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Research Article

Screening of rice landraces for potential drought tolerance through comparative studies of genetic variability and principal component analysis

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Abstract

To identify stable yielding rice landraces with optimum drought tolerance ability, the present comparative study of genetic variability and principal component analysis was carried out based on different morphological traits of 60 landraces of northeast India belonging to upland rice. The sensitivity of the landraces under drought stress conditions was confirmed by the first-order statistics of genetic variation as well as Principal component analysis (PCA) since comparatively more numbers (6) of principal components were found under drought stress over the irrigated conditions with 74.12 per cent of cumulative variability. Characters *viz.,* leaf rolling index, root: culm ratio, the number of spikelets per panicle, the number of filled grains per panicle, 100 seed weight and grain yield per plant were identified as suitable selection indexes for landraces under drought stress conditions. Based upon the eigenvalue and scattered diagram analysis under PCA, the landraces *viz.,* Garomalati, Chikanswari Kabar, Turkey, Tarkol, Maimi Taukha and Madoop were found to be diverse and promising genotypes under drought stress. Hence, these landraces may be utilised as potential parents in the future breeding programme.

Key words: Rice, landraces, drought stress, genetic variability, principal component analysis.

INTRODUCTION

Rice (*Oryza sativa* L.) is the major staple food for one-third of the world's population providing around 80 % of individuals' daily calories (Ashkani *et al.*, 2015). But being a semi-aquatic cereal crop, it requires a relatively higher amount of water for its normal growth in comparison to other crops (Pandey and Shukla, 2015). Rice plant suffers at different stages of their life cycle due to water scarcity under rain-fed conditions. To be more specific, it suffers most during the booting or reproductive stage (Agarwal *et al.*, 2016). The effect of drought on rice is more severe when compared to other food crops in the present scenario of severe climate change. Worldwide, approximately 27 million hectares of rice grown area is subjected to drought stress (Zu *et al.*, 2017). On the other hand, as per World Bank Population projections (2020), the population growth trend in the major rice-growing countries of Asia, as well as, in the world can be expected to increase at an annual average growth rate of 0.9%. Thus, to meet the rising demand of the continuously increasing population with depleting water supply, rice varieties that are highly adapted or tolerant to dry environments are required to be traced out with due gravity (Foley *et al.*, 2011). Despite many studies on drought tolerance of crops, the improvement of drought-tolerant crops is delayed greatly due to largely unknown mechanisms of different crop's responses to drought stress. However, genetic variations in the rice genotypes for drought tolerance were observed by many researchers in their screening and characterization studies on rice germplasm under drought stress (Zu *et al.,* 2017). Thus, to neutralize the adverse effect of drought stress in rice by developing drought-tolerant varieties, a genetic variability study seems to be a useful approach. Genetic variability is the basis for any plant improvement programme towards tracing out new genotypes for a particular purpose. Hence, to plan an efficient breeding programme, reliable estimates of genetic variation through studies of coefficient of variation, heritability and genetic advance are found to be the key components. Variability studies help plant breeders to make a suitable selection of genotypes by assessing the magnitude of genetic improvement (Tuhina-Khatun *et al*, 2015). Apart from this, knowledge of multivariate analysis like principal component analysis (PCA) is also identified as an essential tool in the identification of promising germplasm by analyzing its greater performance in a given condition. In view of the above, the research hypothesis was fixed for the identification of important yield contributing and drought-tolerant traits as well as to trace out potential drought tolerance landraces.

MATERIALS AND METHODS

The experiment was carried out on the farm of the Indian Council of Agricultural Research (ICAR) Complex for the North Eastern Hilly Region, Tripura Centre, Lembucherra, Tripura, (23°90'E, 92°29'N), India. Sixty local rice landraces **(Table 1)** were collected from the different hill ranges of Tripura, a north-eastern state of India and evaluated through Randomised Complete Block Design with three replications. The experiment was conducted under both irrigated (in '*Kharif'* seasons) and artificial drought stress conditions (in 'boro' seasons) for two consecutive years of 2015-16 and 2016-17. Artificial drought stress conditions were imposed in the trial field during the '*Boro'* seasons of those years. For drought stress evaluation of the landraces, an un-bunded, well-drained field was chosen under the local upland ecosystem of the farm complex. The collected seeds were directly sown in dry soil maintaining a spacing of 25 cm x 25 cm. Subsequently, furrow type of irrigation was provided up to 30 days after sowing (DAS). Proper inter culture techniques were carried out at regular intervals to ensure the maintenance of row-row and plant-plant distance and eradication of off-type plants. After 30 DAS, the field was kept unirrigated until the soil surface is completely dried out or the experimental plants showed severe wilting symptoms. When the required levels of soil dryness, as well as plant stress, were observed, the experimental field was abundantly irrigated to saturate the root zone. This irrigation pattern was repeated until harvesting the crop. However, for irrigated trials, no such specifications were followed during field selection as well maintenance of irrigation schedule. Seedlings were transplanted in the puddled field maintaining the same

Table 1. List of rice land races evaluated under the study

S.No.	Name of the land races	S.No.	Name of the land races	S.No.	Name of the land races
1	Kaporok	21	Saanki ka Phool	41	Bongbu
2	Releng	22	Bihar	42	Sadok
3	Beti	23	Chikanswari Kabar	43	Kali Jira
4	MaimiUzrao	24	Bangbu Jhum	44	Gaigash
5	Kalikhasa	25	Lal Biroin	45	Vanbang
6	Chinal	26	DhalaBalam	46	Makajaria
7	American	27	Goria	47	Jilong
8	Khasa Kasam	28	Bahadur	48	American Ration
9	Biroin	29	Maimiwatolok Mandoori	49	Kala Dhan
10	Galong	30	Maimi Hungar	50	Turkey
11	FazuVom	31	Darka Sona	51	Saanki Kachak
12	Garo Malati	32	Tarikol Kolte	52	Maimi Ukhlao
13	Maimi Usha	33	SadaBiroin	53	Maiwasha
14	Maimi Red	34	Maimi Taukha	54	Maimi Watoklok
15	Suri	35	Saluma	55	Santinm Wakhum
16	Lebuka	36	Tarkol	56	Yang Dhan
17	Aaduma	37	Madoop	57	Badaya
18	Fazu Sen	38	Waibang	58	Kanchali
19	Fazu Ngoi	39	Jhum Bini	59	Australian Biroin
20	Beti Kalai	40	Fazu Sen (White)	60	Assam Paisom

Source : Acharjee *et al*.(2019)

plant to plant and row to row distance like drought stress. The precaution was taken to maintain one seedling per hill to keep parity with the stress condition evaluation. Fertilizers were applied @ 100:40:40 N: P: K kg/ha under both conditions.

Twelve morphological traits *viz.,* plant height (cm), the number of productive tiller per plant, panicle length (cm), the number of primary branches per panicle, root length (cm), root: culm ratio, the number of spikelets per panicle, the number of filled grains per panicle, spikelet fertility (%),100 seed weight (g.), harvest index (%) and grain yield per plant (g) were taken into consideration for statistical analysis under irrigated and drought stress conditions. Apart from these, four drought tolerant traits *viz*., seedling vegetative vigour, leaf rolling index, leaf drying index and drought recovery index were also evaluated under drought stress conditions. Five numbers of competitive plants, preferably from the middle rows over the replications, were considered for recording the morphological observation as per the Standard Evaluation System of Rice, IRRI (2002).

In this study, the genetic parameters *viz.* genotypic and phenotypic coefficient of variation (GCV and PCV), heritability (H^2_{bs}), and the genetic advance (GA), were calculated using the formula given by Johnson *et al.* (1955). The whole statistical analysis of genetic parameters including the multivariate analysis of the Principal component was done by using Windostat Version 9.2 from the Indostat service.

RESULTS AND DISCUSSION

The development of rice cultivars with high yield potential under stress can be obtained by screening breeding lines under both favourable and stress conditions (Serraj and Atlin, 2008). Hence, in the present study, the stable yield performance of the landraces under both irrigated and drought stress conditions along with good drought tolerance ability were considered as reliable parameters for screening of the landraces.

Under mean value analysis, most of the yield contributing characters showed lower mean performance in stress condition in comparison to the irrigated condition and the finding is in agreement with the comparative variability study of Singh *et al.* (2018) and Muthuramu and Ragavan (2020) except root length and root: culm ratio. In this regard, Haider *et al.* (2013), opined that plants tolerate drought by lowering their shoot length and developing a large root system for extracting more water from the soil. However, the percentile mean difference between drought stress and irrigated condition were found to be minimal against the traits *viz.,* 100 seed weight and spikelet fertility, whereas, high percentile differences were observed against the traits *viz.,* grain yield per plant and root: culm ratio. The estimates of mean values, GCV, PCV, heritability and genetic advance are presented in **Table 2**. The magnitude of phenotypic and genotypic coefficient of variations (PCV and GCV) were found to be highest in the case of leaf rolling index followed by leaf drying index and grain yield per plant, which is in confirmatory with the findings of Chuchert *et al.* (2018) and Nithya *et al.* (2020) under drought stress. Whereas, under irrigated conditions, the high magnitude of PCV and GCV values are in agreement with the studies of Maurya *et al.* (2018), Meena *et al.*(2019) for grain yield per plant as well as the number of filled grains per panicle and Hossain *et al.*(2015) for root: culm ratio and root length. Under drought stress, the high magnitude of genetic variation values of leaf rolling index and leaf drying index are in agreement with the studies of Haider *et al.* (2012) and Kumar *et al.* (2015). The wide difference in GCV and PCV for leaf drying index under drought stress environment certainly justified the high environmental effect or more specifically the stress effect on the said traits. Although high heritability estimates are effective in the selection of landraces based on the phenotypic expression, heritability estimates along with genetic advances are more useful in predicting the effects for selection of the desired type of landraces (Acharjee *et al*., 2019). Improvement of the genotypic value of a particular character of a new population in comparison to the base population under selection refers to Genetic advance (GA) (Wolie *et al*., 2013). Heritability and genetic advance are found to be very effective selection parameters when considered jointly.

Under the irrigated condition, high estimates of heritability (H^2) coupled with moderate to high genetic advance were observed in various traits and the results are in accordance with the findings of Khan *et al.* (2019), Meena *et al.* (2019) and Perween *et al.* (2020) for grain yield per plant and the number of filled grains per panicle, Perween *et al*. (2020) for the number of spikelets per panicle and Panja *et al.* (2017) for root: culm ratio and root length of rice. Whereas, under drought stress conditions, high magnitudes of heritability with moderate to the high genetic advance of traits are in agreement with Haider *et al.* (2012) for leaf rolling index, Panja *et al.*(2017) for root: culm ratio, Perween *et al.*(2020) and Nithya *et al.*(2020) for the number of filled grains per panicle, the number of spikelets per panicle, grain yield per plant and 100 seed weight of rice. The result implies the predominance of additive gene action for these characters. Thus, based on the findings, it can be concluded that the selection of rice landraces based on these characters would be effective.

Principal Component Analysis is a multivariate analysis to measure the importance and contribution of each component to the total variance. It also can be used for the measurement of the independent impact of a particular trait on the total variance whereas, each coefficient of proper vectors indicates the degree of contribution of all original variables with which each principal component is related (Nachimuthu *et al.*, 2014). Eigenvalue, the contribution of

Table 2. Estimates of Genetic parameters for different Morpho-Physiological characters of 60 rice land races under irrigated and drought stress condition

Character		Range		Mean	GCV (%)	PCV (%)	H^2 (%)	GA as % of mean
	Condition	Min.	Max.					
VGR	D	5.0	9.0	7.17	14.15	18.60	0.57	22.19
LRI	D	0.00	5.00	0.89	137.95	147.01	0.88	266.66
LDI	D	0.00	4.50	1.11	86.06	112.20	0.58	135.99
PH	D	61.24	125.41	86.17	15.14	18.31	0.68	25.79
	I	86.66	148.58	113.55	9.77	12.68	0.59	15.52
PT	D	2.74	4.5	3.47	10.51	16.29	0.41	13.98
	I	3.16	6.08	4.3943	14.24	20.27	0.49	20. 62
PL	D	16.83	29.49	22.87	12.40	15.59	0.63	20.31
	I	17.66	31.99	24.49	12.11	16.09	0.56	18.77
PRI BR	D	5.25	10.24	7.11	14.95	18.87	0.62	24.41
	I	5.16	11.99	7.91	19.51	23.61	0.68	33.20
RL	D	7.11	26.52	14.28	34.44	37.64	0.83	64.94
	I	8.23	21.30	13.55	24.49	27.27	0.80	45.32
R:C	D	0.13	0.35	0.22	26.76	27.99	0.91	52.69
	I	0.07	0.26	0.15	28.13	31.74	0.78	51.35
NSP	D	57.49	195.33	88.51	30.68	33.42	0.84	58.03
	I	59.41	221.49	110.34	32.40	34.61	0.87	62.49
NFG	D	45.41	178.58	74.08	34.45	37.30	0.85	65.55
	I	53.08	209.58	97.73	25.39	37.70	0.88	68.42
SF	D	70.34	91.43	83.06	5.117	6.21	0.67	8.67
	I	78.29	94.65	88.04	4.23	5.26	0.64	7.02
HSW	D	1.10	2.99	2.29	18.60	19.65	0.89	36.25
	I	1.15	3.11	2.48	18.58	19.11	0.94	37.23
HI	D	12.8	40.86	23.81	25.61	29.43	0.75	45.90
	I	15.76	44.42	30.47	20.53	24.75	0.68	35.07
DRI	D	0.39	0.82	0.58	14.68	25.68	0.32	17.30
GYP	D	2.53	21.66	6.53	52.77	57.72	0.83	99.37
	I	5.20	30.35	11.34	46.26	50.42	0.84	87.44

Data for Irrigated condition: Source -Acharjee *et al*. (2019)

Min-Minimum, Max- Maximum, GCV - genotypic coefficient of variation PCV- phenotypic coefficient of variation, H^2 – Broad sense heritability, GA – Genetic advance, D- Drought stress conditions, I- Irrigated conditions.

VGR- Seedling vegetative vigour, LRI- Leaf rolling index, LDI-Leaf drying index, PH - Plant height (cm), PT – Numbers of productive tillers per plant, PL -Panicle length (cm), PRI BR- Numbers of primary branch per panicle, RL-Root length (cm), R: C –Root: Culm ratio, NSP- Number of spikelets per panicle, NFG - Number of filled grains per panicle, SPK-Spikelet fertility (%), HSW-100 Seed weight (g), DRI – Drought recovery Index, HI-Harvest index (%), GYP-Grain yield per plant (g)

variability and Eigenvectors for the principal component axes and component loading of different traits of rice landraces under irrigated and drought stress conditions are presented in **Table 3**.

In the present study, an effort was made to identify the important traits that play prominent roles in classifying the variation existing in the rice landraces as well as to enhance the potential of drought tolerance. As per the

Table 3. Eigen value, contribution of variability and Eigen vectors for the Principal component axes and component loading of different traits of rice landraces under irrigated and drought stress conditions.

Parameters	Irrigated condition					Drought stress condition						
	Principal Components (PCs)					Principal Components (PCs)						
	PC 1	PC 2	PC 3	PC 4	PC 5	PC 1	PC 2	PC 3	PC 4	PC 5	PC 6	PC 7
Eigen Value Root	2.76	2.34	1.35	1.30	0.96	4.49	2.41	1.53	1.31	1.11	1.02	0.15
% Var. Exp.	23.02	19.46	11.21	10.84	8.02	28.05	15.09	9.56	8.16	6.92	6.34	0.09
Cum. Var.Exp.	23.02	42.47	53.68	64.52	72.53	28.05	43.14	52.70	60.85	67.78	74.12	74.20
Traits	Factor loadings after Varimax rotation					Factor loadings after Varimax rotation						
VGR*	-	-	-	-	-	0.33	0.20	0.05	0.01	0.09	0.42	0.15
LRI*	-	-	-	-	-	-0.20	0.46	0.15	-0.17	0.01	0.21	0.09
LDI*	-	-	-	-	-	0.33	-0.06	0.21	-0.08	-0.34	0.19	0.25
PH	0.31	0.36	0.20	0.04	0.21	-0.18	-0.45	-0.12	0.18	0.06	0.15	0.15
PT	0.47	-0.01	-0.23	-0.20	0.08	-0.20	-0.16	0.38	-0.03	0.12	-0.60	0.13
PL	-0.19	0.30	-0.02	-0.37	0.18	-0.31	0.11	-0.28	0.01	0.11	0.24	0.38
PRI BR	0.06	0.46	-0.02	-0.26	-0.29	-0.05	-0.35	0.10	-0.07	-0.69	0.10	0.12
RL	-0.20	-0.19	-0.39	-0.03	-0.44	-0.36	0.23	0.12	0.09	-0.27	0.01	-0.07
R:C	0.20	0.34	0.45	0.15	-0.25	-0.28	0.34	-0.05	0.17	0.00	-0.07	-0.01
NSP	0.14	0.41	-0.35	-0.26	0.00	-0.23	-0.29	0.18	0.12	0.30	0.26	0.06
NFG	0.32	0.10	-0.54	0.22	-0.21	-0.14	0.10	0.19	-0.65	0.01	-0.12	0.43
SPK	0.05	-0.26	-0.05	-0.65	0.33	0.11	0.28	0.17	0.44	-0.26	-0.23	0.00
HSW	-0.41	0.28	-0.27	0.17	0.16	-0.22	0.05	-0.35	-0.36	-0.29	0.04	-0.48
HI	-0.35	0.08	0.19	-0.37	-0.51	-0.09	0.04	-0.54	0.23	-0.18	-0.23	0.49
DRI*	-	-	-	-	-	0.38	0.20	-0.05	0.02	0.01	-0.15	0.15
GYP	-0.39	0.30	-0.13	0.18	0.37	-0.29	0.08	0.39	0.29	-0.14	0.27	0.02

VGR- Seedling vegetative vigour, LRI- Leaf rolling index, LDI-Leaf drying index, PH - Plant height, PT – Numbers of productive tillers per plant, PL -Panicle length, PRI BR- Numbers of primary branch per panicle, RL-Root length, R: C –Root: Culm ratio, NSP- Number of spikelets per panicle, NFG - Number of filled grains per panicle, SPK-Spikelet fertility, HSW-100 Seed weight, DRI – Drought recovery Index, HI-Harvest index, GYP-Grain yield per plant.

* Traits for which analysis was not carried out in the irrigated condition.

criteria set by Brejda *et al.* (2000), the PC with Eigenvalue > 1 and which explained at least 5% of the total variations in the data were considered in the present study for analysis. Accordingly, in our study, the first four Principal components (PC) showed more than ‘1’ eigenvalue and exhibited 64.52 per cent cumulative variability under irrigated conditions. Further, the PC with higher eigenvalues and variables with high factor loading was considered as the best representative of system attributes. As per Raji (2002), to determine the critical limit for the coefficients of the proper vectors, coefficients greater than 0.3 (regardless of the direction, positive or negative) are considered to have a large effect on the overall variation present in the landraces. The PC1 showed 23.02 per cent of total variability comprised of significant loading values (coefficients values greater than 0.3) of most of the important yield contributing traits *viz*., the number of productive tillers per plant, 100 seed weight, grain yield per plant, harvest index and plant height. PC 2 with 19.46 per cent of the total variability is also loaded with high factor values of yield contributing traits of a number of primary branches per panicle, the number of spikelets per panicle. PC 3 and PC 4 were found to be enriched with the high loading values of root: culm ratio, the number of filled grains per panicle and spikelet fertility.

Principal component analysis, however, results in more divergence assessment under drought stress conditions with six numbers of principal components with eigenvalue ≥ 1 and total cumulative variability of 74.12 per cent. Cumulative count of 43.14 per cent of total variability by PC1 and PC2, justify the major contribution of the first two principal components towards tracing out the important traits for enhancing the potential of the rice landraces under drought stress. A major contribution of the first two principal components towards the total variability of rice genotypes under drought stress conditions was also found by Maji *et al.* (2012) and Nachimuthu *et al*. (2014). PC 3, PC 4, PC 5 and PC 6 also contributed significantly with PC wise variability count of less than 10 per cent.

Under drought stress conditions, significant contributions of most of the drought stress indicative traits *viz.,* drought recovery index, root length, leaf drying index and vegetative vigour are found in PC 1. In addition, PC 2 is also found to be enriched with high loading values of drought stress indicative traits like leaf rolling index, root: culm ratio along plant height. PC 3 settled itself as a yield contributory principal component with significant contribution of harvest index, grain yield per plant, the number of productive tillers per plant and 100 seed's weight, while the number of filled grains per panicle render remarkable contribution in PC 4. The result is confirmatory with the findings of Ojha *et al.* (2017) and Pavithra and Vengadessan (2020). Hence, in comparison to the irrigated situation, more specific PC wise categorization of discriminating traits was found under drought stress, wherein, PC 1 and PC 2 were found to be attributed with most of the drought-tolerant traits and PC 3 along with PC 4 categorized as grain yield contributing components. Overall, the traits *viz.,*100 seed weight, harvest index, grain yield per plant and number of filled grains per panicle are found to be worthy for stable performance of the landraces under both irrigated and drought stress conditions. As far as the drought tolerance ability of rice landraces is concerned, factors like drought recovery index, root length, leaf rolling index, leaf drying index and root: culm ratio should be considered with due gravity. The importance of comparative principal component analysis (PCA) towards the quantification of genetic divergence and selection of superior plant type under drought stress were also accessed in the studies of Ojha *et al*. (2017) and Turin *et al.* (2021).

Scree plot explained the percentage of variation associated with each principal component obtained by drawing a graph between eigenvalues and principal component numbers. It displays the eigenvalue associated with a component or factor in descending order versus the number of components or factors. Scree plot depicting eigenvalue variation of Principal components under irrigated and drought stress conditions is elucidated in **Fig. 1**. The ideal pattern in a scree plot is a steep curve, followed by a bend and then a flat or horizontal line (Chandra *et al*., 2017) which is more or less similar to an elbow bend. In this study, it was clear from the depiction of the scree plot that the first three principal components showed the maximum variability under both irrigated and stress conditions. Further, elbow pattern lines are also found after PC3. The PCA scores of 60 rice landraces under irrigated and drought stress condition is presented in **Table 4.**

Based on the trend of scree plot curve, the PCA scores of 60 landraces in the first three principal components were computed and considered as three axes as X, Y and Z. PCA scores of 60 landraces were plotted in graph to get three-dimensional scatter diagrams **(Fig. 2** and **Fig. 3)** Evaluation of rice genotypes through PCA 3D scatter diagram was also carried out by Tejaswini *et al*. (2018) and Ibrahim *et al*. (2021).

According to Tejaswini *et al*. (2018), the genotypes identified on the extremely positive side of both the X and Y axis were considered to be better genotypes against the contributing traits of PC 1 and PC 2, respectively, however, in the 3D (three dimensional) scattered diagram, it was considered an additional vertical Z-axis and in that case, the genotypes plotted higher along the Z-axis will also be considered as better performers against the contributing traits of PC 3.

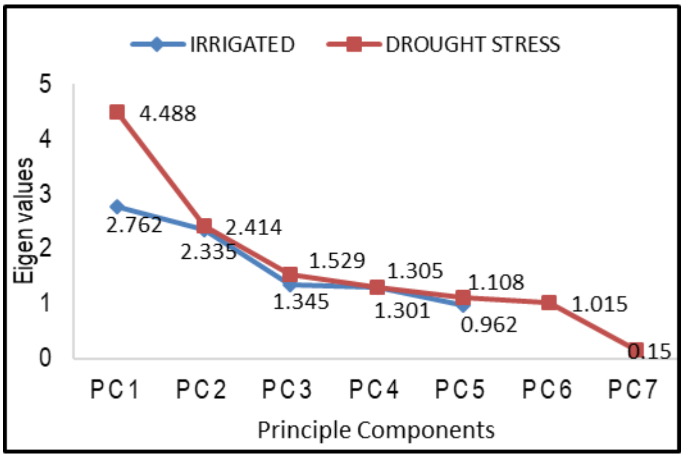

Fig. 1. Scree plot showing eigenvalue variation of Principal components under irrigated and drought stress condition.

Table 4. PCA scores of 60 rice landraces under irrigated and drought stress condition

Irrigated Condition								Drought Stress Condition							
Landraces	PCA X axis	PCA Y axis	PCA Z axis	Landraces	PCA X axis	PCA Y axis	PCA Z axis	Landraces	PCA X axis	PCA Y axis	PCA Z axis	Landraces	PCA X axis	PCA Y axis	PCA Z axis
Kaporok	7.60	-4.78	0.25	Darka Sona	7.05	-6.28	0.39	Kaporok	-10.60	19.19	8.39	Darka Sona	-8.01	18.68	6.76
Releng	6.53	-5.12	1.63	Tarikol Kolte	7.38	-4.96	0.91	Releng	-9.98	19.17	7.03	Tarikol Kolte	-8.67	18.04	6.45
Beti	7.63	-5.69	0.02	SadaBiroin	6.63	-5.94	2.00	Beti	-10.41	20.26	8.18	SadaBiroin	-5.73	17.83	6.99
Maimi Uzrao	7.36	-5.53	1.91	Maimi Taukha	7.04	-5.30	0.69	Maimi Uzrao	-6.64	17.13	6.22	Maimi Taukha	-11.17	23.07	6.73
Kalikhasa	12.68	-7.51	4.09	Saluma	7.52	-6.50	1.16	Kalikhasa	-5.40	18.55	9.99	Saluma	-8.11	21.67	7.46
Chinal	9.11	-5.93	0.94	Tarkol	6.53	-4.36	-1.14	Chinal	-6.76	17.86	8.03	Tarkol	-12.86	21.89	8.52
American	7.30	-5.17	1.23	Madoop	9.81	-5.04	1.00	American	-7.86	17.77	6.59	Madoop	-8.75	16.48	9.17
Khasa Kasam	10.85	-7.12	4.66	Waibang	6.92	-5.84	-0.37	Khasa Kasam	-5.30	17.93	9.02	Waibang	-8.70	22.28	8.34
Biroin	7.20	-5.80	0.46	Jhum Bini	6.33	-4.80	0.71	Biroin	-9.69	19.21	6.79	Jhum Bini	-9.35	19.70	6.83
Galong	8.47	-2.31	-0.89	Fazu Sen (White)	7.89	-7.49	0.41	Galong	-11.68	18.61	7.03	Fazu Sen (White)	-7.38	19.84	7.81
FazuVom	6.35	-5.00	1.90	Bongbu	6.38	-4.91	1.93	FazuVom	-7.61	20.09	6.68	Bongbu	-6.63	17.22	5.48
Garo Malati	8.70	-0.41	-0.66	Sadok	6.21	-5.98	1.62	Garo Malati	-12.60	16.05	8.08	Sadok	-6.46	19.40	6.41
Maimi Usha	7.34	-6.10	1.51	Kali Jira	11.36	-8.49	1.38	Maimi Usha	-7.04	19.21	7.37	Kali Jira	-5.31	19.08	9.59
Maimi Red	6.04	-5.21	0.86	Gaigash	7.01	-4.75	0.56	Maimi Red	-8.37	19.01	6.20	Gaigash	-7.76	17.89	6.82
Suri	7.85	-6.85	1.59	Vanbang	7.89	-6.60	1.21	Suri	-6.06	17.87	7.52	Vanbang	-5.50	17.26	8.01
Lebuka	7.76	-5.35	2.31	Makajaria	9.84	-5.25	3.00	Lebuka	-6.51	17.31	6.65	Makajaria	-5.86	17.39	6.82
Aaduma	10.80	-7.02	0.96	Jilong	8.08	-6.58	1.78	Aaduma	-7.50	18.08	8.45	Jilong	-6.37	19.07	6.73
Fazu Sen	6.71	-5.02	1.81	American Ration	8.69	-6.43	1.32	Fazu Sen	-7.44	18.71	6.17	American Ration	-6.01	17.38	7.23
Fazu Ngoi	7.13	-6.89	0.91	Kala Dhan	7.16	-5.67	0.62	Fazu Ngoi	-7.11	20.91	7.68	Kala Dhan	-7.65	18.00	6.45
Beti Kalai	7.09	-5.44	0.44	Turkey	9.23	-2.20	0.21	Beti Kalai	-8.66	18.32	6.53	Turkey	-8.69	15.76	6.53
Saanki ka Phool	9.67	-6.78	1.88	Saanki Kachak	8.84	-4.54	1.29	Saanki ka Phool	-5.47	17.31	6.78	Saanki Kachak	-7.11	16.38	6.64
Bihar	10.36	-7.46	1.54	Maimi Ukhlao	8.21	-5.14	2.57	Bihar	-6.51	18.27	8.02	Maimi Ukhlao	-6.55	18.13	6.66
Chikanswari Kabar	8.72	-0.93	-0.80	Maiwasha	5.50	-5.76	0.96	Chikanswari Kabar	-12.36	14.59	8.31	Maiwasha	-6.63	17.52	6.42
Bangbu Jhum	5.59	-5.91	1.35	Maimi Watoklok	6.69	-3.27	-0.14	Bangbu Jhum	-6.82	18.35	5.49	Maimi Watoklok	-10.61	19.10	6.16
Lal Biroin	6.20	-5.63	0.74	Santinm Wakhum	7.33	-4.89	2.01	Lal Biroin	-5.93	16.97	7.22	Santinm Wakhum	-5.88	16.80	5.68
DhalaBalam	8.03	-4.35	-0.21	Yang Dhan	8.51	-6.11	2.44	DhalaBalam	-8.61	17.40	7.01	Yang Dhan	-4.04	17.17	6.85
Goria	7.77	-5.69	1.91	Badaya	6.95	-5.67	0.62	Goria	-5.91	17.16	6.19	Badaya	-5.09	17.63	7.43
Bahadur	9.66	-6.56	1.99	Kanchali	9.36	-5.46	3.25	Bahadur	-6.02	17.58	7.39	Kanchali	-5.33	17.48	8.73
Maimiwatolok Mandoori	8.30	-4.67	1.60	Australian Biroin	7.45	-4.41	3.74	Maimiwatolok Mandoori	-6.70	16.50	6.52	Australian Biroin	-7.74	17.26	6.02
Maimi Hungar	5.88	-4.59	-0.51	Assam Paisom	11.59	-6.51	1.21	Maimi Hungar	-10.80	18.74	5.93	Assam Paisom	-7.11	17.09	7.84

Under, irrigated condition, PC1 was loaded with high coefficient values (irrespective of direction) of most of the grain yield-related traits, thus the genotypes reside towards the higher value or right side along with the PCA score I axis (X-axis) of the 3D scattered diagram **(Fig 2.)** may be considered as promising landraces as far as grain yield is concerned. The finding is in confirmatory with Gour *et al.* (2017). Similarly, landraces settled towards the comparatively right side of the Y-axis may also be selected, as PC 2 was enriched with the high coefficient values of grain yield-related traits and grain yield itself. PC 3 was loaded with high factors of root and grain-related traits, thus the landraces, which plotted themselves, higher along the Z-axis also to be considered with due gravity. For convenience in the identification of landraces in the 3D scatter plot, we have cited the serial numbers of the landraces within the parenthesis behind the name of the landraces. Landraces *viz.,* Galong, Garomalati, Chikanswarikabar, Turkey were plotted along the middle to the right of the X-axis and extreme right side of the Y-axis. Hence, these landraces may be selected as better yielders. Interestingly, the same genotypes were also found to be outliers, away from the centre cluster, which revealed the variability of the genotypes from the rest of the set. On the other side, landraces *viz.,* Kalikhasa, Khasakasam and Kalijira plotted themselves high along the Z-axis and extreme right of the X-axis away from the cluster, justifiably, they seem to be desirable landraces with significant values of yield and root related traits. Accordingly, these outlier landraces with significant values along the X, Y and Z-axis may be referred to as potential parents in further breeding programmes.

Under drought stress conditions, PC1 was contributed with high coefficient positive values of drought recovery index, vigour and root length, which are in agreement with the studies of Baghyalakshmi *et al.* (2016), Mishra *et al.* (2019) and Verma *et al.* (2019). Justifiably, the landraces plotted on the right side along the X-axis may be identified as a stable grain yielder with developed root morphology. Similar to the finding of Siahsar *et al.* (2010), positive values for traits like leaf rolling index and root: culm ratio were found to be dominant in PC 2, hence the landraces plotted on the right side of the Y-axis may have better drought escaping capacity. While the landraces plotted high along the Z-axis may be identified as high yield contributors under drought stress conditions as the PC 3 component was enriched with significant-high loading values of grain yield and other grain yield contributing characters. The 3D scattered diagram for drought stress depicts that landraces *viz.,* Garomalati and Chikanswari Kabar, which were grouped under irrigated conditions, positioned themselves in the extreme left side of both X and Y axis but high along the Z-axis, away from the centroid. This position of the landraces for the Y and Z axis proved those as stable yielders with less expression of drought escaping traits under stress. Another two landraces *viz.,* Tarkol and Maimi Taukha settled themselves in the extreme right or high-value side along the Y-axis and high along the Z-axis. They were also been found to be outliers from the central cluster of most of the landraces. Hence, they were identified as diverse but most promising landraces attributed with stable yielding and drought escaping quality under stress. The 3D scatter plot position of the landraces Madoop and Turkey were also found to be significant as those landraces plotted high along the Z-axis and middle way along the X-axis, which justify the adaptability of those landraces under drought stress.

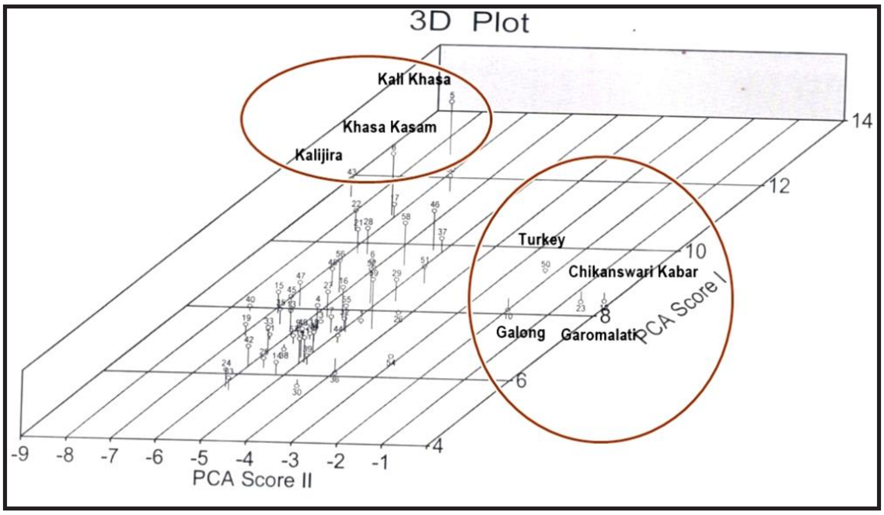

Fig. 2.Three dimensional scattered diagram of PCA under irrigated condition.

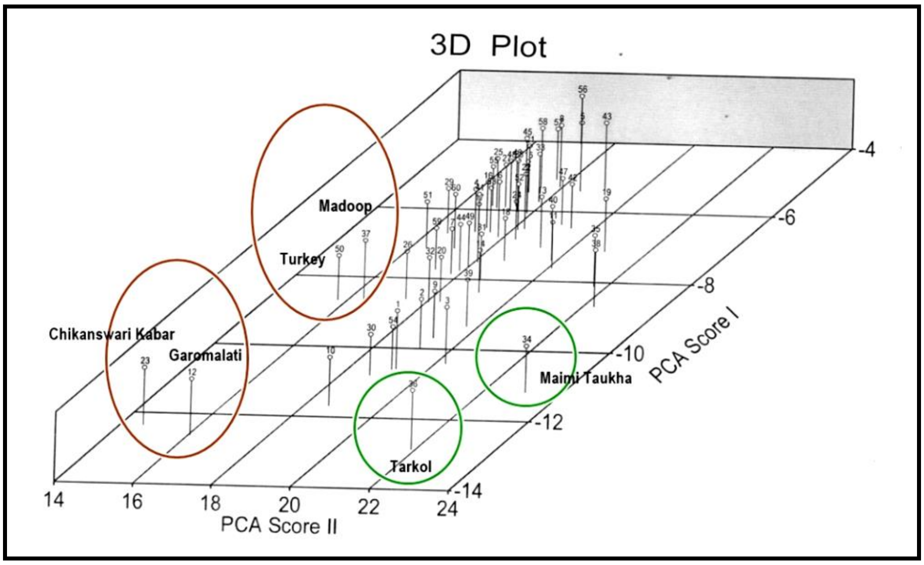

Fig. 3. Three dimensional scattered diagram of PCA under Drought stress condition.

The sensitivity of the landraces under drought stress conditions was confirmed by both the first-order statistics of genetic variation and multivariate analysis of principal components under the study. Therefore, a greater possibility of improvement in the overall performance of the rice landraces through the selection of appropriate traits appears to be existed in drought stress conditions. Based on the genetic variation and principal component analysis, certain yield contributing and drought stress indicative traits *viz.,* 100 seed weight, harvest index, grain yield per plant, the number of filled grains per plant, leaf rolling index, leaf drying index and root length found to be suitable discriminating factors towards screening of rice landraces for potential drought tolerance and yield stability under drought stress conditions. Further, the outlier promising landraces of the 3D scatter plot of PCA *viz.,* Garomalati, Chikanswari Kabar, Turkey, Tarkol, Maimi Taukha and Madoop, could be taken into consideration while selecting suitable parents in future drought stress rice breeding programmes.

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