Journal of Pharmacognosy and Phytochemistry

Available online at www.phytojournal.com

E-ISSN: 2278-4136
P-ISSN: 2349-8234
JPP 2018; 7(3): 2060-2067
Received: 15-03-2018
Accepted: 20-04-2018

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Study of genetic diversity and effectiveness of traits for direct selection under drought as well as non-stress condition for Rainfed upland rice

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Abstract
The present study was carried out on 32 upland rice genotypes (including checks), which were analysed for grain yield (GY) and related traits under contrasting moisture regimes (irrigated and drought stress). Analysis of variance showed that all the characters studied were significantly different. Highest GCV and PCV values were recorded for GY and FLW under drought stress and non-stress conditions respectively. Five characters namely DTF, PH, FLW, FGPP and GY were recorded to have very high heritability as well as GAM under both stress and control conditions. GY, FGPP and ETN were observed to have high or very high GAM values under both conditions. Furthermore, these traits also recorded high to moderately-high heritability and thus, emerged as most promising traits for improvement through selection. Association study revealed that GY is positively and significantly correlated to PH, FGPP and SF% at both genotypic and phenotypic level. Path coefficient analysis revealed a very high positive effect of FGPP and ETN on GY under both control and stress conditions. Additionally, DTF showed negative and positive effects on GY under stress and non stress respectively. Sufficient diversity could be noticed as the genotypes were grouped in to 4 clusters. D^2 and PCA indicated blast tolerant upland genotype CRMAS2620-1 to be a unique one because of its positioning in a sporadic cluster and therefore, could be used as a potential parent for hybridization with highly drought tolerant upland varieties.

Keywords: drought screening, upland rice, PCA, ANOVA, heritability

Introduction
Rice is a staple for nearly half of the world's seven billion people and about 65% of Indian population (Sumanth *et al*., 2017) [30]. Among the different ecologies where rice is cultivated, rainfed areas comprise about 45% of world's total rice area (Maclean *et al*., 2002) [21]. South and South East Asia alone contains about 40 million hectares of rainfed area out of which 20.7 million hectares lies in India. Furthermore, majority of the rainfed area (~16 million hectares) in India is located in the Eastern parts of the country (Singh and Singh, 2000) [29]. Climate changes in the last few decades have resulted in erratic rainfall patterns across the globe. Rainfed areas in particular are most affected by such irregular patterns of rainfall because of their complete dependency on rain as the source of irrigation. Irregular rainfall usually results in drought stress during various stages of crop growth. Moreover, productivity in rainfed upland areas are more adversely affected in comparison to lowland due to drought (Siddiq, 2000) [12]. On the other hand, rice is the most water consuming food grain and loves standing water at all stages of growth. Out of the total water consumption, about 35% is required at the reproductive stage i.e., between Panicle Initiation (PI) and maturity (Agropedia, 2009). Therefore, water scarcity during this critical stage suppresses grain formation and severely affects rice productivity. Water scarcity for even 15 days can reduce yield by 70%during the panicle initiation, 88% during flowering and 52% during grain filling (Yambao and Ingram, 1988) [35]. In order to meet the increasing demand of food grain for the ever increasing population of India, it is essential to develop competent rice varieties with high grain yield under reproductive stage drought stress.
The first step in developing high yielding drought tolerant varieties involves identification of parents having diverse response to stress. Typically, parents must be chosen such that the recipient should be high yielding under non stress and the donor should be drought tolerant with moderate to high yield under stress. This would allow the resulting segregant to perform well under both non stress and stress conditions. In order to identify such genotypes, it is necessary to screen them phenotypically both under stress and non-stress conditions. Two different approaches are utilized by breeders to identify drought tolerant genotypes:

1. Direct approach via selection of grain yield under stress (Venuprasad *et al*., 2007) [16] and 2. Indirect approach of selecting secondary traits associated with stress tolerance (Laffite *et al*., 2003) [18]. However, the selection process can be made more robust by combining these two approaches (Jongdee *et al*., 2006) [15].

Irrespective of whether direct, indirect or combined approach is used for selection, the success of breeding program depends upon the measure of available genetic variability, heritability and genetic advancement of the desired characters. Variability is indispensable for improvement of genetic material. The amount of genetic variability among genotypes is determined by the parameters such as genotypic and phenotypic coefficients of variation (GCV and PCV). Heritability (broad sense) and genetic advancement helps in determining the environmental influence on expression of characters and the improvement potential after selection. In addition, identification of characters/traits that influence grain yield either directly or indirectly is also quite important. This helps in choosing the right characters as selection criteria. Path coefficient analysis is carried out for this purpose (Chakraborthy *et al*., 2010) [8]. Analysis of diversity is an important pre-requisite for any breeding program as it helps in identification of diverse parents that can be hybridized to produce transgressive segregants. Mahalnobis D^2 analysis and Principal component analysis (PCA) are two such powerful tools used to determine the level of diversity among the genotypes (Dash *et al.,* 2015) [9]. With this backdrop, the present study was carried out using some of the promising upland rice genotypes under contrasting moisture regimes to: 1) identify traits governing yield under non stress and drought stress for efficient selection of segregants and 2) assessment of necessary diversity which can be utilised in future backcross breeding programs.

Materials and Methods

Plant Materials

Thirty two upland rice genotypes including drought tolerant (N22 and Sahabhagi Dhan) and susceptible checks (IR20 and IR64) were used in this study (Table 1). The present study was carried out at NRRI, Cuttack.

Table 1: List of genotypes used in this study

Sl. No.	Cultivar Name	Type	Origin	Sl. No.	Cultivar Name	Type	Origin
1	Way Rarem	*indica*	Indonesia	17	Poornima	*indica*	India
2	Vandana	*indica*	India	18	Annada	*indica*	India
3	Sahbhagi Dhan	*indica*	India/Philippines	19	Anjali	*indica*	India
4	Browngora	*indica*	India	20	Vanaprava	*indica*	India
5	Kalyani-II	*indica*	India	21	Blackgora	*indica*	India
6	NDR-1045	*indica*	India	22	Heera	*indica*	India
7	Satyabhama,	*indica*	India	23	Pathara	*indica*	India
8	Sidhant	*indica*	India	24	Dular	*indica*	India
9	Sadabahar	*indica*	India	25	IR20	*Indica*	Philippines
10	Hazaridhan	*indica*	India	26	IR64	*indica*	Philippines
11	Annapurna	*indica*	India	27	Azucena	*japonica*	Philippines
12	Kalinga-III	*indica*	India	28	Curinga	*japonica*	Brazil
13	HND-15	*indica*	India	29	CR-2702	*indica*	India
14	Khandagiri	*indica*	India	30	Mahulata	*indica*	India
15	N22	*indica*	India	31	CR-143-2-2	*indica*	India
16	Selumpikit		India	32	CRMAS 2620-1	*indica*	India

Water Stress Experiment

Irrigated

The entire set of genotypes was grown in irrigated condition. Twenty-five days old seedlings were transplanted in the field and normal irrigation regime along with recommended fertilizer dosage was followed as per standard practice.

Rainout Shelter

Drought tolerance screening was carried out to determine the level of stress tolerance in all the genotypes. The stress screening was carried out in the Rainout Shelter (ROS) facility of NRRI. Seeds were directly sown in the soil and dibbled to a depth of 2cm with spacing of20cm and 10cm between rows and hills respectively. Recommended dosage of fertilizer (N:P:K @ 40:20:20) were applied basally. Irrigation was provided at 3 days interval until 40 days after sowing following which water stress was imposed until soil moisture tension reached -50kPa at 30cm depth.

Observations

Observations were recorded on five competitive plants, of each genotype, from the middle of the rows. Morphological characters such as days to 50% flowering, plant height, panicle length, effective number of tillers, flag leaf length, flag leaf width were recorded precisely. Post harvest data such as number of fertile grains per panicle, spikelet fertility percentage and grain yield (t/ha) were recorded for each of the genotypes for both non-stress and stress experiments.

Evaluation

ANOVA, coefficient of variation (GCV and PCV), broad sense heritability (H^2), genetic advancement as percentage of mean, D^2 and PCA were calculated using Windowstat 9.1 (Indostat services, Hyderabad, India, 2014). Genotypic and phenotypic correlation coefficient were calculated as per the method described by Miller *et al.* (1958) [23] while path coefficient analysis was carried out as per the method suggested by Dewey and Lu (1959) [20]

Results and Discussion

Table 2: ANOVA of 9 morphological characters in upland rice genotypes under a) non stress and b) drought stress conditions

a)

Source of Variation	Df	DTF	PH	PL	ETN	FLL	FLW	FGPP	SF%	GY
Replication	2	0.781	5.202	0.361	0.037	1.739	0.044	30.713	18.331	1653.13
Genotype	31	769.451**	419.591**	18.445**	3.2941**	42.666**	0.304**	380.807**	139.913**	849992.2**
Error	62	3.055	4.937	1.354	0.412	5.083	0.007	19.595	16.112	28693.12

** Significant at 1%

b)

Source of Variation	Df	DTF	PH	PL	ETN	FLL	FLW	FGPP	SF%	GY
Replication	2	0.382	3.327	0.158	0.020	0.619	0.005	2.085	1.159	17112.5
Genotype	31	939.773**	381.290**	18.546**	2.718**	65.527**	0.133**	757.629**	617.546**	732684.4**
Error	62	2.479	11.045	4.016	0.208	2.815	0.006	9.704	8.131	15931.85

** Significant at 1%

DTF: Days to 50% flowering; PH: Plant height (in cm); PL: Panicle length (in cm); ETN: Effective number of tillers; FLL: Flag leaf length (in cm); FLW: Flag leaf width (in cm); GPP: Number of fertile grains per panicle; SF%: Spikelet fertility %; GY: Grain yield (kg/ha)

The ANOVA of 9 agro-morphological characters under differing moisture regimes revealed that the genotypes were highly significantly different (at 1% level) from each other for all the traits studied in both the conditions (Table 2). Similar findings have also been reported by Bekele *et al.* (2013) [6], Sandhya *et al.* (2015) [27] and Sumanth *et al.* (2017) [30].

Table 3: Estimation of components of variation and genetic parameters for 9 agro-morphological characters

		DTF	PH	PL	ETN	FLL	FLW	FGPP	SF%	GY
Range	C	50.0-102.5	70.2-122.5	16.5-25.7	4.4-8.2	20.7-35.3	0.46-1.63	48.2-102.8	53.96-78.74	1710.0-3870.0
	S	39.0-102.0	70.22-112.21	13.6-22.4	3.0-6.6	16.1-36.2	0.41-1.26	8.6-76.6	8.32-64.46	200.0-2300.0
Mean± SE	C	68.38±1.01	94.25±1.28	21.49±0.67	6.45±0.37	29.28±1.30	1.15±0.04	75.60±2.55	66.08±2.31	2821.57±0.09
	S	70.27±0.91	87.93±1.92	18.97±1.16	4.63±0.26	26.74±0.97	0.84±0.05	38.05±1.80	34.45±1.65	1049.06±0.07
GCV	C	23.38	12.47	11.11	15.19	12.09	27.33	14.51	9.72	18.54
	S	25.16	12.63	11.60	19.75	17.10	24.27	41.49	41.37	46.59
PCV	C	23.52	12.69	12.36	18.16	14.33	28.32	15.65	11.46	19.49
	S	25.26	13.19	15.69	22.07	18.21	26.16	42.29	42.19	48.12
H^2	C	98.82	96.55	80.79	69.99	71.14	93.12	86.00	71.92	90.51
	S	99.21	91.78	54.67	80.06	88.13	86.10	96.25	96.15	93.75
GAM	C	47.87	25.25	20.57	26.18	21.00	54.32	27.73	16.98	36.34
	S	51.62	24.93	17.67	36.40	33.07	46.40	83.86	83.56	92.93

SE= Standard Error; GCV= Genotypic coefficient of variation; PCV= Phenotypic coefficient of variation; H^2= Broad sense heritability; GAM= Genetic advancement as percentage of mean

Under control condition, highest range of variation was recorded for FLW followed by DTF and GY while under drought stress it was GY followed by FGPP and SF%. Moreover, lowest range of variation was recorded SF% and PL under control and stress, respectively.

The magnitude of genetic variation was determined by phenotypic and genotypic coefficients of variation (PCV and GCV). The GCV ranged from 9.72 (SF%) to 27.33 (FLW) under control and between 11.60 (PL) to 46.59 (GY) under stress (Table 3). Similarly, PCV values ranged from 11.46 (SF%) to 28.32 (FLW) and 13.19 (PH) to 48.12 (GY) under non stress and stress conditions respectively. For all the characters, PCV values were observed to be slightly higher than GCV. This indicates an environmental influence onexpression of these characters. Similar observations were reported by Anjaneyulu *et al*. (2010) [3] and Idris *et al*. (2012) [14]. According to Deshmukh *et al.* (1986) [11], PCV and GCV values higher than 20% can be considered as high, between 10 and 20% as medium and less than 10% as low. On the basis of this statement, all the characters were observed to have medium to high GCV and PCV values under both non stress and drought conditions. However GY, FGPP and SF% were observed to have the highest PCV and GCV values under drought stress compared to the other characters. As these characters are considered as the most important parameters under drought, sufficient variation for these traits indicates that selection of genotypes for these traits would be most effective for drought tolerance. Singh *et al.* (2015) [28] also reported high GCV and PCV values for GY.

Broad sense heritability estimate provides information (portion of the variation) that could be transmitted through generations. The broad sense heritability could be classified in the range: ≥0.8 as very high, 0.6-0.79 as moderately high, 0.4-0.59 as medium and <0.4 as low (Singh, 2001) [4]. In this context, five characters namely DTF, PH, FLW, FGPP and GY were recorded to have very high heritability under both stress and control conditions. Similar high heritability for GY under reproductive stage drought stress has been reported by Kumar *et al.* (2007) [16]. Heritability estimates for three more traits i.e., ETN, FLL and SF% were observed to be moderately high and high under control and stress respectively. Such high to moderate heritability has been reported for various quantitative traits in rice by Vikram *et al.* (2011) [33] and Saikumar *et al.* (2014) [25, 26]. The heritability estimates of panicle length and flag leaf width were less under stress in comparison to control. This shows that these traits were influenced by the stress environment. Further, it was interesting to note that for some traits such as DTF, ETN, FLL, FGPP, SF% and GY; the heritability values were higher under stress than control. Similar trend reported by Abarshahr *et al.* (2011) [1] corroborates present findings.

Although very high heritability indicates the effectiveness of prospective trait specific, it does not always result in high genetic gain. Therefore, heritability should be used in conjunction with genetic advance for predicting selection of superior genotypes (Ali *et al*., 2002). According to Johnson *et al*. (1995), GAM values between 10-20% are considered as medium and >20% are considered as high. Basing on the proposition, the trait PL was recorded with moderate GAM under stress while SF% under non stress conditions. GY, FGPP and ETN were observed to have high or very high GAM values under both conditions. Furthermore, these traits also recorded high heritability and thus, emerged as most promisingtraits for improvement through selection. Similar results have also been reported by Manickavelu *et al*. (2006) [22], Yadav *et al*. (2011) [34] and Saikumar *et al*. (2014) [25, 26].

Table 4: Genotypic (above diagonal) and Phenotypic (below diagonal) correlation coefficients between yield and related traits of upland rice genotypes under a) non stress and b) drought stress conditions

a: Control

	DTF	PH	PL	ETN	FLL	FLW	FGPP	SF%	GY
DTF	1	0.505**	0.433**	0.146	0.268	0.317*	0.151	0.157	0.471**
PH	0.492**	1	0.114	0.291	0.138	0.231	0.085	0.055	0.374*
PL	0.375*	0.117	1	0.057	0.522**	0.525**	0.111	0.196	0.147
ETN	0.130	0.219	0.047	1	0.256	0.338*	-0.413**	-0.012	0.289
FLL	0.229	0.121	0.427**	0.278	1	0.840**	-0.122	-0.06	0.111
FLW	0.302*	0.231	0.478**	0.268	0.679**	1	-0.225	-0.031	-0.015
FGPP	0.133	0.075	0.085	-0.445**	-0.130	-0.206	1	0.367*	0.608**
SF%	0.124	0.045	0.129	-0.176	-0.085	-0.035	0.484**	1	0.534**
GY	0.439**	0.343*	0.103	0.254	0.112	0.003	0.491**	0.365*	1

b: Drought tress

	DTF	PH	PL	ETN	FLL	FLW	FGPP	SF%	GY
DTF	1	-0.037	-0.337*	-0.212	-0.029	0.2062	-0.465**	-0.516**	-0.308*
PH	-0.208	1	-0.228	0.316*	0.293	0.138	0.228	0.199	0.469**
PL	-0.241	-0.166	1	-0.006	0.203	0.176	0.244	0.327*	0.107
ETN	-0.173	0.300*	-0.053	1	-0.074	-0.170	-0.001	0.067	0.431**
FLL	-0.033	0.260	0.091	-0.031	1	0.71**	0.080	0.145	0.046
FLW	0.198	0.154	0.119	-0.138	0.614**	1	0.077	0.150	-0.033
FGPP	-0.459**	0.207	0.194	-0.013	0.061	0.061	1	0.932**	0.848**
SF%	-0.508**	0.179	0.256	0.046	0.121	0.127	0.934**	1	0.788**
GY	-0.303*	0.435**	0.113	0.351*	0.029	-0.002	0.829**	0.772**	1

The genotypic and phenotypic correlation coefficients among the studied traits showed that magnitude of genotypic correlation is higher than phenotypic correlation which indicates that the relationship was affected by environment at phenotypic level (Table 4). Under both water regimes, GY is positively and significantly correlated to PH, FGPP and SF% at both genotypic and phenotypic level. Similar positive correlations between GY and PH, FGPP and SF% have been previously reported by Bernier *et al.* (2007) [7] and Vikram *et al.* (2011) [33]. On the contrary, Laffite *et al* (2006) reported negative correlation between GY and PH. Under stress condition, GY showed significant negative correlation with DTF while significant positive correlation under control. Similar correlation between GY and DTF has been emphasized earlier by Garrity and O' Toole (1994) and Varma *et al* (2012). Effective Tiller Number (ETN) was positively correlated to GY understress. This emphasizes the importance of high tiller number in breeding for drought tolerance. Hence, selection for more tillers could be highly beneficial for better grain yield under stress. Similar finding by Akhtar *et al*. (2011) supports present findings. Further, traits like FGPP, SF%, DTF and PH were positively associated with GY not only under stress, but also under control and consequently, were supposed to be the supporting traits. This indicates that more emphasis should be given to these traits while targeting for higher genetic gain in GY under stress as well as control condition.

Table 5: Direct (diagonal) and indirect effect of different characters on grain yield under a) Control and b) Drought stress**.**

a: Drought stress

	DTF	PH	PL	ETN	FLL	FLW	FGPP	SF%	Sum
DTF	-0.271	-0.005	-0.004	-0.091	-0.003	-0.036	-0.444	0.003	-0.308
PH	-0.010	0.127	-0.002	0.135	0.028	-0.024	0.217	-0.001	0.47
PL	-0.091	-0.029	0.011	-0.003	0.02	-0.031	0.233	-0.002	0.107
ETN	-0.057	0.040	-0.0001	0.427	-0.007	0.03	-0.001	-0.0004	0.431
FLL	-0.008	0.037	0.002	-0.031	0.096	-0.125	0.076	-0.001	0.046
FLW	0.056	0.018	0.002	-0.072	0.068	-0.177	0.073	-0.001	-0.033
FGPP	-0.126	0.029	0.003	-0.0004	0.008	-0.014	0.954	-0.006	0.848
SF%	-0.14	0.025	0.004	0.029	0.014	-0.027	0.889	-0.006	0.788
Residue	0.156								

b: Control

	DTF	PH	PL	ETN	FLL	FLW	FGPP	SF%	Sum
DTF	0.313	0.021	-0.064	0.079	0.106	-0.128	0.098	0.046	0.471
PH	0.158	0.042	-0.02	0.158	0.054	-0.09	0.055	0.02	0.374
PL	0.136	0.005	-0.149	0.032	0.205	-0.211	0.072	0.057	0.147

ETN	0.046	0.012	-0.009	0.544	0.101	-0.134	-0.268	-0.004	0.289
FLL	0.084	0.006	-0.078	0.140	0.393	-0.338	-0.079	-0.017	0.111
FLW	0.099	0.01	-0.078	0.182	0.330	-0.402	-0.146	-0.009	-0.015
FGPP	0.047	0.004	-0.017	-0.225	-0.048	0.091	0.648	0.107	0.608
SF%	0.049	0.002	-0.029	-0.007	-0.023	0.012	0.238	0.292	0.534
Residue	0.32								

Path coefficient analysis was carried out to assess the magnitude of the contributions of yield related traits to GY under contrasting water regimes. The analysis revealed that FGPP (0.954) had the highest direct contribution on GY under drought stress (Table 5a). Moreover, the characters viz., SF %, PL and PH also contributed indirectly towards GY via this trait. This shows the supremacy of trait “fertile grains” in controlling grain yield. This was followed by ETN with high direct effect on GY (0.427) as well as positive indirect contribution of PH (0.158) via this trait. The trait PH (0.127) also showed considerable positive effect on GY under drought although, none of the other traits showed any significant indirect effect on GY through this trait. Saikumar *et al.* (2014) [25, 26] also reported similar effect of PH on GY in two out of three seasons of drought screening in a cross population derived from wild rice. While DTF showed a direct positive influence (0.313) on GY under control, the effect was opposite (-0.271) under stress. Similar findings have been reported previously by Zahid *et al.* (2006) [36]. This shows a clearly that most of the drought tolerant genotypes mostly have an early maturity duration and ‘escape’ is the predominant drought tolerant mechanism, particularly in most of the land races and upland drought adapted varieties.

Similarly, under control condition, FGPP (0.648), ETN (0.544), FLL (0.393), DTF (0.313) and SF (0.292) showed high direct positive effect on GY (Table 5b). However, other traits, viz., FLW, PH, FLL also contributed significantly, although not directly, but through ETN. This emphasizes the superiority of ETN in offering higher grain yield. Additionally, FLW, PL and ETN recorded high indirect contribution via FLL, hence, could be ascertained for its importance. In addition, PH and PL recorded moderately high indirect contribution via DTF therefore, registered its importance. This was followed by the direct contribution of SF itself and the indirect effect of FGPP through SF hence, could also be stressed upon. Therefore, the traits viz., FGPP, ETN, FLL, DTF could be focussed during selection in control situation. Similar contributions of DTF, ETN and FGPP towards higher grain yield by Dash *et. al*., (1996) [10] corroborates present findings. Comparing both stress and non-stress situation, FGPP and ETN were reported to be the most contributing parameters and should be highlighted during selection of genotypes in drought which could also perform better in control. This is very important because farmers have a preference for genotypes with high yield under non stress as the stress occurs occasionally. In summary, this statement is by and large in agreement with the results of PCV, GCV, GAM and broad sense heritability.

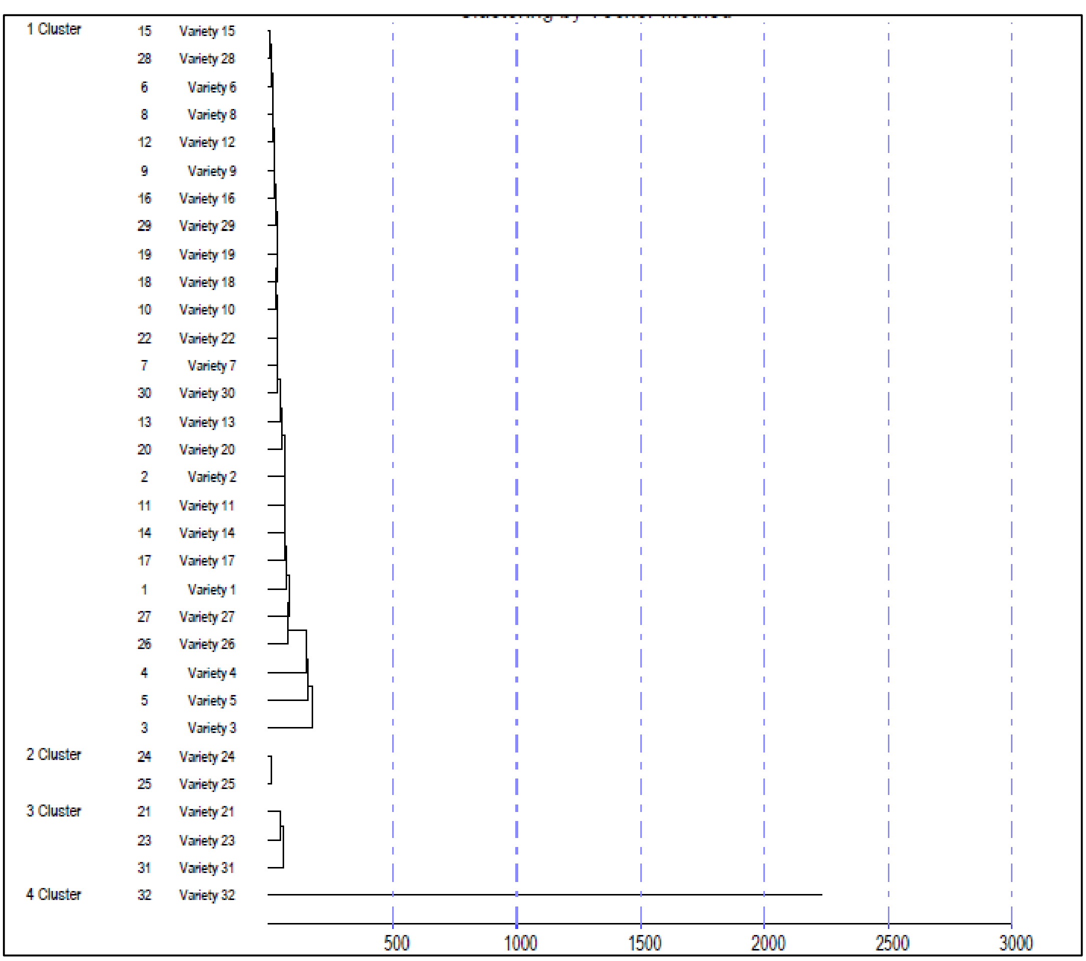

Fig 1: Clustering pattern of 32 genotypes

Coming to utilization of these cultures for parents in hybridization, diversity plays an important role. The diversity study could dissected 32 upland genotypes were divided into 4 distinct clusters. Maximum numbers of genotypes i.e., 26 were grouped into cluster 1. Clusters 2 and 3 comprised two and three genotypes respectively while cluster 4 contained only a single genotype (Fig 1). It is was recorded that the two japonica genotypes *viz.*, Azucena and Curinga are located in same clusters as per expectation. Additionally, Curinga (tropical japonica) grouped with N22 (indica) in the same subcluster although the they are classified differently. Similarly Sahbhagi Dhan, which is a derivative of Way Rarem, grouped with Browngora and Kalyani II whereas, Way Rarem grouped together with Azucena. CRMAS 2620-1 which is a derivative of Vandana grouped separately into a cluster of its own because of its unique combination of characters. Such a clustering pattern indicates that several factors like genetic drift, exchange of breeding material, variation and selection play an important role in determining the diversity, as reported previously by Mall *et al.* (2013).

Table 6: Intra and inter cluster D2 among 4 clusters

	1	2	3	4
1	221.21	683.74	995.04	6666.78
2		34.81	1649.93	7151.0
3			196.76	8088.21
4				0

Highest inter cluster distance was found between cluster 3 and 4 (8088.21) followed by cluster cluster 2 and 4 (7151.0) and cluster 1 and 4 (6666.78). The genotypes belonging to these distant clusters are to be given importance in hybridization programs on the basis of trait specific complementation.

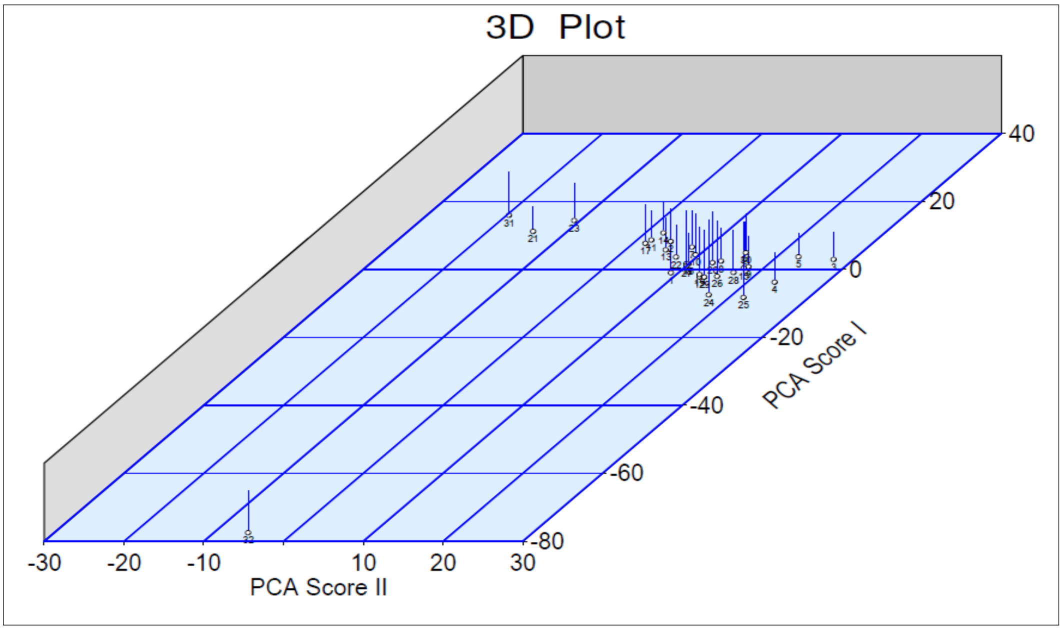

Fig 2: 3D plot based upon first two components of PCA for genotypes under study

PCA showed that the first two components explain a cumulative variation of 80.69%, which is an indication of moderate genetic diversity. 3D plot based upon the first twoprincipal components showed that the genotypes were positioned mostly in agreement with the dendrogram. This further strengthens our earlier hypothesis regarding choice of distant parents for creation of variability through hybridization and transgressive segregants for higher level of drought tolerance.

The unique culture CRMAS 2620-1 could be a potential parent for hybridization with highly drought tolerant parents viz., N22, Sahbhagi Dhan, Azucaen and Curinga. Similarly, cluster 3 consisting of tolerant lines viz., Black gora, Pathara and CR 143-2-2 could be potential parents to be hybridized with Sahbhagi Dhan, Brown gorw and Kalyani-II, in the first two which were supposed to be excellent reproductive stage drought tolerant as evident from PCA 3D plot (Fig 2).

Conclusion

The above study reveals the presence of ample amount of genetic variability among the studied materials. Furthermore, traits such as FGPP followed by SF%, and ETN recorded highest positive effect on GY under contrasting water regimes. In addition, DTF shows a high negative effect on GY under stress. These traits were also found to have sufficiently high heritability indicating their worthiness in selection. Hence, plants that have high number of fertile grains per panicle, high spikelet fertility percentage, high number of tillers and short flowering duration under stress could be considered as suitable parameters for improving the grain yield in upland drought stress. Additionally, diversity study could break up the genotypes in to smaller groups and had a clear indication for choice of parents for hybridization and selection leading to further improvement.

Funding

The funding for this work was provided by ICAR-National Rice Research Institute institutional fund.

Acknowledgment

The authors would like to express their gratitude to Director, ICAR-NRRI for providing the necessary field and laboratory facilities for carrying out the work and Dr. M.K. Kar (Principal

Scientist, Crop Improvement Division, NRRI) for providing all the seed materials

Disclosure of Interest

The authors declare that neither they have any conflict of interest nor they have financial and personal relationship with other people or organizations that could inappropriately influence (bias) their work.

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