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# Evaluation of traditional rice germplasms for alluvial zone of West Bengal –a review

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**Abstract**

Fifty one promising landraces of rice cultivars of three districts viz. Nadia, 24 Parganas(N) and Murshidabad of West Bengal were taken for characterization, estimation of genetic variability, genetic diversity and interrelation among them based on forty six agromorphological characters. The field experiment was carried out at the Zonal Adaptive Research Station, Krishnagar, Nadia, West Bengal during Kharif season of three consecutive years of 2006, 2007 and 2008. The land is mainly gangetic alluvium plain with neutral pH (pH=6), low availability of nitrogen and phosphate and potash content. Observations of various qualitative and quantitative traits were recorded at the different stages of growth. Distinctiveness, Uniformity and Stability (DUS) test was done on twenty eight qualitative traits following the National test guidelines, supplied by Rice Research Institute, Rajendarnagar, Hyderabad. Mean, standard error of mean, standard deviation, coefficient of variation were calculated for each quantitative trait to explore the variability, if any, among the cultivars (Singh and Choudhury, 1977). Genotypic correlations were, in general, higher than the phenotypic correlations and thus suggested that the observed relations among the characters were due to genetic factors. Genetic divergence was assessed among 51 landrace genotypes which were grouped into eleven clusters. Cluster mean was done and the characters which contributed maximum towards genetic divergence among the genotypes were culm diameter>culm length>grain length>Plant height (seedling)>sterile lemma length>grain length/breadth ratio>ligule length>flag leaf angle>culm number in the descending order.

**Keywords**: Landraces, characterization, DUS test, variability, diversity, $D^2$analysis

Rice (*Oryza sativa* L. 2n =24) is one of the most important cereal crops in the world and also life blood of southeast Asia where more than 90 percent of rice is produced and consumed. It is also a major source of livelihood for than 250 million of households.

In Asia 92 percent of the world's rice is grown in 136.642 million hectares and consumed, provides 35-37 percent of the calories to more than 3 billion Asians. In India rice contributes around 45 percent of cereal production and is the main food source for more than 60 percent of the population in the country (Siddiq, 2002) covering 44.6 million hectares of total geographical area.

*Green revolution: the beginning of genetic erosion*

The so-called 'green revolution' in rice started in late 1960s due to cultivation of semi- dwarf cultivars carrying Dee-geo-woo-gen. With application of heavy dose of fertilizer costs are beginning to rise and rice farmers are facing declining profits. Scientists all over the world have tried to transfer the desirable genes from traditional varieties to modern varieties. The present investigation aims at collection, conservation and characterization of collected germplasms for exploitation in breeding program. For this purpose morphological and physiological characters with respect to growing habit, plant height, shape size and colour of the culm, leaf blade, panicle, hull, apiculus and dehulled grain presence or absence of pubescence, grain shape, size growth duration, resistance or tolerance to disease and insect pests, grain quality etc. will be studied to differentiate the land-races from one another for future breeding programme.

*History of rice breeding*

Systematic rice breeding was initiated at the beginning of the 20th century. Early breeding in tropical Asia was aimed at improvement of locally adapted popular varieties largely by pureline selection. Selection and evaluation process was confined to a single center in each region, as breeders then had no idea about the significance of multilocation testing and, as a result, a very large number of improved varieties were under commercial cultivation. Indonesia was the first country, where multilocation testing was started with the objective of reducing the number of varieties. Its successful experience not only prompted many countries to follow suit but also made the breeders realize the need for improving the method of varietal testing. Whereas the use of statistical parameters, such as, variance and standard error helped improved field testing technique, the application of the principles of randomization and analysis of the variance that decide on the field plot design enabled evaluations of test entries more accurately. Rediscovery around this period of Mendel's laws of inheritance, in spite of its potential for unfolding new variability, could hardly change breeding–selection

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approaches, as breeders relied excessively on pure line selection. Nevertheless, it helped to understand the mode of inheritance of scores of agro-botanic traits and floral biology as well as acquire emasculation-pollination skills, which proved valuable when recombination breeding assumed importance.

Irrespective of the method of selection, emphasis of breeding in the beginning was for improvement of traits other than yield. The traditional rice exporting countries, like Burma and Thailand, for instance, placed their breeding thrust on improvement of grain quality, while breeding for resistance to rice blasts, the only killer disease known then, received importance all over Asia. Identification of CO4, a pureline selection from the local variety 'Anaikomban' found resistance to the disease served as the donor to develop the most popular variety CO5, by hybridization. Breeding for high yields was confined to lowland varieties, as breeders believed late maturing varieties to yield more. Thus, single location selection /evaluations under low levels of nutrient management with emphasis largely on improvement of traits other than yield was the general breeding practice until the end of the world war II.

Rice breeding in India was started in 1911 at Dacca (now in Bangladesh) and in the following year at Coimbatore in the old Madras province. Recognizing the importance of rice to India's economy, The Indian Council of Agricultural Research, founded in 1929, sponsored, rice breeding projects in all the major rice growing states and as a result the country had as many as 82 research stations exclusively for rice research by 1950. It was around this period that ICAR's land mark decision led to the establishment of the central and national Rice Research Institute at Cuttack, in Orissa in 1946 for addressing problems of national importance. More organized breeding research that followed at central and state levels led to the release of more than 450 improved varieties all of which, except 27 cross bred varieties, were pure line selections from popular local varieties. Among varieties that remain popular till now, MTU1, MTU15 and HR 19 of Andhra Pradesh; Chin 7 of west Bengal; Columba strains of Maharashtra; GEB 24, CO 25 ASD 1 of old Madras Province; T141 and SR 26b of Orissa; Basmati 370 of Punjab and t1366 of Uttar Pradesh are important. Breeding for adverse growing conditions assigned to problem specific regional centers had also led to the development of varieties, which have hardly any alternative even today. They include among many ARC 353-648 of Assam;DWP-1311 of Andhra Pradesh; ADT 17, PTB 15 and 16 of Madras Province FR 13A and FR 43B of Orissa; Hybrid 84 of West Bengal for deepwater and flood - prone areas; Kalarata 1-24 and Bhurarata 4-10 of Bombay Province, SR 26 B of Orissa; Chin13 and Chin 19 of West Bengal for saline conditions and AKP 1, AKP 3, BCP 2 and BCP 5 of Andhra Pradesh; ASD 4, ASD18 and PTB18 of Madras Province; BAM 15 of Orissa; N22 of Utter Pradesh; Chin 25 and Chin 27 of west Bengal for drought prone situations. Resistance breeding against biotic stresses led similarly to the development of CO25 against blast and MTU 15, TKM 6, SLO 12 and CH 47 against stem borer. There are many more time – tested varieties that came out of resistance breeding. In spite of such an impressive record of breeding achievements the fact remains that the efforts made for yield improvement were of no consequence as compared to what had been done for catering to other agro-ecological and socio-economic needs.

It was immediately after the World War II, when food grain supply became far short of the demand and threatened the word community, that Food and Agriculture Organization (FAO) founded the international rice commission (IRC) within the FAO frame- work to find ways of increasing rice production. The IRC recognized non-lodging habit, fertilizer responsiveness, early maturity and wide adaptability as the important varietal characteristics for achieving higher and stable yields. Accordingly, the FAO launched several regional networks projects such as cataloguing and maintenance of rice genetic stocks, *Indica-Japonica* Hybridization, cooperative varietal Trials, Wide adaptability Test, Variety – fertilizer Interaction in *indica* varieties, Uniform Blast Nursery and International Training Programme in Rice Breeding during 1950-1956.

The international cooperative was instrumental in cataloging major rice varieties of the world and establishing center for maintenance and exchange of germplasms. The ambitious *indica/japonica* hybridization programme launched in 1952 was the early international effort to explore the possibilities of breaking the yield barrier in *indica* rices. Relatively higher yielding ability of japonicas believed them to be due to their non-lodging habit and responsiveness to higher levels of fertilizer, was what prompted the formulation and execution of this massive programme in Asia. Extensive hybridization programme with CRRI at Cuttack as the primary hybridization center and countrywide screening of the segregating material lasting for ten years proved a major disappointment. Except for three varieties viz., ADT 27, an early maturing type found suitable for *kuruvai* season in Tamilnadu and two medium late maturing types viz., Mahsuri and Malinja identified in Malaysia that became widely popular in India and Malaysia respectively, the project hardly yielded any good variety combining the desirable features of Japonica and Indica. Partial sterility and skewed segregation towards parental types have been attributed to low frequency of stable fertile recombinents. Had the breeders been careful to choose tropical *japonica* parents, instead of temperate *japonica* types like Norin 6, Norin 8, Norin 16, Rikue 12, Asahi etc., the genetic hurdle could have been averted. The realization that inter subspecific hybridization strategies would not yield anything substantial led to the abrupt termination of the project, which nearly coincided with the advent of the short statured *indica* variety Taichung (Native) 1 (T(N)1) and *Ponlai* varieties (Taichung 65,Tainan 3 etc). Taichung (native) 1 that heralded the era of plant type- based high yielding varieties is a derivative of the cross between the spontaneous dwarf's mutant Dee-Geo-Wu-Gen and Taiwanese tall variety Tsai-Yuan-Chung. The early maturing dwarf variety well adapted to round- the- year cultivation provided the base for developing the 'plant type' concept and development of a series of high yielding dwarf varieties including the miracle yielder IR 8.

An important development that accelerated breeding research at global level was the establishment of the International Rice Research Institutive (IRRI) in the Philippines in 1960 by the ford foundation and Rockefeller Foundation in cooperation with the Government of the Philippines. Breeding activities began in 1961-62 with the sole objective of evolving non-lodging varieties with high yields, which led to the release of IR 8, the widely adopted miracle yielder suited to irrigated ecology and IR 5, a semi tall variety bred for less favorable environments. It was IR 8 that provided the momentum for development of a series of high yielding dwarf varieties, which included IRRI bred IR 20, IR 36, IR 42, IR 64, IR 72 etc, besides large number by the National Agricultural Research System (NARS). Thrust of the breeding research has been changing over the years with yield, quality and disease pest resistance receiving successively priority attention in the case of irrigated rice, while yield maximization and adaptation to moisture stress and submergence in rain fed rice, involving actively the NARS, most the thrust area research programmes were sponsored and coordinated by IRRI. The multidisciplinary genetic Evaluation and Utilization (GE) programme initiated in 1974 while broadening the breeding efforts at IRRI and NARS led simultaneously to the launching of global testing network called International Rice Testing programme (IRTP). The programme, later renamed as International Network for Genetic Enhancement of rice (INGER), involving over 75 countries and no less than 1000 scientists facilitated free exchange of germplasm (improved and unimproved ) among the participant countries by IRRI's germlasm bank to an unprecedented scale. This one activity not only brought visibility to IRRI but enabled NARS to benefit the maximum. Several varieties named by IRRI were from IRTP/INGER nurseries. In the recent years, IRRI, in partnership with NARS and advance Research Institutes in the developed world, is engaged in strategic research towards achieving food nutrition security on a sustainable basis. Search for new yield thresholds through hybrid technology, new plant type, development and application of Biotechnology- Genetic engineering tools for adding value and finding solution to still unsolved biotic and abiotic stresses and functional genomics are important among them. Continued enrichment and maintenance of the gene bank which remains the 'gene source', for breeders all over, is the most laudable activity of IRRI.

It is the unique combination of short stature, non-lodging habit with profuse tillering and upright foliage, photo-insensitivity, high fertilizer responsiveness and early maturity in the new plant type that has helped break the centuries long yield barrier of the tropical rices. Short duration coupled with period bound maturity has made possible to raise 2-3 crops a year and increasing thereby the total productivity by 2-3 times over the late maturing, season bound traditional tall varieties. The impact of the plant-type based high yielding varieties is evident from various indicators. Many chronically rice deficit countries have become self sufficient and some with sizeable surplus within 10-15 years of their introduction. Growth of rice (paddya) production in Asia has risen to 540.62 million tones by 1997-98 from 292.17 in the triennium ending 1971, while productivity from 2381 kg/ha in 1971 to 3900 kg/ha in the triennium ending 1997-98. Yield and production have registered from two times increase in India to four times increase in the countries like Indonesia and Phillipines during the corresponding period. Largely development of high yielding varieties and their extensive adoption enabled many countries in Asia to register high and steady production growth.

As for India, more than 550 high yielding dwarf varieties have been released for all the major ecologies, the maximum being for irrigated environment. Evolution of varieties for different ecologies at such a rapid pace has been possible because of the coordinated network approach conceived and adopted at national level for material generation and multi location testing. The realization that the entire growth has been on account of top sided attention given to irrigated rice, prompted at national and international levels a shift in breeding emphasis towards long neglected rain fed ecologies, which account for 50% at global level and 55% in India. Rain fed ecology being the most complex and diverse, eco-regional models were conceived by IRRI for characterizing such ecologies and addressing the problems unique of them. The rain fed low land and rain fed upland Consortia – the multi-country projects are close to finding solution to the problems of handicapped ecologies in Asia. The impact of this, coupled with national initiative, is seen today in the steadily increasing productivity and production in the predominantly rain fed eastern part of India.

Ever since the development of the dwarf high yielding varieties, breeders all over have been looking for technologies that would help raise to further the genetic ceiling to yield. Of the two strategies contemplated *viz.* tailoring of physiologically still more efficient plant type and exploitation of hybrid vigour, the later has become a reality since the development in the late seventies of commercially viable hybrid rice technology in China. Its extensive adoption over 18 million ha (55% of the rice area) has helped China add annually 20 million tones to the national rice production making thereby the chronically food deficient countries self sufficient. The knowledge gained from the experience and material support form IRRI and China, proved handy fifteen years later for India to develop hybrid technology suited to its agro-climatic conditions. The success stories of China and India have motivated a few more countries in the region to initiate hybrid rice research.

Thus the nine decade long history of rice breeding comprises three major phases viz., the period of tall varieties with slow yield growth till early fifties, the period of semi-dwarf varieties breaching the yield barrier since mid sixties and the period of hybrid technology marking the second yield breakthrough since eighties. The current breeding emphasis at IRRI and a few other countries like China, Japan and India include (i) tailoring of new plant type varieties capable of yielding 15-20% higher than the best variety available (ii) engineering future rice varieties with novel genes conferring resistance to major insect pests and diseases and (iii) improving the nutritional value of rice through conventional and molecular breeding approaches.

*Development of DUS test guidelines in rice*

Globally, India stands first in rice area (44.6m.ha), second in production (93.0 m.t) after China and contributes to 23.5 % of world rice production. Within the country rice occupies 22.8% of total cropped area, 46.3% of area under cereals and contributes to 42% of total food grain production and continues to play a vital role in the national food security, as it constitutes staple food for two thirds of the population supplying about 33% of food calories. Also being the one of the secondary centres for the origin of rice the country is blessed with a rich diversity with the guess estimate being around 1,20,000 accessions of land races, farmers varieties and wild relatives. Several among the rich pool or rice landraces would come for registration on account of their special qualities, pest/disease resistance, quality features and medicinal use. Further 714 rice varieties are released so far of which 333 varieties are suitable for irrigated areas, 101 for rainfed uplands, 131 for shallow lowlands, 49 for semi deep and deep water areas, 37 for high altitudes, 19 for saline/alkaline and 42 in aromatic scented categories. Had the laws of registering our varieties existed earlier, the whole episode of Basmati patent by Rice Tec, USA would not have arisen, as basmati is a unique quality rice endemic to sub Himalayan tracts of Indian sub-continent, conserved by farmers from a long time and several research efforts made by scientists resulted in the release of many varieties in India. Now that we made a good headway in making our laws many of the breeders varieties and also farmers varieties could be protected through PBR, once they confirm to the basic Distinctiveness, Uniformity and Stability (DUS) test requirements.

The first step to implement our PPVFR provisions is formulation of National Test Guidelines for conducting DUS tests. National Test Guidelines have been developed for 35 crops representing harmonized approach for the testing of new varieties which will form the basis for DUS examination. These contain details on i) subject of guidelines ii) material required iii) conduct of tests, iv) methods and observation, v) grouping of varieties, vi) characteristics and symbols, vii) table of characteristics, viii) explanations on table of characteristics, ix) literature and x) technical questionnaire. The characteristics in the table follow the botanical and chronological order of recording from seed (submitted), seedling, plant (growth habit etc), stem, leaf (blade, petiole, stipule) inflorescence, flower and fruit.

Directorate of Rice Research (Rajendarnagar, Hyderabad) has played a key role in developing National Test Guide Lines for DUS test in Rice in consultation with the National Core Group Experts for development of National Test Guide Lines in crop plants and also with rice crops experts. The National Guidelines for the conduct of Test Distinctiveness, Uniformity and Stability for rice include descriptors to be observed for establishing the distinctiveness, explanation to the descriptors (essential, additional and stress related traits) procedures to be followed and technical questionnaire.

*Genetic variability of yield and yield attributes, character association, heritability and genetic advance*

Burton (1952) has suggested that genetic variability along with heritability should be considered to judge the effect of selection. Studies on genetic variability parameters like GCV, heritability and genetic advance and association of different traits should be considered for identification of suitable genotypes to be used as elite cultivars or for the breeding improvement involving the selected genotypes.

Majumdar *et al.* (1971) studied the genetic variability in respect of different characters in a collection of 10 varieties of rice. Genetic parameters like genotypic coefficient of variation (GCV), phenotypic coefficient of variation (PCV), hertitability, and genetic advance were computed. The result revealed that a large proportion of phenotypic variability was genetic and highly heritable for almost all characters like *plant* height, number of effective tillers, length of panicle, grain yield per plant, weight of 100 grains and grain size (length breadth ratio). They found high GCV values in some characters like grain yield per plant and for plant height which may prove the existance of justifiable genetic distance among the different varieties, a fact, indicative of the efficiency of these strains to be involved in rice improvement programme.

High mean associated with high variability was considered as a better index for selection. It was reported that high GCV and PCV was revealed for panicle length, number of productive tiller per plant (Das and Borthakur, 1974; Unikrisnan, 1980; Sukanya, 1984 and Vijay Kumar, 1990). High heritability coupled with moderate genetic advance was observed in all population for plant height in rice. This indicated the involvement of both additive as well as dominant gene-action in controlling plant height and hence this trait does not offer great scope for improvement by selection (Minidas, 1990).

Chaudhury *et al.* (1980) suggested that grain yield could be improved by exercising selection for high number of spikelets per panicle along with genetic advance were recorded for these characters.

Ghosh *et al.* (1981) reported that the genotypic coefficient of variation was high for grain yield, plant height, ear bearing tillers, number of grain per panicle and low for days to flowering.

According to Shumsuddin (1982), heritability was highest for total number of spikelets followed by grain yield per plant, 100 grain weight and lowest for panicle length. Amirthedevarathinam (1983) observed wide range of genotypic and phenotypic variation in the eleven characters considered in the genetical study on rainfed rice.

Rabindranath *et al.* (1983) recorded the range of variation was highest in number of grains per panicle and lowest in 100 grain weight. PCV was higher than the GCV for all characters.

In 1984, Chauhan and Tandon experimented with 30 rice varieties to measure the extent of genetic variability under two cultural environments *viz.* rainfed upland (direct sown) and irrigated (transplanted). Plant height, effective tiller per plant and grain yield had high heritability and GCV under both the environments. However, the magnitude was higher in upland situation.

Gomathinagasam *et al.* (1988) observed that plant height contributed indirectly to the yield through the all characters considered in his experiment except 1000 grain weight. Loknathan *et al.* (1991) observed that plant height showed high genetic advance and heritability which registered its high potentiality for selection which contradicted the observation of Minidas, 1990.

Rahangadale and Khorgade (1988) found high heritability associated with high genetic advance for the characters like 1000 grain weight and plant height in their evaluation study with 25 indigenous upland rice varieties.

Ruben and Kishanga (1989), recorded that panicle per $m^2$, mature grain per panicle, panicle weight and panicle length were positively correlated with the grain yield.

Panwar *et al.* (1989) found that spikelet number was the main component affecting yield directly.

Bapu and Sundarapandian (1992) observed from the $F_3$ population of the cross between CO-37 and CO-41 and its reciprocals that number of productive tillers, panicle length and plant height were positively correlated with grain yield.

Estimation of GCV, PCV, heritability, genetic advance at 5% selection index for grain yield and other attributes were computed by Rema Bai *et al.* (1992). In all the cases the PCV was higher than GCV indicating environmental influence on the characters like plant height, flag leaf angle, number of panicles bearing tillers per plant, panicle length, number of grains per panicle *etc.* Plant height exhibited a higher value of heritability with a moderate value of genetic advance.

Yadav (1992) found high heritability for the characters like plant height, yield per plant, sterility, harvest index, days to 50% flowering, days to maturity, panicle per plant and seeds per plant.

After studying variability, heritability and genetic advance, Lokaprakash *et al.* (1992) suggested that 1000 grain weight, panicle weight, and number of filled spikelets per panicle were important for the breeder to construct selection indices as they showed high heritability along with high genetic advance for these traits. He also found that the variability was higher for panicle weight, number of panicles bearing tillers per plant and yield per plant but it was low for plant height, panicle length and test grain weight.

Mahajan *et al.* (1993) in their experiment with upland rice genotypes indicated that grain yield per plant was positively and significantly correlated with straw yield per plant and filled grains per panicle and suggested that the filled grains per panicle should be considered as a most important yield contributing character because it exerted a positive direct effect on yield.

Manuel and Rangasamy (1993) reported that the yield was positively correlated with the characters like plant height, panicle per plant, grains per panicle and dry matter production in case of hybrid rice. These results were in agreement with the finding of Bhattacharya (1981) and Ramalingam *et al.* (1995).

Chaubey and Richharia (1993) provided information on heritability, genetic variance and correlation considering 8 yield components of 80 indica rice varieties and found that broad sense heritability was high for all characters except harvest index and panicle weight was the highest contributor to grain yield, but Marwat *et al.* (1994) reported that the productive tillers, panicle length and 1000 grain weight had the highest direct effect on grain yield per plant.

Abd-El-Samie and Hassan (1994) observed highly positive and significant phenotypic correlation between grain yield per hill and number of panicles per hill, grain yield per hill also showed positive and significant correlation with all the yield components except 100 grain weight.

Ganesan *et al.* (1995) observed that grains per panicle, grain yield per plant and dry matter production had high GCV, heritability, and genetic advance and suggested predominance of additive gene effects for the expression of these characters. Days to panicle emergence showed moderate genetic variability along with higher heritability and genetic advance, indicating the extent of scope for further improvement through phenotypic selection.

Sawant *et al.* (1995) reported high expected genetic advance, along with high heritability for panicle length, grains per panicle and 100 grain weight which indicated the predominance of additive gene effects in controlling these traits.

Sawant *et al.* (1996) and Padmavathi *et al.* (1996) studied character association among yield and yield contributing traits and indicated that ear bearing tillers per panicle, 1000 grain weight, panicle length and grain per panicle were positively and significantly correlated with grain yield.

Rao *et al.* (1997) studied genetic variability and character association between yield and its contributing traits in two environments. Irrespective of the environments, high PCV and GCV, coupled with high heritability and high genetic advance were found for spikelet sterility and leaf area index which indicated the predominance of additive gene effects in controlling of these traits. Productive tillers number, harvest index and dry matter production had positive and significant correlation with yield in both the environments.

Rather *et al.* (1997) reported that days to 50% flowering, 1000 grain weight etc. were the important characters which may be considered as direct contributors to yield. Sarawgi *et al.* (1997) indicated that grain yield in rice had significant positive correlation with number of fertile spikelets per panicle, 100 grain weight and harvest index etc.

Luzi-Kihupi (1998) showed that grain yield per hill was positively correlated with all the yield components except percentage of unfilled grains and days to 50% flowering. Plant height, number of filled grains per panicle and grain weight were highly heritable characters. He suggested that number of filled grains per panicle and grain weight could be of use as selection criteria for screening high yielding rice lines. Gholipoor *et al.* (1998) observed that positive genotypic correlation between yield and 100 grain weight, days to maturity but negative significant genotypic association with plant height and suggested that 100 grain weight could be considered for selection of lines with high grain yield.

Meenakshi *et al.* (1999) also observed positive correlation between yield and harvest index along with the characters like tillers per plant, grains per panicle, dry matter production.

Balan *et al.* (1999) evaluated 20 rice genotypes through estimation of genetic parameters under upland condition. High heritability combined with high genetic advance was observed for grain yield indicating the presence of additive gene action for the control of the trait.

Gupta *et al.* (1999) conducted an experiment involving 95 land races of hill rice for variability analysis of yield and its components. The GCV estimate was high for grain yield per plant and grains per panicle whereas for other characters it was low to moderate in magnitude. In general, estimates of PCV were higher than GCV, however, the closeness for GCV and PCV for 100 grain weight, plant height suggested that these characters were least influenced by the environmental factors. Grains per panicle showed highest estimate of heritability and genetic advance.

Kaw *et al.* (1999) took 94 rice genotype (38 japonica/ indica $F_1$, 36 indica/ japonica $F_1$ and 20 parents) for evaluating genetic variability under 3 cold stressed environments. Heritability estimate was highest for plant height and lowest for panicle length.

*Genetic divergence*

Singh (1983) estimated genetic divergence of 32 varieties of rice and grouped them into 9 clusters. He observed that genotypes even chosen from the same eco geographical region were found to be scattered in different clusters. Plant height contributed maximum role in total genetic diversity followed by sterile grain and grains per panicle. Utilizing the genotypes within clusters which are highly divergent, wide spectrum of variability may be created through hybridization.

Pandey and Ghorai (1986) studied genetic divergence employing 48 improved varieties of rice grown in different geographical regions and observed the parallelism between genetic diversity and geographical distribution. But these genotypes were grouped into a number of clusters and clustering was greatly influenced by the environments. Genotypic variance was high for grains /panicle and culm length.

Singh *et al.* (1986) assessed genetic divergence among 50 cultivars of low land rice and grouped them into 10 clusters. He also opined that genetic diversity was not related to geographical distribution. He found that plant height, sheath length, kernel length and breadth, test weight, panicle length and number of spikelets were mainly responsible for genetic divergence.

De *et al.* (1988) grouped 75 strains of rice into 13 clusters and found 100 grain weight and number of grains per panicle were the highest contributors to $D^2$ values.

Roy and Panwar (1993) estimated genetic divergence between 99 genotypes of rice on the basis of grain yield along with 9 related traits and grouped them into 16 clusters. The results indicated that significant genetic divergence was created in the genotypes mainly by panicle per plant, grains per panicle, grain yield per plant, spikelets per plants.

Sawant *et al.* (1995) carried out divergence study in 75 genotypes of rice and grouped them into ten clusters on the basis of eight yield component characters. He found sufficient inter cluster distance and suggested that the genotypes in different clusters were diverse from each other.

Singh *et al.* (1996) measured genetic divergence among 40 genotypes of rice on the basis of yield component data and grouped them into 6 clusters. Grain yield contributed the most, 40.6% of total divergence and plant height contributed 16.5%. The genotypes between clusters having better cluster distance were recommended for inclusion in hybridization programme as these were expected to produce variable segregants.

Rao and Gomathinayagam (1997) assessed divergence among 40 drought tolarent rice genotypes by growing them under semi-dry conditions at two different locations and found the importance of genotype-environment interaction in clustering pattern of the genotypes.

Mokete *et al.* (1998) estimated genetic divergence within 25 genotypes of rice on the basis of yield component data and grouped them into 5 clusters. The genotypes belonging to the clusters revealed substantial difference in the means for important yield contributing characters. So the genotypes belonging to these clusters from ideal pairs for planning a hybridization programme.

Kandola and Panwar (1999) studied genetic divergence among 52 endogenous and exotic genotypes of rice on the basis of 60 agro-morphological and quality characters and grouped them into 11 divergent clusters and found no association between genetic and geographic diversity and concluded that hybridization among genotypes drawn from widely divergent clusters with high yield potential is likely to produce heterotic combinations and wide variability in segregating generations.

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