowering and relative water content. Progressive decrease in the range of variability was observed for traits like number of effective tillers, grain yield per plant and leaf area index. Total sugars and total proteins show very little variation over genotypes. These results are in agreement with observations of Courtois *et al* (2000) [9] that relative water content and leaf survival exhibit genetic variation among rice cultivars under water-stress conditions.

The overall genotypic variances ranged from (0.11 – 1886.11) under moisture stress conditions. Highest values of genotypic variance were observed for plant height (1886.11) and lowest for proline content (0.11). Phenotypic variance ranged between (0.11 – 1891.73) under moisture stress conditions. It was found highest for plant height (1891.73) low for proline (0.12). The highest genotypic coefficient of variation and phenotypic coefficient of variation were observed for total sugars (68.47, 68.58 respectively) and low for days to 50% flowering (41.81, 41.83 respectively). Similar finding for days to 50% flowering has earlier been reported by Venkateshwarlu (2001) [29], Biradar *et al.* (2007) [5], Reddy *et al.* (2013) [25]. Gomez and Kalamani (2003) [15] reported significant variation among eleven landraces for all traits especially biological yield per plant, root length and root weight during selection for drought tolerance. Heritability is good index for identification of traits. It is important selection parameter and provides clues on possible improvement (Makeen *et al.,* 2007) [22]. Under moisture stress conditions, the broad sense heritability revealed higher estimates for almost all traits i.e. plant height, days to 50% flowering, number of effective tillers, relative water content at 30 days after transplanting, relative water content at 60 days after transplanting, root length at 35 days after transplanting, leaf area index at 30 days after transplanting, leaf area index at 60 days after transplanting, total sugars, total proteins, grain yield (0.98-0.99) and moderate for proline content (0.92). The reliability of the phenotypic value depends on the estimates of heritability for a particular character. Therefore high heritability helps in the effective selection for a particular character (Dhanwani *et al* 2013) [11]. Recent studies have shown moderate to high heritability of grain yield under drought (Bernier *et al.,* 2007; Venuprasad *et al.,* 2007; Kumar *et al.,* 2008) [3, 30, 19], thus opening area for direct selection for grain yield instead of secondary traits. High genetic advance was observed for plant height (88.69) and low for proline content (0.66) under water stress. Gomez and Kalamani (2003) [15] also reported high heritability coupled with high genetic advance for plant height, biological yield per plant and number of panicle. Rice cultivars are reported to differ in their ability to produce grain under water limited conditions (Lafitte and Courtois, 2002) [9]. The traits related to decrease in photosynthetic rate under plant water stress or reduced leaf water potential has been reported to be due to increasing stomatal diffusive resistance (Barrs, 1968; Boyer, 1970) [1, 6]. High degree of leaf rolling and leaf drying (as assessed by using scale of 0-9 according to standard evaluation system of IRRI) may be due to the fact that dry atmospheric conditions can desiccate reproductive structures in rice probably because of thin cuticle and abortion (O'Toole *et al* 1984) [24]. This suggests that significant improvement in dryland performance might be possible in rice if the cuticle contained additional wax. Dissecting out the traits of importance and genomic regions influencing the response of drought tolerance and yield traits on grain yield contributes towards knowing the genetic mechanism of drought tolerance in rice. Further, the screening of genotypes performing well under moisture stress will aid the breeder towards the development of drought tolerant varieties. The results suggest that yield stability under water-limited conditions was related to less reduction in relative water content, increased leaf area index and accumulation of solutes like total sugars and proline content over a period of growth cycle.

The above findings suggest that the genotypes, K-39, Basmati-370 and RR-564 can be identified as tolerant to moisture stress condition.

With the predicted increased severity and frequency of drought occurrence in days to come, it is necessary to commit resources to develop a trained mass of drought breeders and Physiologists. Realization has to be generated among breeders to screen breeding lines under severe stress with mean yield of less than 1.5 t ha-1. Rejecting trials with high yield under drought rather than rejecting trials with low yield could strengthen regulations to conduct rainfed trials unirrigated. For rainfed drought-prone ecosystems, the most appropriate strategy would be to test yield under two situations, irrigated and severe drought, in order to select lines combining high yield under both situations. This would require additional resources to be added to the present system of testing. Proof of concept that conventional breeding based on direct selection for yield under artificially imposed drought stress can result in actual gains in drought resistance (Venuprasad *et al.,* 2007; Kumar *et al.,* 2008; Jongdee *et al.,* 2006) [30, 19, 13] needs to be introduced in breeding programs.

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