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# Multivariate Classification of Promising Paddy Cultivars on the Basis of Physical Properties

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## ABSTRACT

Properties of materials play important role in the development of processing, storing and handling equipment. Genetic diversity is one of the important tools to qualify genetic variability in both cross and self-pollinated crops. Through this study, efforts were made to find out variability and relationship between paddy cultivars of various economically important traits. Paddy of twenty two selected genetically diverse strains was evaluated for physical and optical characteristics. The moisture content of kernels of selected paddy cultivars ranged from 7.89 to 14.15% (DWB). Multivariate classification techniques were applied to determine the coherent physical and optical characteristics in order to reduce dimensionality problems. The properties heavily loaded on different components are dimensional with frictional in first principal component, dimensional and optical in the second component and optical with gravimetric in the third components found responsive for major variations (79.36%) in the Eigen analysis of data. The observed physical and optical characteristics differed significantly and found to be cultivar dependent, which has paved the way for the classification of selected paddy cultivars on the basis of principal component and cluster analysis. Accordingly, the dominating similar prominent physical and optical characters formed at least three verifiable distinct separate and coherent clusters of paddy cultivars, indicating the usefulness multivariate analysis in identifying promising cultivars with the appropriateness in design and development of agricultural and processing equipment based on opto-physical characteristics.

*Keywords:* Paddy, oryza sativa, physical properties, principal component analysis, cluster analysis

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## INTRODUCTION

Paddy (*Oryza sativa* L) is a widely cultivated cereal crop of the family Gramineae. The paddy production in India has witnessed

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more than three folds increase in the past 50 years and contributed to more than one fifth of the total paddy production in world. The present production figure of paddy in India is 152.6 MMT (FAO, 2013). Among 23 recognized species of *Oryza* in the world, *sativa* is widely cultivated mainly due to economic reasons with limited cultivation of *glaberrima* on ritual context specifically grown in West Africa. Also, the desired attributes such as disease and insect resistances with higher climatic adaptability of other wild species have been explored to transfer the desired characteristics to cultivated species through inter breeding for the development of diverse improved paddy variants. The diversities among the cultivars also existed for kernel size, shape, cooking, colour, flavour, milling, nutritive value and their ability to make different rice products. Apart from calorie and protein, rice being staple food, also supplies to some extent vitamins and minerals in the poor-man's diet.

Paddy undergoes different levels of processing prior to its conversion into usable form (Singh & Prasad, 2012) for various product preparations (Prasad *et al*., 2013). The knowledge of physical properties comprised of dimensional, gravimetric and frictional characteristics are thus necessary in the design of equipment for their effective implementation in various operations (Mohsenin, 1980; Sahay & Singh, 1994; Ghadge & Prasad, 2012) starting from harvesting till their conversion into edible form mainly as white rice or rice powder (Prasad *et. al.,* 2012). The obtained data on opto-physical properties may be utilized in the development of equipment related to direct seeded rice (DSR) technology in order to have associated potential benefits of labour, water (20-25%) and cost of cultivation (Kamboj *et al*., 2012).

Multivariate statistical methods have been applied for the classification of paddy genotypes based on coherent physical and optical characteristics to reduce dimensionality problems. Principal component analysis (PCA) and cluster analysis (CA) as multivariate statistics are often employed purposely (Kara, 2009) to get the relationships among parameters of the original data matrix (Kosa *et al*., 2001). The multivariate analysis has successfully been applied by the author in characterization of okra genotypes (Sharma & Prasad, 2010a; Prasad & Sharma, 2012).

The comparative characteristics of Indian promising paddy varieties for their classification based on the physical and optical properties are not available yet. Hence, the present study was conducted to determine the physical and optical properties of paddy in order to classify it based on the chemo-metric approach supported by the clustering technique of multivariate analysis.

## MATERIALS AND METHODS

Twenty two cultivars of paddy kernels were procured from different agro climatic regions of India (Table 1). The acquired cultivars of paddy were cleaned in an air classifier to remove the foreign matter, broken and immature kernels. The initial moisture

TABLE 1
Paddy cultivars and source

| Paddy cultivar | Source | Symbol |
|---|---|---|
| BR 4-10 | Chaudhary Charan Singh Haryana Agricultural University, Hissar, Haryana | 1 |
| CSR 10 | Indian Agricultural Research Institute, New Delhi | 2 |
| Haryana Mahak 11 | Chaudhary Charan Singh Haryana Agricultural University, Hissar, Haryana | 3 |
| HBC 19 | Chaudhary Charan Singh Haryana Agricultural University, Hissar, Haryana | 4 |
| HKR 95-157 | Chaudhary Charan Singh Haryana Agricultural University, Hissar, Haryana | 5 |
| HKR 95-407 | Chaudhary Charan Singh Haryana Agricultural University, Hissar, Haryana | 6 |
| HKR 99-66 | Chaudhary Charan Singh Haryana Agricultural University, Hissar, Haryana | 7 |
| HKR H7 | Chaudhary Charan Singh Haryana Agricultural University, Hissar, Haryana | 8 |
| IR 64 | Indian Agricultural Research Institute, New Delhi | 9 |
| Jehlum | Sher-e-Kashmir University of Agricultural Sciences and Technology, Jammu & Kashmir | 10 |
| Muchhal | Chaudhary Charan Singh Haryana Agricultural University, Hissar, Haryana | 11 |
| Palman 579 | Punjab Agricultural University, Ludhiana, Punjab | 12 |
| PAU 201 | Punjab Agricultural University, Ludhiana, Punjab | 13 |
| Pusa 1121 | Punjab Agricultural University, Ludhiana, Punjab | 14 |
| Pusa Basmati | Indian Agricultural Research Institute, New Delhi | 15 |
| Pusa Sugandh | Indian Agricultural Research Institute, New Delhi | 16 |
| Shabnam | Seed Collection Centre, Sangrur, Punjab | 17 |
| Shalimar 1 | Sher-e-Kashmir University of Agricultural Sciences and Technology, Jammu & Kashmir | 18 |
| Shalimar 2 | Sher-e-Kashmir University of Agricultural Sciences and Technology, Jammu & Kashmir | 19 |
| Shalimar 3 | Sher-e-Kashmir University of Agricultural Sciences and Technology, Jammu & Kashmir | 20 |
| Sugandha | Seed Collection Centre, Sangrur, Punjab | 21 |
| Usha | Seed Collection Centre, Sangrur, Punjab | 22 |

content of paddy cultivars was determined as per standard method (USDA, 1990) and it was found to vary between 7.89±0.37 to 14.15±0.28% (dry weight basis). The physical properties of paddy cultivars were determined for the dimensional, gravimetric and frictional characteristics (Ghadge & Prasad 2012).

### *Physical Properties*

The dimensional characteristics were evaluated for three major perpendicular dimensions: length (L), breadth (B) and thickness (T). The dimensions were measured manually using a dial type vernier caliper (Mitutoyo Corporation, Japan) with the least count of 0.02 mm.

The geometric mean dimension (*GMD*) and aspect ratio (*AR*) of the sample were assessed using the relationship given by Mohsenin (1980) as:

$$GMD = (LBT)^{1/3} \tag{1}$$

$$AR = \frac{B}{L} \times 100 \tag{2}$$

The criteria used to describe the shape of paddy kernel are sphericity and aspect ratio. Thus, the sphericity (SPH) was accordingly computed (Mohsenin, 1980) as:

$$SPH = \frac{(LBT)^{1/3}}{L} \times 100 \tag{3}$$

The surface area (*SA*) of paddy kernel was evaluated using the relationship given by McCabe *et al.* (1986) as:

$$SA = \pi(GMD)^2 \tag{4}$$

The weight of the paddy samples was recorded using electronic balance (Ishida Co. Ltd., Japan) to an accuracy of 0.001 g. The bulk density (*BD*) of the seed sample was evaluated using the methods suggested by Williams *et al*. (1983). True density (*TD*) was determined using liquid displacement technique (Shepherd & Bhardwaj, 1986). Toluene as liquid was used in spite of water to prevent absorption and also to get the benefit of low surface tension (Ogut, 1998). The porosity (POR) of seeds was computed from the values of true density and bulk density by using the following relationship by Mohsenin (1980):

$$POR = \frac{TD - BD}{TD} \times 100 \tag{5}$$

The angle of repose (AOR) was determined using the relationship:

$$AOR = tan^{-1} \frac{(2H)}{D} \tag{6}$$

Where, H and D are the height and diameter of the heap in mm.

The static coefficient of friction (COF) was determined for four frictional surfaces namely glass (COFG), galvanized iron sheet (COFGI), plywood parallel (COFPAR) and plywood perpendicular (COFPER). A plastic cylinder of 50 mm diameter and 60 mm height was placed on an adjustable tilting flat plate faced with the test surface and filled with nearly 100 g sample. The cylinder was raised slightly to avoid touching the surface. The structural surface with material filled cylinder on it was inclined gradually until the cylinder just started to slide.

### *Optical Properties*

The optical characteristics of the paddy samples were evaluated using the Hunter Colorimeter (Gretag Macbeth, Model No. i5, USA) in terms of l, a, b and ΔE values, where, l corresponds to the luminance or brightness and a, b to the chromaticity. The 'a' value particularly represents the red-green component from positive to negative values; the 'b' value represents the yellow-blue component in similar ways (Prasad *et al*., 2010a; Prasad *et al*., 2010b). Total colour difference (ΔE) is the measure of modulus of the distance vector between the reference colour values and the actual colour coordinates. The total colour difference indicates the colour difference from the standard plate or the reference sample colour (Rhim *et al*., 1999), which was evaluated as:

Where, $l_0$, $a_0$ and $b_0$ represented the least observed colour values among the selected paddy cultivars. The total colour difference can be used for the analytical classification on optical basis as small , distinct (and very distinct (colour difference (Adekunte *et al*., 2010).

### *Statistical Analysis*

In order to determine any statistically significant effects prevailed due to paddy cultivars, analysis of variance (ANOVA) was carried out and critical difference (CD) at $P \leq 0.05$ was determined. Descriptive statistics including the means of each attributes were determined and represented graphically for assessing the varietal performance and dependent separations. Principal components analysis (PCA) and hierarchical cluster analysis (CA) for multivariate data were statistically analysed using MINITAB v 13.2 and Microsoft Excel v 2000. The principal component and hierarchical cluster analyses provided the characteristic patterns to classify the selected 22 paddy cultivars. Clustering of the samples was done according to Ward (1963) based on minimizing the loss of information from joining two clusters (Sharma & Prasad, 2010a; Sharma & Prasad, 2010b).

## RESULTS AND DISCUSSION

### *Physical Properties*

The comparative characteristic variability of twenty two paddy cultivars (Fig.1) with their overall individual response with respect to their mean is presented in Figures 2 and 3. The analysis of variance (ANOVA) revealed that the differences in selected cultivars were significant for all the attributes indicating the presence of associated variability among them ($p \leq 0.05$). The length (L), breadth (B) and thickness (T) of the paddy cultivars varied from 8.10±0.40 to 11.83±0.40 mm, 2.19±0.08 to 3.06±0.19 mm and 1.77±0.11 to 2.20±0.06 mm, respectively. The comparison of the dimensional data with the existing work on paddy can play a vital role in machine design and thus be sufficient in making symmetrical projections towards process equipment adaptation (Mohsenin, 1980). The geometric mean diameter (GMD), which integrates three major dimensional parameters, varies from 3.46±0.01 to 3.85±0.14 mm. Aspect ratio (AR) and sphericity (SPH) of the samples varied in the range of 18.92±0.00 to 36.154±0.68% and 31.16±0.58 to 45.48±0.92%, respectively. Lower values of sphericity with intermediate value of aspect ratio suggest that the paddy tend towards a cylindrical shape rather spherical indicating a likely difficulty in getting the kernel to roll than sliding on surface. This tendency of sliding is necessary in the design of hoppers or sowing equipment. As evident, the surface area (SA) of the paddy kernels ranging from 37.68±0.28 to 46.67±3.43 $mm^2$ is a relevant tool in determining the material shape. The dimensional characteristics of the selected paddy cultivars significantly differ ($p \leq 0.05$) to each other, support the results reported by Reddy and Chakraverty (2004).

The significant ($p \leq 0.05$) difference in bulk density (BD) 323.863±2.281 to

612.126±11.713 kg/m$^3$ and true density (TD) 756.533±3.101 to 1521.737±3.069 kg/m$^3$ have been found evident from the works of Correa *et al*. (2007), Muramatsu *et al*. (2007), and Singh *et al*., (2005). Higher level of porosity (POR) ranging from 46.42±1.68 to 75.17±0.08% has indicated the dependency on bulk and true densities of the material.

The frictional characteristics for paddy cultivars were found to have significant difference. The experimental values of the angle of repose (AOR) ranged from 30.555±0.288 to 43.807±2.788° (Fig.3). Similar trends have been reported by Ghasemi *et al*. (2008) for emptying angle of repose for rough rice. The coefficient of friction (COF) was found to be minimum for glass surface (COFG) and maximum for plywood surface vertically aligned (Fig.3). The differences in the values may be due to the fact that the roughness of the material used for determining the coefficient of friction (Correa *et al*., 2007). Thus, the frictional characteristics have imperative roles in the food grain processing, particularly in the designing of the hopper and sowing equipment applied for the purpose of direct seeded rice technology.

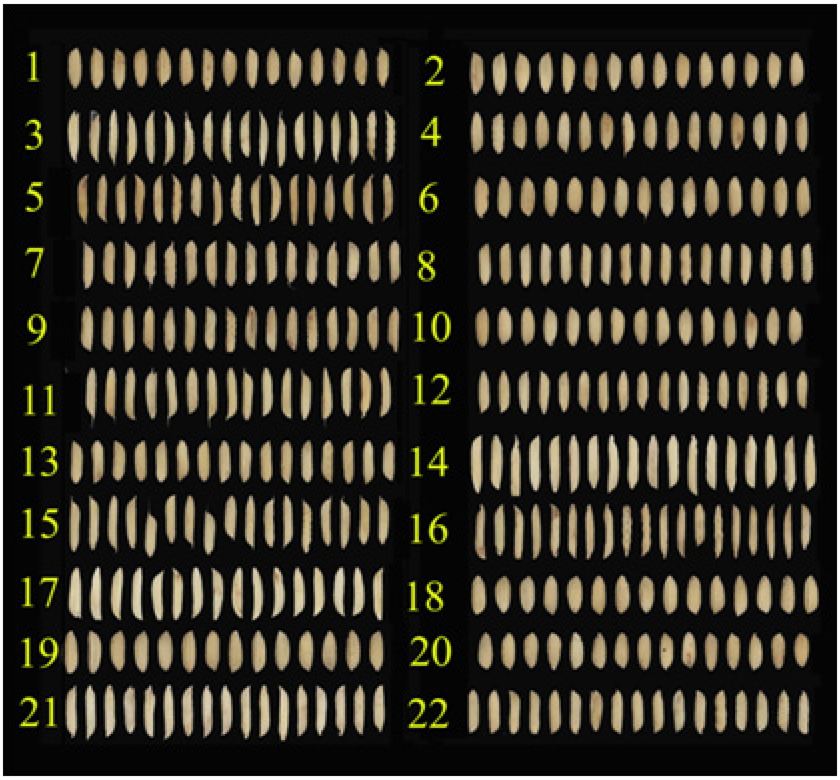


Fig.1: Charged coupled device snapshot showing selected paddy cultivars

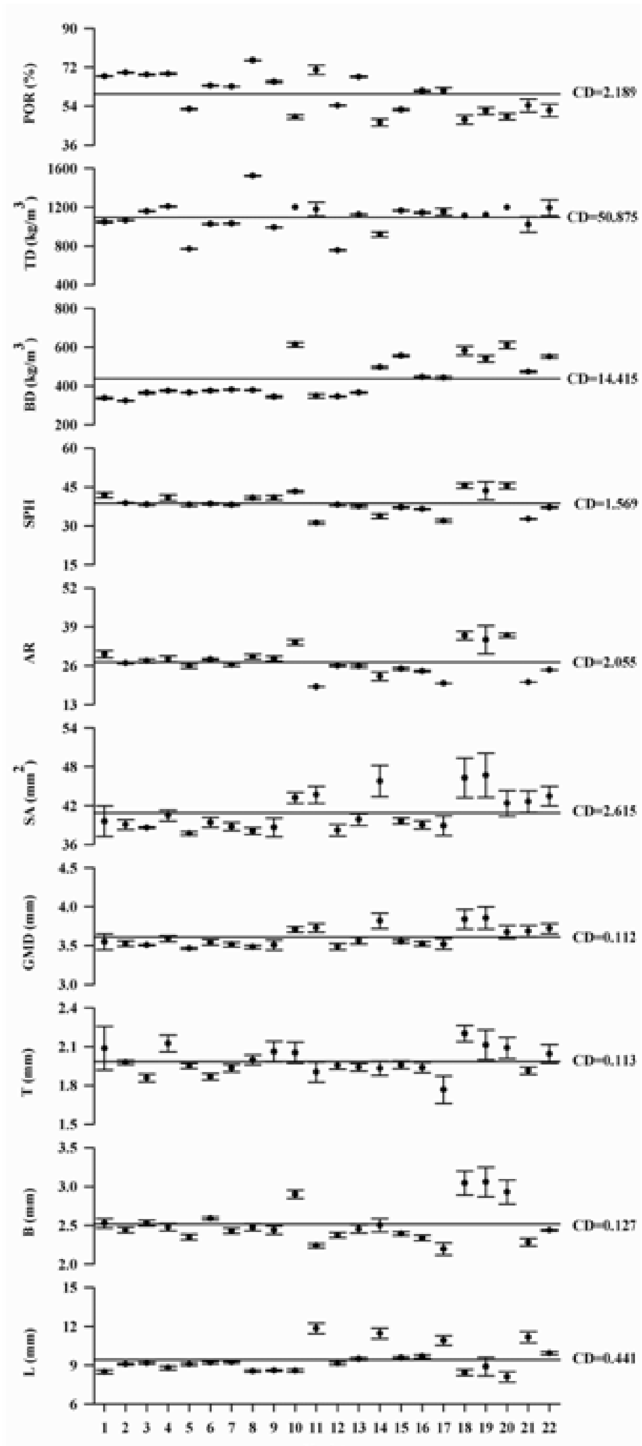


Fig.2: Dimensional and gravimetric properties of selected paddy cultivars

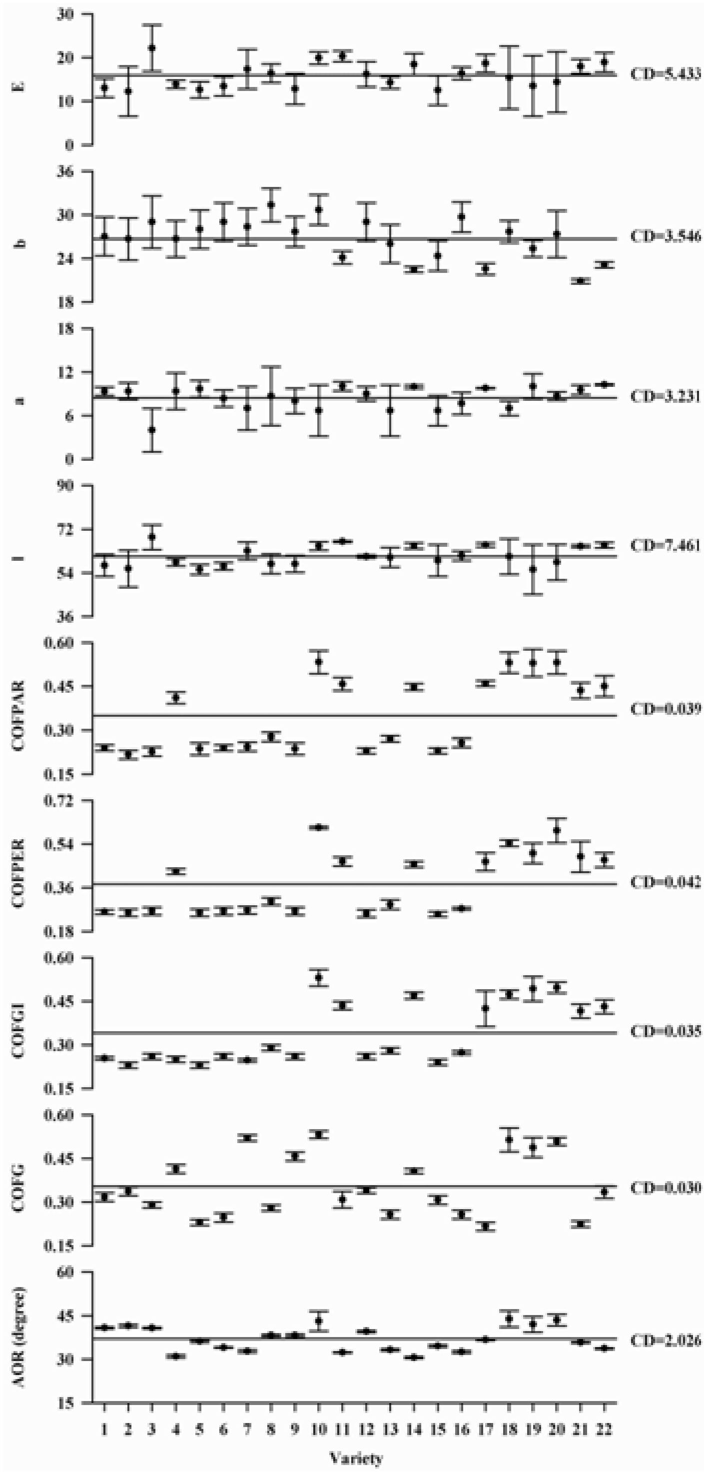


Fig.3: Frictional and optical properties of selected paddy cultivars

TABLE 2
Correlation matrix of variable properties of the paddy cultivars

| Variables | B | T | GMD | SA | AR | SPH | BD | TD | POR | COFG | COF GI | COF PER | COF PAR | AOR | l | a | b | DE |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| L | -0.59 | -0.62 | 0.24 | 0.24 | -0.86 | -0.92 | -0.06 | -0.14 | -0.04 | -0.44 | 0.25 | 0.15 | 0.19 | -0.61 | 0.62 | 0.36 | -0.73 | 0.50 |
| B | | 0.70 | 0.59 | 0.59 | 0.92 | 0.84 | 0.61 | 0.18 | -0.45 | 0.73 | 0.52 | 0.52 | 0.52 | 0.65 | -0.26 | -0.20 | 0.30 | -0.15 |
| T | | | 0.45 | 0.45 | 0.76 | 0.81 | 0.38 | 0.16 | -0.26 | 0.69 | 0.24 | 0.35 | 0.36 | 0.43 | -0.43 | 0.08 | 0.21 | -0.40 |
| GMD | | | | 1.00 | 0.26 | 0.15 | 0.68 | 0.10 | -0.57 | 0.49 | 0.85 | 0.80 | 0.84 | 0.13 | 0.24 | 0.25 | -0.43 | 0.23 |
| SA | | | | | 0.26 | 0.15 | 0.67 | 0.10 | -0.57 | 0.49 | 0.84 | 0.79 | 0.84 | 0.13 | 0.23 | 0.25 | -0.43 | 0.22 |
| AR | | | | | | 0.98 | 0.42 | 0.19 | -0.26 | 0.69 | 0.23 | 0.28 | 0.26 | 0.72 | -0.46 | -0.28 | 0.55 | -0.34 |
| SPH | | | | | | | 0.32 | 0.18 | -0.18 | 0.66 | 0.09 | 0.17 | 0.15 | 0.68 | -0.54 | -0.26 | 0.59 | -0.42 |
| BD | | | | | | | | 0.25 | -0.80 | 0.47 | 0.76 | 0.75 | 0.73 | 0.29 | 0.18 | -0.05 | -0.20 | 0.16 |
| TD | | | | | | | | | 0.37 | 0.06 | 0.21 | 0.28 | 0.27 | 0.07 | 0.12 | -0.18 | 0.14 | 0.22 |
| POR | | | | | | | | | | -0.38 | -0.6 | -0.54 | -0.53 | -0.20 | -0.10 | -0.11 | 0.27 | -0.03 |
| COFG | | | | | | | | | | | 0.43 | 0.47 | 0.46 | 0.39 | -0.07 | -0.14 | 0.22 | -0.04 |
| COFGI | | | | | | | | | | | | 0.94 | 0.95 | 0.28 | 0.39 | 0.25 | -0.35 | 0.43 |
| COFPER | | | | | | | | | | | | | 0.99 | 0.25 | 0.34 | 0.25 | -0.33 | 0.37 |
| COFPAR | | | | | | | | | | | | | | 0.21 | 0.31 | 0.31 | -0.38 | 0.34 |
| AOR | | | | | | | | | | | | | | | -0.23 | -0.21 | 0.36 | -0.11 |
| l | | | | | | | | | | | | | | | | -0.23 | -0.33 | 0.94 |
| a | | | | | | | | | | | | | | | | | -0.49 | -0.20 |
| b | | | | | | | | | | | | | | | | | | -0.13 |

*Optical Properties*

The optical properties, l, a and b values of the samples lie in the range of 55.333±2.082 to 68.667±5.132, 4.00±2.92 to 10.243±0.110 and 20.865±0.292 to 31.333±2.309, respectively. The value of total colour difference (ΔE) which varied from 12.230±4.861 to 22.134±4.641 further confirms the existence of very distinct colour difference (Adekunte *et al*., 2010) with a variety of specific associated characteristic variability (p≤0.05) in distinguishing on the basis of considered parameter (Fig.3).

*Multivariate Analysis*

The correlation matrix of physical and optical characteristics spread over dimensional (seven), gravimetric (three), frictional (five) and optical (four) attributes are shown in Table 2. Nearly, 80% of the correlation coefficients in the matrix are over 0.20 (Table 2). Kernel length was observed having positive significant correlation with optical parameters (l, a, ΔE) whereas negative correlation with dimensional (breadth, sphericity, aspect ratio, thickness), optical (b value) and frictional (AOR) attributes. The strong correlation is indicative for the cultivar associative character towards longer kernel length and the feeble correlation vice versa. The results are in agreement with the physical properties of white rice reported elsewhere (Bhatia *et al*., 2009).

The data set of the observed measurements was subjected to principal component analysis (PCA), which has eliminated the prevailed variations of highly inter-correlated nature. The initial statistics of the Eigen analysis is given in Table 3. It can be seen that three principal components (PCs) appeared to account for 79.36% of the total variance in the data. According to Kaiser Criterion (Kaiser, 1960), only the first four PCs could be retained because the Eigen values of more than one reduced dimensionality descriptor space to four. The descriptors were represented graphically in the form of loading plot for three components (Fig.4).

TABLE 3
Eigen analysis of principal components

| No. | Eigen value | Individual Percent | Cumulative Percent |
|---|---|---|---|
| 1 | 7.524 | 39.60 | 39.60 |
| 2 | 5.480 | 28.84 | 68.44 |
| 3 | 2.075 | 10.92 | 79.36 |
| 4 | 1.252 | 6.59 | 85.96 |
| 5 | 0.722 | 3.80 | 89.75 |
| 6 | 0.663 | 3.49 | 93.25 |
| 7 | 0.447 | 2.35 | 95.60 |
| 8 | 0.330 | 1.74 | 97.33 |
| 9 | 0.228 | 1.20 | 98.53 |
| 10 | 0.152 | 0.80 | 99.33 |
| 11 | 0.083 | 0.44 | 99.77 |
| 12 | 0.021 | 0.11 | 99.88 |
| 13 | 0.010 | 0.05 | 99.93 |
| 14 | 0.006 | 0.03 | 99.97 |
| 15 | 0.004 | 0.02 | 99.99 |
| 16 | 0.002 | 0.01 | 100.00 |
| 17 | 0.000 | 0.00 | 100.00 |
| 18 | 0.000 | 0.00 | 100.00 |

The loading of components on the principal axes indicated the presence of variability among the selected paddy cultivars (Fig.4). In order to study the prevailed pattern for the measured attributes and to categorize factors that are substantively meaningful, the chemo-metric approach was applied. It can be seen that the first component explaining 39.60% of variance is highly correlated both positively (porosity) and negatively (dimensional properties, coefficient of friction and other gravimetric properties). Thus, it classifies and distinguishes the score of paddy cultivars on the basis of these components. The second principal component explaining 28.84% of total variance is highly correlated with most of the observed parameters leaving the gravimetric attributes, while the third component has explained only 10.92 % of the total variance and is loaded with mainly the optical attributes and the mass per unit volume occupied by different paddy cultivars as represented in terms of true density (Fig.2).

Fig.4 illustrates the biplot of scores and loadings on the three principal components for the observed parameters of the paddy cultivars. The biplot of principal component 1 (PC1) and principal component 2 (PC2) shows the separation of the paddy cultivars according to their respective scores. The first quadrant of the plot contains samples having positive PC1 and PC2 scores. The cultivars forming a distinct cluster with five cultivars, namely Muchhal (11), PUSA 1121 (14), Shabnam (17), Sugandha (21) and Usha (22), are found loaded with the length and colour difference (ΔE) attributes (Fig.4). Another distinct cluster formed by cultivars Jehlum (10), Shalimar 1 (18), Shalimar 2 (19) and Shalimar 3 (20), the short bold rice kernel characteristics and occupied their position in third quadrant in principal space (Fig.4). The remaining 13 cultivars have formed a separate cluster and occupied their place in the fourth quadrant in principal space (Fig.4).

A graphical depiction of classification based on measured characteristics of selected paddy cultivars was obtained by means of cluster analysis (CA) of standardized compositions using Ward's method (Ward, 1963) as an amalgamation rule and squared Euclidean distances as the measure of proximity between samples. A dendogram is shown in Fig.5. As a result of applying CA to the principal component score matrix, the paddy cultivars were grouped into three different clusters (Table 4) supporting the findings obtained using principal component analysis. It was revealed that clusters I, II and III have 5, 4 and 13 cultivars, respectively. The formed first cluster represents mainly the long grain rice varieties (Singh & Prasad, 2013) and was found susceptible to breakage during milling (Singh & Prasad, 2012). The clustering pattern of paddy cultivars reveals considerable characteristic diversity among themselves pertaining basically on the attributes of dimensional and total colour difference characteristics by occupying three clusters. Thus, the above characterizations of paddy cultivars on the basis of dissimilarity in scores with respect to extracted principal components justify the existence of variability and may be used varietal improvement programme with the development of equipment pertaining to the processing and agricultural purposes.

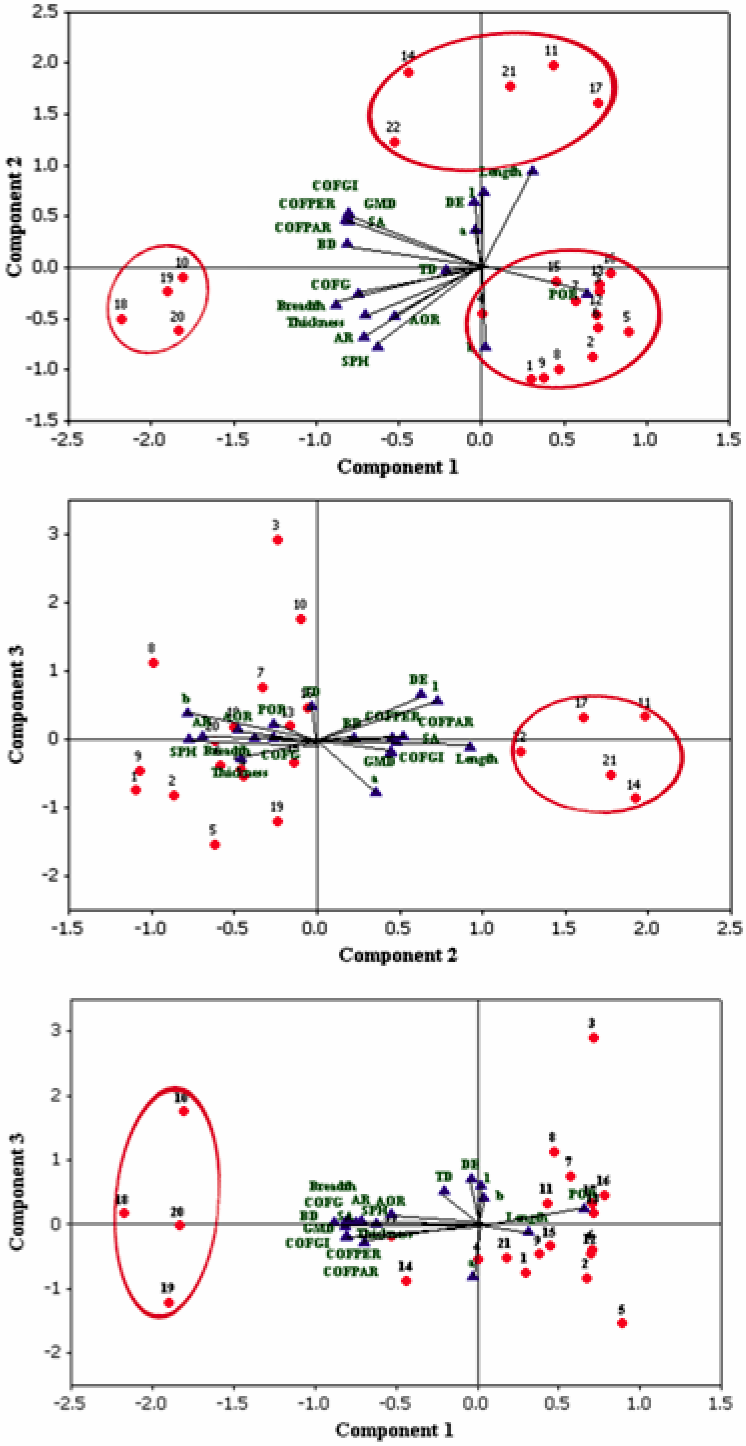

Fig.4: Biplot of loadings and scores for paddy cultivars on principal axes 1, 2 and 3

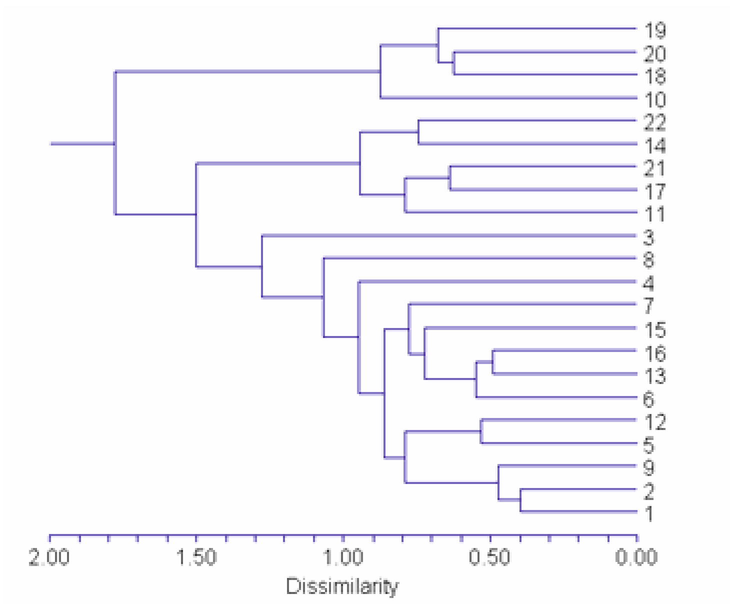


Fig.5: Dendogram of Cluster Analysis for selected paddy cultivars

TABLE 4
Distribution of 22 paddy cultivars into three clusters

| Cluster No. | Paddy cultivars in different cluster |
|---|---|
| I | Muchhal (11), PUSA 1121 (14), Shabnam (17), Sugandha (21) and Usha (22) |
| II | Jehlum (10), Shalimar 1 (18), Shalimar 2 (19) and Shalimar 3 (20) |
| III | BR 4-10 (1), CSR 10 (2), Haryana Mahak 11 (3), HBC 19 (4), HKR 95-157 (5), HKR 95-407 (6), HKR 99-66 (7), HKR H7 (8), IR 64 (9), Palman 579 (12), PAU 201 (13), PUSA Basmati (15) and PUSA Sugandh (16) |

## CONCLUSION

Characteristic variations among physical and optical properties existed among the paddy cultivars. Cultivars Muchhal, PUSA 1121, Shabnam, Sugandha and Usha showed greater potentials in terms of handling attributes as it may outperform processing as compared the other cultivars due to significant dimensional variations. This indicates the usefulness multivariate analysis in identifying promising cultivars for the likely possibility to produce new recombinants with desired characters or appropriateness in the development of agricultural and processing equipments based on the opto-physical characteristics.

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