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Phenological characters and genetic divergence in aromatic rices

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Phenological properties of rice cultivars determine their yield potential, local agronomic suitability and ability to escape from drought and natural calamities. This study was conducted to assess the genetic diversity of aromatic rice genotypes on the basis of phenological characters. 40 genotypes composed of 32 local aromatic, 5 exotic aromatic and three non-aromatic rice cultivars were used in the experiment. Multivariate analysis grouped the genotypes into 6 clusters. In discriminant function analysis (DFA) function 1 and function 2 together absorbed 99.9% of total dispersion. The most contributing characters participated in the clustering were growth duration, flowering duration, basic vegetative phase (BVP) and relative photoperiod sensitivity. Inter-cluster D^2 value was the maximum between cluster i and iii and minimum was found between ii and iv. Cluster i and ii possessed the majority of genotypes having shorter BVP and strong photoperiod sensitivity. Therefore these genotypes can be used in the objective type of breeding programme and also for successful crop production in the post flood situation especially in the disaster-prone countries of south Asia.

Key words: Basic vegetative phase, photoperiod sensitivity, growth duration, phenology, aromatic rice.

INTRODUCTION

Phenological properties of a plant are measured in time duration between distinct critical changes in its life cycle. Crop duration interactively determined by the genotype and the environment (Vergara, 1976). The time interval between sowing and flowering in rice (*Oryza sativa* L.) comprises 3 successive phases; a basic vegetative phase (BVP), a photoperiod-sensitive phase (PSP) and a post-PSP phase (Yin and Kropff, 1997). Phenological properties of rice cultivars determine their yield potential, local agronomic suitability and ability to escape from drought and natural calamities (Bagchi et al., 1995; Dingkuhn et al., 1995). In the deep water rice culture, photoperiod sensitive cultivars lengthen their duration to ensure that maturity does not occur before flood recession.

Rice crops vary strongly in their sensitivity to photoperiod and to a lesser extent in their sensitivity to temperature (Ritchie, 1993; Dingkuhn and Miezan, 1995). At optimum temperatures, crop duration depends mainly on cultivar-specific duration of BVP, which varies between 20 and 70 days for cultivated rice (Chang and Vergara, 1985). Under fully inductive conditions, the BVP is followed within a few days by panicle initiation (PI). If conditions are not inductive, however, BVP is followed by an extended PSP during which floral induction takes place and which ends with the initiation of inflorescence (Collinson et al., 1992; Sie et al., 1998).

Through the centuries of cultivation and selection, thousands of rice cultivars have been evolved, which are well adapted to the local environments. Many of those rice cultivars also possess good taste and qualities and are preferred by the people. A group of such rices is known as aromatic rices. This rice, by its name, is characterized by the presence of aroma in it and often slender in shape. Since the dawn of civilization, thousands of locally adapted genotypes of aromatic rices have evolved because of natural and human selection (Singh et al., 2000). In the consideration of consumption, aromatic rices constitute a small special group that is regarded as best in quality. Most of the aromatic rice genotypes, in Bangladesh and all over the world, are photoperiod sensitive in nature. However, there is a great extent of varia-

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tions in phenological characters among these genotypes.

Study of genetic divergence among the plant materials is a vital tool to the plant breeders for an efficient choice of parents for plant improvement. Genetically diverse parents are likely to contribute desirable segregants and or to produce high heterotic crosses. Parents identified on the basis of divergence for any breeding program would be more promising (Arunachalam, 1981). Grouping or classification of genotypes based on suitable scale is quite imperative to understand the usable variability existing among them. For the assessment of variation on multivariate scale, Mahalanobis' D^2-statistic has proved to be a powerful technique (Murty and Arunachalam, 1966).

This study was therefore undertaken to evaluate the phenological characters of aromatic rices from different sources and to determine genetic distance/relationship among them on the basis of cluster analysis.

MATERIALS AND METHODS

The experiment was conducted at the farm of Bangladesh Rice Research Institute (BRRI) in 2005. A total of 40 rice germplasm composed of 32 local aromatic, 5 exotic and 3 non-aromatic rice varieties as standard checks, were selected for this research (Table 1). Among the 3 non-aromatic varieties, BR28 is a modern Boro, BR39 is a modern T. Aman variety and the third one, Nizersail was used as a standard check for comparing photoperiod sensitivity among the genotypes (Miah and Sarkar, 1990). Exotic genotypes used in the study include Basmati PNR346 from Pakistan; Sarwati and Sugandha-1 from Nepal and Khazar and Neimat from Iran. The rest materials are representing their distribution throughout Bangladesh. 40 rice genotypes formed the treatment variables and were assigned randomly to each unit plot of 5 m × 2 m dimension. 30 days-old seedlings were transplanted at the spacing of 20 cm × 20 cm on August 15, 2005 following randomized complete block design (RCBD) with 3 replications. Fertilizers P-K-S-Zn were applied at 25-35-10-3 kg ha^{-1} in the form of triple super phosphate, muriate of potash, gypsum and zinc sulphate, respectively as basal dose at final land preparation. Because of wide genotypic variation in phenollogical development and yield potential, varieties differed enormously in attaining panicle initiation (PI) stage and in the requirement of nutrient elements. Nitrogen was top-dressed as urea in 2 - 3 splits to the contrary of a common dose with fixed time routine. The amount of urea and time of application were determined with the help of a leaf colour chart (Ladha et al., 1998).

One square meter area was selected and marked in each plot for tiller count. After 1 month of transplanting, tillers were counted at every alter-nate day and continued until diminishing trend of tiller number. Thus the number of days required for maximum tillers was recorded. Days to heading, 50% flowering and complete flowering were re-corded based on visual observation. Days to maturity at the time when more than 80% grains on the panicles were fully ripened. For the determination of dormancy period, seed germination of freshly harvested seeds was evaluated.

A parallel experiment was carried out in a glass house to determine photoperiod sensitivity of the test materials. Seeds were sown in earthen pots on March 15, 2005. Nizersail, a local photoperiod sensitive variety, was used as a standard check. A total of 160 pots (40 varieties × 2 treatments × 2 replications) were used for this purpose. 5 seedlings were grown in each pot. Among 4 sets of pots, 2 sets were kept in 2 open rooms made of bamboo. The bamboo structures were covered by thick and dark black canvas from 5:00 pm to 6:30 am to ensure 13.5 h of dark period and 10.5 h of light period for the test materials. The photoperiod treatment was started at 15 DAS and continued up to booting stage. The rest 2 sets were grown at natural photoperiod under similar cultural practices. The following calculations were done as described by Miah and Sarkar (1990).

BVP = (GD at 10.5 h photoperiod) – 30 days

PSP = (GD at control set) – (GD at 10.5 h photoperiod)

$$\text{RPS (\%)} = \frac{PSP\ of\ the\ test\ entry}{PSP\ of\ Nizersail} \times 100$$

Where, GD = growth duration in days (sowing to heading), BVP = basic vegetative phase, PSP = Photoperiod sensitive phase, and RPS = relative photoperiod sensitivity

In data processing steps, genotypic and phenotypic coefficient of variations were estimated according to Burton (1952). The ANOVA was done by IRRISTAT windows 4.01. Genetic divergence among the genotypes was assessed using D^2 statistic (Mahalanobis, 1936) extended by Rao (1952). Discriminant function analysis (DFA) was done for conformity of the results and to verify precision level of clustering (Huberty, 1994). These analyses were performed under software SPSS v11.0.

RESULTS AND DISCUSSION

Extent of variability in phenological characters

Lengths of different phases and stages in the life cycle of 40 rice genotypes are presented in Table 1. Maximum tillering stage is considered as a climax of a rice plant's vegetative growth. Duration, required for attaining maximum tillering stage, varied in a wide range of 65 to 85 days. Gandho kasturi required longest period followed by Kalijira Tapl-73 (82 days) and Darshal (78 days). Sugandha-1 reached at the ceiling number of tillers within the shortest period followed by Basmati tapl-90 and BR28 (66 days). The time interval between sowing and 1st heading (starting of panicle emergence in a plot) was the longest for Gandho kasturi (112 days). The second longest duration was required by Kalijira Tapl-73 (110 days) which was followed by BR38, Nizersail and Radhuni pagal (107 days). In the plot of BR28, it emerged its first panicle within the shortest period of 77 days followed by Basmati PNR346 and Neimat (78 days). In cases of 50% flowering and complete heading and full maturity, the duration requirements of genotypes showed more-or-less similar trend. Maturity duration is the final and cumulative result of all phenological responses. It determines the success of crop harvest by farmers in a vulnerable environmental situation. In the present study, the crop harvesting was started with BR28 at 116 days after sowing (DAS) and ended at 154 DAS (Gandho kasturi). Kalijira Tapl-73 required 149 days to complete life cycle followed by Khazar and Radhuni pagal (145 days). The second

Table 1. Durations of different stages in vegetative and reproductive phases of forty rice genotypes (average over 3 replications).

Name of genotype	Days to maximum tillers	Days to 1st heading	Days to 50% flowering	Days to complete heading	Flowering duration (days)	Maturity (days)
01. Badsha bhog	70	94	105	112	18	134
02. Baoi jhak	67	94	101	107	13	131
03. Basmati Tapl-90	66	89	100	107	18	129
04. Basmati PNR 346	76	78	89	95	17	119
05. Begun bichi	68	93	101	107	14	131
06. Benaful	76	103	109	116	13	139
07. Bhog ganjia	71	94	103	111	17	135
08. BR28	66	77	86	92	15	116
09. BR38	76	107	111	113	6	140
10. BR39	73	88	94	99	11	125
11. Chinigura	73	99	104	111	12	135
12. Chinikani	75	104	110	120	16	140
13. Darshal	78	105	112	122	17	144
14. Doiar guro	77	102	107	113	11	141
15. Elai	72	101	105	109	8	136
16. Gandho kasturi	85	112	122	128	16	154
17. Gandhoraj	72	100	105	112	12	136
18. Hatisail	76	96	106	112	16	137
19. Jamai sohagi	75	93	99	109	16	136
20. Jata katari	69	94	102	109	15	132
21. Jesso balam	75	100	105	110	10	139
22. Jira katari	71	93	103	111	18	135
23. Kalijira Tapl-73	82	110	119	124	14	149
24. Kalomai	71	97	104	111	14	134
25. Kamini soru	73	96	103	110	14	133
26. Kataribhog	70	95	104	110	15	134
27. Khazar	72	91	99	109	18	128
28. Laljira Tapl-130	76	107	116	123	16	145
29. Niemat	72	78	89	96	18	118
30. Nizersail	76	107	110	114	7	144
31. Philippine katari	67	92	99	107	15	129
32. Premful	70	95	104	108	13	134
33. Radhuni pagal	77	107	114	121	14	145
34. Rajbhog	74	104	109	113	9	144
35. Sai bail	69	94	104	111	17	133
36. Sakkor khora	74	102	107	111	9	138
37. Sarwati	72	84	93	101	17	122
38. Sugandha-1	65	86	93	100	14	123
39. Tilkapur	73	97	104	110	13	137
40. Ukni madhu	66	92	100	106	14	130
CGV	5.95	9.12	7.32	7.25	20.44	6.17
PCV	6.49	9.49	7.35	7.53	20.92	6.19
SE	0.68	1.38	0.42	1.26	0.46	0.42
F prob. value	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01

shortest life span was had by Neimat (118 days) and Bansmati PNR346 was immediate follower having 119 days of maturity duration. All phenological characters were found to vary in a wide range depending rice culti-

vars as well as micro and macro environments (Fukai, 1999; Dingkuhn and Asch, 1999; Raïssc et al., 2004). Flowering duration is an important character that is frequently considered before release of a variety for commercial cultivation. It is the time interval between first heading and complete heading (≥90% flowering) in plot. Shorter flowering duration ensures the visible uniformity of a crop field which is always preferred by farmers. Among the genotypes, BR38 showed best uniformity of flowering with shortest duration of 6 days. In this series, Nizersail was in the next position (7 days) followed by Elai (8 days). The longest flowering duration (18 days) was observed in the plots of Badshabhog, Basmati Tapl-90, Jirakatari, Khazar and Neimat.

Data on basic vegetative phase (BVP), photoperiod sensitivity and seed dormancy period are presented in Table 2. Recorded BVP showed a great extent of variability over the genotypes. Shortest BVP was recorded 19 days for Benaful. BR38 and Elai were close neighbours with 20 and 23 days of BVP. Doiar guro proved its longest BVP with 67 days followed by Khazar (65 days) and Bhog ganjia (58 days). According to statement of Chang and Vergara (1985), BVP may vary from 20 to 70 days in cultivated rice. In the experiment of Yin and Kropff (1997) the duration of BVP varied among 20 rice cultivars ranging from 16.7 to 45.4 days. An extreme variation was found in photoperiod sensitive (PSP). An absolute absen-ce of PSP in the cultivar Neimat (0 day) was an excep-tional phenomenon. A very minimum PSP (2 days) was in Khazar. On the contrary, a very long PSP of 174 days was observed in 2 genotypes viz. Benaful and BR38 followed by Gando kasturi (171 days). Relative photo-period sensitivity, calculated in percentage on the basis of standard check Nizersail, was also found to vary in the similar trend ranging from 0 to 103%. The length of PSP was reported to vary between 3.6 and 75.6 days (Yin and Kropff, 1997). Seed dormancy period, a post-harvest phenological trait, showed a large extent of variability among the genotypes. Maximum dormancy period 91 days was recorded in Darshal and minimum 5 days in Basmati PNR346.

The genotypic and phenotypic coefficients of variations for each and every character were also showed the Tables 1 and 2. Highest genotypic coefficient of variation (GCV) was recorded 48% for seed dormancy followed by photoperiod sensitivity (41%). Lowest value of GCV was observed for days to maximum tillers (6%) followed by days to flowering (7%). The rest of the characters hold GCV in the range of 9 - 31%. Higher GCV in a character gives the better opportunity for a cross combination to get wider variation. All the characters showed little differences between PCV and GCV which indicated negligible influence of environment on the expressions of these characters. Low GCV and PCV for plant height and panicle length were as reported by Das and Rahman (1984). Amin et al. (1992) observed closeness of PCV and GCV for a few characters and much difference between PCV and GCV for others.

Interrelationship among the phenological traits

Correlation coefficient analysis measures the linear relationships between characters and determines the selection of component characters for plant improvement (Singh, 2000). Relationships among the different phenollogical traits were determined through simple correlation co-efficient (r) and are presented in Figure 1. In the analysis, it is found that flowering duration is a totally independent character showing neither positive nor negative relation with any other phenological trait. There was a negative correlation between BVP and PSP, however, the r value was not significant (r = -0.49). Significant positive relations were established among photoperiod sensitivity, growth duration and seed dormancy period (r = 0.67 to 0.77). Several researchers made effort on the analyses of grain yield and related components of modern, lowland and winter rice varieties. And they reported different levels of correlation among the traits (Bai et al., 1992; Manuel and Palanisamy, 1989; Vange et al., 1999).

Clustering of genotypes by multivariate analysis

All of the 10 phenological characters were subjected to cluster analysis to establish a Euclidean linkage map (Figure 2). Six linkage groups were identified on the basis of Euclidean distances among the genotypes. The linkage groups were further characterized by discriminant function analysis (DFA) using the same parameters as for the cluster analysis. In the step-wise process of DFA 4 functions were identified under which only 4 characters viz. growth duration (sowing to 50% flowering), flowering duration, BVP and relative photoperiod sensitivity (RPS) participated in the discrimination (Table 3). Function 1 and 2 collectively explained 99.9% of the total variance (Table 4). Function 1 alone was composed of all 4 characters mentioned above. The F1 versus F2 scatter plot (Figure 3) shows that this analysis differentiated well between the linkage groups. Only these 2 functions were considered for the construction of understandable 2-dimension graph, as these 2 can account for more than 80% of total dispersion (Huberty, 1994).

Intra-cluster and inter-cluster distances were (Mahalanobis' D^2) were calculated from step-wise DFA. The highest intra-cluster distance was computed for cluster i (composed of 23 genotypes) and the lowest was for cluster Vi (composed of 2 genotypes). All the intra-cluster distances were lower than inter-cluster distances (Table 5). It indicated a wider genetic diversity among the genotypes of different groups than those in the same group that is, within group genotypes they were closely

Table 2. Photoperiod sensitivity and seed dormancy period of 40 rice genotypes (average over 3 replications).

Name of genotype	Basic vegetative phase (days)	Photoperiod sensitive phase (days)	Relative photoperiod sensitivity (%)	Seed dormancy period (days)
01. Badsha bhog	30	154	91	20
02. Baoi jhak	33	151	89	66
03. Basmati Tapl-90	53	114	67	21
04. Basmati PNR 346	40	20	12	5
05. Begun bichi	35	148	87	51
06. Benaful	19	174	103	34
07. Bhog ganjia	58	125	74	54
08. BR28	38	17	10	20
09. BR38	20	174	102	86
10. BR39	41	49	29	31
11. Chinigura	39	150	89	61
12. Chinikani	49	144	85	64
13. Darshal	27	168	99	91
14. Doiar guro	67	125	74	71
15. Elai	23	168	99	59
16. Gandho kasturi	30	171	101	82
17. Gandhoraj	41	150	89	50
18. Hatisail	38	148	87	67
19. Jamai sohagi	37	143	84	21
20. Jata katari	29	155	91	44
21. Jesso balam	30	161	95	76
22. Jira katari	32	150	89	76
23. Kalijira Tapl-73	49	150	89	67
24. Kalomai	24	164	96	82
25. Kamini soru	27	159	94	40
26. Kataribhog	31	154	91	61
27. Khazar	65	2	1	7
28. Laljira Tapl-130	43	153	90	86
29. Niemat	39	0	0	11
30. Nizersail	27	169	100	81
31. Philippine katari	29	154	91	59
32. Premful	29	156	92	60
33. Radhuni pagal	35	162	95	64
34. Rajbhog	26	168	99	83
35. Sai bail	34	152	90	37
36. Sakkor khora	35	157	92	76
37. Sarwati	46	24	14	6
38. Sugandha-1	34	36	21	27
39. Tilkapur	42	145	85	60
40. Ukni madhu	26	156	92	56
CGV	30.63	40.53	40.53	47.52
PCV	30.69	40.53	40.53	47.59
SE	0.43	0.43	0.25	0.76
F prob. value	<0.01	<0.01	<0.01	<0.01

related. Accordingly, 6 clusters had significant distances from each other at $P_{0.01}$ level. Inter-cluster D^2 value was maximum between i and iii while the minimum D^2 value was found between ii and iv. Several researchers per-

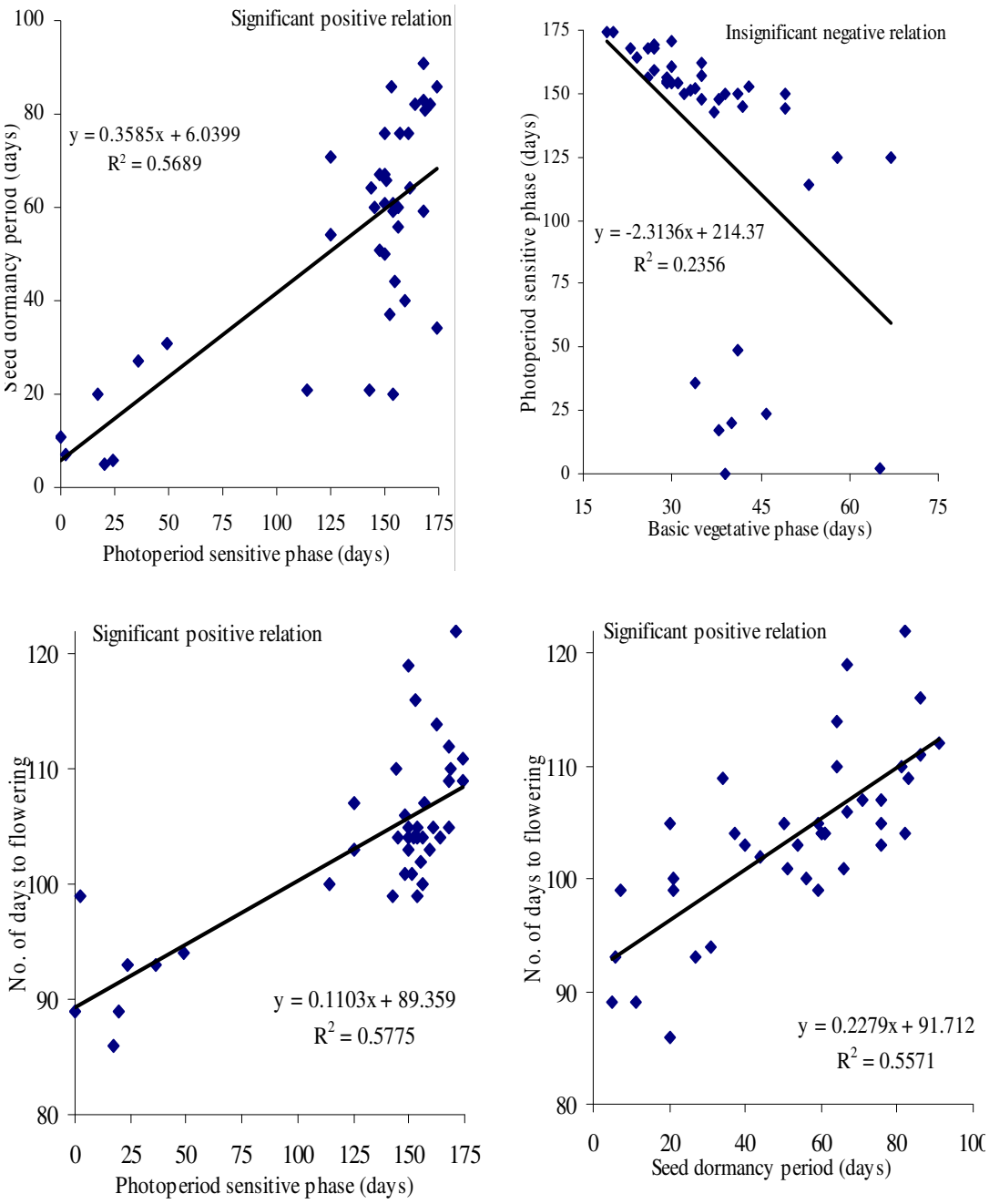

Figure 1. Interrelations of different phenological parameters in aromatic rice genotypes.

formed D^2 analysis to identify distinct clusters on the basis of different physio-morphological characters in rice (Wu and Hung, 1998; Soni et al., 1999; Chauhan and Singh, 2003). The genotypes belonging to highly diverged clusters should be used in hybridization programme for obtaining wide spectrum of variations in the segregating population (Chawdhury, 1994). On the other hand, Bashar (2002) suggested the selection of genotypes belonging to moderate diversity in order to exploit benefits of heterosis. Above all, the selection of genotypes is dependent on the objective of breeding programme. In the present study, majority of traditional aromatic rice germplasm are included in the cluster i which is characterized by longest growth duration, medium long BVP and the highest photoperiod sensitivity (Table 6). On the other hand group vi was found to hold shortest growth duration, very long BVP and almost insensitivity to photoperiod. Dingkuhn and Asch (1999) also identified several groups of rice cultivars on phenological responses in West Africa. In the current study, we have identified a large collection of genotypes (cluster i and ii) with shorter BVP and strong photoperiod

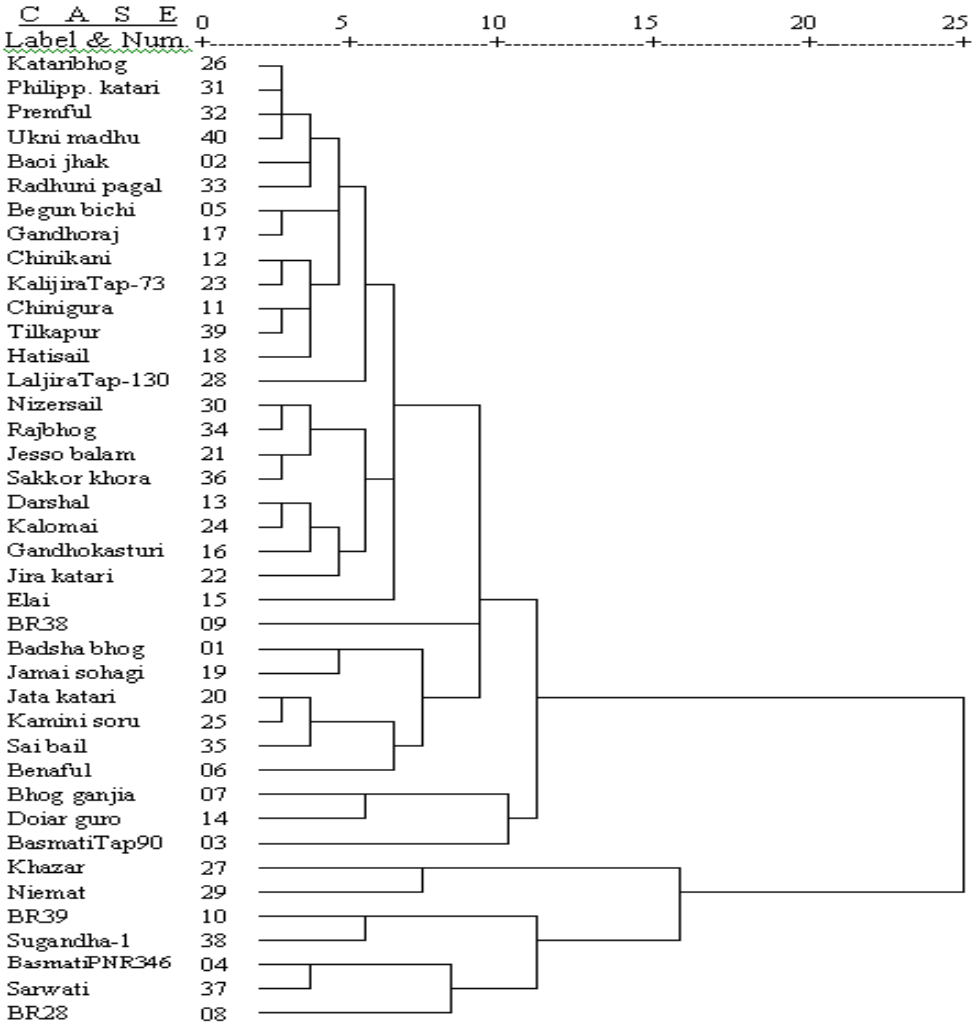

Figure 2. Dendrogram of 40 rice genotypes using average linkage between groups through hierarchical cluster analysis.

Table 3. Canonical discriminant function coefficients showing most contributing characters in clustering.

Character	Functions			
	1	2	3	4
Growth duration (sowing to 50% flowering)	–0.29	–0.09	–0.01	0.20
Flowering duration	0.21	0.04	0.36	–0.01
Basic vegetative phase	0.25	0.15	–0.02	–0.01
Relative photo. sensitivity	0.51	0.04	0.01	–0.04

Table 4. Contribution by each of discriminant functions in grouping of rice genotypes.

Function	Eigenvalue	% of Variance	Cumulative %	Canonical correlation
1	191.46	99.3	99.3	0.99
2	1.15	0.6	99.9	0.73
3	0.13	0.1	100.0	0.34
4	0.07	0.0	100.0	0.25

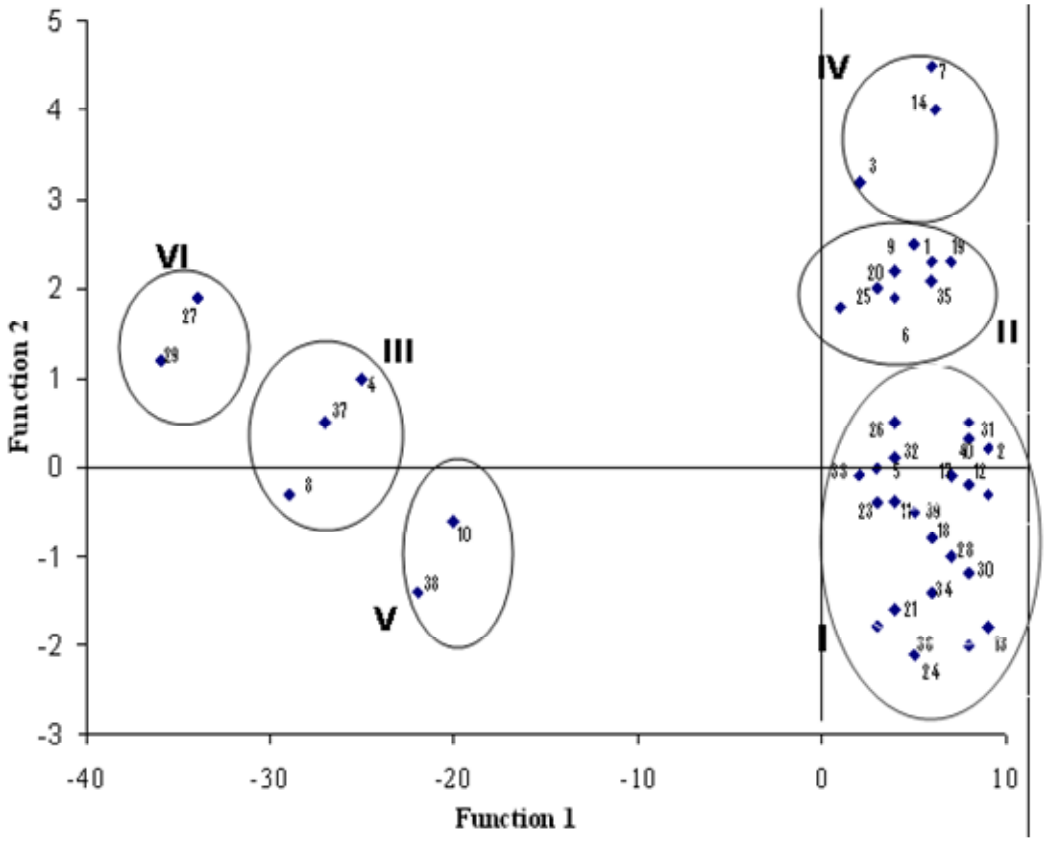

Figure 3. Graphic illustration of discriminant analysis for 6 clusters of 40 rice genotypes.

Table 5. Intra- and inter-cluster Mahalanobis distances (D^2) among 6 linkage groups.

Cluster	i	ii	iii	iv	v	vi
I	14.01					
II	17.89**	9.57				
III	694.83**	138.55**	8.25			
IV	24.87**	14.06**	284.01**	5.78		
V	378.96**	94.73**	14.26**	187.20**	4.81	
VI	606.25**	161.72**	15.50**	300.97**	25.36**	4.02

Table 6. Features of the clusters based on the mean values of parameters participated in clustering process.

Cluster	Growth duration (sowing to 50% flowering)	Flowering duration	Basic vegetative phase	Relative photo. sensitivity
I	106.7	12.4	33.6	92.2
II	104.7	14.1	28.0	93.6
III	89.3	16.3	41.7	12.0
IV	103.3	15.3	59.3	71.7
V	93.5	12.5	37.5	25.0
VI	84.0	18.0	52.0	0.5

sensitivity having potentiality of early flowering to escape cold injury.

Conclusion

The study made a database on phenological characters of aromatic rices. A good number of genotypes with very short BVP and strong photoperiod sensitivity have been identified. These genotypes can be successfully grown as ultra-short duration crops in the post flood agriculture programme in disaster-prone area.

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