

Original Research Article

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Morphological Characterization of Different Rice Genotypes under Drought Stress Conditions

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ABSTRACT

Rice is one of the most important staple foods for the human population. More than 2000 million people obtain 60–70% of their calories from rice and its products in Asia alone. It is the grain with the second highest worldwide production. China, India, Indonesia and Bangladesh are the largest producers of rice. Climate change and global warming are two main reasons that concern sustainable food production. Drought is a major environmental stress factor that affects the growth and development of rice plants. Drought or soil water deficit can be chronic during the period of plant growth. Thus, understanding drought stress and water use in relation to plant growth are utmost important for sustainable agriculture. Keeping the severe effects of drought in mind, the present investigation was carried out in the Norman E. Borlaug Crop Research Centre and Department of Plant Physiology, G.B. Pant University of Agriculture and Technology Pantnagar, to evaluate morphological characterization of different drought tolerant rice genotype under field condition. In this experiment, 16 genotypes of rice were taken with three replications of each genotype. Two treatments were given at the time of flowering i.e., irrigated (control) and non irrigated (drought). The different observations were taken like Plant height, Number of tiller, grain yield, total dry matter, leaf area index and 1000 grain weight. Under the investigation, it was observed that plant height, total dry matter, leaf area index rest other parameters all are decreased under drought (non irrigated) condition compared to control (irrigated) condition. Therefore, morphological parameters may be used for screening of drought tolerant varieties of rice.

Keywords

Drought, Rice, Plant height, Total dry matter, Leaf area index, Grain yield, 1000 grain weight

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Introduction

Rice is mostly cultivated for direct food consumption by 3 billion people in the world. After wheat, rice is the second largest consumed crop which provides 80% calorie for world's population whereas, the consumption of rice in the world increased by 40% in last 30

years (Anonymous, 2015). It is a semi-aquatic plant and production of rice is very sensitive to drought stress (Wassmann *et al.*, 2009). Drought is the most common and complex phenomenon which can occur at any time for a long period, affecting a large array of physiological, biochemical and molecular process (Geng *et al.*, 2008). Drought stress is

the insufficiency of moisture content in the soil resulting in the reduction of growth, development and yield of rice plant (Blum, 2011). To cope up with drought stress, different morphological, biochemical and physiological adaptations are there (Tripathy *et al.*, 2000). Morphological characteristics like root/shoot length, leaf area, leaf length and width are affected by drought stress. To survive under stress there is increase in root length and decrease in leaf area. Rice plant can avoid drought stress through increased root length which helps plant to extract water from deeper soil layer and decreased transpiration rate by leaf rolling (Gouda *et al.*, 2012). Secondly, rice can escape from drought through short growth duration of genotype to avoid terminal drought stress (Bing *et al.*, 2006). Different physiological mechanisms such as osmotic adjustment (Wei *et al.*, 2014), stomatal conductance (Comstock 2002) or drought response index (DRI) are the important traits used by rice plant to avoid stress (Guan *et al.*, 2010). Rice plants affected by drought stress show increase in chlorophyll content, proline content, and total soluble content but show decrease in amylose and malondialdehyde content (Wei *et al.*, 2014). Rice can recover from drought which occur during vegetative growth but it cannot recovered during flowering stage result in reduction in grain yield (Xangsayasane *et al.*, 2014). Drought stress shows its effects at cellular level by hindering the cell division or in cell elongation, thus decreases in turgor pressure (Skoto and Muhammad, 2014). Cell elongation is more effected by drought stress causing shunted growth (Jaleel *et al.*, 2009). Thus, drought stress shows retarded development in root and reduction in photosynthetic rate by closing stomata that limits diffusion of CO₂. Due to drought conditions, there is variation in photosynthetic pigment such as chlorophyll and carotenoids which directly affect photosynthetic rate and ultimately affect economic yield (Yang *et al.*, 2014).

Drought is an environmental disaster that reduces production of rice. For crop production drought is the most limiting factor which directly affects productivity of rice and it is a very severe problem in many regions of the world (Mostajeran and Eichi, 2009). Creating drought tolerant varieties of rice is an important challenging task for agriculturist. To facilitate the development of tolerant varieties which survive and give better yields under drought conditions, a thorough understanding of the various morphological, biochemical, physiological and molecular characters that govern the yield of rice under water stress condition is a prerequisite. Eastern India is highly vulnerable to abiotic stresses such as drought, salinity, alkalinity, periodic cycles of submergence, low soil fertility, flooding and mineral nutrient deficiency. Therefore, productivity of rice in this particular area is low. A large portion of the world's farms are rain fed where the water supply is unpredictable and droughts are common. By using high yielding varieties in china and increasing chemical fertilizers the increase in yield of rice was found from 1970 to 1990 is 3.37% (Anonymous, 2005). Because of green revolution, food security in Asia has improved in past decades due to which there is increase in productivity of rice. The total rice growing area is 151 million ha of world land out of which one third area is under rainfed lowlands (Anonymous, 2005), where, rice is grown banded fields under non-irrigated conditions, only depends on natural rain. During the growing season the only cause of crop failure in rainfed lowland rice cultivation is insufficient rainfall. Because of continuous increase in global population, the demand of rice production is also increasing. It is predicted that the world's population will increase by 8 billion till 2030, therefore there is need to increase rice productivity by 40% (Bernier *et al.*, 2008). The enhancement of rice yields in drought stress has been a goal of

agricultural scientist for several decades. In present study, 16 genotypes of rice are evaluated under drought stress condition.

Materials and Methods

The present investigation was carried out during kharif 2015 at Dr N.E. Borlaug's Crop Research Centre and Department of Plant Physiology, College of Basic Sciences and Humanities, Govind Ballabh Pant University of Agriculture and Technology, Pantnager, Udham Singh Nagar District (Uttarakhand). The seeds of rice genotypes, namely, IET 22747, IET 23216, IET 23223, IET 23335, IET 23337, IET 24672, IET 24674, IET 24677, IET 24683, PHY 1, PHY 2, PHY 4, PHY 5, PHY 6, PHY 7, PHY 8, were obtained from the Directorate of Rice Research, Rajendranagar, Hyderabad. The seeds of all genotypes were sown on 15 June 2015 and the seedlings were transplanted on 6th July 2015. The drought stress treatment was given during flowering by stopping the supply of water. The control block/strip was supplied with water at regular time interval. Different morphological e.g. Plant height, Number of tillers, total dry matter, grain yield, Leaf area index and 1000 grain weight were studied during this experiment.

Results and Discussion

Plant height

The data presented in fig. 1 shows that compared to control, the plant height decreases in all the rice genotypes under drought stress. At flowering, the maximum plant height was found in PHY 8 (130.44cm) and minimum in IET 23216 (105.89cm) under control condition but during drought stress the maximum plant height was found in PHY 2 (116.0cm) and minimum was found in IET 24677 (95.36cm). The percentage reduction in plant height due to drought stress in

decreasing order as follows: PHY 4 (22.75) > IET 24677 (20.83) > PHY 8 (20.78) > PHY 5 (19.25) > IET 23223 (18.48) > PHY 7 (16.90) > IET 23335 (16.89) > IET 23337 (12.65) > PHY 6 (12.36) > IET 24672 (12.07) > IET 24683 (10.01) > IET 24674 (8.89) > PHY 1 (7.96) > PHY 2 (6.45) > IET 22747 (5.89) > IET 23216 (5.35). The maximum percent reduction (%) was observed in PHY 4 (22.75) and minimum in IET 23216 (5.35).

Number of tillers

Tillers are branches that develop from the leaf axils at each unelongated node of the main shoot or from other tillers during vegetative growth. When the fifth leaf on the main culm emerges, the first leaf of the tiller comes from the axil of the second leaf on that culm. Similarly, when the sixth leaf on the main culm emerges, the first leaf of the tiller comes from the axil of the third leaf on that culm. The data presented in fig. 2 shows that under drought stress condition the number of tillers per plant at flowering increased in 11 rice genotypes- IET 22747, IET 23335, IET 23337, IET 24674, IET 24677, IET 24683, PHY 2, PHY 4, PHY 5, PHY 6 and PHY 7, while it decreased in rest of the genotypes namely PHY 8, PHY 1, IET 24672, IET 23223, IET 23216. At flowering, the maximum number of tiller was found in IET 24672 (8.56) and minimum in IET 23335 (4.56) under control condition but during drought stress the maximum number of tiller was found in IET 24672 (7.89) and minimum was found in PHY 8 (6.01). The percentage reduction in number of tiller due to drought stress of different rice genotypes in decreasing order were as follows- PHY 8 (19.11) > PHY 1 (17.91) > IET 23216 (13.23) > IET 24672 (7.79) > IET 23223 (3.50). The maximum percent reduction (%) was observed in PHY 8 (19.11) and minimum in IET 23223 (3.50). The percentage increase in number of tiller of different rice genotypes in

decreasing order were as follows- IET 23335 (68.29) > PHY 4 (36.73) > IET 24683 (34.78) > PHY 7 (25.00) > IET 22747 (16.32) > PHY 2 (12.00) > IET 24677 (8.35) > IET 23337 (7.40) > PHY 6 (7.14) > PHY 5 (6.15) > IET 24674 (3.12). The maximum percent increase (%) was observed in IET 23335 (68.29) and minimum in IET 24674 (3.12)

Total dry matter

The data presented in fig. 3 shows that under drought stress, the total dry matter at flowering decreases in all rice genotypes. The maximum total dry matter was found in IET 24672 (2062.58 g/m²) and minimum was in IET 23335 (1208.33 g/m²) in control. The maximum total dry matter was observed in rice genotype IET 23337 (1790.83 g/m²) and minimum was in IET 24674 (728.39 g/m²) under drought stress. It was non-significant for treatment (T), but significant for genotypes (G) and T×G interactions. The percentage reduction in total dry matter in decreasing order were as follows – IET 24674 (60.62) > IET 23223 (56.14) > PHY 5 (54.67) > IET 22747 (50.77) > PHY 2 (49.03) > IET 23216 (43.55) > PHY 4 (43.23) > PHY 8 (41.44) > IET 24677 (40.95) > IET 24683 (31.54) > PHY 7 (31.24) > PHY 6 (23.36) > IET 24672 (20.70) > IET 23335 (15.67) > IET 23337 (7.77). The maximum percent reduction was observed in IET 24674 (60.62) and minimum in IET 23337 (7.77).

Grain yield

The data presented in fig. 4 shows that the grain yield per m² (g/m²) at harvest decreases in all the rice genotypes under drought stress treatment as compared to control. The maximum grain yield was observed in PHY 4 (1013.33) and minimum in PHY 8 (717.00) under control condition. It was maximum in rice genotype IET 23216 (770.00) and the minimum was in IET 24672 (363.00) under

drought stress treatment. It was statistically non-significant for treatment (T), but significant for genotypes (G) and T×G interactions.

The percentage decrease in grain yield (Economic yield) of different genotypes in decreasing order were as follows- IET 24672 (52.47) > PHY 4 (49.24) > PHY 8 (37.24) > IET 24674 (36.60) > IET 24683 (33.58) > IET 23335 (31.19) > PHY 7 (27.96) > IET 24677 (26.34) > IET 23223 (24.17) > IET 23337 (23.98) > PHY 6 (23.32) > IET 23216 (17.09) > PHY 1 (14.85) > IET 22747 (14.67) > PHY 2 (13.37) > PHY 5 (12.80). The maximum percent reduction (%) was observed in IET 24672 (52.47) and minimum in PHY 5 (12.80).

Leaf area index

The data presented in fig. 5 shows that under drought stress treatment the leaf area index decreased in all the rice genotypes. It was maximum in IET 24683 (6.49) and minimum in IET 24672 (5.09) under control condition.

The maximum leaf area index was recorded in rice genotype PHY 1 (4.80) and the minimum was recorded in IET 24677 (2.65) under drought treatment. It was statistically non-significant for treatment (T), but significant for genotypes (G) and T×G interactions. The percentage reduction in leaf area index (LAI) in different rice genotypes under drought stress in decreasing order were as follows- IET 23335 (56.02) > IET 24677 (51.99) > PHY 5 (47.56) > IET 22747 (47.32) > IET 23223 (43.89) > PHY 6 (43.31) > IET 24683 (43.25) > PHY 4 (40.86) > IET 24674 (38.75) > PHY 7 (37.28) > IET 23337 (35.94) > PHY 8 (34.24) > PHY 2 (29.65) > PHY 1 (22.64) > IET 24672 (21.77) > IET 23216 (17.89). The maximum percent reduction was observed in IET 23335 (56.02) and minimum in IET 23216 (17.89).

Fig.1 Plant height at flowering of different genotypes of rice under control and drought stress condition

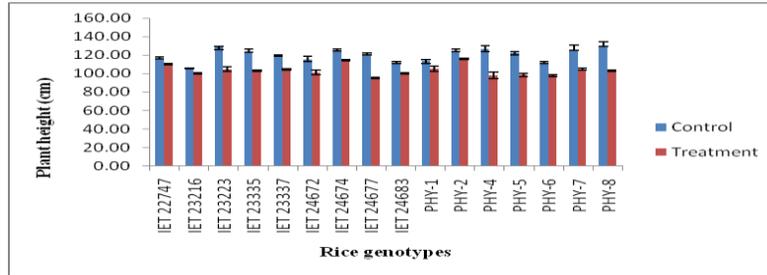


Fig.2 Number of tillers at flowering of different genotypes of rice under control and drought stress treatment

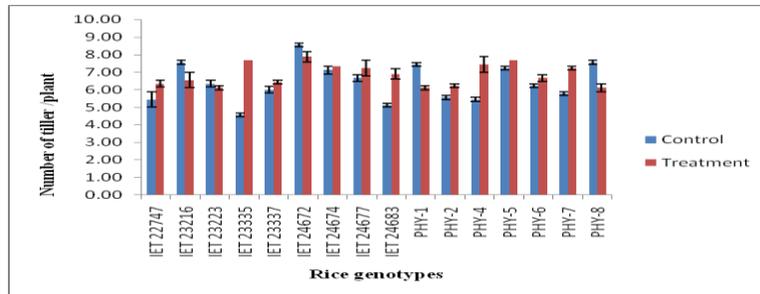


Fig.3 Total dry matter at flowering of different genotypes of rice under control and drought stress

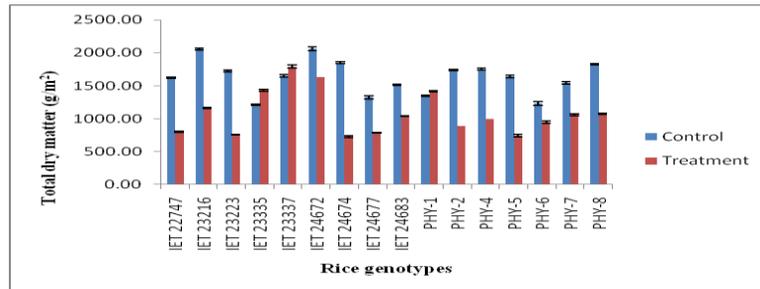


Fig.4 Grain yield of different genotypes of rice under control and drought stress treatment

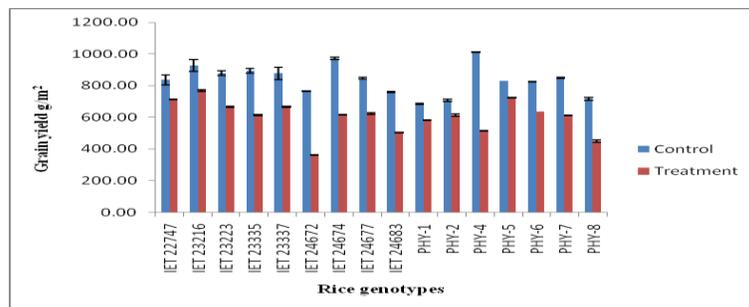


Fig.5 LAI of different genotypes of rice under control and drought stress treatment

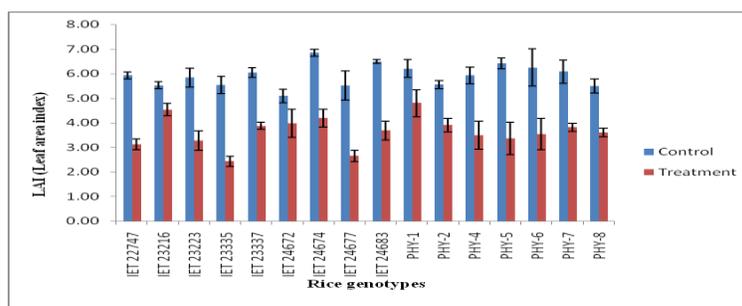
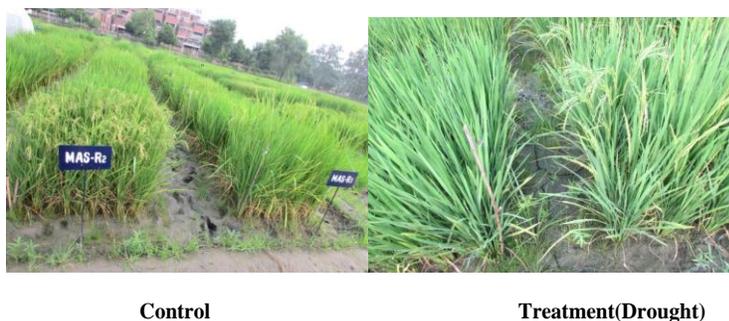
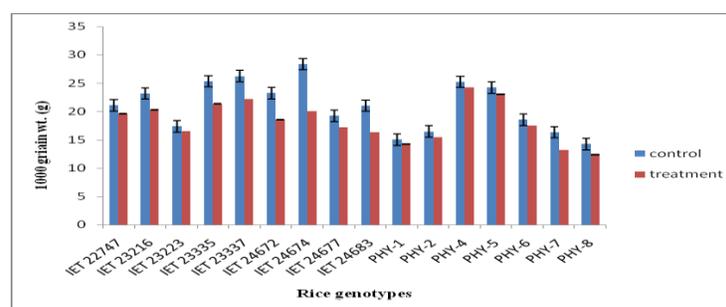


Fig.6 1000 grain weight of different genotypes of rice under control and drought stress treatment



1000 grain weight

Data presented in Fig. 6 under drought stress treatment depicts that 1000 grain weight was decreased in all the rice genotypes. It was maximum in IET 24674 (28.35 g) and minimum in PHY 8 (14.25) under control condition. The maximum 1000 grain weight was observed in rice genotype PHY 4 (24.23g) and the minimum was recorded in PHY8 (12.38g) under drought treatment. It was statistically non-significant for treatment (T), but significant for genotypes (G) and

T×G interactions. The percentage reduction in thousand grain weight due to drought stress of different genotypes of rice in decreasing order were as follows- IET 24674 (29.28) > IET 24683 (22.25) > IET 24672 (20.26) > PHY 7 (18.87) > IET 23335 (15.85) > IET 23337 (15.31) > PHY 8 (13.12) > IET 23216 (12.34) > IET 24677 (10.35) > IET 22747 (6.83) > PHY 2 (6.13) > PHY 6 (5.60) > PHY 1 (5.13) > PHY 5 (4.83) > IET 23223 (4.78) > PHY 4 (4.04). The maximum percent reduction was observed in IET 24674 (29.28) and minimum in PHY 4 (4.04).

The plant height is the most important agronomic trait of rice which is controlled by environmental conditions. Plant height is attributed to rate of culm elongation, number of internode per plant, elongation in leaf and leaf blade. The culm is composed of series of nodes and internodes. Internode elongation is closely associated with growth duration. Due to decrease in turgor pressure, cells growth is sensitive to drought stress. During division in meristematic cells, the production of daughter cells, leads to increase in cell growth. Less absorption of water by xylem during stress condition inhibit the division in meristematic cells due to which there is less production of daughter cells and ultimately reduction in cell growth (Nonami, 1998). The results suggest that as drought stress increases there is decrease in plant height. They are inversely related to each other. It might be due to the reduction in cell division or reduction in cell enlargement under drought stress (Islam *et al.*, 2001).

Drought affects expansion of growth as well as elongation of growth (Shao *et al.*, 2008) which reduces cell enlargement more as than cell division (Jiang *et al.*, 2007) and also impair number of tillers (Mostajeran *et al.*, 2009). The number of productive tillers, grain weight and spikelet sterility are the most important components of yield (Sheehy *et al.*, 2001) that are affected by different environmental factors like abiotic and biotic stress among which drought is considered to be agronomically important. Drought stress during vegetative stage reduces number of tillers. Water stress during tillering or before also reduces tiller number. Production of tillers is highly sensitive to drought stress and tiller production in rice is an agronomical important trait (Li *et al.*, 2003). Tiller number is also correlated with dry weight of panicle (Paulsen, 1987). The results show that the number of tillers per hill decreased under drought stress. The reduction in no of tillers

during drought stress might be due to the insufficient production of assimilates or may be the plant cannot carry out normal physiological activities such as photosynthesis etc. under water stressed condition (Zubarer *et al.*, 2007). Total number of tillers per plant might be increased as a result of short term high temperature during vegetative growth. The number of tillers per square meter during the early growth period was generally larger under temperature and the maximum tillering stage was earlier than under normal temperature conditions (Yang and Heilman, 1993).

Results also suggested that there is decrease in total dry matter in rice genotypes. It might be due to inhibition of photosynthetic rate. The results are in confirmation with previous workers (Hossain, 2001). The dry matter allocation in leaf blade, leaf sheath, culm and panicle were influenced greatly by drought stress. The increase in total dry matter might be due to weight increase in culm plus leaf sheath *i.e.* the partitioning increases in straw carbon. At flowering, dry weight of panicle decreased and was supposed to be induced by pollen sterility, which lead to the nutrient transport impeded at culm and resulted in the dry matter increase in culm plus leaf sheath (Guo-hua *et al.*, 2013).

At booting stage (Pantuwan *et al.*, 2002), drought stress can interrupt with floret initiation which causes sterility in spikelet and due to this there is decrease in grain yield and ultimately poor paddy yield (Kamoshita *et al.*, 2004). Water-stress decreases productivity via reducing the filling period of grain, through disturbing gas exchange characteristics of leaf, disrupting transport and loading through phloem and reducing the length of tissues of source and sink (Farooq *et al.*, 2009). Reduction in productivity might be due to decrease in rate of CO₂ assimilation, decrease in conductance via stomata, photosynthetic

pigments, short size of leaf, decreased extension of stem, reduced water status, decreased WUE, decreased in activities of enzymes which synthesize sucrose and starch, such that this leads to a decrease in yield and development of (Anjum *et al.*, 2011). Reduction in economic yield in rice genotypes might be due to the inhibition of rate of photosynthesis and reduced translocation of assimilates towards reproductive parts due to less soil moisture. The result are in confirmation with Hossain (2001) who conducted pot experiment under different level of drought and observed that grain yield decreased with decrease in soil water level.

Due to drought stress there is decrease in plant leaf and width and finally decrease in leaf area. Decrease in leaf area index under drought stress might be due to reduction in cell division of meristematic tissue. The results of the experiment are in agreement with earlier work (Hossain, 2001)

It was found that severe drought stress decreases 90% yield by affecting spikelet sterility, grain width, grain length and finally decrease in grain weight (Mohammed *et al.*, 2010). The decline in weight of grains might also be due to the drought induced reduction in leaf size, disturbed plant water relations, reduced assimilate partitioning, and finally reduction in weight of grain. (Anjum *et al.*, 2001). The reduction in grain weight depends on the duration of drought stress, drought severity and stage of crop growth (Kumar *et al.*, 2014). Similar results were recorded by (Islam *et al.*, 1994).

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