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FORMULATING PHENOLOGICAL EQUATIONS FOR RAINFED UPLAND RICE IN BASTAR PLATEAU AND ASSESSMENT OF GENOTYPE X ENVIRONMENT INTERACTION

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Abstract

Upland rice encompasses 12 percent of global rice production area in the lowest yielding ecosystem, produced by poorest farmers with 0.5 ha average operational holdings. Due to subtle selection over long period of time, upland rice has become drought tolerant potential crop and harbors great genetic potential for future water limited rice. It has also precious traits like high pestilent insect resistant possibility and short growing season. In present investigation, 18 new genotypes were tested for upland ecology during *Kharif* 2013 and 2014, to identify promising genotypes and formulate phenological relationships at phenotypic and genotypic levels and estimate G x E interactions with uncertain weather parameters. The test populations exhibited enough variation to carry on crop breeding research however, genotypes responded differentially to water stress and late season drought with respect to morphological and yield traits. Considering secondary productivity factors (SPF), days to flowering, plant height, panicles per unit area, spikelet fertility and harvest index was observed to be major contributors for water scarce survivals. Biased selection for earliness cause reduction in grain yield due to shortened vegetative phase hence, research is to be focused to minimize the yield penalty associated with earliness. Among the genotypes evaluated, IR-83381-B-B-137-3 and IR-86857-46-1-1-2 was found to be promising for rainfed breeding programme as parent material. Based on results of farmer's field and station trials, existing upland rice variety CR 40 is concluded as promising for upland ecology and will be crucial to uplift the economy of poor and marginal farmers of Chhattisgarh.

Key words: Upland rice, Rainfed ecosystem, Stress physiology, G x E interactions.

Introduction

Rice and depleting water level: Rice is the cereal food stuff which forms an important part of more than three billion people's diet around the world (Shrivastava *et al*., 2014). The potentially yielding ability of currently available rice varieties has to be increased twice by 2020 to meet the existing demand through utilizing valuable yield genes and genes containing resistance to biotic and abiotic stress (Kanbar *et al*., 2010; Fisher *et al*., 2012). Rice is cultivated in highly diverse situations that range from flooded wetland to rainfed dryland (Degenkolbe *et al*., 2009). Irrigated rice, which accounts for 55% of the global rice area, provides 75% of production and consumes about 90% of the freshwater resources, used for agriculture in Asia (Sandhu *et al*., 2013). Since, water requirement for rice cultivation is quite higher i.e. 2500 litres to produce 1 kg of grain (Bouman *et al*., 2007), and is expected that rice production will be decreased due to water stress in many Asian countries (Shrawan *et al*., 2012; Guimarães *et al*., 2013), affecting more than 19 millian ha (Lifitte *et al*., 2006). Higher water requirement is probably due to large area of lowland long durational irrigated rice. Thus it's necessary to opt for varieties requiring limited water (Matsumoto *et al*., 2014) to sustain food security in climate change era.

Upland rice: New challenges and opportunities: Rice production in Asia has witnessed 2.6 times gain since 1961, preliminary result of green revolution which dramatically increased the rice productivity in high input irrigated system. However, the rainfed rice which occupies 32 percent of Asian rice growing area has benefitted less from green revolution (Jambhulkar & Bose, 2014). Upland rice is grown in unpuddled fields where, by default, good soil drainage and uneven land surface renders the accumulation of water impossible. Upland rice ecology is much harsh environment for rice production where intermittent moisture deficit is the major constraint (Hanamaratti *et al*., 2005) and cause a yield penalty from 12 to 46 per cent (Oak *et al*., 2006). It is grown with little or no fertilizer input with direct seeded methodology in moisture deficit unsaturated soils (Aditya & Bhartiya, 2013). Further, poor ability of varieties to produce economic quantity of grain, due to the concomitant poor panicle yield, caused by varying degrees of water stress, makes rice production risky and unattractive due to low yield of 1 to 2 tones/hectare (Atlin *et al*., 2006; Adewusi & Nassir, 2011). Looking for current and predicted water scarcity, increasing irrigation is not a viable option to alleviate drought problems in rainfed rice growing system (Fischer *et al*., 2012). Therefore, genetic management strategies should be undertaken for cultivating rice with less water and maximizing extraction of soil moisture and its efficient use in crop establishment and growth to enhance biomass and yield.

This paper attempts to define the current status of breeding for upland rice. Genetic and physiological mechanism contributing to maintain grain yield under upland conditions are discussed along with prevailing genotypic and environment interactions which is of utmost significance among unpredictable micro and macro environments.

Materials and Methods

Simulation of upland environment and experiment: The experiment 01 was undertaken with 18 genotypes under rainfed conditions during *Kharif* 2013 and *Kharif* 2014 at Upland Rice Breeding Block of S. G. College of Agriculture and Research Station, Jagdalpur, IGKV, Raipur, Chhattisgarh. An upland ecology simulation model was created by choosing experimental plot where no water accumulates and cent percent rainfed treatment was given during entire life cycle of crop. Sowing was completed by just onset of monsoon by direct seeding in agronomically standardized geometry in 10sq M plot with two replications. Trench was made in periphery of experimental plot to avoid no water accumulation. The data was recorded for 10 quantitative characters namely days to flowering, crop duration, plant height, and panicles per sq M, panicle length, spikelets per panicle, spikelet fertility, grain yield, biological yield and harvest index. In experiment 02 twenty three national released varieties and promising genotypes were evaluated to indentify suitable variety for Bastar plateau. The trial consists of two environments and two locations in SGCARS, Jagdalpur and village Tandpal (District Bastar) under fully rainfed farmer's agriculture.

Statistical Assessment: The mean over replication of each character were subjected to statistical analysis. Pearson's correlation coefficients were calculated and data was analyzed using unweighted paired group method using cetroids. Cluster analysis was done using to yield dendrogram depicting the morphological relatedness among upland rice cultivars. Principal component analysis was also used to detect the underlying source of morphological variability. For statistical analysis software Window State Version 9.1 was used.

Results and Discussions

Assessment of entries: The potential of upland ecology for rice production is limited by occasional cessation of rainfall, spanning for days to weeks (Kamoshita *et al*., 2008; Abarshahr *et al*., 2011). Occurrence of water stress at vegetative state has relatively lower negative impact on grain yield than occurrence at the reproductive stage where grain yield is reduced by up to 30 percent (Nassir & Adewusi, 2012).Hence, if soil moisture begins declining after soft dough stage, crop will finish its growth without significantly alteration in grain yield. However, when stress is imposed at milking and hard dough stage, spikelet fertility and chaffiness (Asch *et al*., 2005; Botwright *et al*., 2008; Yue *et al*., 2006) will reduce the final yield (Jun *et al.*, 2000; Yang & Zhang, 2006). In present investigation, entry R-RF-95 flowered earliest among all (75 and 79 DAS) (*Kharif* 2013 and 2014 respectively) and accordingly had smallest plant height (106 and 76 cm). It recorded 275 and 285 panicles per square meter with 20 and 21.4 cm average panicle size. However, number of spikelet was less per panicle (82 and 68) and spikelet fertility was 85.5 and 89 percent. Genotype PM-6004 recorded maximum grain yield (2.9 and 2.86 kg/plot) with comparative higher spikelet fertility (93.50 and 97 %) and 42.5 percent harvest index. Entry IR-84887-B-15 with 106.25 cm plant height, 272 panicle per unit area, 84 grain per panicle and 89.25 percent spikelet fertility, yielded 2.74 kg/plot. The harvest index was 40.25 percent. Sahbhagidhan, the check variety, has optimum plant height (92.5cm), panicle length (21.60cm), high spikelet per panicle (93) and spikelet fertility (94.5%) but had lesser number of panicles per unit area (227) and lower harvest index (35.75%) reduced the grain yield. Among the entries evaluated, IR-83381-B-B-137-3, IR-86857-46-1-1-2 and IR-84857-46-1-1-6 found to be promising for rainfed breeding programmes as parent material. The frequency distributions of biennial experiment have been depicted in Fig. 1.

Milking stage > soft dough stage > hard dough stage

During the late season water stress, the capacity of assimilate transmission into seeds increases and is considered as useful physiological phenomenon under drought stress conditions (Singh, 2003). Moreover, the amounts of assimilate transferring from stems and leaves to filling grains will increase parallel with drought stress (Kumar *et al*., 2006). Therefore, crop should surpass at least milking and soft dough stage prior to soil surface begins to dry. Present study reveals that beyond the most appropriate agronomic practices that enable plants to better use soil water, need is bred for genotypes with greater capacity to adapt under irregular rainfall and able to maintain better plant water status, especially when stress occurs around flowering and grain formation (Fukai *et al*., 2008), since leaf and panicle water potential are very highly associated with panicle exertion and anther dehiscence (Guimarães *et al*., 2013).It can be concluded that, while undertaking upland breeding, panicles per unit area, number of spikelet per panicle, spikelet fertility and harvest index are important secondary yield parameters. Under monsoon seizing drought spikelet fertility should be above average while maintaining harvest index maximum.

Secondary productivity factors (SPFs) in expression of yield: Grain yield is the end expression of genotypes with respect to economic dry matter. Amount and extent of dry matter production is a unique feature genotype and to produce higher unit yield it has to produce some secondary productivity factors (SPF) like higher numbers of panicles, lengthy panicles, higher spikelets etc. Moreover, genotype can have optimum SPFs but may not yield higher because of micro and macro environmental contributions. Therefore, it's necessary to indentify SPFs accurately and validate role of genetics and environment in determination of yield pathway. Further, upland rice accentuated by the unpredictable genotypic performance in many rice growing regions (Samonte *et al*., 2005; Atlin *et al*., 2006; Nassir & Ariyo, 2011). Direct selection for yield has been the most commonly used selection strategy by cereal breeders to improve yield in water limiting environment (Araus *et al.*, 2002; Banziger *et al.*, 2006). Nonetheless, several secondary traits associated with the understanding of stress tolerance and the effects crop yields have also been identified and studied to some extent (Price *et al*., 2002; Kumar *et al.*, 2008).Therefore, Genotypic, phenotypic and environmental correlations were worked out to ascertain these factors and external contribution.

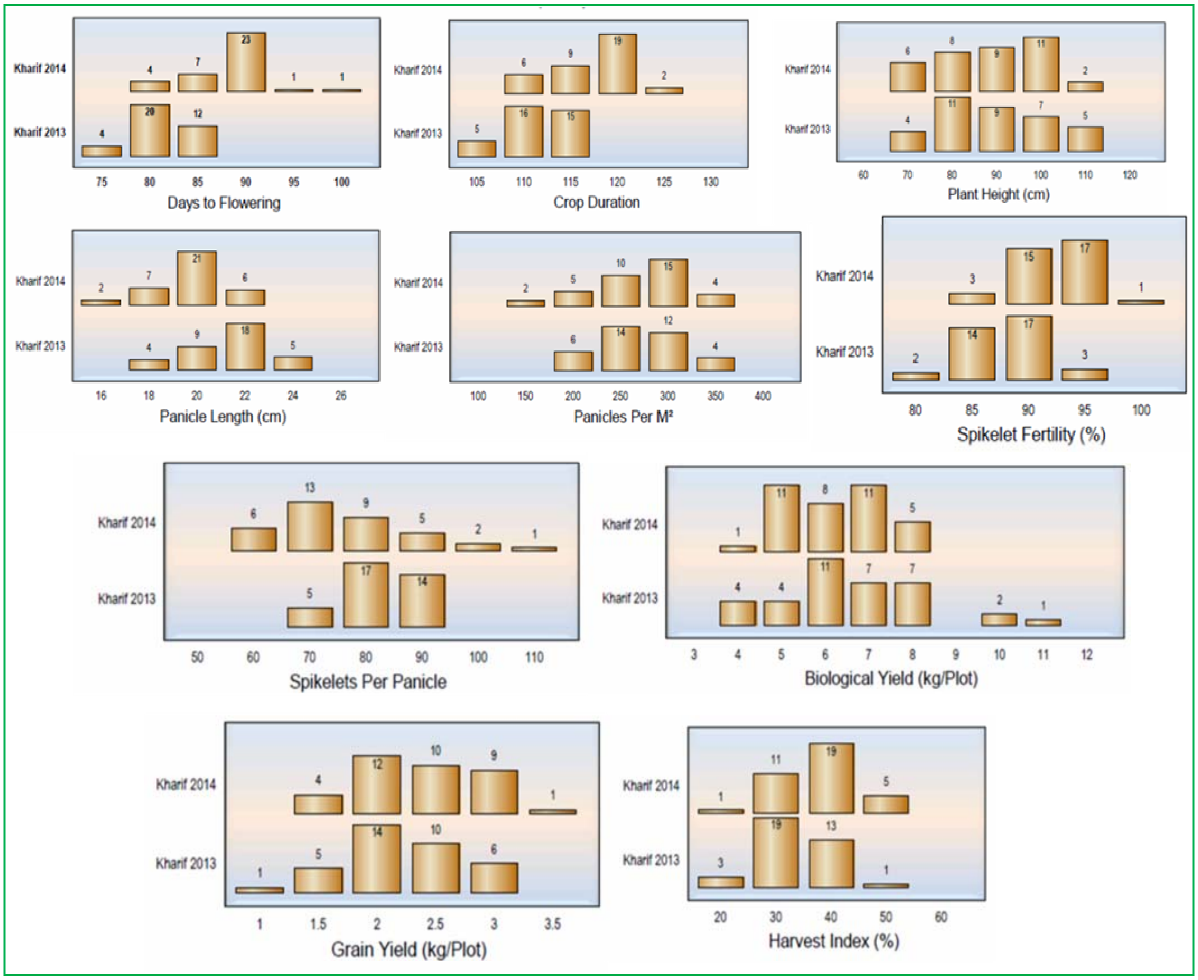

Fig. 1. Frequency distribution of biennial experiment.

Days to flowering was found to be negatively associated with grain yield (Figs. 2 & 3) (-0.1941, -0.2986*, -0.2586 for 2013, 2014 and pooled over environment respectively) and is quite interesting in upland rice research. In irrigated rice it has positive association with grain yield due to availability of lengthy preflowering span however; in rainfed ecology biased selection for earliness makes the association negative (Lanceras *et al.,* 2004). Spikelet fertility is found to be positively linked with prolonged vegetative growth (0.0255, 0.5682**, 0.2685*) because of ample supply of food material. Plant height was observed to be very important in operating grain yield via panicle length (0.2518, 0.3233*, 0.2841*), spikelet per panicle (0.2821*, 0.5840**, 0.4737**), spikelet fertility (0.5058**, 0.4560**, 0.4756**) and biological yield (0.3972**, 0.2383, 0.3181**) (Agbo & Obi *et al*., 2005). Greater plant height improves panicle productivity and produce deep root system which aids in moisture interrupt survival. However, negative association of plant height with grain yield has also been reported earlier (Lafitte *et al.,* 2006) because, usually, rice genotypes with greater plant height often produce large plant size, intercept more light and use water faster by transpiration, leading to rapid depletion in plant water status (Kamoshita *et al*., 2004), higher dead leaf scores, and more spikelet sterility (Kato *et al*., 2007). Spikelet fertility recorded positive association with days to flowering (0.1242, 0.4490**, 0.2896*), crop duration (-0.0255, 0.5682**, 0.2685*), plant height (0.5058**, 0.4560**, 0.4756**) and spikelets per panicle (0.1644, 0.4779**, 0.3259**).

Grain yield was positively and significantly associated with total crop biomass (0.6669**, 0.6122**, 0.6185**), plant height (0.5059**, 0.4145**, 0.4541**), days to flowering and crop duration (Manna *et al.,* 2006; Eradasappa *et al.,* 2007). Information on inter association of yield components showed nature and extent of their relationship with each other. This will help in simultaneous improvement of different characters along with yield in breeding programmes. Harvest index (HI), measurement of photosynthetic efficiency of genotypes, is among the critical parameters for upland rice breeding. Higher HI estimates assures the linear partition of carbon assimilates to panicles (Chakraborty & Chakraborty, 2010). As per theoretical background, HI was found to have negative relationship with days to flowering and crop biomass since prolonged vegetative phase cause the crop suffers from monsoon switch drought. In rainfed scenario it’s mandatory to opt for genotypes which have discriminate formation and translocation of carbohydrate.

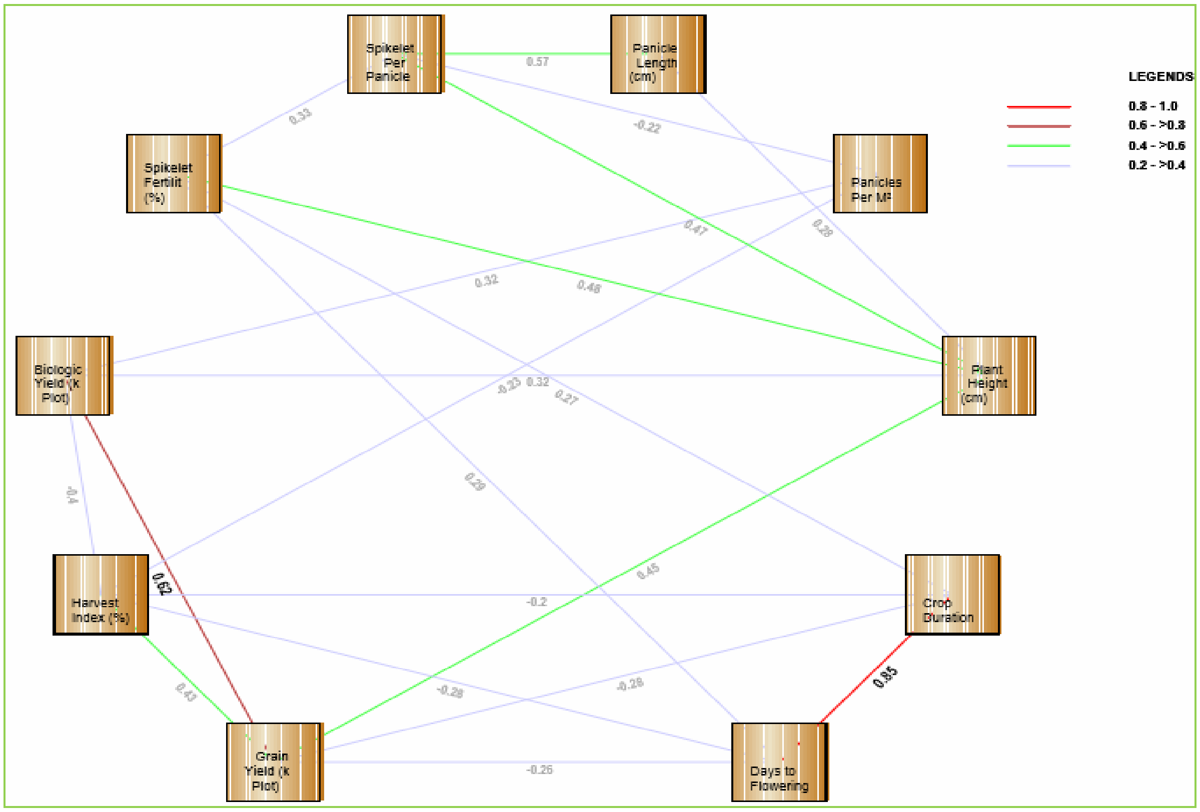

Fig. 2. Character association among upland rice parameters.

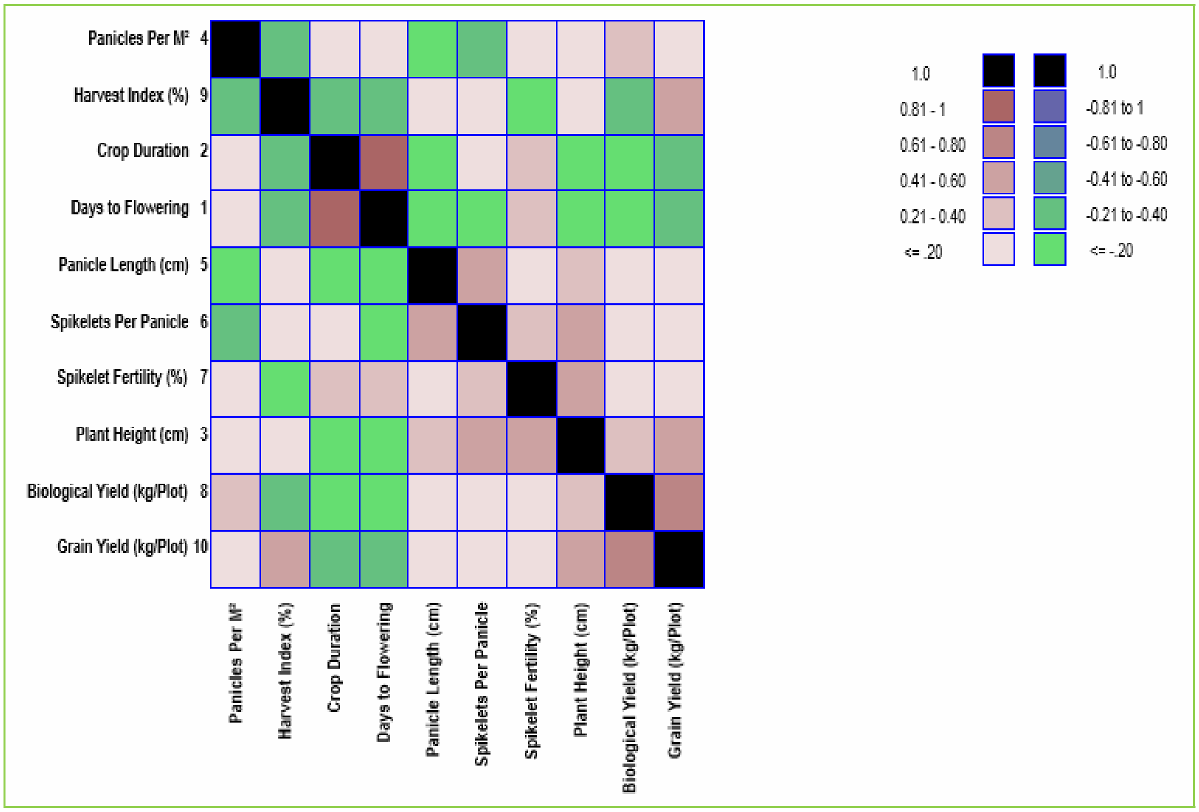

Fig. 3. Shaded correlation matrix.

Partitioning of direct and indirect effect: From the above study it was clear that, secondary traits were affecting grain yield but it was necessary to find out whether they influence yield directly or via other characters. Panicles per square meter do not have effect on yield per se, but alters the yield significantly via days to flowering, crop duration, spikelet per panicle and biological yield. In present study, biological yield has maximum direct effect on grain yield (Fig. 4) (0.9485) and indirect effect was 0.2200 mainly due to plant height (0.3018), panicles per square meter (0.3071) positively and harvest index negatively (-0.3788). Hence, biological yield should be higher in upland genotypes, which will in turn increase plant height, panicle length. HI had maximum direct effect of (0.6824) and indirect effect was majorly contributed by biological yield (-0.3310), days to flowering (-0.2331) and crop duration (-0.1668) (Srivastava *et al*., 2014). The residual was 0.2530 indicating lesser effect of other factors than under study. Regression coefficient was recorded to be 0.9360. Higher and negative effect of most of the traits shows that genotype should have optimum genetic regulation over canopy reproductive factors.

The study summarizes biological yield and harvest index as major yield determining factors. However genotype should have such genetic makeup to utilize photosynthates in economic fashion. The lower values of residual effects reveals that there is more effect of crop phenology by physiological and biochemical reactions and buffer to internal and external stress environments. It's very important that genotype should able to attain its optimum growth even under fluctuating moisture level.

Assessment of level of diversity: Development of variety from limited genetic resource have laid the lowering down of genetic diversity in modern cultivars (Guang & Xiong-Ming, 2006; Ahmad *et al*., 2012). Earlier worker have reported the presence higher diversity in exotic germplasm (Lacap *et al*., 2007) therefore, entries from diverse geographical origin *viz*., IRRI, Phillipines, IGKV, Raipur and other sources were incorporated in upland research programme. To discern pattern of variation, PCA was performed in all genotypes simultaneously (Fig. 5). Eigen values well represented the variation accounted for principal components and eigen vectors indicating the correlation among principal components. First five principal components exhibited more than one eigen values and accounted 82 percent of total variation comprised of 38.95 (PC I), 20.80 (PC II), 14.67 (PC III) and 10.69 (PC IV). The characters with high variability are expected to provide high level of genetic gain during further breeding programs (Aliyu *et al*., 2000; Gana, 2006, 2013). Days to flowering, panicles per square meter, spikelet fertility and biological yield were identified as traits for maximum variability. Among the genotypes 1st PC was related to days to flowering, panicle per unit area and spikelet fertility while 2nd PC was associated with plant height, panicle length and spikelet per panicle.

On the basis of Ward's linkage cluster analysis five clusters were formed to identify relative genetic closeness of test genotypes (Chakravarthi & Naravaneni, 2009; Sohrabi *et al*., 2012; 2013). Cluster II and III harbored maximum of five genotypes (Fig. 6) while cluster V two IRRI genotypes assuring comparative diversity of exotic material. Score plot results of combined analysis of all genotypes substantiated the results that accessions have sufficient genetic diversity with scattered position of genotypes across the plot. Genotypes 01, 03 and 17 had maximum distance from other genotypes indicating to be most distinct one.

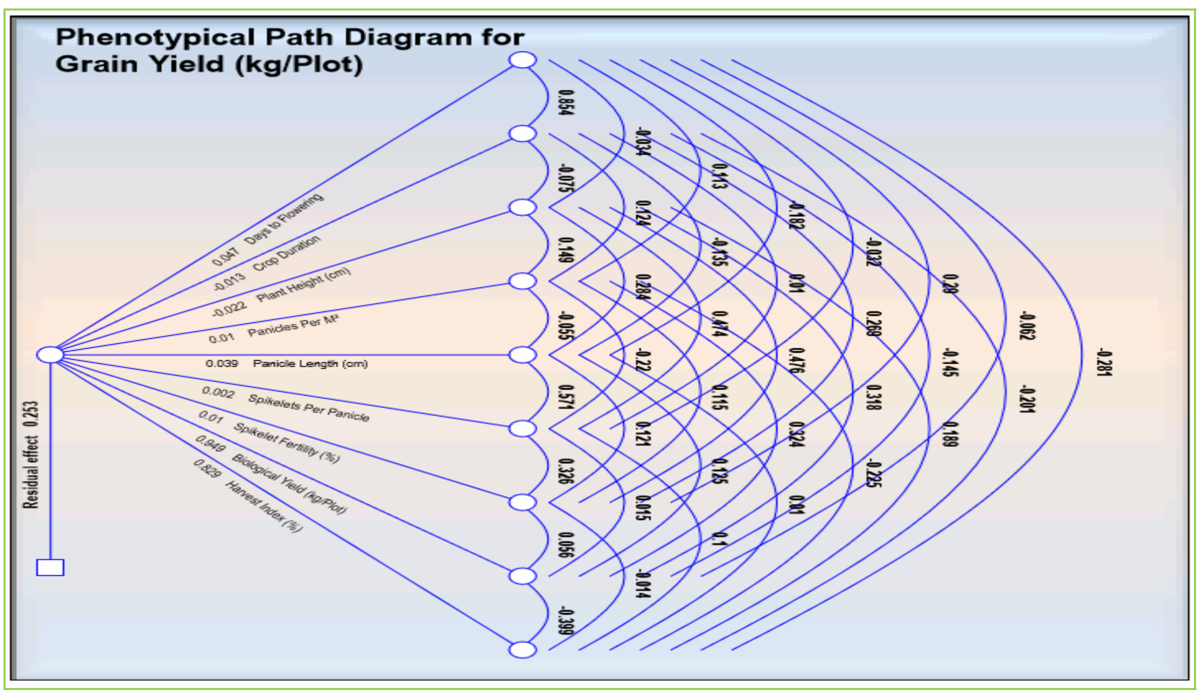

Fig. 4. Cause effect relationship.

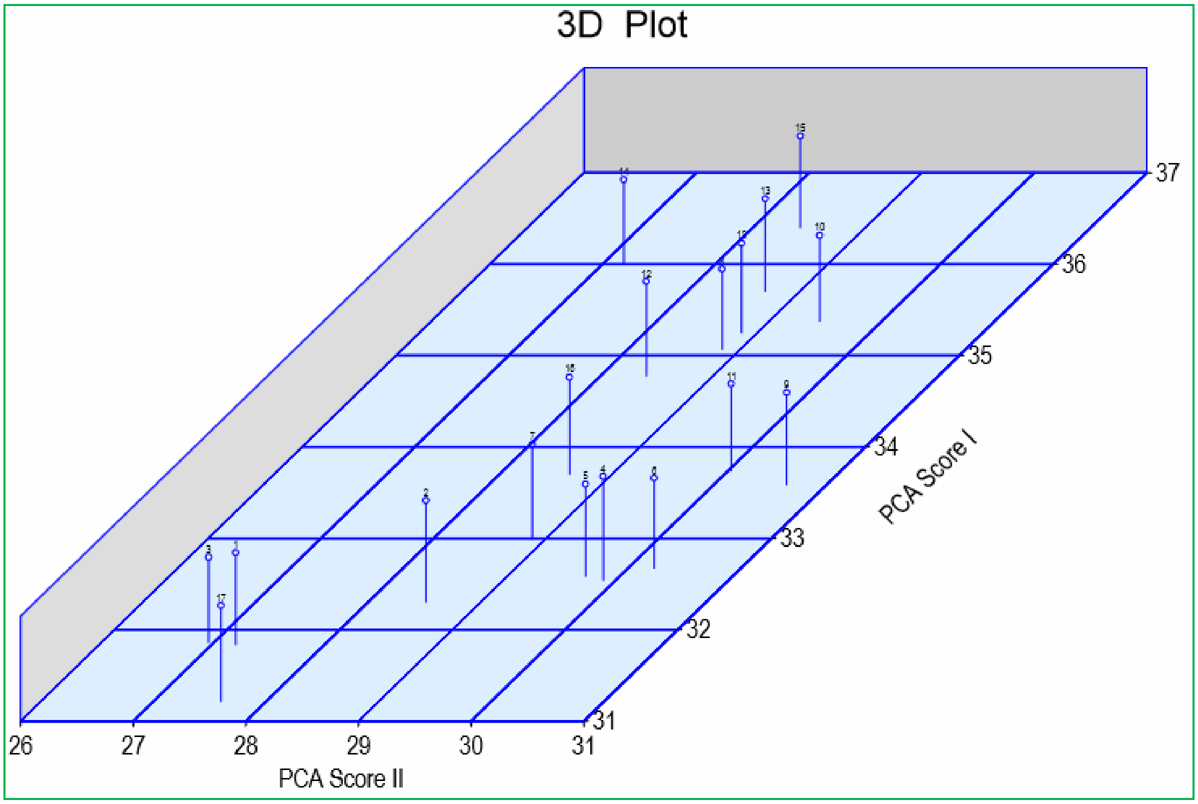

Fig. 5. PCA analysis 3D plot.

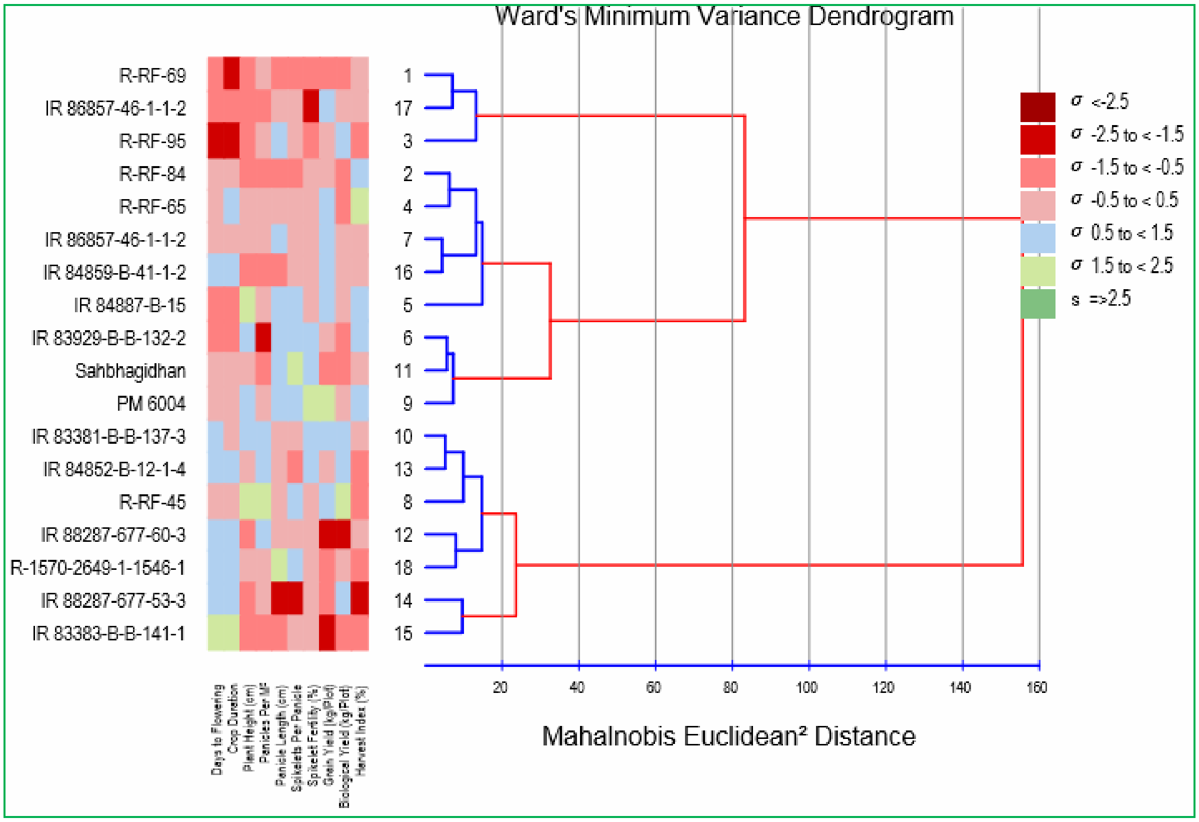

Fig. 6. Clustering pattern among genotypes.

Genotype x environment studies-biplot analysis: With the inherent variability of upland rice ecologies for moisture levels, and the attendant interaction with environment for several traits, varieties and traits identified as having the potential for drought tolerance in a location may not necessarily exhibit consistency overtime and or over a large area (Nassir & Ariyo, 2006, 2007; Botwright *et al*., 2008). Therefore, an attempt was made to assess interaction of genotype and environment based on biennial (*Kharif*, 2013 and 2014) experiments. The use of biplots to quantify the genotype environment interaction (IGE) is widespread since the GE effects can be visualized in a single graph, which facilitates the comparison of genotypes and their interaction with the environments (Balestre *et al*., 2010). Recently, the IGE analysis using biplots similar to the AMMI technique, which has the advantage of decomposing the joint effect of genotype (G) and GE (G + GE) by principal component analysis, has been evolved that differing from the original AMMI analysis that decomposes only GE (Yan *et al*., 2000, 2007; Gouch, 2006). The method is called GGE biplot analysis which identifies G x E interaction pattern of multi-environment data and clearly shows which variety performs best in which environments (Lakew *et al*., 2014).

In present study, the first principal component axis (IPCA 1) explained 38.95% of total variation while IPPC2 explained 20.80%. Thus, the two axes together accounted for 59.75% of the GGE variation for grain yield (Balestre *et al*., 2009a; 2009b.According to the biplot, genotypes PM 6004, IR 84887-B-15 and IR 83381-.B-B-137-3 were recorded vertex position (Fig. 7). These genotypes were the best or the poorest genotypes in some or all of the environments because they were farthest from the origin of the biplot (Yan & Kang, 2003). In this biplot, environments are also divided into different sectors. The first sector represents environment A, B and D; with genotype IR 83381-.B-B-137-3 as the best yielder genotype and the second sector represents C; with genotype IR 84887-B-15 as the most favorable while the third sector represents C; with genotype R-RF-95 as the winner genotype. The other vertex genotype, R-RF-45 which was located far away from all of test environments, implied that it did not yield well at any of the test environments. In multienvironmental graph for grain yield revealed that all genotypes followed approximate similar pattern except for R-RF-45, R-RF-95 and R-RF-65R which showed considerable alteration in grain yield. In the year 2013, grain yield was higher for almost all genotypes (Figs. 8 and 9). However, biological yield varied significantly with environment but followed similar genotypic pattern. Thus, despite of reduction on crop biomass, physiological buffering capacity of maintained the grain yield.

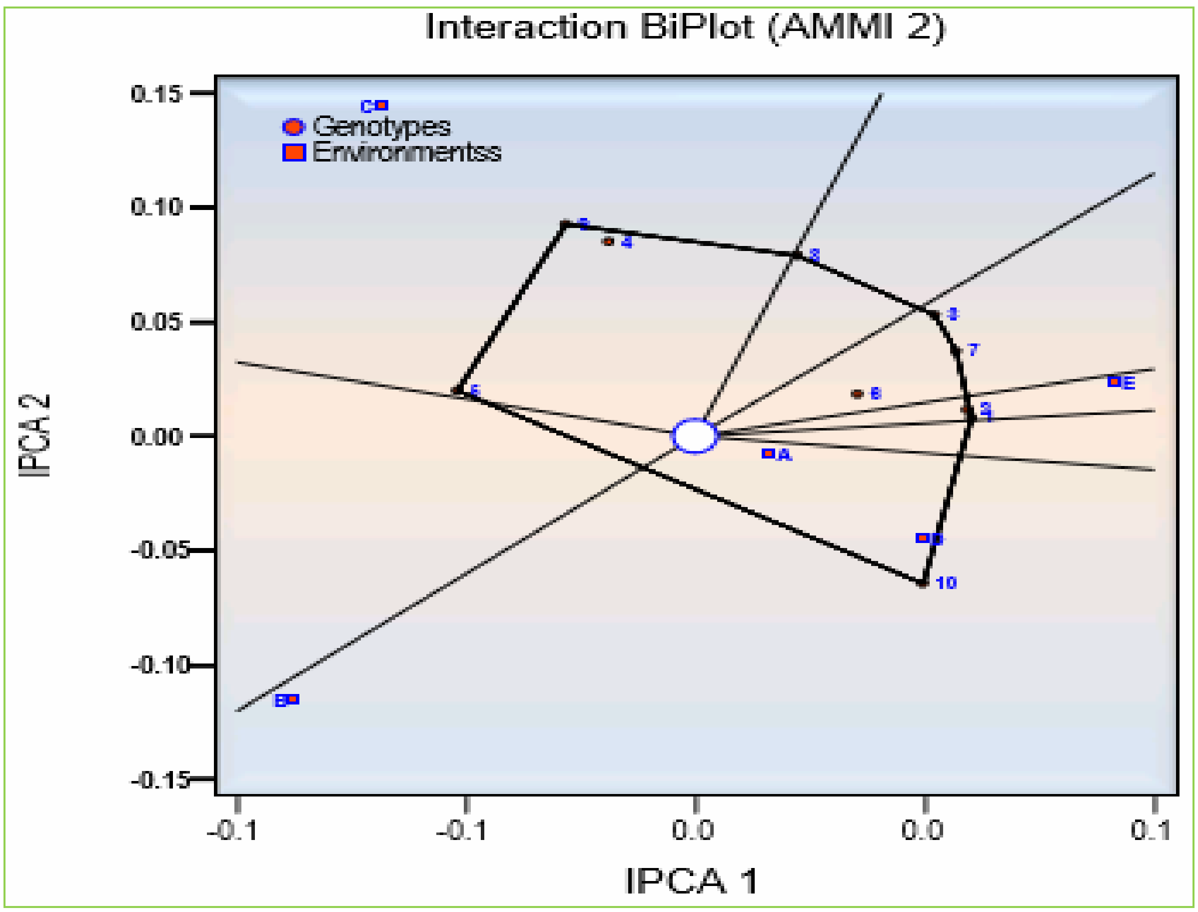

Fig. 7. Biplot analysis.

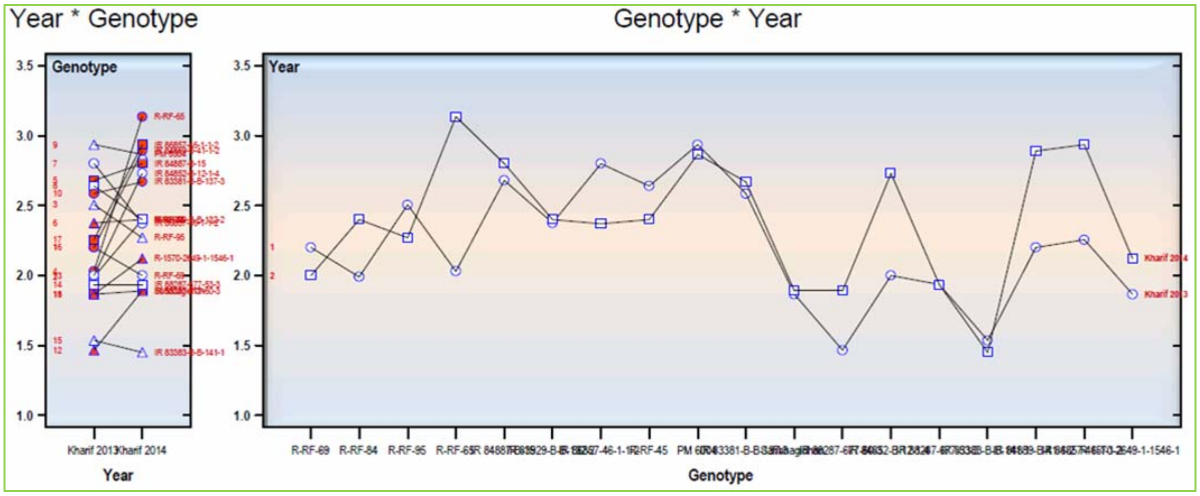

Fig. 8. Grain yield in *Kharif* 2013 and 2014.

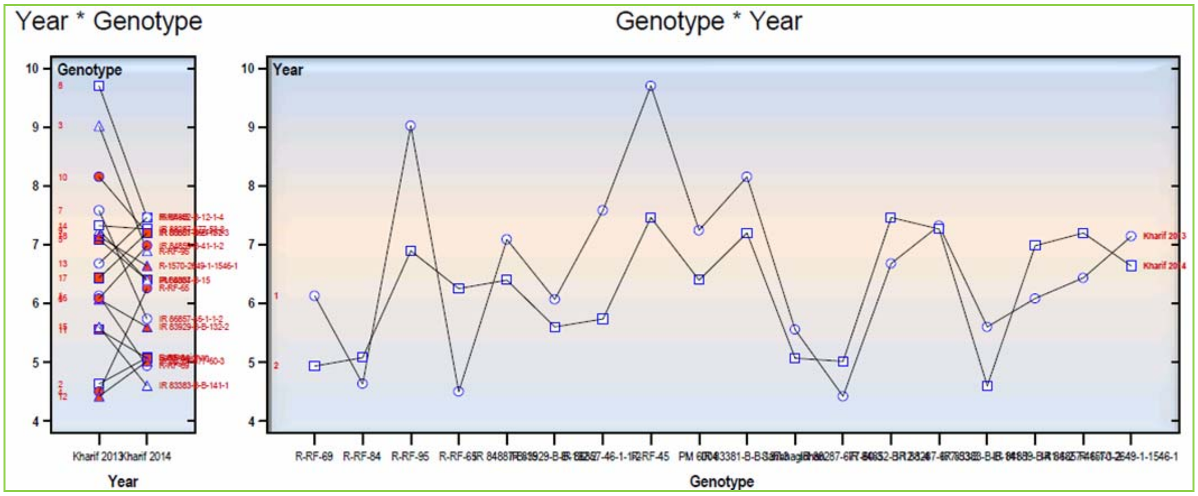

Fig. 9. Biological yield in *Kharif* 2013 and 2014.

Conclusion

Shortage of water instigated a reduction in assimilate availability between panicle initiation and anthesis and between anthesis and maturity, culminating into negative effects on grain yield. Over the years, research reports have shown that rice reacts to drought stress with reductions in height, leaf area and biomass production, tiller abortion, changes in root dry matter and rooting depth, particularly deep rooting and a delay in reproductive development, especially flowering. The development of drought tolerant varieties for good level grain yield under conditions of water stress has received some amount of research attention. Direct selection for yield under drought conditions may not be particularly rewarding and preferred laying emphasis on traits related to drought tolerance. Traits including continued early flowering, early maturation, and increase in harvest index and reduction in plant height have been associated with moisture stress tolerance in upland rice.

Reference

Abarshahr, M., B. Rabiei and H.S. Lahigi. 2011. Genetic variability, correlation and path analysis in rice under optimum and stress irrigation regimes. *Not. Sci. Biol*., 3(4): 134-142.

Adewusi, K.M. and A.L. Nassir. 2011. Assessment for drought adaptive and reproductive traits of field-planted upland rice genotypes in a derived Savannah ecology. *J Pl Breed and Crop Sci*., 3(11): 283-292.

Aditya, J.P. and A. Bhartiya. 2013.Genetic variability, correlation and path analysis for quantitative characters in rainfed upland rice of Uttarakhand hills. *J. Rice Res*., 6(2): 24-34.

Agbo CU and Obi IU. 2005. Yield and yield component analysis of twelve upland rice genotypes. *J. Agri. Food Env. and Ext*., 4(1): 29-33.

Ahmad, M.Q., S.H. Khan and F.M. Azhar. 2012. Decreasing level of genetic diversity in germplasm and cultivars of upland cotton (*Gossypium hirsutum*) in Pakistan. *J. Agric. Soc. Sci*. 8: 92-96.

Aliyu, B., M.O. Akoroda and S. Padulosi. 2000. Variation within *Vignareticulata. Hooke FII Nig. J. Gene*., pp. 1-8.

Araus, J.L., G.A. Slafer, M.P. Reynolds and C. Royo. 2002. Plant Breeding and Drought in C3 Cereals: What Should we breed for? *Ann. Bot*., 89: 925-940.

Asch, F., M. Dingkuhn, A. Sow and A. Audebert. 2005. Drought-induced changes in rooting patterns and assimilate partitioning between root and shoot in upland rice. *Field Crops Res.*, 93: 223-236.

Atlin, G.N., H.R. Lafitte, D. Taob, M. Laza, M. Amante and M. Courtois. 2006. Developing rice cultivars for high-fertility upland systems in the Asian tropics. *Field Crops Res*., 97: 43-52.

Balestre, M., J.C. Souza, R.G. Von Pinho, R. L. Oliveira and M.V.P. Paes. 2009a. Yield stability and adaptability of maize hybrids based on GGE biplot analysis characteristics. *Crop Breeding and Applied Biotechnology*, 9: 226-234.

Balestre, M., R.G.V. Von Pinho, J.C. Souza and R.L. Oliveira. 2009b. Genotypic stability and adaptability in tropical maize based on AMMI and GGE biplot analysis. *Genetics and Molecular Research*, 9: 123-1135.

Balestre, M., V.B.D. Santos, A.A. Soares and M.S. Reis. 2010. Stability and adaptability of upland rice genotypes. *Crop Breeding and Applied Biotechnology*, 10: 357-363.

Banziger, M., P.S. Setimela, D. Hodson and B. Vivek. 2006. Breeding for improved abiotic, stress tolerance in maize adapted to Southern Africa. *Agric. Water Manage*., 80: 212-224.

Botwright Acuna, T.L., H.R. Lafitte and L.J. Wade. 2008. Genotype and environment interactions for grain yield of upland rice backcross lines in diverse hydrological environments. *Field Crops Res*., 108(2): 117-125.

Bouman, B.A.M., R.M. Lampayan and T.P. Tuong. 2007. Water management in irrigated rice: coping with water scarcity. Los Baños, Philippines: International Rice Research Institute: 54.

Chakrabory, R. and S. Chakraborty. 2010. Genetic variability and correlation of some morph metric traits with grain yield in bold grained rice (*Oryza sativa* L.) gene pool of Barak valley. *American Eurasian J. Sust. Agri*., 4(1): 26-29.

Chakravarthi, B.K. and R. Naravaneni. 2009. SSR marker based DNA fingerprinting and diversity study in rice (*Oryza sativa*. L). *Afr. J. Biotechnol*., 5(9): 684-688.

Degenkolbe, T., P.T. Do, E. Zuther, D. Repsilber, D. Walther, D.K. Hincha and K.I. Kohl. 2009. Expression profiling of rice cultivars differing in their tolerance to long term drought stress. *Plant Mol. Biol*., 69: 133-153.

Eradasappa, E. Nadarajan, K.N. Ganapathy, J. Shanthala and R.G. Satish. 2007. Correlation and path analysis for yield and its attributing traits in rice (*Oryza sativa* L.). *Crop Res.*, 34: 156-159.

Fischer, K.S., S. Fukai, A. Kumar, H. Leung and B. Jongdee. 2012 .Field phenotyping strategies and breeding for adaptation of rice to drought. *Frontiers Physiol*., 3: 282.

Fukai, S., J. Basnayake and O. Makara. 2008. Drought resistance characters and variety development for rainfed lowland rice in Southeast Asia. In: (Ed.): R. Serraj, J. Bennett and B. Hardy. Drought frontiers in rice - crop improvement for increased rainfed production. Singapore: World Scientific Publishing. pp.75-89.

Gana, A.S. 2006. Variability studies of the response of rice varieties to biotic and abiotic stresses. Unpublished Ph.D. Thesis, University of Ilorin.

Gana, A.S., S.Z. Shaba and E.K. Tsado. 2013. Principal component analysis of morphological traits in thirty-nine accessions of rice (*Oryza sativa* L.) grown in a rainfed lowland ecology of Nigeria. *J. Pl. Breed and Crop Sci*., 5(10): 120-126.

Gouch, H.G. 2006. Statistical analysis of yield trials by AMMI and GGE. *Crop Sci*., 46: 1488-1500.

Guang, C. and D. Xiong-Ming. 2006. Genetic diversity of source germplasm of upland cotton in china as determined by SSR marker analysis. *Acta. Genet. Sinca*. 33: 733-745.

Guimarães, C.M., F.S. Luís, H.N.R. Paulo and C.D.L.S. Ana. 2013. Tolerance of upland rice genotypes to water deficit. *Revista Brasileira de Engenharia Agrícola e Ambiental*., 17(8): 805-810.

Hanamaratti, N.G., S.K. Prashanthi, V.V. Angadi and P.M. Salimath. 2005. Rice research in rainfed drill sown rice in Karnataka. In: Five Decades of Rice Research in Karnataka, Directorate of Research, University of Agricultural Sciences, GKVK, Bengaluru, pp. 55-68.

Jambhulkar, N.N. and L.K. Bose. 2014. Genetic variability and association of yield attributing traits with grain yield in upland rice. *Genetika*. 46(3): 831-838.

Jun, L., T. Dokawa and T. Hirasawa. 2000. The effects of irrigation regimes on the water use, dry matter production and physiological responses of paddy rice. *Plant Soil*, 223: 207-216.

Kamoshita, A., R. Rodriguez, A. Yamauchi and L.J. Wade. 2004. Genotypic variation in response of rainfed lowland rice to prolonged drought and dewatering. *Plant Prod Sci*., **7**: 406-420.

Kamoshita, A., R.C. Babu, N.M. Boopathi and S. Fukai. 2008. Phenotypic and genotypic analysis of drought-resistance traits for development of rice cultivars adapted to rainfed Environments. *Field Crops Res.*, 109: 1-23.

Kanbar, A., M. Toorchi, T. Motohashi, K. Kondo and H.E. Shashidhar. 2010. Evaluation of discriminant analysis in identification of deep and shallow rooted plants in early segregating generation of rice (*Oryza sativa* L.) using single tiller. *Aus. J. Basic Appl. Sci.* 4(8): 3909- 3916.

Kato, Y., A. Kamoshita and J. Yamagishi. 2007. Evaluating the resistance of six rice cultivars to drought: root restriction and the use of raised beds. *Plant and Soil*, 300: 149-161.

Kumar, A., J. Bernier, S. Verulkar, H.R. Lafitte and G.N. Atlin. 2008. Breeding for drought tolerance: Direct selection for yield, response to selection and use of and lowland-adapted populations drought-tolerant donors in upland. *Field Crops Res*., 107: 221-231.

Kumar, R., A.K. Sarawgi, C. Ramos, S.T. Amarante, A.M. Ismail and L.J. Wade. 2006. Partitioning of dry matter during drought stress in rainfed lowland rice. *Field Crops Res*., 98(1): 1-11.

Lacap, J.M., D. Desauw, M. Rajab, J.L. Noyer and B. Hau. 2007. Microsattelite diversity in tetraploid Gossypium germplasm: assembling a highly informative genotyping set of cotton SSRs. *Mol. Breed*. 19: 45-58.

Lafitte, H.R., G. Yongsheng, S. Yan and Z.K. Li. 2006.Whole plant responses, key processes, and adaptation to drought stress: the case of rice. *J. of Exp. Bot*., 58(2): 169 -175.

Lakew, T., S. Tariku, T. Alem and M. Bitew. 2014. Agronomic performances and stability analysis of upland rice genotypes in North West Ethiopia. *Int. J. Scientific and Res. Pub*., 4(4): 1-9.

Lanceras, J.C., P. Griengrai, J. Boonrat and T. Theerayut. 2004. Quantitative trait loci associated with drought tolerance at reproductive stage in rice. *Plant Physiol*., 1: 84-399.

Manna, M., Ali M.D. Nsim and B.G. Sasmal. 2006**.**Variability, correlation and path coefficient analysis in some important traits of low land rice. *Crop Res.*, 31(1): 153-156.

Matsumoto, S., T. Tsuboi, G. Asea, A. Maruyama, M. Kikuchi and M. Takagaki. 2014. Water Response of Upland Rice Varieties Adopted in Sub-Saharan Africa: A Water Application Experiment. *J. Rice Res.*, 2: 121.

Nassir, A.L. and K.M. Adewusi. 2012. Performance of established and improved interspecific rice genotypes under variable soil moisture. *Experimental Agri. & Horti*., 1929-0861-2012-12-1.

Nassir, A.L. and O.J. Ariyo. 2006. Plant character correlations and pathanalysis of grain yield in rice *(Oryza sativa)*. *J. Genet. Breed*., 60: 161-172.

Nassir, A.L. and O.J. Ariyo. 2007. Multivariate analysis of variation of field planted upland rice (*Oryza sativa* L.) in a tropical habitat. *Malays Appl. Biol*., 36: 47-57.

Nassir, A.L. and O.J. Ariyo. 2011. Genotype x Environment Interaction and Yield-Stability Analyses of Rice Grown in Tropical Inland Swamp. *Not. Bot. Hort. Agrobot. Cluj*., 39(1): 220-225.

Oak, M.B., J. Tsubo, M. Fukai, S. Fisher, K.S. Cooper and M. Nesbitt. 2006. Use of drought response index for identification of drought tolerant genotypes in rainfed lowland rice. *Crop Sci. Res.*, 99(1): 48-58.

Price, A.H. 2002. QTLs for root growth and drought resistance in rice. In: *Molecular techniques incrop improvement*, (Eds.): D.S. Mohan Jain and B.S. Ahloowalia. Kulwer Academic Publisher, Norwell, MA, USA, pp. 563-584.

Samonte, S.O.P.B., L.T. Wilson, A.M. McClung and J.C. Medley. 2005. Targeting cultivars onto rice growing environments using AMMI and SREG GGE Biplot analyses. *Crop Sci*., 45: 2414-2424.

Sandhu, N., S. Jain, A. Kumar, B.S. Mehla and R. Jain. 2013. Genetic variation, linkage mapping of QTL and correlation studies for yield, root and agronomic traits for aerobic adaptation. *BMC Genetics*.14 (104): 1471-2156.

Singh, K.A. 2003. Enhancing rice productivity in water stressed environments. IRRI Publications DOI No: 10.1142/ 9789814280013_0013.

Sohrabi, M., M.Y. Rafii, M.M. Hanafi and M.A. Latif. 2013. Genetic divergence of Malaysian upland rices revealed by microsatellite markers. *Plant Omics Journal*. 6(3): 175-182.

Sohrabi, M., M.Y. Rafii, M.M. Hanafi, A. Siti Nor Akmar and M.A. Latif. 2012. Genetic diversity of upland rice germplasm in Malaysia revealed by quantitative traits. *Sci World J*. DOI: 10. 1100/2012 /416291.

Sohrabi, M., M.Y. Rafii, M.M. Hanafi, A. Siti Nor Akmar and M.A. Latif. 2012. Genetic diversity of upland rice germplasm in Malaysia revealed by quantitative traits. *Sci World J*. DOI: 10.1100/2012 /416291.

Sravan, T., N.R. Rangare, B.G. Suresh and K.S. Ramesh. 2012. Genetic variability and character association in rainfed upland rice (*Oryza sativa* L.). *J of Rice Res.*, 5(1&2): 24-29.

Srivastava, N., S.K. Pathak, S. Gampala, V.J. Singh, B.G. Suresh and G.R. Lavanya. 2014. Evaluation of exotic upland rice germplasm for grain yield and its component characters in rainfed ecosystem (*Oryza sativa* L). *Int. J. Food Agri. and Vet. Sci.*, 4(2): 102-109.

Yan, W. and M.S. Kang. 2003. GGE biplot analysis: a graphical tool for breeders, In M. S. Kang, ed. Geneticists, and Agronomist. CRC Press, Boca Raton, FL.

Yan, W., M.S. Kang, B. Ma, S. Wood and Carnelius. 2007. GGE biplot vs AMMI analysis of genotype by environment data. *Crop Sci*., 47: 643-655.

Yang, J. and J. Zhang. 2006. Grain filling of cereals under soil drying. *New Phytol.*, 169(2): 223-236.

Yue, B., W. Xue, L. Xiong, X. Yu, L. Luo, K. Cui, D. Jin, Y. Xing and Q. Zhang. 2006. Genetic basis of drought resistance at reproductive stage in rice: separation of drought tolerance from drought avoidance. *Genetics*, 172: 1213-1228.

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