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EVALUATION OF *AUS* RICE GENOTYPES GROWN UNDER RAINFED AND IRRIGATED CONDITIONS

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Abstract

Bangladesh must keep increasing the production of rice (*Oryza sativa* L.), which is consumed by more than half of the world's population in order to ensure a steady supply of food for everyone. A field experiment was conducted to select short durated with high yield potential *Aus* rice genotypes under rainfed condition in a split plot design with three replications. Two water regimes (irrigated and rainfed) were imposed into main plot and 39 *Aus* rice genotypes were assigned into sub plots. In order to categorize the genotypes into various groups, multivariate studies including cluster analysis, principal component analysis (PCA), and discriminantfunction analysis (DFA) were carried out using fifteen quantitative plant traits. Results based on agronomic traits, the genotypes were grouped into six clusters. Early maturing genotypes are represented in cluster II, and genotypes with outstanding yield performance under irrigation are grouped in cluster III. Additionally, clusters III and IV indicate genotypes that mature quickly and a high yield potentiality under rainfed conditions, respectively. Biological yield played a very vital role under both irrigated and rainfed conditions. PCA revealed that PC 1, 2, 3, 4, and 5 described 84.90% variation under irrigated and 84.83% variation in rainfed condition, altogether. Stepwise DFA showed function 1 and 2 accounted for a cumulative of 95.40% of total variance in irrigated and of 92.3% variance in rainfed condition. BR24, Rupsail, Kachilon, Kachiloon2, Darial, Katak-Tara2, BRRI dhan43, Bowalia, BRRI dhan55 and BR14 showed the best performance under rainfed condition. The genotypes like Laksmilota, Loroi, Dhala Saita-3 and Kala manik can be used for further study as early maturing genotypes.

Keywords: Agronomic traits, genotypes, multivariate, cluster analysis.

Introduction

More than half of the world's population is fed by the important grain crop known as rice (Ghosh *et al*., 2018). Rice is consumed in large quantities in developing and Asian countries. Nearly 95 percent of the world's rice is produced in Asian countries, and roughly half of the world's population consumes it. Rice is the third most important agricultural commodity after sugarcane and maize (Pengkumsri *et al.,* 2015). It is the primary source of dietary energy in 17 Asian and Pacific countries, 9 North and South American countries, and 8 African countries (Rathna Priya *et al.,* 2019). It is grown in over a hundred countries, with a total harvested

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area of about 160 million hectares and a production of over 700 million tons each year (IRRI, 2013). Rice is a staple food grain in Bangladesh. It is grown on nearly 11.25 million hectares of land, accounting for about 82 percent of the total cropped area, and is grown in three growing seasons: *Aus* (May-August), Aman (July-December), and Boro (November-June), all of which have remained relatively stable over the past three decades (Islam *et al.,* 2016). During this time, total rice acreage is expected to decrease to 10.28 million hectares from 11.25 million hectares (BRRI, 2011). In Bangladesh, it is consumed by 156 million people. The population is growing at a rate of two million people per year, and by 2050, the total population will be 238 million. To feed this ever-increasing population, an increase in total rice production is needed. At the same time, due to the construction of industries, factories, houses, roads, and highways, total cultivable land is declining at a pace of more than 1% each year (Shelley *et al.,* 2016). Rice production must be expanded to feed Bangladesh's ever-growing population, either by increasing arable land, boosting per-hectare yield, or minimizing yield gaps (Ghosh *et al.,* 2015). It is impossible to increase arable land in our densely populated country, but it is possible to reduce the yield gap. Rice output, on the other hand, can be enhanced by boosting per hectare yield, which must be increased by 53.3 percent to meet the country's demand (Mahmud *et al.,* 2012). Natural calamities such as floods, salt, drought, and water scarcity are the main obstacles to increasing per hectare productivity. Among the natural calamities drought or water stress is the most notable one (Ghosh *et al.,* 2021).

One of the most pressing issues of the twenty-first century is water shortage, which is anticipated to worsen as a result of rapid global climate change (Ghosh *et al.,* 2022). Water resources are under pressure as a result of population increase, economic development, urbanization, dietary changes, widespread civil unrest and regional wars, migration, and pollution (Zarei, 2020). For every one degree Celsius of global warming, renewable water supplies will be reduced by 20% or more for 7% of the world's population (Portmann *et al.,* 2013). Irrigated agriculture accounts for 40% of world crop yield on only 20% of farmed area. Drought has an economic impact of up to 84 percent on agriculture, with major implications for food security. Desertification's direct and long-term effects on land and soil quality, soil structure, organic matter, and soil moisture, and thus on agricultural production, are exacerbated by water constraint (FAO, 2016). According to climate models, global warming would exacerbate drought as a result of increased evapotranspiration, albeit there will likely be major regional variances, with drought frequency and intensity increasing by 1 to 30% in extreme drought land areas by 2100 (Fischlin *et al.,* 2007). About 32% of rice-growing areas in Asia are under rainfed agriculture. In Bangladesh, during the rice growing season, *Aus* rice is cultivated under rainfed conditions (FAO, 2011). Drought stress affects unbounded upland, bounded upland, shallow rainfed, mid-lowland rainfed, and water short irrigated areas the most. Around 23 million hectares of rainfed rice are affected by drought around the world (Serraj *et al.,* 2011).

In Bangladesh, *Aus* rice is typically grown between April and August. This crop's vegetative phase lasts from April to May, during which time rainfall is erratic in nature. The crop suffers from moisture stress when the rain ceases. At June and July, it's in the reproductive stage. The total rainfall in these two months is highly variable and frequently insufficient to meet the evapotranspiration needs of *Aus* rice. As a result, rice suffers from water stress, which inhibits assimilate translocation and grain formation. Rice is extremely sensitive to water stress throughout the reproductive stage, which results in a considerable decrease in grain output (Palanog *et al.,* 2014). The extent of the yield loss is determined by the growth stage and duration, as well as the intensity of drought stress (DS). In one trial, severe DS applied during the vegetative stage and mild DS administered during the flowering stage resulted in yield losses of 20% and 28%, respectively (Kumar *et al.,* 2014). Water stress at or before panicle initiation reduces the number of potential spikes and inhibits assimilate translocation to the grains, resulting in low grain weight and a rise in empty grains. As *Aus* rice is direct-seeded and grown in rainfed upland environments, it could be affected by drought at any stage from seedling to reproductive stage (Biswas, 2014). Furthermore, due to massive irrigation-dependent Boro rice cultivation, the ground water level is diminishing day by day. As a result, the Government of Bangladesh has decided to increase *Aus* and *Aman* rice production rather than *Boro* rice production in order to reduce the pressure of ground water table. Increased *Aus* rice productivity could eventually replace *Boro* rice production. On the other hand, Research of *Aus* rice documentation is limited in Bangladesh. Hence, it is necessary to find out *Aus* rice genotypes with short duration, high yield potential and water stress tolerance characters, so that it can be grown economically under rainfed condition. With that background problem and opportunity, this study was initiated to evaluate *Aus* rice genotypes for high yield performance with short duration under rainfed condition.

Materials and Methods

Descriptions of the study site

The experiment was conducted at the research field of the Department of Agronomy, Bangabandhu Sheikh Mujibur Rahman Agricultural University (BSMRAU), Gazipur during *aus* season. Experimental site belongs to Madhupur Tract under agro ecological zone (AEZ) 28 at geographic coordinate 24^{o}05' North latitude and 90^{o}16' East longitude. The soil of the experimental site is belonging to Salna series representing shallow Red-Brown terrace soil in Bangladesh classification and Inceptisols in USDA classification (Brammer, 1996), which is characterized by silty clay loam within 50cm from the surface and is acidic in nature. The climatic condition of the area is sub-tropical, wet and humid. Heavy rainfall occurs during June-July (269 to 370 mm) and scanty rain during November to February (0 to 55 mm).

Treatments and design of the experiment

The experiment was laid out in a Split Plot Design with three replications. Two sets of treatment viz. Irrigation levels (irrigated and rainfed) and 39 *aus* rice genotype were used in this study (Table 1). The experimental area was divided into three blocks, each block represent one replication. Each block was divided into

Table 1. *Aus* rice genotypes used in the experiment

Genotype code	Genotype name	Genotype code	Genotype name	Genotype code	Genotype name
G1	Dhala Saita	G14	Loroi	G27	BRRI dhan43
G2	Dhala Saita 2	G15	Boteswar	G28	BR 24
G3	Dharial	G16	Laksmilota	G29	BR 26
G4	Dular	G17	Kala Manik	G30	BRRI dhan55
G5	Khasi Panja	G18	Buri Katari 2	G31	BRRI dhan57
G6	Katak Tara	G19	Katak Tara 2	G32	Nerica 1
G7	Pan Bira	G20	Kachilon	G33	BRRI dhan42
G8	Paspai	G21	Kachilon 2	G34	BR 21
G9	Pukhi	G22	Bowalia	G35	BR 16
G10	Rupsail	G23	Bowalia 2	G36	BRRI dhan48
G11	Surja Mukhi	G24	Bolorum	G37	Nerica 10
G12	Hasha Kumira	G25	Nerica ABSS	G38	BINA dhan12
G13	Dhala Saita 3	G26	BRRI dhan55(2)	G39	BR 14

two main plots. Irrigation levels (irrigated and rainfed) were given in main plots. Thirty nine *aus* rice genotypes placed into the sub plots which was used as planting materials. The size of unit main plot was 29.25 m × 1 m. The spacing was 25 cm × 15 cm (RR × PP). The distance between two adjacent main plots was 0.5 m. The distance between two blocks was 2 m. Total area was 321.75 m^2 for conducting this experiment.

The land was prepared by repeated ploughing and cross-ploughing. Polythene sheets were used to cover rainfed plots to keep water out. According to the Fertilizer Recommendation Guide (FRG) 2018, the recommended fertilizer doses were applied to the plot. Total amount of triple super phosphate, muriate of potash and gypsum were applied during final land preparation. Nitrogenous fertilizer was applied in three split; first split was applied as basal dose. The second and third splits of nitrogen fertilizer were applied at 35 and 55 DAS, respectively. Sprouted seeds were sown in line sowing method. Irrigation was used on irrigated plots as needed, but rainfed plots were depended to moisture for rainfall. Four rice seeds were sown in a hill by hand. Intercultural operations viz. gap filling and thinning, weeding, and plant protection measures were done as and when needed to ensure normal growth of the crop.

Sampling and data collection

The crop was harvested at the physiological maturity stages, when 85% of the grains of the panicle became golden yellow in color and data was recorded from randomly selected five plants and then averaged on yield and yield attributing characters including- days to flowering (DF), days to maturity (DM), plant height (PH), number of tillers hill^{-1} (TT), number of effective tillers hill^{-1} (ET), number of non-effective tillers hill^{-1} (NET), panicle length (PL), number of grains panicle^{-1} (GP), number of filled grains panicle^{-1} (FG), number of unfilled grains panicle^{-1} (UEG), 1000-grain weight (TW), grain yield m^{-2} (GY), straw yield m^{-2} (SY), biological yield m^{-2} (BY), and harvest index (HI) were recorded following standard procedures. To compensate for the objective of the study we will discuss only the characters which are very closely related to our objectives.

The grains were cleaned and dried to a moisture content of 14%. Straws were air dried properly. Fifteen agronomic variables were considered in the cluster analysis, principal component analysis (PCA) and discriminant function analysis (DFA).

The formula used for different parameters:

$$\text{Grain yield} = \frac{\text{100-Sample moisture content (\%)}}{\text{100-Desired moisture content (\%}} \times \text{fresh weight of grain (IRRI, 2017)}$$

Biological yield = Grain yield + Straw yield

Harvest index (%) = EI/BI × 100 (Gardner *et al*., 1985)

Where, EI= Economic yield (grain yield)

BI= Biological yield (grain yield + straw yield)

Analysis of Data

The collected data were analyzed statistically using analysis of variance technique and the differences among treatment means were adjudged by Duncan's Multiple Range Test (Gomez and Gomez, 1984). Analysis was done with SPSS-16. Non-hierarchical K-mean cluster and discriminant function analysis (DFA) was performed to classify the genotypes into a number of groups. Through stepwise procedures of DFA, PCA, Chi-square test, structure matrix of variables, test of equality of group means were done. Descriptive analysis including range, mean, co-efficient of variation (CV) and skewness of the plant characters with frequency distribution was employed to estimate and describe the performance of the genotypes in terms of each character.

Results and Discussion

Yield and Yield Attributes of *Aus* Rice Genotypes

Descriptive statistics of different agronomic traits are presented in Table 2.

Plant height

Under irrigated condition among 39 genotypes, plant height of ten genotypes ranged from 90 to 110 cm, nineteen genotypes ranged 110 to 140 cm and ten genotypes showed plant height more than 140 cm (Fig. 1A). In case of rainfed condition the plant height ranged between 91.60 cm and 160.70 cm with a mean of 127.45 cm. Plant height of seven genotypes ranged from 90 to 110 cm and twenty-two genotypes ranged 110 to 140 cm and another ten genotypes found more than 140 cm (Fig. 1B). In irrigated treatment plant

Table 2. Descriptive statistics of the plant characters of 39 *Aus* rice genotypes under irrigated and rainfed condition

Plant Characters	Minimum		Maximum		Mean		SD		CV%	
	I	R	I	R	I	R	I	R	I	R
PH	91.5	91.6	160	160.7	126.61	127.45	17.56	17.22	13.87	13.51
TT	9.50	7.50	19.0	21.60	14.25	13.76	2.39	2.65	16.77	19.26
ET	4.30	5.50	15.2	16.60	9.78	10.33	2.60	2.32	26.58	22.46
NET	8.00	8.40	22.5	26.70	16.05	17.74	3.76	3.86	23.43	21.76
PL	20.60	17.8	29.2	29.00	24.49	24.14	1.91	2.12	7.80	8.78
GP	74.00	70.0	245	234.0	129.62	119.38	45.92	40.22	35.43	33.69
FG	28.00	40.0	180.	193.0	95.26	89.56	41.22	37.04	43.27	40.21
UEG	8.00	9.00	92.0	82.00	34.36	29.82	22.67	15.49	65.98	51.95
TW	17.30	17.06	30.87	29.58	22.91	22.44	3.43	3.21	14.97	14.30
SY	330.67	309.33	1120	1066.7	648.48	676.90	180.60	200.90	27.85	29.68
GY	101.33	94.40	634.7	549.33	314.39	290.08	103.44	99.53	32.91	34.31
BY	496	474.67	1701.3	1429.30	962.87	967.00	236.68	255.44	24.58	26.42
HI	11.77	10.00	45.93	44.83	32.81	30.19	7.80	7.56	23.77	25.04
DF	65.00	64.00	96.00	93.00	76.46	75.31	6.91	6.73	9.04	8.94
DM	86.00	86.00	127.0	122.00	102.15	100.82	7.99	7.37	7.82	7.31

Abbreviations: SD, standard deviation; CV, Coefficient of variation; I, Irrigated; R, Rainfed; PH, Plant height; TT, No. of total tillers hill^{-1}; ET, No. of effective tillers hill^{-1}; NET, No. of non-effective tillers hill^{-1}; PL, panicle length; GP; Grains panicle^{-1}; FG, No. of filled grain panicle^{-1}; UEG, No. of unfilled grain panicle^{-1}; TW, 1000 grain weight; SY, straw yield (g m^{-2}); GY, grain yield (g m^{-2}); BY, Biological yield (g); HI, Harvest index (%); DF, Days to flowering; DM, Days to maturity

height was higher due to have sufficient water; reduced height was found in rainfed due to reducing transpiration rate for their survival. Due to the differences of genetic makeup, genotypes responded differently to changing environment. The genotypes varied in size, with some being tall, some being medium-sized, and yet others being small. Under rainfed condition, the majority of genotypes had exhibited lower plant height performance. As a result, the mean plant height under such circumstance was lower. Ashfaq *et al.* (2012) who reported that water stress condition reduces the plant height. Several researchers in an attempt to explain the reduction in plant height under drought stress have attributed it to the limited cell length and reduced green leaves which act as source for carbon assimilation (Sing *et al.,* 2017).

Number of total tillers hill^{-1}

Under irrigated condition the number of tiller ranged between 9.50 and 19 with a mean of 14.25. Seven genotypes tiller number ranged from 8 to 12, twenty-four genotypes 12 to 16 and eight genotypes showed number of tiller more than 16 (Fig. 1C). At rainfed condition, the number of tiller ranged between 7.50 and 21.60 with a mean of 13.76. Three genotypes ranged from 5to 10, twenty-four genotypes

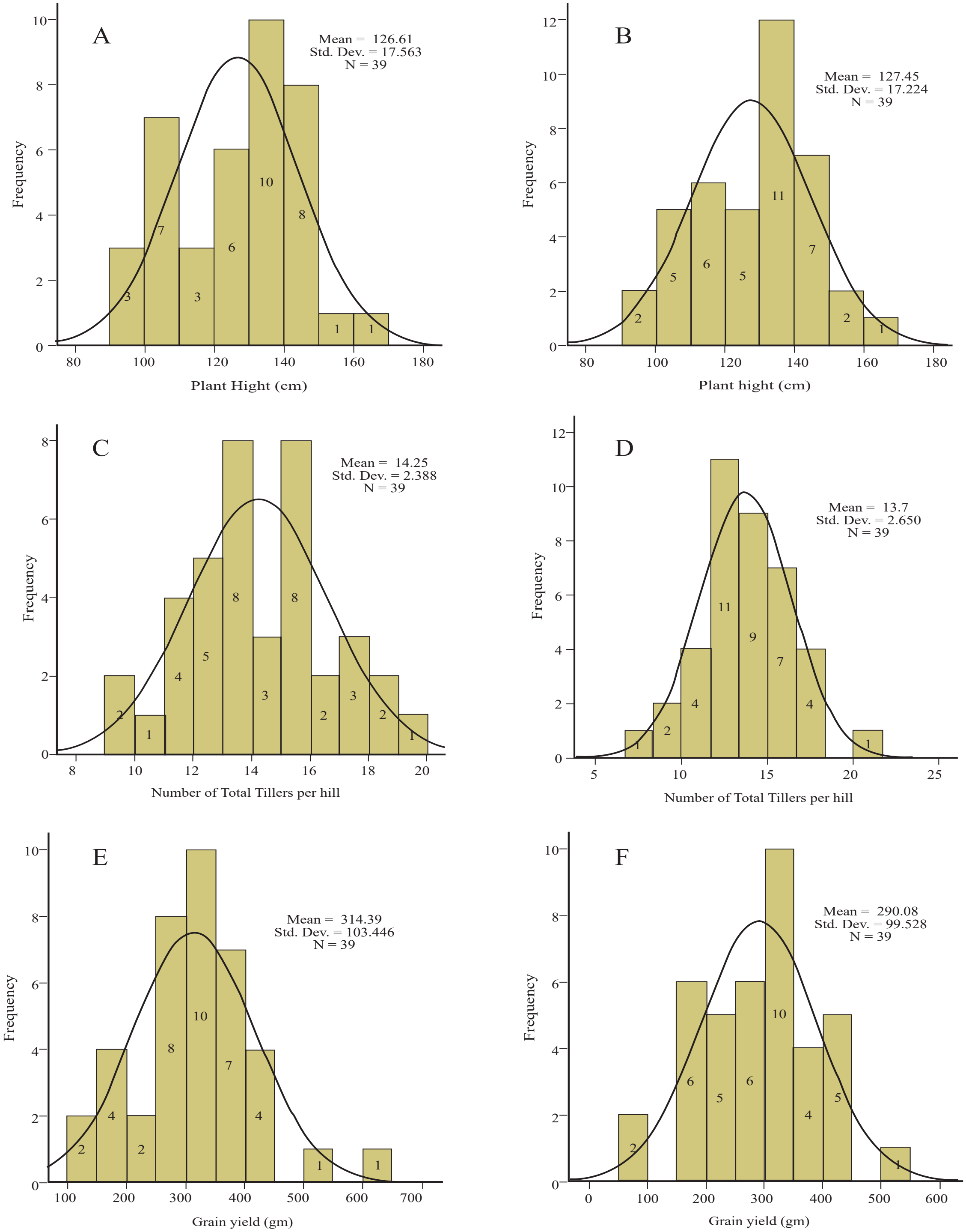

Fig. 1. **Frequency distribution of 39 *aus* rice genotypes for plant height (A=Irrigated; B= Rainfed), number of total tillers per hill (C=Irrigated; D= Rainfed) and grain yield (E=Irrigated; F= Rainfed).**

ranged 10 to 15 and twelve genotypes showed number of tiller more than 15 (Fig. 1D). Water maintains cell turgidity, which influences total tiller numbers in the different cultivars. Various genotypes responded to changing environments in different ways because of genetic differences. Under rainfed conditions, the majority of genotypes had increased total numbers of tillers per hill, which was also one of our desired features in order to get larger yields under such challenging conditions. It also acts as a major component of tissue, a component in chemical reactions, a solvent for and a mode of translocation for metabolites and minerals within the plant body. Due to aforementioned reasons, the number of total tillers was higher under irrigated condition. The lower number of tillers was observed in rainfed due to lack of water and varieties were compelled to save water for their existence. Results are supported by Bunnag and Pongthai (2013) observation that the number of tillers significantly decreased during water stress.

Grain yield

In irrigated condition the grain yield (g m^{-2}) of 27 genotypes ranged from 200 to 400 g. The grain yield of four genotypes ranged 400 to 450 g and two genotypes showed grain yield more than 450 g (Fig. 1E). At rainfed condition the grain yield ranged between 94.4 and 549.33 g with a mean of 290.08 g. At rainfed condition the grain yield of twenty-five genotypes ranged from 200 to 400 g. Six genotypes showed grain yield more than 400 g (Fig. 1F). Getting a higher amount of harvestable yield is the ultimate goal of cultivating crops. A lot of photosynthates were created in an irrigated environment because there was enough water to support high stomatal conductance and CO_2 transfer into the leaves. In that situation, the plant generated more leaf area, more effective tillers and filled grains, more test weight, fewer unfilled grains, irrigation water, and rainwater, all of which were necessary for the plants to keep functioning metabolically. Under rainfed situation yield was reduced. A similar result of yield reduction under drought stress condition was reported by Basnayake *et al.* (2006). They reported 12 to 46% reduction in grain yield under drought affect condition. In other studies reported that estimated yield reduction due to drought from 9 to 51% in rice genotypes in multi-locational trial conducted in three year in the target environment. Results are also endorsed with the findings of Ghosh *et al.* (2018) and they perceived a significant reduction of yields in water stress condition.

Straw yield

At irrigated condition the straw yield (g m^{-2}) of fourteen genotypes ranged from 400 to 600 g. The straw yield of seventeen genotypes ranged 600 to 800 g and six genotypes showed straw yield) more than 800 g (Fig. 2A). At rainfed condition twelve genotypes ranged from 400 to 600 g. The straw yield of fourteen genotypes ranged 600 to 800 and another ten genotypes showed straw yield more than 800 g (Fig. 2B). Variation in straw yield among genotypes under both conditions might be due to improper internode elongation, fertilizations and intercultural operations. Straw yield varied significantly due to variety. The reasons for higher straw yield was due to higher plant height and total tillers hill^{-1} i.e. the combined effect of plant height and tiller number (Alim, 2012). Drought stress drastically decreased the number of panicles plants^{-1} as well as straw and grain yield as compared to well-watered control (Mumtaz *et al.,* 2019).

Biological yield

At irrigated condition the biological yield (g m^{-2}) ranged between 496.0 g and 1701.3 g with a mean of 962.87 g. Twenty five genotypes ranged from 450 to 1000 g, nine genotypes ranged 1000 to 1150 g and another five genotypes showed biological yield more than 1150 g (Fig. 2C). At rainfed condition nineteen genotypes ranged from 500 to 1000 g, thirteen genotypes ranged 1000 to 1200 g and another six genotypes showed biological yield more than 1200 g (Fig. 2D). Irrigated condition favors higher biological yield as compared to rainfed conditions and this might be due to luxurious growth, environmental factors, etc.

Days to maturity

Days to maturity time ranged between 86 and 127 days after sowing with a mean of 102.15 days under irrigated condition. Fig. 2E showed a distinct variability in days to maturity time of the genotypes and exhibited nearly a normal distribution with skewed towards right ($\alpha = 0.744$). About 76.92% genotypes showed 95 to 110 days to maturity under irrigated condition. Under rainfed condition days to maturity ranged between 86 and 122 days with an average of 100.82 days. Among the 39 genotypes, 71.79% genotypes showed 95 to 110 day to maturity (Fig. 2F). Different genotype possess distinct genetical make up that's why variations in days to maturity occurred.

Correlation among plant characters

Under irrigated condition, the correlation coefficient among the plant characters showed that out of 105 coefficients, 34 genotypes were significant at *p* 0.01, 11 were significant at *p* 0.05 and others were insignificant. Under rainfed condition, 28 genotypes were significant at p 0.01, 17 were significant at *p* 0.05 and others were insignificant (Table 3).

Grouping of genotypes through Multivariate Analysis

K-means non-hierarchical cluster was done using fifteen plant characters having high correlation coefficient for grouping 39 rice genotypes. Considering these plant characters all the rice genotypes were grouped into six clusters by non-hierarchical K-mean cluster analysis (Table 4). Maximum number of genotypes (14) under irrigated condition was concentrated in cluster IV, 10 genotypes were in both the cluster I and VI, and two genotypes were in the cluster II and V. Only one genotype was found in the cluster III. Under rainfed condition, maximum genotypes (eight) were found in both cluster III and V, seven genotypes were in the cluster IV, six genotypes were found in both cluster I and II, and four genotypes were found in cluster VI.

Characterization of Clusters

Cluster I: Under irrigated condition, the genotypes of this cluster were characterized by moderate PH(126.07 cm), TT (13.35), ET (10.13), NET (17.68), PL(24.50 cm), GP(127), FG (85), UEG (42), TW (24.21g), SY (670.40 g m^{-2}), GY(283.47 g m^{-2}), DF (78 DAS), DM (104), BY(953.87 g $^{-2}$) and HI(29.64%).Under rainfed condition, the genotypes of this cluster were characterized by lowest PH(110.20 cm), TT(12.21), NET(19.68), GP(84), FG(58), UEG(26), SY(387.56 g m^{-2}), GY(172.18 g

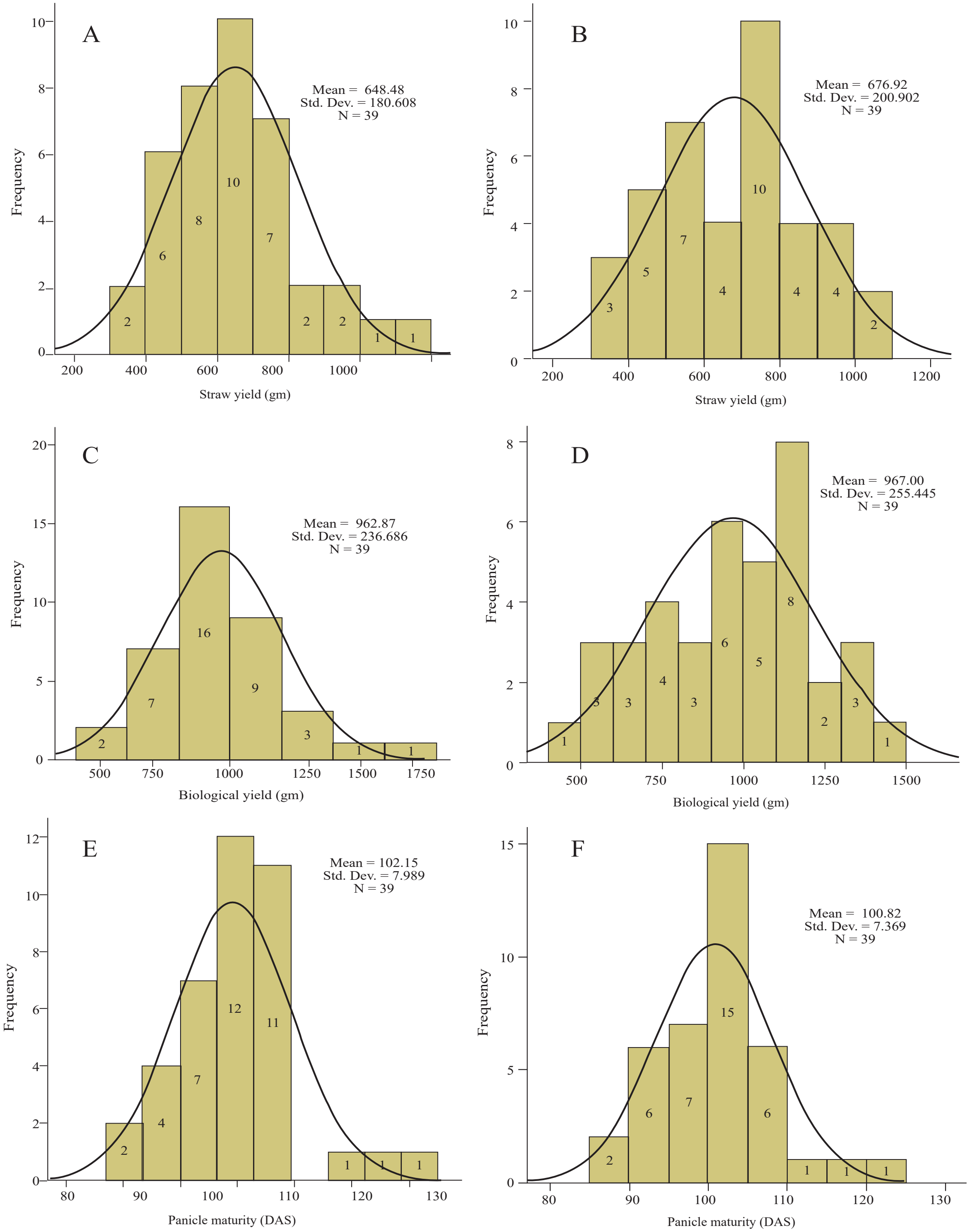

Fig. 2. Frequency distribution of 39 *aus* rice genotypes for straw yield (A=Irrigated; B= Rainfed), biological yield (C=Irrigated; D= Rainfed) and panicle maturity (E=Irrigated; F= Rainfed)

Table 3. Correlation coefficient of fifteen agronomic traits of 39 *Aus* rice genotypes under irrigated and rainfed condition

Irrigated

	PH	NT	ET	NET	PL	GP	FGP	UGP	TGW	SY	GY	DF	DM	BY	HI
PH	1														
TT	-0.39*	1													
ET	-0.28	0.54**	1												
NET	-0.07	0.41*	-0.5*	1											
PL	0.48**	-0.34*	-0.25	-0.07	1										
GP	0.39*	-0.31	-0.31	0.03	0.44**	1									
FEG	0.52**	-0.29	-0.25	-0.02	0.44**	0.87**	1								
UEG	-0.17	-0.09	-0.18	0.10	0.07	0.44**	-0.05	1							
TW	0.05	-0.24	-0.27	0.06	0.11	-0.11	-0.27	0.25	1						
SY	0.42**	-0.25	-0.11	-0.13	0.43**	0.56**	0.38*	0.44**	0.15	1					
GY	0.54**	-0.21	0.11	-0.3*	0.43**	0.41**	0.58**	-0.21	-0.14	0.34*	1				
DF	0.05	-0.20	-0.03	-0.17	0.32*	0.59**	0.33*	0.59**	0.06	0.64**	-0.02	1			
DM	-0.10	-0.14	-0.01	-0.13	0.29	0.53**	0.26	0.60**	0.03	0.53**	-0.11	0.94**	1		
BY	0.56**	-0.28	-0.03	-0.25	0.52**	0.61**	0.54**	0.24	0.05	0.91**	0.7**	0.48**	0.36*	1	
HI	0.17	0.04	0.19	-0.16	0.07	-0.08	0.25	-0.6**	-0.25	-0.4**	0.63**	-0.5**	-0.5**	-.09	1

*Correlation is significant at the 0.05 level (2-tailed) and ** correlation is significant at the 0.01 level (2-tailed), Abbreviations: PH= Plant height (cm), TT= Number of tillers hill^{-1}, ET= Effective tillers hill^{-1}, NET= Non effective tillers hill^{-1}, PL= Panicle length (cm), GP= Grains panicle^{-1}, FG= Filled grains panicle^{-1}, UEG= Unfilled grains panicle^{-1}, TW= 1000 grain weight (g), SY= Straw yield (g m^{-2}), GY= Grain yield (g hill^{-1}), DF= Days to flowering, DM= Days to maturity, BY= Biological yield (g m^{-2}), HI= Harvest index (%)

Table 3. Correlation coefficient of fifteen.
Rainfed

	PH	NT	ET	NET	PL	GP	FGP	UGP	TGW	SY	GY	DF	DM	BY	HI
PH	1														
TT	0.11	1													
ET	0.02	0.76**	1												
NET	-0.4**	-0.7**	-0.4**	1											
PL	0.44**	-0.21	-0.10	0.15	1										
GP	0.41**	-0.31	-0.13	0.23	0.40*	1									
FG	0.54**	0.27	-0.17	0.08	0.44**	0.92**	1								
UEG	-0.21	-0.15	0.05	0.39*	-0.01	0.38*	0.004	1							
TW	0.05	-0.22	-0.15	0.32*	0.14	-0.20	-0.23	0.01	1						
SY	0.41**	0.21	0.36*	-0.10	0.45**	0.46**	0.42**	0.18	0.02	1					
GY	0.41**	0.08	0.28	-0.03	0.34*	0.43**	0.06	-0.03	0.01	0.37*	1				
DF	0.05	-0.26	0.03	0.35*	0.38*	0.5**	0.32*	0.52**	0.04	0.40*	0.11	1			
DM	-0.10	-0.33*	0.03	0.43**	0.32*	0.48**	0.27	0.60**	0.04	0.35*	0.04	0.90*	1		
BY	0.48**	0.20	0.39*	-0.09	0.48**	0.53**	0.52**	0.12	0.02	0.93**	0.68**	0.36*	0.3	1	
HI	0.05	-0.03	-0.02	0.01	-0.04	0.04	-0.12	-0.18	-0.06	-0.4**	0.63**	-0.26	-0.2	-0.1	1

*Correlation is significant at the 0.05 level (2-tailed) and ** correlation is significant at the 0.01 level (2-tailed), Abbreviations: PH= Plant height (cm), TT= Number of tillers hill^{-1}, ET= Effective tillers hill^{-1}, NET= Non effective tillers hill^{-1}, PL= Panicle length (cm), GP= Grains panicle^{-1}, FG= Filled grains panicle^{-1}, UEG= Unfilled grains panicle^{-1}, TW= 1000 grain weight (g), SY= Straw yield (g m^{-2}), GY= Grain yield (g hill^{-1}), DF= Days to flowering, DM= Days to maturity, BY= Biological yield (g m^{-2}), HI= Harvest index (%)

Table 4. List of six clusters of 39 *Aus* rice genotypes classified by K-mean clustering based on fifteen agronomic traits under irrigated and rainfed condition

Cluster no.	Irrigated condition		Rainfed condition	
	Genotype code	Genotypes name	Genotype code	Genotypes name
I	G3, G5, G8, G15, G16, G26, G27, G30, G35, G38	Dharial, Khasi Panja, Paspai, Boteswar, Laksmilota, BRRI dhan55(2), BRRI dhan43, BRRI dhan55, BR 16, BINA dhan12	G1, G2, G17, G31, G32, G36	Dhala Saita, Dhala Saita 2, Kalamanik, BRRI dhan57, Nerica 1, BRRI dhan48
II	G2, G31	Dhala Saita 2, BRRI dhan57	G7, G9, G11, G26, G37, G39	Pan Bira, Pukhi, Surjamukhi, BRRI dhan55(2), Nerica 10, BR 14
III	G28	BR 24	G12, G14, G18, G20, G23, G29, G33, G34	Hasha Kumira, Loroi, Buri Katari 2, Kachilon, Bowalia 2, BR 26, BRRI dhan42, BR 21
IV	G1, G4, G9, G12, G13, G14, G17, G18, G29, G32, G33, G34, G36, G37	Dhala Saita, Dular, Pukhi, Hasha Kumira, Dhala Saita 3, Loroi, Kalamanik, Buri Katari 2, BR 26, Nerica 1, BRRI dhan42, BR 21, BRRI dhan48, Nerica 10	G3, G19, G24, G25, G28, G30, G38	Dharial, Katak Tara 2, Bolorum, Nerica ABSS, BR 24, BRRI dhan55, BINA dhan12
V	G10, G24	Rupsail, Bolorum	G5, G6, G10, G15, G16, G21, G22, G27	Khasi Panja, Katak Tara, Rupsail, Boteswar, Laksmilota, Kachilon 2, Bowalia, BRRI dhan43
VI	G6, G7, G11, G19, G20, G21, G22, G23, G25, G39	Katak Tara, Pan Bira, Surjamukhi, Katak Tara 2, Kachilon, Kachilon 2, Bowalia, Bowalia 2, Nerica ABSS, BR 14	G4, G8, G13, G35	Dular, Paspai, Dhala Saita 3, BR 16

m^{-2}), BY(559.73 g), and DF(72 DAS). The number of NET (19.68) and TW (23.75g) were highest in cluster I. The other characters were moderate in this cluster (Table 5).

Cluster II: Under irrigated condition, genotypes of this cluster were characterized by the highest TT (16.30). The lowest PH (115.50 cm), GP (94), FG (54), DF (70 DAS), DM (97 DAS) that's why grain yield (186.67 g m^{-2}) is also lowest. Cluster II is early maturing and lowest yield producing. Under rainfed condition, the genotypes of this cluster were characterized by the highest SY (994.67 g m^{-2}), BY (1296.9 g m^{-1}), DF (79 DAS), and DM (105 DAS). The other characters viz. PH (132.40 cm), TT (13.63), ET (10.43), NET (18.38), PL (25.08 cm), GP (142), FG (108), UEG (34), TW (22.57 g), GY (302.22 g m^{-2}) and HI(23.14%) were moderate in this cluster (Table 5).

Cluster III: The genotypes under irrigated condition of this cluster were characterized by the highest PH (160.30 cm), NET (20.70), PL (27.40 cm), GP (245), FG (153), UEG (92), TW (29.60 g), SY (1066.73 g m^{-2}), GY (634.67 g m^{-2}), DF (83 DAS), DM (106 DAS), BY (1701.3 g). The TT (11.10) and ET (6.90) were the lowest in cluster III. The HI (37.30%) was highest in this cluster. Cluster III is the highest yield producing. Under rainfed condition, the genotypes of this cluster were characterized by the lowest PL (22.85 cm), UEG (26), TW (21.18 g), and DM (98 DAS). The rest of the characters were moderate in this cluster (Table 5).

Cluster IV: The genotypes under irrigated condition of this cluster were characterized by moderate PH(117.16 cm), TT(15.03), NET(15.77), GP(105), FG(80), TW(22.08 g m^{-2}), SY(512.38 g m^{-2}), GY(281.14 g m^{-2}), DF(73 DAS), DM(98 DAS), BY(793.52 g m^{-2}), HI (35.12%). Only the ET (10.33) was found highest in this cluster. The PL (23.50 cm), UEG (25) were the lowest in cluster IV. Under rainfed condition, highest PL (25.13 cm), GP (143), FG (115), GY (396.19 g m^{-2}), DF (79 DAS) was found. BY (1181.7 g) was second highest. The rest genotypes were moderate in this cluster (Table 5). This is the highest grain yield (g m^{-2}) producing cluster under rainfed condition.

Cluster V: The genotypes under irrigated condition of this cluster were characterized by second highest GYPH, Plant height; TT, No. of total tillers hill^{-1}; ET, No. of effective tillers hill^{-1}; NET, No. of non-effective tillers hill^{-1}; PL, panicle length; GP; Grains panicle^{-1}; FG, No. of filled grain panicle^{-1}; UEG, No. of unfilled grain panicle^{-1}; TW, 1000 grain weight; SY, straw yield (g m-^{2}); GY, grain yield (g m^{-2}); BY, Biological yield (g); HI, Harvest index (%); DF, Days to flowering; DM, Days to maturity (376 g m^{-2}) producing cluster. The lowest NET(14.55), TW(21.51 g), HI(26.83%) and the highest DM(106 DAS) and rest of the characters were moderate in this cluster. Under rainfed condition, the genotypes of this cluster were characterized by the highest PH(134.90 cm), and HI(35.95%). The rest characters were moderate in this cluster V (Table 5).

Cluster VI: Under irrigated condition, the genotypes of this cluster VI were characterized by second highest PH (137.18 cm) and the highest DM (106 DAS). The rest characters were moderate in this cluster. Under rainfed condition, the genotypes of this cluster VI were characterized by the highest TT (17.37), ET (13.37, and UEG (35). NET (15.82), and HI (22.74%) were the lowest in this cluster. The rest characters were moderate in cluster VI (Table 5).

Principal Component Analysis

Principal Component Analysis (PCA) clearly and concisely explained the genetic diversity of 39 rice genotypes. Based on the correlation matrix (Table 3), fifteen plant characters were analyzed using PCA. A linear transformation of fifteen plant characters was performed by PCA that generated a new set of fifteen independent variables known as principal components. These were described by latent root (Eigen value) and latent vectors. Latent root associated with each principal component measures the contribution of each principal component to the total variance; where the coefficient of latent vector associated with a given principal component indicate the degree of contribution of each original variable to the principal component.

Under irrigated condition, first five PCs had Eigen values more than 1 and explained 34.36%, 21.31%, 12.69%, 9.64%, 6.88% of

Table 5. Comparison profile of the six groups of 39 *Aus* rice genotypes classified by K-means clustering under irrigated and rainfed condition

Plant characters	Irrigated						Rainfed					
	Clusters						Clusters					
	I	**II**	**III**	**IV**	**V**	**VI**	**I**	**II**	**III**	**IV**	**V**	**VI**
No. of genotypes	10	2	1	14	2	10	6	6	8	7	8	4
DF	78.00	70.00	83.00	73.00	82.00	79.00	72.00	79.00	73.00	79.00	73.00	76.00
DM	104.00	97.00	106.00	98.00	106.00	106.00	99.00	105.00	98.00	103.00	99.00	103.00
PH	126.07	115.50	160.30	117.16	136.80	137.18	110.20	132.40	122.60	134.20	134.90	128.40
TT	13.35	16.30	11.10	15.03	14.95	13.81	12.21	13.63	13.93	14.10	12.71	17.37
ET	10.13	6.95	6.90	10.33	9.25	9.63	8.30	10.43	9.60	10.82	10.55	13.37
NET	17.68	16.20	20.70	15.77	14.55	14.62	19.68	18.38	16.86	17.55	17.78	15.82
PL	24.50	24.20	27.40	23.50	26.80	25.20	22.97	25.08	22.85	25.13	24.32	24.97
GP	127.00	94.00	245.00	105.00	162.00	155.00	84.00	142.00	99.00	143.00	139.00	98.00
FG	85.00	54.00	153.00	80.00	120.00	124.00	58.00	108.00	73.00	115.00	106.00	64.00
UEG	42.00	40.00	92.00	25.00	42.00	31.00	26.00	34.00	26.00	28.00	32.00	35.00
TW	24.21	25.45	29.60	22.08	21.51	21.87	23.75	22.57	21.18	23.44	21.61	22.68
SY	670.40	330.67	1066.73	512.38	1032.03	762.13	387.56	994.67	536.00	785.52	644.00	792.00
GY	283.47	186.67	634.67	281.14	376.00	373.07	172.18	302.22	233.67	396.19	359.33	237.33
BY	953.87	517.33	1701.3	793.52	1408.0	1135.2	559.73	1296.9	769.67	1181.7	1003.3	1029.3
HI	29.64	35.97	37.30	35.12	26.83	32.87	30.82	23.14	30.19	33.38	35.95	22.74

Abbreviations: DF, Days to flowering; DM, Days to maturity; PH, Plant height; TT, No. of total tillers hill^{-1}; ET, No. of effective tillers hill^{-1}; NET, No. of non-effective tillers hill^{-1}; PL, panicle length; GP; Grains panicle^{-1}; FG, No. of filled grain panicle^{-1}; UEG, No. of unfilled grain panicle^{-1}; TW, 1000 grain weight; SY, straw yield (g m^{-2}); GY, grain yield (g m^{-2}); BY, Biological yield (g); HI, Harvest index (%).

the total variation individually and 84.90% together. Under rainfed condition, first five PCs had Eigen values more than 1 and explained 30.93%, 21.28%, 14.60%, 9.40%, 8.59% of the total variation individually and 84.82% together (Table 6).

The variables with high positive contribution to PC 1 were GP, SY (g m^{-2}), BY (g m^{-2}), DF, DM, FG, PL (cm), GY (g m^{-2}), UEG, TW (g), NET. The variables with negative contribution to PC 1 were HI (%), NT, ET and NET. Under rainfed condition, plant characters that separate genotypes along the PC 1, 2 and 3 were PH (cm), NT, ET, NET, GP, FG, UEG, SY (g m^{-2}), GY (g m^{-2}), BY (g m^{-2}), DF , DM, PL (cm), HI(%), and TW (g). The variables with high positive contribution to PC 1 were GP, BY (g m^{-2}), SY (g m^{-2}), FG, PL (cm), GY (g m^{-2}), UEG, TW (g), and NT, NET. The variables with negative contribution to PC1 were TT, HI (%) and TW (g) (Table 7).

PH, Plant height; TT, No. of total tillers hill^{-1}; ET, No. of effective tillers hill^{-1}; NET, No. of non-effective tillers hill^{-1}; PL, panicle length; GP; Grains panicle^{-1}; FG, No. of filled grain panicle^{-1}; UEG, No. of unfilled grain panicle^{-1}; TW, 1000 grain weight; SY, straw yield (g m^{-2}); GY, grain yield (g m^{-2}); BY, Biological yield (g); HI, Harvest index (%); DF, Days to flowering; DM, Days to maturity

Table 6. Initial and extracted Eigen values and percent of variation in respect of fifteen characters of 39 rice genotypes in irrigated and rainfed condition

Principal component	Irrigated			Rainfed		
	Eigen values			Eigen values		
	total	% of variance	cumulative %	total	% of variance	cumulative %
1	5.15	34.36	34.36	4.64	30.93	30.93
2	3.19	21.31	55.67	3.19	21.28	52.22
3	1.90	12.69	68.36	2.19	14.60	66.83
4	1.44	9.64	78.01	1.41	9.40	76.23
5	1.03	6.88	84.90	1.28	8.59	84.82
6	0.67	4.52	89.42	0.65	4.38	89.20
7	0.61	4.08	93.51	0.59	3.99	93.20
8	0.41	2.76	96.27	0.40	2.68	95.88
9	0.30	2.02	98.29	0.26	1.74	97.63
10	0.20	1.35	99.64	0.15	1.01	98.65
11	0.04	0.27	99.92	0.12	0.79	99.44
12	0.01	0.07	100.00	0.06	0.43	99.88
13	0.00	0.00	100.00	0.01	0.11	100.00
14	0.00	0.00	100.00	0.00	0.00	100.00
15	0.00	0.00	100.00	0.00	0.00	100.00

Table 7. Latent vectors associated with the first principal components under both irrigated and rainfed condition

Plant Characters	Irrigated condition			Rainfed condition		
	Principal Component (PC)			Principal Component (PC)		
	1st	2nd	3rd	1st	2nd	3rd
PH	0.545	0.529	-0.305	0.487	0.511	-0.330
TT	-0.487	-0.134	0.369	-0.199	0.790	0.463
ET	-0.283	0.102	0.907	0.073	0.620	0.576
NET	-0.177	-0.244	-0.618	0.208	-0.819	-0.129
PL	0.644	0.241	-0.168	0.650	0.010	-0.195
GP	0.847	0.042	-0.044	0.849	-0.101	-0.236
FG	0.701	0.435	-0.052	0.770	0.085	-0.442
UEG	0.440	-0.706	0.006	0.362	-0.467	0.444
TW	0.083	-0.300	-0.428	-0.006	-0.251	-0.032
SY	0.844	-0.169	0.110	0.756	0.331	0.379
GY	0.485	0.771	0.183	0.561	0.437	-0.382
BY	0.856	0.208	0.164	0.813	0.431	0.149
HI	-0.235	0.864	0.081	-0.093	0.189	-0.670
DF	0.733	-0.502	0.282	0.693	-0.410	0.347
DM	0.642	-0.571	0.308	0.641	-0.513	0.388

Representative Genotypes

Group centroid of each cluster represented the optimum values of function 1 and function 2 resulted from the cumulative effects of all genotypes and very close to the group centroid and might be considered most representative (might not be the best) of the group. Under irrigated condition, G15 (Boteswar) in cluster I, G2 (Dhala Saita 2) in cluster II, G28, (BR 24) in clusters III, G9 (Pukhi) in cluster IV, G24 (Bolorum) in cluster V and G6 (Katak Tara) in cluster VI might be considered as more representative genotype of their respective groups (Fig. 3A). Under rainfed condition, the genotype no. G2 (Dhala Saita 2) in cluster I, G26 (BRRI dhan55) in cluster II, G29 (BR 26) in cluster III, G25 (N-ABSS) in cluster IV, G5 (Khashi Panja) in cluster V and G36 (BRRI dhan48) in cluster VI might be considered as more representative genotype of their respective groups (Fig. 3B).

Selection of genotypes for rainfed on the basis of yield

The performance of 39 rice genotypes illustrated separately under both irrigated (irrigated) and rainfed condition. The statistical data of both treated plants are illustrated (Table 8). Under the irrigated condition, most of the cases performance of the plants showed better as compared to the rainfed condition. The difference was more pronounced in case of grain yield and straw yield (g m^{-2}). Data revealed that under irrigated condition (the

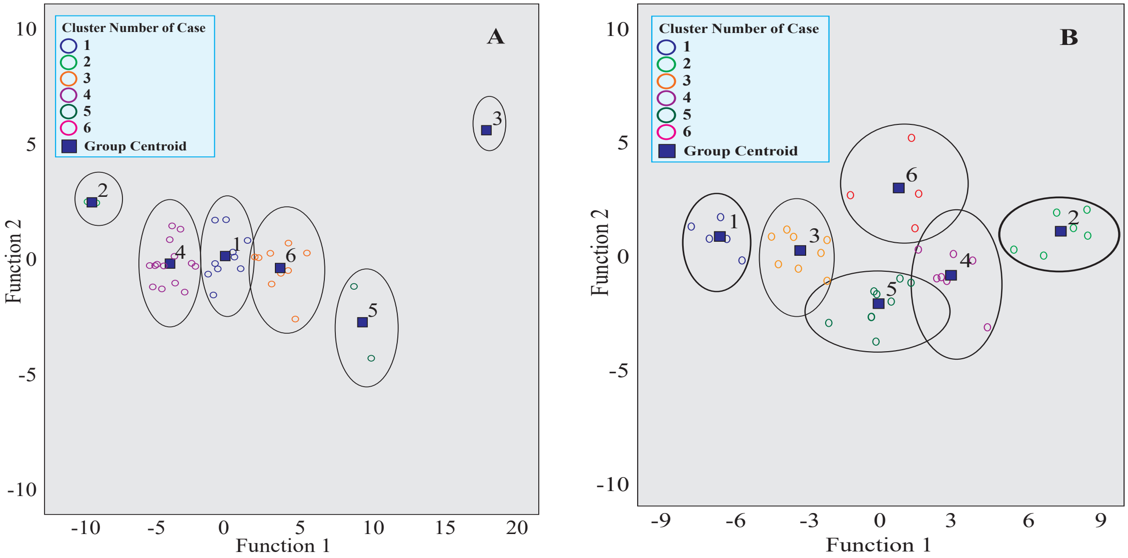

Fig. 3. **Graphical illustration of the discriminant function analysis of six groups of 39 rice genotypes under irrigated (A) and rainfed (B) condition.**

Table 8. Yield performance of *Aus* rice genotypes according to their respective clusters under irrigated and rainfed condition

Irrigated				Rainfed			
Cluster no.	genotype code	genotype name	Yield (g m^{-2})	Cluster no.	genotype code	genotype name	Yield (g m^{-2})
III	G28	BR 24	634.66	IV	G28	BR 24	549.33
V	G10	Rupsail	421.33	IV	G3	Dharial	410.66
V	G24	Bolorum	330.66	IV	G30	BRRI dhan55	400.00
VI	G20	Kachi Lon	517.33	IV	G24	Bolorum	373.33
VI	G21	Kachi Lon 2	426.67	IV	G19	Katak Tara 2	362.66
VI	G22	Bowalia	410.66	IV	G25	Nerica ABSS	362.66
VI	G19	Katak Tara 2	405.33	IV	G38	BINA dhan12	314.66
VI	G23	Bowalia 2	384.00	V	G27	BRRI dhan43	432.00
VI	G6	Katak Tara	373.33	V	G10	Rupsail	416.00
VI	G7	Pan Bira	362.66	V	G15	Boteswar	362.67
VI	G11	Surja Mukhi	346.66	V	G16	Laksmilota	346.67
VI	G25	Nerica ABSS	312.00	V	G21	Kachiloon 2	346.60
VI	G39	BR 14	292.00	V	G22	Bowalia	336.00
I	G8	Paspai	320.00	V	G5	Khashi Panja	325.33
I	G3	Dharial	309.33	II	G39	BR 14	400
I	G26	BRRI dhan55(2)	293.33	II	G37	Nerica 10	346.67

yield performance of cluster III in grain yield (g m^{-2}) was highest (634.67 g m^{-2}) followed by cluster V (376 g m^{-2}) and cluster VI (373.07 g m^{-2}). Under irrigated condion genotype G28 (BR 24) produced highest grain yield (634.66 gm^{-2}), followed by G20 (Kachilon), G21 (Kachiloon 2), G10 (Rupsail), G22 (Bowalia), G19 (Katak Tara 2), G23 (Bowalia 2), G4 (Dular), G27 (BRRI dhan43) and G15 (Boteswar) (Table 25). Other genotypes had grain yield less than 373.33 gm^{-2}.

Under rainfed condition, the highest grain yield was in cluster IV (396.19 g m^{-2}) followed by cluster V (359.33 g m^{-2}) and cluster II (302.22 g m^{-2}). Cluster IV had seven genotypes and cluster V had eight genotypes in rainfed condition. Under rainfed condition genotype G28 (BR 24) produced highest grain yield (549.33), followed by G27 (BRRI dhan43), G10 (Rupsail), G3 (Dharial), G30 (BRRI dhan55), G39 (BR 14), G24 (Bolorum), G15 (Boteswar), G19 (Katak Tara) and G25 (Nerica ABSS). Other genotypes had grain yield less than 362.67 gm^{-2} (Table 8). Considering all the factors specially grain yield (gm^{-2}) G28 (BR 24), G10 (Rupsail), G20 (Kachilon), G21 (Kachiloon 2), G3 (Darial), G19 (Katak Tara 2), G27 (BRRI dhan43), G22 (Bowalia), G30 (BRRI dhan55) and G39 (BR 14) might be considered as the best genotypes.

Conclusion

Genotypes of irrigated condition perform better than those under rainfed condition. The difference was more pronounced in case of grain yield (g m^{-2}). Under both irrigated and rainfed conditions, the genotypes Laksmilota, Loroi, Dhala Saita 3, and Kala Manik demonstrated early maturity (86 to 91 DAS). Considering the yield and yield contributing characters, BR-24, Rupsail, Kachilon, Kachiloon2, Darial, Katak tara2, BRRI dhan43, Bowalia, BRRI dhan55 and BR-14 exhibited the best performance under rainfed condition.

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Conflict of interest

The authors declare no conflict of interest.

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