DOI 10.5958/0976-1926.2017.00018.3

Characterization of Some Aromatic Farmers' Varieties of Rice (*Oryza sativa* L.) from West Bengal and Adjoining States

Sudhansu Mahato[1], Dinesh Tulsiram Surje[1], Swarnajit DebBarma[1] and Bidhan Roy[2*]
[1]Department of Genetics and Plant Breeding, [2]Department of Seed Science and Technology, Uttar Banga Krishi Viswavidyalaya, Pundibari, Cooch Behar-736165, India*

(Received: 20 February 2015; Revised: 16 May 2016; Accepted: 4 June 2016)

The genetic variability was assayed in 35 aromatic Farmers' Varieties (FVs). High magnitude of variability was observed for all the characters under study. High heritability was observed for days to 50% flowering, plant height, number of panicles per plant, panicle length, number of grains per panicle, 100-grain weight, grain length, grain breath and grain yield. The collective contribution of the yield contributing characters resulted in high yield for Rampha, Laldhyapa-1, A-1-1, Kauka, Kalakali and Joha Bora. Khasa, Radhunipagul, Mohanbhog, Gobindobhog, Kalojeera, Badshahbhog, Tulsibhog, Tulaipanji, Bora, Joha Bora, Silathia Bora, Jailung Lal Komal, Ghee Bora, Birai, Kabra, Rampha, Kolajoha-Big, Kolajoha-Small and Konkoni Joha were classified as the FVs having strong aroma. Grain yield showed highly significant positive association with number of panicles per plant, 100-grain weight and grain thickness. Positive direct effect on grain yield/plant was observed in number of panicles/plant, 100-grain weight, and grain length and breadth.

Key Words: Aroma, Farmers' variety, Heritability, Path analysis, Variability

Introduction

Rice (*Oryza sativa* L.) is one of the most important food crop in the world, grown in over 164 million hectares of land with overall worldwide production of 731.2 million tonnes per annum (FAO, 2013). Countries in Southeast Asia are heavily reliant upon rice. Among the rice growing countries, India has the largest area accounting for about 31% of the global area. India accounts for nearly one-fourth (22%) of the rice produced in the world with the first place occupied by China. Rice varieties have different productivities, grain qualities, grain appearance and aroma. Many aromatic rice varieties are produced in India, Thailand, Pakistan, Bangladesh, Nepal, Iran, Afghanistan, Myanmar and Indonesia. Aromatic rice cultivars that are popular in Thailand are Thai Hom Mali rice, Jasmine rice, and Thai Fragrant rice. In India the famous aromatic rice is Basmati, which has medium texture with a slender shape and long grain and less chalkiness (Kamath *et al*., 2008). Besides the much sought after Basmati types, which get premium price in international markets, the hundreds of indigenous short grain aromatic cultivars and landraces are grown in pockets of different states of India. Almost every state has its own collection of aromatic rices, which perform well in native areas (Shobha Rani and Krishnaiah, 2001). These aromatic rice varieties possess exemplary quality traits like aroma, fluffiness and taste. However, the genetic improvement in these rice varieties is very much neglected as they lack export value *per se*.

The aroma of rice plays a role in its consumer acceptability. Aroma of rice is caused by chemical compounds that can easily evaporate. More than 100 compounds that contribute to the aroma of rice have been identified. Some of these volatile compounds contribute to consumer acceptance of certain types of rice, whereas other compounds contribute to consumer rejection. The popcorn-like smell of aromatic rice stemming primarily from its 2-acetyl-1-pyrroline (2-AP) content is preferred by many consumers. The 2-AP was detected in one of the famous aromatic rice 'Khaw Dawk Mali-105' (Laksanalamai and Ilangantileke, 1993; Bourgis *et al.*, 2008). Weber *et al.* (2000) stated that 2-AP content in aromatic rice is 15 times greater than that of non-aromatic rice. Gene controlling the level of 2-AP expression is *OsBADH2* (Niu *et al.*, 2008). More recently, an eight base pair-deletion and three SNPs in exon 7 of the gene encoding betaine aldehyde dehydrogenase 2 (*BADH2*) on chromosome 8 of rice were identified as the probable cause of aroma in aromatic rice (Bradbury *et al.*, 2005).

**Author for Correspondence: Email- bcroy10@yahoo.com*

Rice aroma also depends on environmental conditions and cultivation management. Aroma in scented rice depends on the levels of 2-AP content and it varies with genetic background and environmental conditions (Nadaf *et al*., 2006). Basmati variety will be more aromatic if cultivated in area having relatively cool temperature in the afternoon (25-32 °C) and night (20-25 °C) with humidity of about 70-80% during primordial and grain filling stages (Singh, 2000). In view of the importance of the aromatic rice in the national and international markets, the aim of present study was to quantify genetic variability in important yield contributing characters in a set of 35 aromatic FVs and assessment of character associationships through correlation and path coefficient analyses under the humid sub-tropics of Terai Zone of Cooch Behar, West Bengal.

Materials and Methods

Germplasm Collections

Thirty-five aromatic Farmers' Varieties (FVs) of rice were used in this study. These FVs were collected from West Bengal, Assam and Manipur. Details of the genotypes are given in Table 1. The field experiment was carried out at the Instructional Farm of Uttar Banga Krishi Viswavidyalaya, Pundibari, Cooch Behar, West Bengal. The farm is situated at 26º19′86″ N latitude and 89º23′53″ E longitude, at an elevation of 43 meter above mean sea level. The climatic condition of *Terai* Zone is sub-tropical in nature with high rainfall, high humidity and prolong winter season.

Morphological Characterization

Thirty days old seedlings were transplanted (single seedling per hill) in plots measuring 3 × 1.5 m area in randomized block design with two replications. Row to row and plant to plant spacing were 30 and 20 cm, respectively. Standard agronomic practices compatible to the humid tropic of *Terai* Zone were followed to obtain good crop stand. Five random plants were selected from each entry from each replication for recording the data using the guidelines of IRRI (IRRI, 2002). Observations were recorded on days to 50% flowering, plant height (cm), number of panicles per plant, panicle length (cm), grain density, number of filled grains per panicle, filled grain percentage, number of chaffy grains per panicle, grain sterility (%), total grains per panicle, 100-seed weight (g), grain length (mm), grain width (mm), grain thickness (mm) and grain yield per plant (g).

Aroma Testing

Aroma was evaluated through cooked rice aroma test following the method as described by Allidawati (1989). One gram of rice was placed in test tube of 15 mm × 150 mm containing 10 ml of dH_2O. The test tube was then covered with aluminum foil and cooked in boiling water for 15 minutes. After the samples were cooled down, the aluminum foil was opened and the score of each sample was recorded by a panel of experts (panelists) who have experience in evaluation of aroma and quality of rice. The scores were averaged and classified into aromatic, slightly aromatic and not aromatic.

Table 1. Name of the Farmers' Varieties of rice used in this study and their place of collection

S.No.	Name of the FV	District/ State of cultivation	S.No.	Name of the FV	District/ State of cultivation
1.	Khasa	Maldah, W.B.	19.	Konkoni Joha	Assam
2.	Radhunipagal	Nadia, W.B.	20.	Sial Bhomra	Assam
3.	Mohanbhog	Nadia, W.B.	21.	Jhagrikartik	Assam
4.	Gobindobhog	Nadia, W.B.	22.	Sadanunia	Cooch Behar, W.B.
5.	Kalojeera	Cooch Behar, W.B.	23.	Kataribhog	Alipurduar, W.B.
6.	Badshabhog	Maldah, W.B.	24.	Khama	Alipurduar, W.B.
7.	Tulsibhog	Alipurduar, W.B.	25.	Bhiganmachhuya	Assam
8.	Tulaipanji	Uttar Dinajpur, W.B.	26.	A-1-1	Alipurduar, W.B.
9.	Bora	Assam	27.	Laldhyapa-1	Alipurduar, W.B.
10.	Joha Bora	Assam	28.	Singra	Alipurduar, W.B.
11.	Silathia Bora	Assam	29.	Kalakali	Alipurduar, W.B.
12.	Jailung Lal Komal	Assam	30.	Marichsal	Alipurduar, W.B.
13.	Ghee Bora	Assam	31.	Kauka	Alipurduar, W.B.
14.	Birai	Assam	32.	Laghidhan	Alipurduar, W.B.
15.	Kabra	Assam	33.	Dubari Komal	Assam
16.	Rampha	Assam	34.	Hatidat Komal	Assam
17.	Kolajoha Big	Assam	35.	Ranga Komal	Assam
18.	Kolajoha Small	Assam			

Table 2. Analysis of variance for different characters in rice

Characters	Source of variation with d.f.		
	Replication (1)	Treatment (34)	Error (34)
Plant height	0.6071	471.2316**	0.7285
Days to 50% flowering	-0.0357	362.8456**	0.1922
No. of panicles/ plant	0.2057	49.9270**	0.0478
Panicle length	0.0975	7.5545**	0.0179
Grain density	0.7560	11.1154**	0.0425
No. of filled grains/ panicle	595.9714	5237.0771**	26.8905
Filled grain (%)	9.9804	28.7132**	0.6734
No. of chaffy grains/ panicle	6.4129	181.7336**	1.7212
Grain sterility (%)	10.0338	28.7144**	0.6723
No. of total grains/ panicle	478.8286	6265.3311**	27.1374
100 grains weight	0.0084	0.5740**	0.0052
Grain length	0.1843	3.5144**	0.1274
Grain breadth	0.0112	0.2704**	0.0152
Grain L/B ratio	0.0835	0.6641**	0.0365
Grain thickness	0.0066	0.1069**	0.0167
Grain yield/ plant	13.9214	258.9746**	6.5962

Statistical Analysis

The experimental design used was RBD using 35 treatments (genotypes) with two replications. The data were subjected to standard statistical methods of analysis of variance (ANOVA), correlation and path analysis using AgRes Statistical Software, (c) 1994 Pascal Intl Software Solutions, Version 3.01. Path coefficient analysis is simply standardized partial regression coefficient, which splits this correlation coefficient into measures of direct and indirect effects of a set of independent variables on these dependent variables.

Results and Discussion

Genetic Variability

The present investigation was undertaken to quantify the nature and magnitude of variability, heritability and genetic advance in respect of 16 agronomic and grain characters in a set of 35 aromatic FVs of rice. Efforts were also made to understand character associationship through correlation and path analyses. Genotypes were found to be significantly different from each other in respect of all the characters studied (Table 2).

Classification Based on Grain Type

Based on classification of Govindaswami (1985) the grains of these 35 FVs were classified into four groups *viz*., long slender (LS), medium slender (MS), long bold (LB) and short bold (SB). Eleven FVs were classified under long slender, five FVs were medium slender, 13 were long bold and six FVs were short bold (Table 3). Grain shape determines the selling price of this important commodity. This character largely depends on grain length, breadth and L:B ratio. Long slender grain influences the consumers' acceptance of the genotype in the market.

Classification Based on Strength of Aroma

The Indian subcontinent has the *Nature's Gift* of Basmati rice that has been accepted as the best scented, long and slender grain in the national and international markets and gets premium price. In addition to Basmati, many local landraces are grown traditionally which excel in aroma, grain quality and cooking quality. 'Tulaipanji' of Daskhin Dinajpur district of West Bengal equally satisfies the grain quality as that of Basmati rice.

Table 3. Classification of FVs based on grain type as per the recommendation of Govindaswami (1985)

Classes	Name of the Farmers' Varieties	No. of FVs
Long Slender	Tulaipanji, Jailung Lal Komal, Birohi, Kabra, Kolajoha Big, Kataribhog, A-1-1, Kalakali, Dubari Komal, Hatidat Komal, Sadanunia	11
Medium Slender	Tulsibhog, Joha Bora, Silathia Bora, Kolajoha Small, Sial Bhomra	5
Long Bold	Radhunipagal, Bora, Ghee Bora, Rampha, Jhagrikartik, Khama, Bhiganmachhuya, Laldhyapa-1, Singra, Marichsal, Kauka, Laghidhan, Ranga Komal	13
Short Bold	Khasa, Mohanbhog, Gobindobhog, Kalojeera, Badshabhog, Konkoni Joha	6

Many FVs have strong aroma, but their other plant characters and/or grain characters may not be *at par* with the modern high yielding varieties. Most of those aromatic FVs are poor yielders, for examples, Kalonunia, Tulaipanji (Mandal *et al*., 2013), Kalojeera and Mohanbhog. On the other hand, few aromatic FVs possess high yielding ability, such as Gobindobhog and Badshabhog. Those FVs may be brought under cultivation through improved agronomic practices. In West Bengal, those strongly scented rices are generally used in preparation of *Khir* during special occasions and also offered during different auspicious occasions.

The collected germplasm was classified under two groups based on aroma as per the guidelines of (Allidawati, 1989; Anonymous, 2004; Lestari, 2011) (Table 4). A sizable numbers of aromatic FVs possessed strong aroma and those cultivars also fetched high prices in the local market. These cultivars may be released with modern agronomic practices to improve yield potential and subsequently popularization of their cultivation.

Khasa, Radhunipagul, Mohanbhog, Gobindobhog, Kalojeera, Badshahbhog, Tulsibhog, Tulaipanji, Bora, Boha Bora, Silathia Bora, Jailung Lal Komal, Ghee Bora, Birai, Kabra, Rampha, Kolajoha-big, Kolajoha-Small and Konkoni Joha were classified as the FVs having strong aroma. Few of these FVs are very popular in Assam (Ghee Bora, Silathia Bora, Kolajoha-big and Kolajoha-Small) and West Bengal (Gobindobhog, Badshabhog, Khasha, Tulaipanji, Kalobhog etc.). Rest all the other FVs have been recorded as mild aromatic cultivars, namely, Sial Bhomra, Jhagrikartik, Sadamunia, Kataribhog, Khama, Baigon Machhuya, A-1-1, Laldhyapa-1, Singara, Kalakali, Marichsal, Kauka, Dubari Komal, Hatidat Komal and Ronga Komal.

Donor's Identification for Different Argonomic Characters

The FVs showed desirable characteristics based on individual character were listed in Table 5. The FV, such as, Sadanunia was found to be superior for the important plant characters (days to 50% flowering, plant height, number of panicles per plant, grain type and grain yield per plant). The FV Rampha was found better for the characters, such as, panicle length, 100-grain weight, grain type and yield. The FV A-1-1 was found to be superior in respect of number of panicles per plant, lower percentage of chaffy grains per panicle, grain type and yield per plant.

The most important desirable characters for the rice cultivation under multiple cropping system are days to 50% flowering, plant height, number of panicles per plant, panicle length, number of filled grains per panicle, spikelet sterility, 100-grains weight, grain type and finally the yield per plant. The FVs Tulsibhog and Sadanunia showed earliness for grain maturity. Generally the FVs are long duration, but these two FVs were found to be of medium duration. Sadanunia also have some other desirable characters like, plant height, number of panicles per plant, grain type and grain yield per plant.

High number of panicles per plant was recorded for Rampha, Kalakali, Khasha, Laldyapa-1, Sadanunia and A-1-1. Longer panicles were observed for the FVs namely, Marichsal, Birohi, Kolajoha Big, Rampha, Khama, Singara and Gobindobhog. The FVs which showed higher number of filled grains per panicle were Badshabhog, Mohanbhog, Sial Bhomra, Kolajoha Small, Khama, Gobindobhog and Bhiganmachhuya. Low spikelet sterility was observed for Tulaipanji, A-1-1, Kamar, Mohanbhog, Silathia Bora and Radhunipagal. Higher 100-grains weight was documented for Hatidat Komal, Rampha, Dubari Komal, Laldhyapa, Ghee Bora, Joha Bora, Rongakomal and Silathia Bora. Long slender grain was witnessed for Tulaipanji, Jailung Lal Komal, Birohi, Kabra, Kolajoha Big, Kataribhog, A-1-1, Kalakali, Dubari Komal, Hatidat Komal and Sadanunia.

The collective contribution of the yield attributing characters resulted high yield for the FVs namely, Rampha, Laldhyapa-1, A-1-1, Kauka, Kalakali, Joha Bora, Khama, Sadanunia, Hatidat Komal, Marichsal and Dubari Komal. High yield of these genotypes were probably governed by moderate to high number of panicles per plant, grains per panicle and 100-

Table 4. Genetic variability of the collected Farmers' Varieties of rice in respects of aroma

Classes	Name of the farmers' varieties	No. of FVs
Strong aroma	Khasa, Radhunipagul, Mohanbhog, Gobindobhog, Kalojeera, Badshahbhog, Tulsibhog, Tulaipanji, Bora, Boha Bora, Silathia Bora, Jailung Lal Komal, Ghee Bora, Birai, Kabra, Rampha, Kolajoha-big, Kolajoha-Small, Konkoni Joha	19
Mild aroma	Sial Bhomra, Jhagrikartik, Sadamunia, Kataribhog, Khama, Baigon Machhuya, A-1-1, Laldhyapa-1, Singara, Kalakali, Marichsal, Kauka, Dubari Komal, Hatidat Komal, Ronga Komal	16

Table 5. Donors identification for different argonomic characters among 35 famers' varieties of rice

Character	Genotype
Days to 50% flowering	Tulsibhog, Sadanunia
Plant height	Sadanunia, Mohanbhog, Katarybhog, Jailung Lal Komal, Bora, Jhagrikartick
No. of panicle per plant	Rampha, Kalakali, Khasha, Laldyapa-1, Sadanunia, A-1-1
Panicle length	Marichsal, Birohi, Kolajoha Big, Rampha, Khama, Singara, Gobindobhog
No. of filled grains per plant	Badshabhog, Mohanbhog, Sial Bhomra, Kolajoha Small, Khama, Gobindobhog, Bhiganmachhuya
Filled grain percentage	Mohanbhog, Silathia Bora, Radhunipagal, Kalojeera, Badshabhog, Kabra, Gobindobhog
Number of chaffy grains per panicle	A-1-1, Tulsibhog, Kalojerra, Radunipagal, Kabra, Kauka
Spikelet sterility (%)	Tulaipanji, A-1-1, Kamar, Mohanbhog, Silathia Bora, Radhunipagal
Total number of grains per panicle	Badshabhog, Mohanbhog, Sial Bhomra, Konkoni Joha, Kolajoha Small
Grain density	Badshabhog, Mohan bhog, Sial Bhomra, Kolajoha Small, Bhiganmachhuya, Silathia Bora, Joha Bora
100-grain weight	Hatidat Komal, Rampha, Dubari Komal, Laldhyapa, Ghee Bora, Joha Bora, Rongakomal, Silathia Bora
Grain length	Khama, Dubari Komal, Ranga Komal, Sial Bhomra, Kolajoha Big, Rampha
Grain breadth	Badshabhog, Tulaipanji, Tulsibhog, Kataribhog, Sadanunia, Kolajoha Small
Grain L:B ratio	Tulaipanji, Kataribhog, Jailung Lal Komal, Birohi, Kalakali, Kalojeera, Kabra, A-1-1, Dubari Komal, Hatidat Komal
Grain type (Long Slender)	Tulaipanji, Jailung Lal Komal, Birohi, Kabra, Kolajoha Big, Kataribhog, A-1-1, Kalakali, Dubari Komal, Hatidat Komal, Sadanunia
Grain yield/plant	Rampha, Laldhyapa-1, A-1-1, Kauka, Kalakali, Joha Bora, Khama, Sadanunia, Hatidat Komal, Marichsal, Dubari Komal

grain weight. For genetic improvement of rice several promising donors were identified (Table 5), which may be used in the breeding programmes.

Genetic Parameters

The estimates of different genetic parameters *viz*., genotypic coefficient of variation (GCV), phenotypic coefficient of variation (PCV), heritability (H^2) and genetic advance (GA) were presented in Table 6.

The PCV estimates were found to be higher than corresponding GCV estimates for all the characters under consideration, which suggested their involvement in influencing the expression of these characters (Table 6). Similar result was also reported by Suresh and Anbuselvam (2005), Hasib (2005), Karad and Pol (2008), Kumar and Senapati (2013). GCV and PCV for grain thickness differed significantly and was found to be more prone to environmental changes than other characters. This abreast with the findings of Reddy *et al.* (1997a-b).

Impact of environment on the expression of any character is studied by estimating GCV and PCV. It was revealed less difference in corresponding GCV and PCV values for all the characters studied for associationship except grain thickness. It indicates marginal control of environment in governing these characters. Ramalingam *et al*. (1994) and Borbora and Hazarika (1998) also reported similar results.

Heritability estimates were found to be high for days to 50% flowering (99.0%), plant height (99.0%),

Table 6. Variability and genetic parameters for different characters in rice

Character	Variance			GCV	PCV	h2 (BS)	G.A. as % of mean
	Phenotypic	Genotypic	Environmental				
Plant height	235.98	235.252	0.728	10.30	10.32	0.99	21.19
Days to 50% flowering	181.59	181.327	0.192	10.01	10.02	0.99	20.62
Number of panicles/plant	24.97	24.940	0.048	27.46	27.49	0.99	56.53
Panicle length	3.76	3.768	0.018	7.690	7.70	0.99	15.80
No. of filled grain/panicle	2631.98	2605.093	26.891	31.60	31.76	0.98	64.76
No. of chaffy grain/ panicle	91.72	90.006	1.721	38.69	39.05	0.98	78.95
100-grain weight	0.29	0.284	0.005	28.89	28.57	0.98	57.81
Grain length	1.82	1.693	0.127	18.89	19.59	0.93	37.53
Grain breadth	0.14	0.128	0.015	14.08	14.89	0.89	27.42
Grain thickness	0.06	0.045	0.017	11.64	13.63	0.72	20.49
Grain yield/plant	132.78	126.189	6.596	39.50	40.42	0.95	79.32

number panicles per plant (99.0%), panicle length (99.0%), number of filled grains per panicle (98.0%), 100-grain weight (98.0%), grain length (93.0%), grain breath (89.0%) and grain yield (95.0%). High heritability along with high genetic advance for number of filled grains per panicle, number of panicles per plant and 100-grains weight were also reported by Tripathi *et al.* (1999), Sarkar *et al.* (2005), Suresh and Anbuselvam (2005), Karad and Pol (2008), Mulugeta *et al.* (2012), Kumar and Senapati (2013).

H^2 in broad sense indicates the extent of genetic control of a character and it reflects the efficiency of selection to improve upon a particular character. Thus, characters endowed with high values may be used as selection criteria in genetic improvement of grain yield. High H^2 for quantitative characters are useful as it enables in effective selection based on the phenotypic performance. It also indicates the correspondence between genotype and phenotype. Similar results were also reported by Roy and Kar (1992), Ramalingam *et al.* (1994), Sarawgi and Soni (1994), Yadav (1992) and Reddy *et al.* (1997 a-b) for days to 50% flowering and plant height, Sarma and Roy (1993), Sawant and Patil (1995), and Roy *et al* 2001) for number of filled grains per panicle and 100-grain weight. High GCV coupled with high heritability indicating effectiveness of selection based on these characters.

High genetics advance was observed for number chaffy grains per panicle (78.95), number of filled grains per panicle (64.76), grain yield per plant (79.32), 100-grains weight (57.81) and number of panicles per plant (56.53) (Table 6).

A character attracts more attention which displays high degree of heritability for genetic improvement through simple selection. But to assess the maximum effect of selection, GA is simultaneously computed. Johnson *et al.* (1955) and Panse (1957) opined that H^2 estimate with simultaneous consideration of GA values would be more useful than H^2 alone in predicting the efficiency of selection. High GA coupled with high H^2 were observed for number of filled grains per panicle, grain yield per plant, 100-grains weight and number of panicles per plant. Ghosh *et al.* (1981), Kaul and Kumar (1982), Sawant *et al.* (1995) also reported similar result for number of field grains per panicle, 100-grain weight and grain yield per plant. High heritability coupled with high GA indicates the predominance of additive gene action and selection for these characters based on phenotypic value would result in more efficient breeding programmes. Simple selections like mass and family selections would be effective to accumulate such additive genes, which may further improve upon their performances.

Character Associationship

For analysis of character associationship, 11 characters were considered instead of 16 characters. The characters derived from other basic characters such as grain density, filled grain percentage, spikelet sterility (%), total grains per panicle and grain L:B ratio were not included here. The genotypic and phenotypic coefficients of correlation between the characters in all possible combinations are presented in Table 7.

Grain yield showed high significant positive association with number of panicles per plant (0.668, 0.651), 100-grains weight (0.617, 0.598) and grain thickness (0.449, 0.410) both at genotypic and phenotypic levels. This character showed significant positive correlation (0.334) with grain length at genotypic level, whereas it showed positive insignificant association with grain length. Grain yield per plant also showed positive correlation with plant height and grain thickness. It showed negative association with days to 50% flowering, panicle length and number of filled grains per panicle. Grain yield per plant registered high significant negative association with number of chaffy grains per panicle. This is very desirable characters association, because with decrease in number of chaffy grains per panicle will increase grain yield of rice.

Most of the plant characters of economic importance such as grain yield per plant are extremely complex in inheritance and generally associated with several other characters. Furthermore, expression of such characters by and large is influenced by the environment, which increases the complexity of inheritance pattern and in shaping such characters in breeding programmes. Hence, knowledge of the degree of genotypic and phenotypic correlations between yield and other component characters as-well-as among themselves becomes imperative. Correlation studies provide better insight in understanding yield components, which help in choosing proper selection criteria (Johnson *et al.*, 1955). Maximum combinations of heritability and correlation coefficient values are necessary to execute more efficient selection than direct selection for improved grain yield *per se*. Genotypic correlation generally

Table 7. Genotypic (G) and phenotypic (P) correlations among yield and its attributes in rice

Char.		X2	X3	X4	X5	X6	X7	X8	X9	X10	X11
X1	G	0.321	0.085	0.236	0.024	0.021	-0.029	0.278	0.107	0.130	0.079
	P	0.320	0.085	0.235	0.025	0.028	-0.028	0.265	0.101	0.103	0.074
X2	G		-0.112	0.0980	0.270	0.196	0.020	0.116	0.135	-0.200	-0.060
	P		-0.112	0.097	0.269	0.194	0.019	0.111	0.128	-0.175	-0.059
X3	G			-0.189	-0.235	-0.211	-0.157	0.094	-0.174	-0.186	0.668**
	P			-0.189	-0.233	-0.208	-0.155	0.090	-0.166	-0.160	0.651**
X4	G				-0.337**	0.037	0.087	0.252	0.071	0.152	-0.108
	P				-0.336**	0.037	0.083	0.243	0.064	0.132	-0.103
X5	G					0.438**	-0.260	-0.280	-0.143	-0.084	-0.298
	P					0.430**	-0.255	-0.276	-0.137	-0.067	-0.293
X6	G						-0.249	-0.199	-0.069	-0.162	-0.341*
	P						-0.241	-0.182	-0.066	-0.131	-0.332*
X7	G							0.344*	0.708**	0.433**	0.617**
	P							0.328*	0.667**	0.364**	0.598**
X8	G								0.310	0.275	0.334*
	P								0.283	0.221	0.318
X9	G									0.684**	0.449**
	P									0.579**	0.410**
X10	G										0.242
	P										0.239

X1: Plant height; X2: Days to 50% flowering; X3: Number of panicles/plant
X4: Panicle length; X5: No. of filled grains/panicle; X6: No. of chaffy grains/ panicle
X7: 100-grains weight; X8: Grain length; X9: Grain breadth
X10: Grain thickness; X11: Grain yield per plant

appears due to linkage, pleiotropic effect of the genes and effect of selection. These act either singly or in combination. Estimates of genetic association along with phenotypic correlationships not only display a clear picture of the extent of inherent association but also indicate the quantum of phenotypically expressed correlation influenced by the environment. When any variables are involved in a study, correlation becomes complex, however, meaningful conclusions generally emerge. Genotypic correlationships obtained from a number of genotypes are likely to be higher than those obtained from segregating population in view of the fact that the genotypes stabilize when established under continuous selection process in relation to independent set of genes.

Genotypic correlations were slightly higher than their corresponding phenotypic correlations in this study, which indicated that there is better association between two characters genetically, but the phenotypic value reduced due to significant interaction of the genotype with environment. Johnson *et al*. (1955) also suggested that the low phenotypic correlations might be due to masking/modifying effect of the environment in genetic association between characters. Similar results were observed in several crops including rice (Reddy *et al*., 1997a). For selection purpose, phenotypic correlation is of little practical value unless genotypic and environmental correlations are concurrently considered for pairs of characters. Genotypic correlation is generally used in selecting a character as a means to improve other character. Environmental correlation has no general value as such in selection process except it provides information about the relationship of characters irrespective of genetic differences among the genotypes.

Grain yield showed significant positive association with plant height, number of panicles per plant, 100-grain weight, grain length, grain breadth and grain thickness at genotypic and phenotypic levels. These results indicate that increase in one variable will cause increase in the other and *vice versa*. Similar results were also reported by Yadav (1992), He and Chen (1992), Rao and Saxena (1999) and Meenakshi *et al*. (1999), for number of panicles per plant; Chauhan and Tandon (1984), Paramasivam (1991), Surek *et al*. (1998) and Bagali *et al*. (1999) for 100-grain weight. A positive correlation between desirable characters is essential, which may help in simultaneous improvement of both characters. Very high value of association of grain yield per plant was found with 100-grains weight. Yuan *et al*. (1995) also suggested that the most important character affecting grain weight per panicle was found to be the number of filled grains per panicle. The genetic improvement in respect of an independent character can be achieved by applying strong selection to a particular character, which is genetically correlated with the dependent character. Grain length, grain breadth and grain thickness showed insignificant positive association with grain yield indicating the independent nature of the two characters (Singh and Narayanan, 1993). Chakraborty and Hazarika (1994) reported positive and significant association of grain breadth with yield.

A positive correlation between important characters is desirable since it helps in simultaneous improvement of both the characters (Simmonds, 1979). They may be used as selection criteria to improve upon the grain yield in rice. Therefore, selection for number of panicles per plant and 100-grain weight could be effective in improving grain yield per plant. Deosarkar *et al*. (1989), Luzi-Kihupi (1998) also suggested that grain weight were used as efficient selection criteria for increased grain yield in rice.

Path Coefficient Analysis

Yield is the multiplicative end product of several component characters (Whitehouse, 1958; Grafius, 1959). These are mutually associated which in turn impair the true association existing between a component character and grain yield. The complexity of character relationship among themselves and with grain yield do not provide comprehensive picture of relative importance direct and indirect influence of each characters to the yield since resultant yield is the combined effects of various factors complementary or counteracting. Path coefficient analysis provides an effective means of untangling direct and indirect causes of association and permits a critical examination of specific forces acting to produce a given correlation. It measures the direct and indirect contributions of independent variables on dependant variables. Therefore, to understand the relationship between yield per plant and related characters, path analysis was computed using simple genotypic correlation coefficient values between characters and has been presented in Table 8.

Maximum positive direct effect on grain yield per plant was observed in number of panicles per plant (0.829) followed by 100-grains weight (0.672), grain length (0.127) and grain breadth (0.074). The correlation coefficients between grain yield and direct effect of number of panicles per plant and 100-grains weight did not differ much. This explains the true relationship and a direct selection through these characters will be more effective.

The direct effect of plant height (-0.009) and grain thickness were found to be negative. However, the correlation coefficients were found to be positive, which indicates that the direct effects seem to be the cause of correlation. In such situation, the indirect casual factors are to be considered simultaneously for efficient selection.

Residual effect indicates the involvement of the other associated characters in governing grain yield, which was not considered in this study. The residual effect was 44.82%, so, independent variables could explain only 55.18% of the variability for grain yield per plant. The reason seems to be due to the presence of low and

Table 8. Path coefficient (Genotypic) analysis showing direct (Bold) and indirect effects of component traits in rice genotypes

Cha.	X1	X2	X3	X4	X5	X6	X7	X8	X9	X10	Yield Corrl.
X1	-0.009	-0.010	0.070	-0.005	-0.053	-0.005	-0.194	0.035	0.007	-0.006	0.079
X2	-0.003	-0.031	-0.092	-0.002	-0.611	-0.047	0.013	0.015	0.010	0.009	-0.060
X3	-0.001	0.003	0.829	0.004	0.532	0.051	-0.105	0.012	-0.013	0.008	0.668
X4	-0.002	-0.003	-0.157	-0.023	0.763	-0.009	0.056	0.032	0.005	-0.007	-0.108
X5	-0.000	-0.008	-0.195	0.008	-2.264	-0.105	-0.176	-0.035	-0.010	0.004	-0.298
X6	-0.000	-0.006	-0.174	-0.000	-0.991	-0.240	-0.166	-0.025	-0.005	0.007	-0.341
X7	0.000	-0.001	-0.130	-0.002	0.593	0.060	0.672	0.044	0.052	-0.019	0.617
X8	-0.002	-0.003	0.776	-0.006	0.634	0.048	0.231	0.127	0.023	-0.012	0.334
X9	-0.001	-0.004	-0.145	-0.002	0.323	0.017	0.476	0.039	0.074	-0.308	0.449
X10	-0.001	0.006	-0.154	-0.004	0.191	0.039	0.291	0.035	0.053	-0.045	0.242

Residual Effect = 44.823%

X1: Plant height **X2:** Days to 50% flowering **X3:** Number of panicles/plant
X4: Panicle length **X5:** No. of filled grain/panicle **X6:** No. of chaffy grain/ panicle
X7: 100-grain weight **X8:** Grain length **X9:** Grain breadth
X10: Grain thickness **X11:** Grain yield per plant

insignificant correlations of plant height, days to 50% flowering, panicle length, number of filled grains per panicle and number of chaffy grains per panicle with grain yield. Besides the characters considered in this study, inclusion of some other additional characters might have covered the full range of variation for grain yield per plant.

References

Allidawati dan B Kustianto (1989) Metode uji mutu beras dalam program pemuliaan padi. hlm. In: M Ismunadji, M Syam, dan Yuswadi (eds.) *Dalam*. Padi Buku 2. Pusat Penelitian dan Pengembangan Tanaman Pangan, Bogor, Indonesia, pp 363-375.

Anonymous (2004) *Laboratory Manual on Rice Grain Quality Procedure*. Directorate of Rice Research, Rajendranagar, Hyderabad, India, pp 1-20.

Bagali PG, Shailaja Hittalmani and HE Shashidhar (1999) Character association and path coefficient analysis in Indica × Japonica double haploid population of rice. *Oryza* **36**: 10-12.

Borbora TK and Hazarika GN (1998) Study of genetic variability, heritability and genetic advance for panicle characters in rice. *Oryza* **35**: 19-21.

Bourgis F, R Guyot, H Gherbi, E Tailliez, I Amabile, J Salse, M Lorieux, M Delseny and A Ghesquière (2008) Characterization of the major fragrance gene from an aromatic japonica rice and analysis of its diversity in Asian cultivated rice. *Theor. Appl. Genet*. **117**: 353-368.

Bradbury LMT, TL Fitzgerald, RJ Henry, Q Jin and DLE Waters. (2005). The gene for fragrance in rice. *Plant Biotech. J*. **3**: 363-370.

Chakraborty S and MH Hazarika (1994) Association analysis between grain yield and its components in rice. *Oryza* **31**: 263-265.

Chauhan VS and JP Tandon (1984) Genetic variability and character association in hill Rice. *Oryza* **21**: 138-142.

Deosarkar DB, MB Misal and YS Nerkar (1989) Variability and correlation studies for yield and yield contributing characters in breeding lines of upland rice. *J. Maharastra Agril. Univ.* **14**: 28-29.

Food and Agriculture Organization (2013) Rice Market Monitor. *FAO*. 16 **(2)**: 1.

Ghosh AK, PK Bhattacharya and AN Asthana (1981) Genetic variability in indigenous rice varieties of Meghalaya. *Indian J. Agric. Sci*. **51**: 281-283.

Govindaswami S (1985) Post harvest technology I quality features of rice. In: *Rice Research in India*. Indian Council of Agricultural Research, New Delhi, pp 627- 642.

Grafius JE. 1959. Heterosis in barley. *Agron. J*. **51**: 551-554.

Hasib KM (2005) Genetic variability, interrelations and path analysis for panicle characters in scented rice. *Crop Res*. Hisar. **30**: 37-39.

He SV and SJ Chen (1992) Analysis on the effects of major characteristics on the yields of rice varieties using grey relational grade analysis. *Guongdong. Agri. Sci*. **1**: 4-6.

IRRI (2002) Standard Evaluation System for Rice, International Rice Research Institute, Los Baños, Philippines.

Johnson HW, HF Robinson and RE Comstock (1955) Estimation of genetic variability and environments variability in Soybean. *Agron. J*. **47**: 314-318.

Kamath S, JKC Stephen, S Suresh, BK Barai, AK Sahoo, KR Reddy and Bhattacharya KR (2008) Basmati rice: Its characteristics and identification. *J. Sci. Food Agri*. **88**: 1821-1831.

Karad SR and KM Pol (2008) Character association, genetic variability and path-coefficient analysis in rice (*Oryza sativa* L.). *International J. Agril. Sci*. **4**: 663-666.

Kaul ML and H Kumar (1982) Genetic variability in rice. *Genetica Agararia* **36**: 257:260.

Kumar Awaneet and BK Senapati (2013) Genetic parameters and association studies for important quantitative traits in advanced lines of Sambamahsuri derivatives. *J. Crop Weed* **9**:156-163.

Laksanalamai V and S Ilangantileke (1993) Comparison of aroma compound (2 acetyl-1-pyrroline) in leaves from pandan (*Pandanus amaryillifolius*) and Thai fragrant rice (Khaw Dawk Mali-105). *Cereal Chem*. **70**: 381-384.

Lestari AP, B Abdullah, A Junaedi and H Aswidinnor (2011) Performance of grain quality and aroma of aromatic new plant type promising rice lines. *Indonesian J. Agri. Sci*. **12**: 84-93.

Luzi kihipi A (1998) Interrelationship between yield and some selected agronomic characters in rice. *African Crop Sci. J.* **6**:323-328.

Mandal D, M Ghosh, D Mazumdar and A Biswas (2013) Baseline survey for Tulaipanji rice production status in Uttar Dinajpur district of West Bengal, India. *J. Crop Weed* **9**: 148-150.

Meenakshi T, DRA Amirtha and S Backiyarani (1999) Correlation and path analysis of yield and some physiological characters in rain fed rice. *Oryza* **36**: 154-156.

Mulugeta Seyoum, Sentayehu Alamerew and B Kassahun (2012) Genetic Variability, Heritability, Correlation Coefficient and Path Analysis for Yield and Yield Related Traits in Upland Rice (*Oryza sativa* L.). *J. Plant Sci*.**7**: 13-22.

Nadaf AB, S Krishnan, and KV Wakte (2006) Histochemical and biochemical analysis of major aroma compound (2-acetyl-1-pyrroline) in basmati and other scented rice (*Oryza sativa* L.). *Curr. Sci.* **91**: 1533-1536.

Niu X, W Tang, W Huang, G Ren, Q Wang, D Luo, Y Xiao, S Yang, F Wang, BR Lu, F Gao and T Lu (2008) RNAi-directed downregulation of *OsBADH2* results in aroma (2-acetyl- 1-pyrroline) production in rice (*Oryza sativa* L.). *BMC Plant Biol*. **8**: 100.

Panse VG (1957) Genetics of quantitative characters in relation to plant breeding. *Indian J. Genet*. **17**: 318-328.

Paramasivan KS (1991) Correlation studies in dwarf rice accessions. *Oryza* **28**: 237-239.

Ramalimgam J, N Nadarajan, P Tangasamy and C Vannirajan (1994) Genetic variability for panicle characters in rice. *Oryza* **31**: 56-57.

Rao, SS and RR Saxena (1999) Correlation and regression analysis in upland rice. *Oryza* **36**: 82-84.

Reddy JN, D Pani and JK Roy (1997b) Variability and character association in low land rice. *Indian Agri.* **41**: 159-165.

Reddy JN, RN De and AV Surya Rao (1997a) Correlation and path analysis in low land rice under intermediate (0-50 cm) water depths. *Oryza* **34**: 187-190.

Roy A and MK Kar (1992) Heretibility and correlation studies in upland rice. *Oryza* **29**: 195-199.

Roy B, M Hossain and F Hossain (2001) Genetic variability in yield components of rice (*Oryza sativa* L.). *Environ. Ecol*. **19:** 186-189.

Sarawgi AK and DK Soni (1994) Variability analysis in rice under irrigated and rain fed situations. *Current Res. Univ. Agril. Sci*. (Bangalore) **23**:33-35.

Sarkar KK, KS Bhutia, BK Senapati, SK Roy, S Panda and AB Mandal (2005) Genetic variability and relationships between grain yield and its component traits in rice (*Oryza sativa* L.). *Environ. Ecol.* **23**: 702-706.

Sarma RN and D Roy (1993) Studies on variability and internationship of yield attributes in *Jhum* rice. *Annal. Agri. Res.* **14**: 311-316.

Sawant DS and SL Patil (1995) Genetic variability in rice. *Annals Agril. Res*. **16**: 59-61.

Sawant DS, SL Patil and VG Sodaye (1995) Genetic variability and heritability in segregating generation of rice crosses. *Annals Agrl. Res*. **16**: 201-205.

Shobha Rani N and K Krishnaiah (2001) Current status and future prospects for improvement of aromatic rices in India. In: *Specialty Rices of the World: Breeding, Production and Marketing*. Science Publishers, Inc., USA, pp 49-78.

Simmonds NW (1979) Principles of crop improvement. Longman, London.

Singh P and SS Narayanan (1993) Correlation in Plant breeding. In: *Biometrical Techniques in Plant Breeding*. Kalyani Publisher, New Delhi, pp. 52-61.

Singh VP (2000) The Basmati rice of India. In: RK Singh, US Singh and GS Khush (eds.) *Aromatic Rices*. Oxford & IBH Publ. Co. Pvt. Ltd., New Delhi, India.

Surek H, ZK Karkut and O Bilgin (1998) Correlation and path analysis for yield and yield components in rice in a 8-parent half diallel set of crosses. *Oryza* **35**: 15-18.

Suresh R and Y Anbuselvam (2005) Variability studies for yield and its component traits in rice (*Oryza sativa* L.). *Res. Crops* **6**: 293-294.

Tripathi AK, SK Sinha and S Bhandarkar (1999) Studies on variability, heritability and genetic advance of semi-deep water rice. *Adv. Plant Sci*. **12**: 233-235.

Weber DJ, R Rohilla and US Singh (2000) Chemistry and biochemistry of aroma in aromatic rice. In: RK Singh, US Singh and GS Khush (eds.) *Aromatic Rices*. Oxford & IBH Publ. Co. Pvt. Ltd., New Delhi, India, pp 29-46.

Whitehouse RNH, TB Thomson and MAM De valle Riberio (1958) Studies on the breeding of self pollinated cereals 11. The use of a diallelcross analyses in yield prediction. *Euphytica* **7**:147-169.

Yadav RK (1992) Genetic variability, correlation studies and their implication in selection of high yielding genotypes of rice. *Adv. Plant Sci*. **5**: 306-312.

Yuan Quin, Quan LiYong, Zhan SiZhen, Wu Yulan, Wang YiBao and Zhang Guo Qiang (1995) Analysis of heterosis, combining ability and path coefficient in Japonica rice hybrids. *Acta Agriculturae Shanghai* **11**: 23-27.