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Effect of Drought Stress on Contrasting Cultivars of Rice

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ABSTRACT: *Drought stress is a serious concern threatening food production and security. In current scenario, we need to produce water stress-resistant varieties for avoiding food security problems. In the present study contrasting cultivars of drought tolerant (Vandana) and sensitive (IR64) were subjected to drought stress in two different seasons i.e., Rabi and Kharif and were analysed in dry seeded and transplanting conditions. Morphological and agronomic traits were analyzed at vegetative and reproductive stages. Noticeably, plant height, SPAD, biomass and panicle length was positively correlated with 100 grain weight and total plant yield for dry seeded and transplanted conditions. Number of tillers and panicle weight was negatively correlated with 100 grain weight and total plant weight in dry seeded conditions while positively correlated under transplanted conditions. SPAD values were negatively correlated with total plant yield in transplanting conditions. The present study provides the information about the significant variation within drought- tolerant and -sensitive rice genotypes for improving drought tolerance in rice.*

Keywords: *Chlorophyll content, Morphological traits, Drought stress, Biomass and Yield components.*

INTRODUCTION

The rapidly growing population world-wide enhanced the usage of natural resources specially water to take care of every day demand. Shrinking of water resources, an alarming situation has created threats to sustainable crop production in different parts of the world, especially Asia, where two-thirds of the global population resides (Wallace *et al*., 2003[1] and Khush 2005[2]). The recent scenario of global climate alters, unpredictable rainfall patterns, and uneven distribution of rainwater leads to severe drought spells in rain fed areas. Altogether, these changes have already been shown to off-set a significant portion of the increases in average yields that during the past three decades arose from technology, CO_2 fertilization and other factors (Lobell et al., 2011[3]). Therefore, food security in the twenty-first century will rely increasingly on the release of cultivars with improved resistance to drought conditions and with high yield stability (Borlaug, 2007[4]; Swaminathan, 2005[5]; Pennisi, 2008[6]; Luo, 2010[7]; Tester and Langridge, 2010[8]; Reynolds *et al*., 2011[9]; Serraj *et al*., 2011[10]; Chapman *et al*., 2012[11]).

Rice is one of the most important staple food crops of the earth, accounting for more than half of global calorie intake. Rice is one of the diversely cultivated crops grown under different condition and adapted accordingly such as, grown under irrigation, on rainfed sloping upland, on rainfed plain upland, on rainfed lowland, and in deepwater conditions. It is highly likely that rain-fed rice growing areas will undergo severe spells of drought stress, resulting in a high decline in yield. Drought stress is one of the major constraints to rice production and yield stability in rain-fed upland ecology and estimates indicated that 70% of the yield losses can be attributed to drought (Bray *et al*., 2000[12]). Apart from managing water resources, genetic improvement of rice cultivars could be a good alternative to conquer the problem of drought stress. Levitt, 1972[13] classified the diverse mechanisms or strategies of drought resistance into two broad categories: dehydration avoidance and dehydration tolerance. In this respect, morpho-physiological features [e.g., deep roots, early flowering, deposition of epicuticular waxes, osmotic adjustment (OA), etc.] that enable the plant, or parts thereof, to maintain hydration are classified under dehydration avoidance. Because of drought many biochemical and physiological parameters include photosynthesis, respiration, ion uptake, respiration,

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growth hormones and nutrient metabolism are affected and it causes reduction in cell enlargement as compared to cell division (Farooq *et al.*, 2008[14]).

The development of rice cultivars that can survive under severe drought stress is desirable for sustaining rice production in rain-fed environments. The "omics" approach offers novel opportunities for yield under drought conditions. Pheonmics is an important and preliminary tool for the dissection and more target manipulation of rice cultivars under drought conditions. There is need to analyze the factor affecting the phenotypic data under drought stress.

In addition to seedling screening which is commonly used approach to determine the tolerance of genotypes against drought is the assessment of the germination ability of the seeds under induced water stress conditions. Screening with aqueous solutions of poly ethylene glycol-6000 and mannitol (Costa *et al.*, 2004[15]; Fanti and Perez, 2004[16]) aided the identification of cultivars having higher levels of tolerance to drought in rice (Pirdashti *et al.*, 2003[17]).

In the present study a comparative analysis was done for evaluation of drought tolerant attributes as morphological, agronomic, physiological and biochemical parameters in drought -tolerant and -susceptible rice cultivars. Two cultivars were assessed in two seasons i.e., Rabi and Kharif and also in transplanted and dry seeded conditions in the field developed for drought phenotyping of rice. Different seasons exhibited differential results.

MATERIALS AND METHOD

Plant material

For the current study, two popular rice varieties: a drought tolerant Vandana and high yielding IR 64 which is drought sensitive were used. The sowing was done at Directorate of Rice Research, Hyderabad, India. (78° E longitude, 17æ% 10" N latitude and 542 msl altitude) during 2010 and 2011 rice growing seasons: transplanting Kharif and dry seeded Rabi.

Types of Drought screening

Direct dry seeded condition

Each genotype was planted in two rows, with distance of 15 × 20 cm between the plants and one seedling/ hill. The plants were replicated two times in alpha lattice design with the same set of genotypes in two experiments (under normal and drought conditions). The plants were irrigated twice a week for control plots from sowing until harvesting. The drought stress was applied after 51 days of plant growth, by with-holding the water for further irrigation in drought stress field. The dry seeded field in drought conditions was irrigated when the leaf rolling symptoms were observed. Weeding was carried out every fortnight. The agro-physiological traits such as plant height (cm), tiller number per hill and chlorophyll content (SPAD) were measured. The scoring was done every three days during drought stress following the IRRI scale, based on the visual observation of leaf rolling and drying. At reproductive stage, 50% flowering and yield parameters like panicle length, panicle weight, 100 grain weight, biomass weights and total yield per plant were also recorded.

Meteorological data of Rabi

Total amount of rain fall during the duration of Rabi 2010 & 2011 experiment was 0.0 mm at both vegetative and reproductive stages. Lack of any natural rain fall resulted in crop being exposed to be severe drought stress. The different parameters recorded during 2010 Rabi season: the mean relative humidity during the experiment period was 58, maximum evaporation 8.01, wind velocity 6.2 and maximum average temperature 40.25°C. The mean of relative humidity during the experiment period was 53.28. Maximum evaporation 6.44, wind velocity 6.23 and the average maximum temperature was 39.2 °C was recorded in 2011 Rabi growing season. Based on the above mentioned meteorological data, it can be deduced that the crop had suffered severe drought stress.

Transplanting conditions

In the transplanting method of drought screening, both genotypes were initially grown in the nursery for 30 days and subsequently, the seedlings were transplanted both for study under normal as well as stress conditions at ICRISAT, Hyderabad, India during 2010 and 2011 rice growing seasons. The planting was done in single rows, following the same practices as in case of direct seed sowing. However, in this experiment, the materials were replicated two times randomly with the same set of genotypes in two sets (under normal and drought conditions). After three weeks of sowing, drought stress was imposed by using flush irrigation (surface irrigation without standing water after irrigation). Life saving irrigation was done after observing the severe leaf rolling symptoms. This process was continued till harvesting. Similar to the dry seeded method, the agro-physiological traits at vegetative and yield traits at reproductive stage were recorded.

Meteorological data of Kharif

Total amount of rainfall received during duration of kharif 2010 experiment was 36.05 mm the majority of which was recorded during July and August at vegetative stage but at reproductive stage low rain fall was recorded. Thus the plants were exposed to drought conditions. The mean relative humidity during the experiment period was 78.2, maximum evaporation 7.6, wind velocity 10.8 and maximum average temperature 34.8 was recorded. The total amount of rainfall during the duration of the experiment in 2011 was 0.2 mm. The mean of relative humidity during the experiment period was 56.3. Maximum evaporation 10.2, wind velocity 7.9 and the average maximum temperature was 38.1 °C. The average rain fall of this rice growing season was very low. Thus the crop suffered severe drought stress.

Fertilizer application

For fortification of plant growth, nitrogen fertilizer in the form of urea (95 kg per hectare) was used. Depending upon the plant nutrition requirement, 45kg of urea was used at puddling, 25 kg during tillering and 25kg at flowering stage. The soil was also supplemented with 25 kg of P_2O_5 and 25 kg of K_2O at the time of puddling in both dry seeded and transplanting conditions.

Evaluation of drought resistance

For evaluation of drought resistance in the present investigation, different indices were calculated through grain yield in two drought stress conditions, as stress sensitivity index (SSI) and relative drought index (RDI) proposed by Fischer and Maurer, 1978[18]. Tolerance index (TOL) which represents yield differ-ence between a genotype under stress and non-stress environ-ments was also computed (Rosielle and Hamblin, 1981)[19]. Arithmetic mean index or Middle Product (MP) index represented by using the yield mean of genotype in two environments was also studied. Geometric mean index (GMP) introduced by Fernandez, 1992[20] and harmonic mean index (HM) was also calculated.

RESULTS AND DISCUSSION

Analysis of drought stress under transplanting conditions

The effect of drought stress was evaluated in rice varieties of Vandana and IR 64 in two different seasons Kharif and Rabi (2010 and 2011). The analysis of variance for agro-physiological characters e.g., plant height, number of tillers per plant, SPAD, biomass, 100 grain weight and total yield in Kharif 2010 and 2011 was employed. The plant height was found to increase under drought stress for both varieties. Vandana was 1cm smaller in 2010 and 5cm in 2011 under drought stress, while IR 64 showed 3.63 cm in 2010 and 11.08 cm in 2011. Drought stress exerted highest difference for plant height on Vandana and IR 64 during both years of Rabi 2010 and 2011. Zhao *et al.*, (2010)[21] has reported that drought tolerant genotypes can be determined by measuring some traits such as yield potential, plant height in both control and drought stress conditions. There was a significant difference between the two varieties in grain yield and its components, with having higher grain yield and weight per plant. A distinct difference in grain yield among culms was found for both varieties. For Vandana, there was significant difference between biomass and plant weight (**Table 1**). For the IR 64, control had the highest grain yield and significantly higher than stress. However, there was no significant difference in plant weight (**Fig. 1**). It has been demonstrated that reduction of plant height (Zhao *et al.*, 2010)[21], number of tillers (Rahman *et al.*, 2002)[22], chlorophyll content (Hawkins *et al.*, 2009)[23], biomass accumulation (Lilley and Fukai, 1994)[24] and yield/plant (Farooq *et al.*, 2015)[25] and its components are the functions of water use by plants (Balota *et al.*, 2008)[26] as an indicator of the response of plants to water stress.

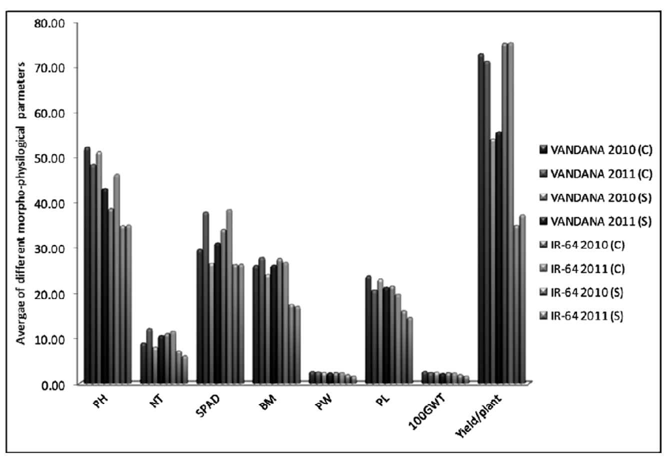

Figure 1: Comparison of plant height, number of tillers, SPAD, biomass, plant weight, plant length, 100 grain weight and yield per plants of two rice cultivars Vandana and IR-64 under transplanting conditions during two successive years 2010-11.

Table 1
Cumulative, Eigenvalue and Percent variability of different factors based on Principal Component Analysis under transplanting conditions

Varieties	*Coord 1*	*Coord 2*	*Coord 3*	*Coord 4*	*Coord 5*	*Eigenvalue*	*Percent*
VANDANA 2010 (C)	0.29909	0.42523	0.42468	-0.36075	-0.04911	2371.2	88.273
VANDANA 2011 (C)	0.29264	-0.03898	-0.57695	0.012377	0.016358	236.9	8.8191
VANDANA 2010 (S)	-0.07744	0.65989	0.036651	0.14944	-0.02787	52.741	1.9634
VANDANA 2011 (S)	-0.06139	0.036588	-0.13707	0.7005	0.3044	24.559	0.91426
IR-64 2010 (C)	0.29723	-0.51945	0.58157	0.24867	-0.02606	0.70173	0.02612
IR-64 2011 (C)	0.34921	-0.2413	-0.35443	-0.35626	-0.12022	0.10187	0.00379
IR-64 2010 (S)	-0.56663	-0.13883	-0.02244	0.015504	-0.71359	0.006546	0.00024
IR-64 2011 (S)	-0.53271	-0.18315	0.047992	-0.40948	0.61607	-3.34E-13	-1.24E-14

Table 2
Cumulative, Eigenvalue and Percent variability of different factors based on Principal Component Analysis under dry seeded conditions

Varieties	*Coord 1*	*Coord 2*	*Coord 3*	*Coord 4*	*Coord 5*	*Eigenvalue*	*Percent*
VANDANA 2010 (C)	-0.30347	-0.29262	-0.20681	0.17592	0.34746	1540.3	81.549
VANDANA 2011 (C)	-0.38375	-0.21923	-0.16181	0.22781	-0.50163	251.6	13.32
VANDANA 2010 (S)	-0.00297	-0.32799	-0.0621	-0.49903	0.53652	46.119	2.4417
VANDANA 2011 (S)	-0.00309	-0.18052	-0.18496	-0.12827	-0.43047	30.132	1.5953
IR-64 2010 (C)	-0.08708	0.74697	-0.37491	0.24684	0.24829	20.189	1.0689
IR-64 2011 (C)	-0.29997	0.36493	0.65039	-0.40543	-0.14072	0.4589	0.024295
IR-64 2010 (S)	0.73955	0.078358	-0.19837	-0.22925	-0.21849	0.021051	0.001115
IR-64 2011 (S)	0.34078	-0.1699	0.53857	0.6114	0.15905	2.13E-13	1.13E-14

Analysis of drought effect for dry seeded conditions

As experimentally designed, we followed dry seeded method in two different seasons (Kharif 2010 and Rabi 2011). The drought effect on varieties was significant with the trait of plant height, number of tillers, chlorophyll content, biomass, plant weight and plant length during both the seasons Kharif 2010 Rabi 2011. The reduced plant biomass of all lines, irrespective of tolerance, could be one of the possible causes of a relative yield decline in few drought-tolerant lines, with the onset of drought stress. Kharif 2010 and Rabi 2011 seasons have shown transgressive phenotypic significance of drought effect on both varieties for 100 grain weight and yield per plant (**Table 2**). The mean values of yield per plant ranged from 41.17 to 17.40 during Rabi 2010-11. Drought stress during cropping season directly affects the grain yield; particularly the stress at reproductive stage is most devastating (Venuprasad *et al.*, 2009a[27]; Lanceras *et al.*, 2004[28]). Water stress, at any stage, would reduce grain yield but in reproductive stage yield reduction will be more may be due to decrease in translocation of assimilates towards reproductive organs (Rahman *et al.*, 2002)[22]. The reasons for grain yield reduction with water stress mainly were decreases in the number of filled spikelets and 1000 grain weight as reported by Jana *et al.*, 1971. Rahman *et al.*, 2002[22] reported that the number of tillers per hill was decreased significantly under moisture stress at different growth stages.

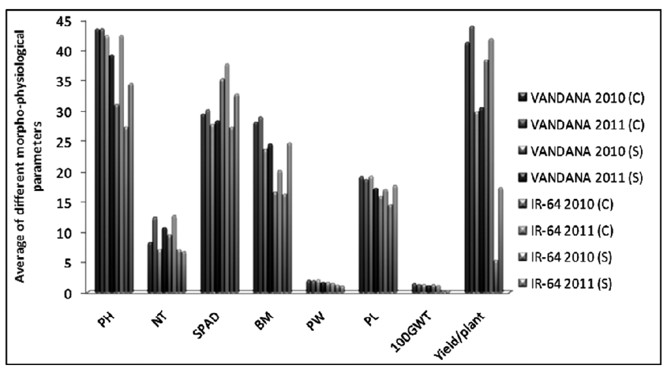

Figure 2: Comparison of plant height, number of tillers, SPAD, biomass, plant weight, plant length, 100 grain weight and yield per plants of two rice cultivars Vandana (tolerant) and IR-64 (sensitive) under transplanting conditions during two successive years 2010-11.

Principal component analysis

The principal component analysis (PCA) obtained from the morphological traits of rice genotypes, showed variation in Eigen values and proportion (Husson *et al.*, 2010)[30]. PCA axis with higher eigenvalue gives the best description of the variance observed; first two co-ordinates explained most of variations in both seasons (Kharif and Rabi) genotypes. In rabi the variation existed in successive two years was PC1 81.54 and PC2 13.32% respectively. Similarly, in khrafi the first two principal co-ordinates explain all variations of PC1 88.8% and PC2 8.2% respectively. ANOVA also indicated that the effect of drought stress was significant for yield and panicle traits in both years and significant differences were observed for yield traits between both the years under direct seeded as well as transplanting conditions.

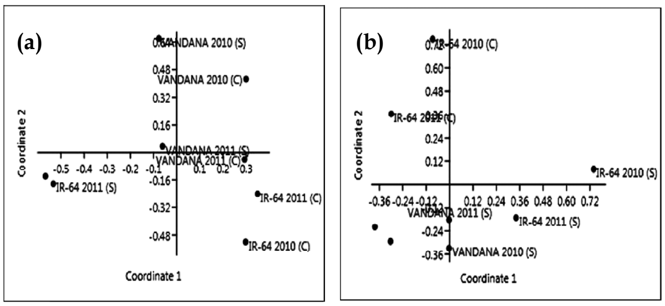

Figure 3: Principal component analysis of drought tolerant varieties (Vandana and IR-64) of two successive years of 2010 and 2011, Khrafi (a) and Rabi (b).

CONCLUSION

The drought sensitive (Vandana) and tolerance (IR 64) genotypes was evaluated by using different indices, which has provided us the prominent association among the parameters recorded. The genotypes were exposed to two different conditions of drought which has directed us to understand their potential under drought stress. The present study has illustrated that the high-yielding have proved under transplanting conditions.

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