GENETIC VARIATION AND CHARACTER ASSOCIATION IN F_4 POPULATIONS OF BORO RICE (*Oryza sativa* L.)

BY

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CERTIFICATE

This is to certify that the thesis entitled "GENETIC VARIATION AND CHARACTER ASSOCIATION IN F_4 POPULATIONS OF BORO RICE (Oryza sativa L.) TO SELECT HIGH YIELDING SHORT DURABLE LINES" submitted to the Faculty of Agriculture, Sher-e-Bangla Agricultural University (SAU), Dhaka, in partial fulfillment of the requirements for the degree of ***MASTER OF SCIENCE (MS) IN GENETICS AND PLANT BREEDING****, embodies the results of a piece of bonafide research work carried out by MAHBUBA JAMIL, Registration no. 07-02283, under my supervision and guidance. No part of the thesis has been submitted for any other degree or diploma.*

I further certify that such help or source of information, as has been availed of during the course of this investigation has duly been acknowledged.

Dated: December, 2014
Place: Dhaka, Bangladesh

Prof. Dr. Md. Shahidur Rashid Bhuiyan
Supervisor

DEDICATED TO

MY

PARENTS AND TEACHERS WHO

LAID THE FOUNDATION OF MY

SUCCESS

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ABSTRACT

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A field experiment was conducted with 25 F_4 materials and 4 parents of *Oryza sativa* L. at the experimental field of Sher-e-Bangla Agricultural University, Dhaka to study the genetic variability, correlation and path coefficient analysis during December 2013 to May 2014. Fourteen characters were studied to find out the suitable traits for the improvement of rice yield. The selected genotypes were found significantly variable for most of the characters. Comparatively phenotypic variances were higher than the genotypic variances for all the characters studied. Also PCV were higher than the GCV for all the characters studied. All characters showed high heritability. All characters except days to flowering and days to maturity showed moderate to high genetic advance in percent mean. High heritability coupled with moderate to high genetic advance in percent mean is governed by additive gene action which is better for selection. On the other hand, the significant positive correlation with seed yield per hectare was found in days to maturity, number of secondary branches per panicle, number of filled grains per panicle, total number of spikelet per panicle and yield per plant. Path coefficient analysis revealed that plant height, number of total tillers per plant, number of effective tillers per plant, number of secondary branches per panicle, number of filled grains per panicle and 1000-seed weight had the positive direct effect on yield per hectare. The residual effect was found 0.164 which indicated that 83.6% of the variability was accounted for fourteen yield and yield contributing traits in the present studies. Rest 16.4% variability might be controlled by other yield contributed traits that was not included in the present investigation. So direct selection based on these traits would be effective for improvement of these F_4 materials. Twenty six plants were selected from G8 (BR 26 ×BRRI dhan29, S1P8), G9 (BR 26×BRRI dhan 29, S1P10), G10 (BR 26×BRRI dhan 36, S7P1), G15 (BRRI dhan 28×BRRI dhan 29, S2P2), G16 (BRRI dhan 28×BRRI dhan 29, S2P3), G17 (BRRI dhan 28×BRRI dhan 29, S2P4), G18 (BRRI dhan 28×BRRI dhan 29, S2P5), G19 (BRRI dhan 28×BRRI dhan 29, S2P6), G20 (BRRI dhan 28×BRRI dhan 36, S7P1), G22 (BRRI dhan 28×BRRI dhan 36, S7P6), G23 (BRRI dhan 28×BRRI dhan 36, S7P8), G24 (BRRI dhan 28×BRRI dhan 36, S7P9) and G26 (BRRI dhan 29×BRRI dhan 36, S5P5) on the basis of days to maturity, total number of spikelet and yield per plant.

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SOME COMMONLY USED ABBREVIATIONS

ABBREVIATION	ELABORATION
AEZ	Agro-Ecological Zone
ANOVA	Analysis of variance
et al.	and others
BRRI	Bangladesh Rice Research Institute
cm	Centimeter
CV	Co-efficient of variance
^0C	Degree Celsius
DAT	Date after transplanting
df	Degree of freedom
DMRT	Duncan's New Range Test
EC	Emulsifiable Concentration
ECV	Environmental coefficient of variance
F_4	4^{th} Filial Generation
F_5	5^{th} Filial Generation
GCV	Genotypic coefficient of variance
g	Gram
K	Selection differential
KR	Kiloroentgen (unit of gamma radiation)
MP	Muriate of Potash
PCV	Phenotypic coefficient of variance
m	Meter
TSP	Triple Super Phosphate
r	Replication
RCBD	Randomized Complete Block Design
SAU	Sher-e-Bangla Agricultural University
t	Ton
%	Percentage

CHAPTER I

INTRODUCTION

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INTRODUCTION

Rice (*Oryza sativa* L.) is the staple food for a large proportion of the world's population (Zhang, 2007). It is a self pollinated cereal food crop under the family Poaceae having chromosome number 2n = 24 under the order Cyperales and class Monocotyledons (Hooker, 1979). It is perennial, bisexual cereal crop but cultivated as annual crop. It has 24 species, of which 22 are wild and two *viz. Oryza sativa* and *Oryza glaberrima* are cultivated (Ray, 1985). Rice cultivated from 53° N latitude to 35° S. *Oryza sativa* and *Oryza glaberrima* were originated from South and Southeast Asia, 90% of this crop is grown and consumed here (Nanda, 2002). Indian subcontinent is the ancestral home *Oryza sativa*. It has three major sub-species- *indica*, *japonica* and *javanica* (Purseglove, 1985). The rice cultivars grown in Bangladesh belong to sub species *indica* (Alim, 1982).

In Bangladesh, rice is historically associated with cultural rites and rituals of Bangladeshi people. She is now fourth in position for rice production in the world and recently the millennium development goal of the elimination of extreme poverty and hunger achieved in Bangladesh by increasing rice productivity as it account for 92% food grain production annually in the country (Anonymous, 2000). Total rice production in Bangladesh was about 10.97 million tons in 1971 when the country's population was only about 70.88 million whereas the country is now producing about 34.45 million tons rice to feed her 157.90 million people as staple food (Anonymous, 2014). The population of Bangladesh is still growing by two million every year and may increase by another 30 million over the next 20 years. Thus, Bangladesh will require extra 27.26 million tons of rice. During this time total rice area will also shrink to 10.28 million hectare (Anonymous, 2012). Not only in Bangladesh but also the world must have to produce 60% more rice than it produce in 1995 to meet the demands by 2030 (Virmani *et al.*, 1997). Increasing of this production must be achieved on less land with less labor, less water, less pesticide and the achievement must be sustainable.

Rice is grown in three overlapping season, namely *aus*, *aman* and *boro* (Rashid, 1994). *Boro* rice has been gaining much importance in Bangladesh. Among these three seasons of rice *boro* is the longest season and producing the highest grain yield (Gomosta *et al.*, 2006). Bangladesh produced around 19.1 million tons of rice from *boro* (January-May, 2014), which is 2% more than last year production (18.78 million tons) and *boro* contributes 55% total rice production area in Bangladesh (Anonymous, 2014). The average per hectare yield of *boro* rice is higher than that of *aus* and *aman* rice (BRRI, 2013). It is under consideration that total rice production area is decreasing day-by-day due to high population pressure and production rate is decreasing also with the decreased total *boro* crop area due to crop competition with some profitable vegetables. So there is no scope to increase the rice area. Further increasing rice production, therefore, must come from exploitation of the momentum created by another green revolution for higher yield which has already been started in China though exploiting heterosis in rice. As *boro* is the main season of rice production, high yielding as well as short duration varieties are required for this season. With the availability of short duration HYV of *boro* rice, farmers will be able to grow any 3rd crop between T. *aman* and *boro* rice (Hassan and Quddus, 2014). The present problem of *boro* rice varieties is long growth duration which reduces chance of growing other profitable crops.

It can be minimized by using improved short duration *boro* varieties. Inter-varietal crosses and evaluation of generations need to be performed to select high yielding short duration materials for using them in generating *boro* rice varieties. As yield is a complex character and influenced by various other characters therefore, it is essential to understand the association of other characters with yield in addition to the information on genetic variability. Yield contributing traits are interrelated themselves and highly influenced by the environments (Chandra *et al.*, 2007; Prasad *et al.*, 2001; Eswara R. *et al.*, 2013). The path analysis has been used by plant breeders to support in identifying traits that are promising as selection criteria to improve crop yield and to detect the amount of direct and indirect effect of the causal components on the effect component (Bose *et al.*, 2005; Indu R. *et al.*, 2008; Ali *et al.*, 2009; Chandra *et al.*, 2009; Mohsin *et al.*, 2009; Akhatar *et al.*, 2011; Cyprian and Kumar, 2011). Efficiency of indirect selection depends on the magnitude of correlations between yield and target yield components (Bose *et al.*, 2007; Idris *et al.*, 2012; Dhanwani *et al.*, 2013; Pratap *et al.*, 2014).

Considering the above idea the present investigation was conducted with the following objectives:

- To study genetic variation and character association of traits,
- To study direct and indirect effect of traits on yield and
- To select high yielding short duration F_5 materials for further trial

CHAPTER II

REVIEW OF LITERATURE

CHAPTER II
REVIEW OF LITERATURE

Rice has wide adaptability to different environmental conditions, as it is evident from its worldwide distribution. Yield of rice variety is determined by the morphological parameters such as plant height, number of effective tiller, number of spikelet per panicle, number of filled grain and yield per plant as well as by environmental factors. Many studies on the variability, interrelationship and path co-efficient analysis have been carried out in many countries of the world. The review of literature concerning the studies presented under the following heads:

2.1. Genetic parameters
2.2. Correlation coefficient
2.3. Path coefficient

2.1. Genetic parameters

Genetic variability is a prerequisite for initiating a successful breeding program aiming to develop high yielding varieties. A good number of literatures concerning the variability in the *Oryza species* are available. Some of those are presented here.

Ketan and Sarkar (2014) reported 26 idigenous *aman* rice cultivars and found that high heritability was observed days to flowering, plant height, 1000 spikelet weight, panicle length. Number of spikelet per panicle recorded the highest genetic advance followed by plant height and number of secondary branches. High heritability in conjunction with high genetic advance was registered for plant height, days to flowering and number of secondary branches. High heritability in conjunction with low genetic advance was observed for panicle length. Spikelet yield per plant was significantly correlated with number of secondary branches per panicle at phenotypic level while number of spikelet per panicle and fertility percentage at genotypic and phenotypic level. Phenotypic coefficient of variation (PCV) was higher than the genotypic coefficient of variation (GCV) for flowering, plant height, number of secondary branches, 1000-spikelet weight and panicle length.

Dutta *et al.* (2013) studied 68 genotypes for twelve agronomical important characters to estimate variability and genetic parameters. Considering genetic parameters, high genotypic and phenotypic coefficient of variations, high heritability (broad sense) and genetic advance as percentage of mean were shown by eight characters viz. tillers per plant, days to flowering, harvest index, spikelet per panicle, spikelet density, panicle per plant and spikelet yield. Thus these characters were under the influence of additive gene action and a satisfactory selection program.

Seyoum *et al.* (2012) conducted a field experiments using 14 rice genotypes during the main rainy seasons of 2009 and 2010 at three rain fed upland locations of Southwest Ethiopia to estimate the genetic variability, heritability of grain yield and yield contributing traits in upland rice. Days to 50% flowering, plant height, grains per panicle, spikelet per panicle, thousand grains weight and grain yield showed relatively high GCV and PCV estimates. High heritability was obtained for plant height (92.17%), followed by 50% flowering (90.16%), thousand grains weight (83.17%), days to 85% maturity (82.45%), panicle length (79.25%) and spikelet per panicle (60.25%) which indicates high heritable portion of variation. High to medium estimates of heritability and genetic advance were obtained for plant height, days to 50% flowering, panicles per plant, spikelet per panicle, grains per panicle and thousand grains weight, indicating the roles of additive gene action and a good scope of selection using their phenotypic performance.

In order to estimate genetic variability and relationships among some agronomic traits of rice an experiment were conducted with 30 varieties of rice under two irrigation regimes by Abarshahr *et al.* (2011). Broad-sense heritability varied from 0.05 for brown grain width to 0.99 for plant height and number of spikelet for panicle under optimum irrigation and from 0.1 for brown grain width to 0.99 for plant height. Evaluation of phenotypic and genotypic coefficient of variations (CV) showed that the lowest and highest phenotypic CV under optimum irrigation regime was observed to panicle fertility percentage and paddy yield and genotypic CV was related to brown grain width and plant height, respectively, while under drought stress condition, days to 50% flowering had the lowest phenotypic and genotypic CV and paddy yield and plant height had the highest phenotypic and genotypic CV. Furthermore, the lowest and highest expected genetic advance using selection intensity of 10% (i =1.75) were evaluated for brown grain width and plant height under optimum irrigation regime, respectively.

Akinwale *et al.* (2011) evaluated 12 rice genotypes in the International Institute of Tropical Agriculture, Ibadan, Nigeria during 2008/2009 cropping season. Genotypic coefficients of variation were lower than the corresponding phenotypic coefficients in all the traits studied, indicating considerable influence of the environment on the expression of the traits. High to medium broad sense heritability estimates observed on days to heading, days to maturity, plant height, grain yield and number of grains per panicle, panicle weight, number of panicles per m^2 and panicle length. The low broad sense heritability observed for the number of tillers per plant and 1000 grain weight is indicative of the influence of the environment on these traits. Low heritability of these traits indicates the ineffectiveness of direct selection for these traits. High to medium heritability and genetic advance were recorded for the number of grains per panicle, grain yield, panicle weight and the number of panicles per plant.

Prajapati *et al.* (2011) assessed thirty eight rice genotypes at Field Experimentation Centre, Department of Genetics and Plant Breeding, Allahabad School of Agriculture, Allahabad during *kharif*, 2009. The experiment was conducted to study the 12 quantitative traits to examine the nature and magnitude of variability, heritability and genetic advance. High estimates of heritability coupled with high genetic advance as percent of mean was observed for harvest index followed by number of spikelet per panicle, number of panicles per hill and number of tillers per hill. High estimates of heritability coupled with moderate genetic advance as percent of mean was observed for flag leaf width followed by days to 50% flowering, panicle length and biological yield per hill.

Sadeghi (2011) used 49 rice varieties (*Oryza sativa* L.) in an experiment to determine variability, heritability and correlation between yield and yield components for 2 years. He found broad sense heritability range from 69.21% (plant height) to 99.53% (grain width).

Selvaraj *et al.* (2011) studied variability, correlation and path coefficient on 21 rice genotypes for grain yield and other yield attributes. Analysis of variance revealed considerable variability among the genotypes for all the characters. The phenotypic correlation coefficient (PCV) values were slightly greater than genotypic correlation coefficient (GCV), revealing negligible influence of environment in character expression. High heritability coupled with high genetic advance and high GCV were observed for number of tillers/plant followed by number of productive tillers per plant, plant height and grain yield / plant.

Subbaiah *et al.* (2011) studied the extent of variability and genetic parameters with 16 parents and 48 hybrids for nine yields and its components and 25 quality characters. The magnitude of difference between PCV and GCV was low for all the traits, indicating less environmental influence. High GCV and PCV were recorded for harvest index, total number of productive tillers per plant and gelatinization temperature in parents, number of grains per panicle, gelatinization temperature and amylase content in hybrids. High heritability coupled with high genetic advance as percent of mean were recorded for gelatinization temperature, harvest index, total number of productive tillers per plant, number of grains per panicle, karnel length, karnel L/B ratio and grain yield per plant in case of parents and gelatinization temperature, amylase content, total number of productive tillers per plant, number of grains per panicle and harvest index in case of hybrids indicating the additive gene effects in the genetic control of these traits and can be improved by simple selection in the present breeding material.

Singh *et al.* (2011) evaluated 81 rice genotypes during *kharif*, 2010 for 13 quantitative traits to examine the nature and magnitude of variability, heritability and genetic advance. Analysis of variance revealed that the differences among 81 genotypes were significant for all the characters except flag leaf width. Among the all traits number of spikelet per panicle exhibited high estimate of genotypic coefficient of variation (GCV) and phenotypic coefficient of variation (PCV) followed by harvest index, grain yield per hill and number of panicles per hill. Broad sense heritability was highest which suggested that this trait would respond to selection owing their high genetic variability and transmissibility. Maximum genetic advance as percent of mean was recorded for number of spikelet per panicle with high value of heritability.

Ullah *et al.* (2011) studied ten traditional fine Biroin rice and found that the higher genotypic coefficient of variations was found in case of grains per panicle followed by grain yield per plant, 1000-grain weight and panicles per plant. High heritability with high genetic advance in percentage of mean was recorded for the characters grains per panicle, grain yield per plant and 1000-grain weight indicating role of additive gene action in the expression of these traits.

Jayasudha *et al.* (2010) carried out an experiment on 47 genotypes revealed that a high genotypic and phenotypic coefficient of variation was observed for grain yield per plant, harvest index, pollen fertility (%) and spikelet fertility (%). Characters like pollen fertility (%), spikelet fertility (%), days to 50 % flowering and grain yield per plant showed high value of heritability coupled with high genetic advance.

Ghosal *et al.* (2010) evaluated 18 advanced breeding lines for yield and yield contributing characters to observe their variability, associations and direct and indirect effect on yield during *boro* season, 2009. All the tested characters showed significant variation. Effective tillers/m^2 and spikelet sterility (%) had high genotypic variance, high heritability, high genetic advance and high genotypic coefficient of variation. Effective tillers/m^2, panicle length (cm), thousand grain weight (g) and growth duration (days) showed significant positive association with grain yield.

Nandeshwar *et al.* (2010) evaluated 25 F_2 progenies derived from the crosses involving HYV and quality rice during *kharif*, 2005. High GCV and PCV were observed for grain yield plant $^{-1}$, panicle number plant $^{-1}$ and panicle weight. High heritability was observed against all the characters studied excepting panicle weight, grain number panicle $^{-1}$ and grain breadth. Grain yield plant $^{-1}$ showed maximum genetic advance as percentage of mean followed by panicle number plant $^{-1}$, plant height and panicle weight respectively.

Nandan *et al.* (2010) did an experiment to evaluate thirty three genotypes for identifying their efficiency with respect to 20 yield and quality traits. They found high heritability with high genetic advance as percent of mean was registered for number of effective tillers per plant, panicle weight, number of grains per panicle, number of spikelet per panicle, 1000 grain weight, kernel length before cooking (KLBC), length breadth(L/B) ratio, water uptake ratio and grain yield per plant.

Yadav *et al.* (2010) carried out a field experiment was to establish the extent of association between yield and yield components and others characters in rice. They found high heritability coupled with high to moderate genetic advance as % of mean was observed on plant height, seed yield per plant, biological yield, harvest index, test weight and number of spikelet per panicle suggesting preponderance of additive gene action in the expression of these characters.

Anbanandan *et al.* (2009) studied four crosses of F_2 generation were advanced to F_3 and F_4 generations to study variability, heritability and genetic advance of four crosses of rice genotypes. Among the four crosses studied, cross 1 exhibited superior *per* se performance in both F_3 and F_4 generations for almost all the economic characters studied including yield. This cross also recorded increased performance from F_3 to F_4 generations. This indicated the improvement of the genotypes as the generation progresses. High GCV and PCV values were observed for grain yield per plant for cross 1 followed by cross 2 in both F_3 and F_4 generations. Also cross 1 and cross 2 recorded high heritability and genetic advance for the characters *viz.* number of productive tillers per plant, 1000-grain weight and grain yield per plant in both F_3 and F_4 generations. This indicated that these characters are controlled by additive gene action. Hence the expected progress under selection could be obtained in the early generation itself. Genetic improvement for quantitative traits can achieved through a clear understanding of the nature and amount of variability present in the genetic stocks and the extent to which the desirable traits are heritable. Therefore, information on the genetic parameters such as coefficient of variation, heritability, genetic advance and the influence of environment on the expression of these characters will help the breeder to evolve suitable cultivars within a short time.

Bisne *et al.* (2009) conducted an experiment on 44 rice genotype in Raipur, Chhattisgarh in *kharif* 2005 for 13 characters. Low, moderate and high genotypic and phenotypic coefficient of variations was observed. High genotypic and phenotypic co-efficient of variations were expressed by harvest index, total number of filled spikelet per panicle, 100-grain weight and spikelet fertility percentage. High heritability coupled with high genetic advance was exhibited by harvest index, total number of chaffy spikelet per panicle, grain yield per plant, total number of filled spikelet per panicle and spikelet fertility percentage and selection may be effective for these characters.

Kumar *et al.* (2009) carried out an experiment to study the selection criteria for selecting high yielding genotypes in two different early segregating F_2 and F_3 populations by estimating heritability and genetic correlation between yield and its main economic traits in their subsequent F_3 and F_4 generations of two crosses in rice. The heritability estimates were high for spikelet/main panicle and 100-grain weight, whereas it was medium to low for grain yield and low for panicles/plant.

Vange (2009) conducted a field experiments in 2005 in the Experimental Farm Station of the University of Agriculture, Makurdi, Nigeria to evaluate the performance and genetic diversity of some upland rice accessions. Genotypic coefficient of variability (GCV) was generally lower than phenotypic coefficient of variability (PCV). Days to 50% heading, days to maturity, flag leaf area, panicle weight, panicle length, number of branches/panicle, number of seeds/panicle, grain weight/panicle and seed yield showed very low differences between their PVC and GCV values. Also these traits had high estimates for heritability and genetic advance.

Karad *et al.* (2008) observed a wide range of variability in yield and yield contributing characters. The PCV was slightly higher than GCV for almost all the characters. The parameters of genetic variability revealed high GCV values for number of mature and immature panicles mt.sq.$^{-1}$, 1000 grain weight and plant height. The estimate of heritability together with genetic advance was high for 1000 grain weight, number of mature and immature panicles and plant height.

Kole *et al.* (2008) studied variability for twelve morphological characters were studied on 18 morphologically distinct mutants in M_4 generation along with their two mother genotypes (IET 14142 and IET 14143), which were developed from Tulaipanja, an aromatic non-basmati rice cultivar of West Bengal. Genotypic and phenotypic coefficients of variation were high for flag leaf angle and panicle number; moderate for grain number per panicle, straw weight, harvest index and grain yield per plant; and low for days to flower, plant height, panicle length, spikelet number, spikelet fertility (%) and test weight. High heritability accompanied by high to moderate genetic advance for flag leaf angle, panicle number, grain number, straw weight and grain yield indicated the predominance of additive gene action for the expression of these characters.

Padmaja *et al.* (2008) reported genetic variability, genotypic and phenotypic coefficients of variation, heritability and genetic advance for eleven characters in one hundred and fifty genotype including five check varieties of rice were studied. The analysis of variance revealed that there were highly significant differences for all the characters except leaf width and 100-seed weight among the genotypes. The estimates of genotypic and phenotypic coefficient of variation (GCV and PCV) were high for all the characters except days to 50% flowering and panicle length, which had moderate genetic advance along with high heritability indicating the involvement of additive type of gene action in controlling these characters.

Bharadwaj *et al.* (2007) concluded an experiment in which heritability and genetic advance were studied in three New Plant Type (NPT) based crosses of rice for thirteen characters in two environments of normal and high dose of nitrogen. Significant genetic variability was observed between the two final generations

Jaiswal *et al.* (2007) made an investigation to study the variability for yield and quality trait in twenty-five indigenous aromatic rice genotypes. Highest genetic co-efficient of variation was recorded for grains yield per plant and number of panicle bearing tillers among yield traits and length/breadth ratio for quality traits. High heritability (broad sense) coupled with high genetic advance was observed for yield per plant, number of panicle bearing tillers and number of grains per panicle.

Karim *et al.* (2007) made an attempt to study variability and genetic parameter analysis in 41 aromatic rice genotypes. The phenotypic variance was higher than the corresponding genotypic variance for the characters. These differences were in case of number of panicles per hill, number of primary branches, number of filled grains per panicle, spikelet sterility (%) and grain yield per hill indicating greater influence on environment for expression of these characters.1000-grain weight and days to maturity showed least difference between phenotypic and genotypic variance, which indicated additive gene action for expression of the characters. Considering genetic parameters high genotypic coefficient of variation (GCV) value was observed for 1000-grain weight followed by spikelet sterility (%), grain yield per hill and number of filled grains per panicle, whereas days to maturity showed very low GCV. High heritability with high genetic advance in percent of mean (GAPM) was observed for 1000-grain weight followed by spikelet sterility (%) and number of filled grains per panicle indicated that these characters were under additive gene control and selection for improvement might be effective. Days to maturity showed high heritability but low genetic advance (GA) (%), which indicated that non additive gene effects were involved for phenotypic expression of this character.

Sharma *et al.* (2006) evaluated 39 upland rice genotypes for the estimation of genetic variability. The significant mean sum square indicated strong variability for days to 50% flowering. Though days to 50% flowering had high heritability (92.8%), it had low GCV.

Sankar *et al.* (2006) conducted an experiment with 34 rice genotypes and high heritability as well as genetic advance was obtained for productive tillers plant^{-1}.

Zia-Ul-Qamar *et al.* (2005) conducted an experiment involving nine genotypes of aromatic group and eight genotypes of non-aromatic group separately to study yield and yield components in rice. The study was conducted at the Nuclear Institute for Agriculture and Biology, Faisalabad during 2001-02. Analysis of variance reflected significant differences among the genotypes for all the traits studied in both the groups. Broad sense heritability estimates for various traits ranged from 56–89% in the non-aromatic group and 46-99% in the aromatic group. In both the groups, the phenotypic coefficients of variability were higher than their respective genotypic coefficients of variability for all the traits, indicating the effect of the environment on character association.

Sarma and Bhuiyan (2004) studied genetic variation and divergence in 58 aus rice genotypes and observed highest broad- sense heritability for plant height.

Chand *et al.* (2004) studied nineteen genotypes of *aman* paddy (Oryza *sativa*) emanating from different sources different sources were evaluated for spikelet yield and their components during *kharif*. Heritability and genetic advance as percentage of mean were high for 1000- spikelet weight

Hossain and Haque (2003) reported that both genotypic and phenotypic variances were found highly significant in all the traits with little higher phenotypic variations as usual. Similarly the low differences between the phenotypic and genotypic coefficient of variations indicated low environmental influences on the expression of the characters. High heritability coupled with high genetic advance of yield, grains per panicle, days to flowering and height suggested effective selection for improvement of these characters could be made.

Kumari *et al.* (2003) reported that plant height showed high heritability coupled with modern genetic advances.

Patil *et al.* (2003) evaluated 128 traditional aromatic rice genotypes and found high heritability for 100-grain weight associated with yield/hectare.

Yield per hectare is the most important consideration in rice breeding program, but yield is a complex character in inheritance and may involve several related components. Rice yield is a product of number of panicles per unit area, number of spikelet per panicle, percentage of filled grains and weight of 1000 grains (Datta and Khanam, 2002). It is therefore important to know the factors or traits that influence grain yield directly or indirectly or both, and to determine heritability and genetic predicted. Improving rice (*Oryza sativa* L.) grain yield per unit land area is the only way to achieve increased rice production Because of the reduction in area devoted to rice production.

Bidhan *et al.* (2001) studied the genetic variability, heritability, and genetic advance for yield and yield components in 25 medium duration rice genotypes West Bengal, India, during *kharif*, 1996-97. Observations were recorded for 1000- grain weight and 1000- grain weight exhibited less environmental effect and high heritability coupled with high genetic advance in percentage of mean.

Iftekharuddaula *et al.* (2001) studied twenty-four modern rice varieties of irrigated ecosystem with a view to finding out variability and genetic association for grain yield and its component characters. All the characters tested were showed significant variation among the varieties. The highest genetic variability was obtained in spikelet /panicle and grains/panicle. High heritability together with high genetic advance in percentage mean was observed in plant height, 1000 grain weight, grains/panicle and spikelet/panicle.

Prasad *et al.* (2001) studied eight fine rice genotypes to observe genetic variability and selection criteria for some yield contributing characters through correlation and path coefficient analysis. 1000 grain weight, number of effective tillers/plant, number of fertile grains/panicle and yield/plant showed high genotypic coefficient of variation and high heritability along with high genetic advance in percentage of mean, pointed out their importance for achieving genetic gain through selection.

Shanthi and Singh (2001) found significant variation among the genotypes for all characters studied. Panicle length exhibited low variation between phenotypic and genotypic coefficient of variations.

Tomar *et al.* (2000) found that PCV and GCV, the flag leaf width, panicle length, number of primary branches/panicle, yield/plant and number of effective tillers/plant were found to be the important characters. Both the heritability and genetic advance were found high for the number of grains/panicle, number of primary branches/ panicle and 1000-grain weight, which indicated the governance by additive gene action. The panicle length, 1000-grain weight, harvest index, biological yield, flag leaf length and its width had high heritability but low genetic advance suggesting that these traits had greater influence of the non-additive gene action with a big role of non-genetic factors in their expression. Moderate heritability estimates associated with moderate genetic advance for some traits suggested that additive and non-additive gene effects were equally important in the inheritance of these characters.

A high heritability of 93.1% was observed for plant height in some rice genotypes by Kaw *et al.* (1999). Similar findings were also reported by Ashvani *et al.* (1997).

Ashura (1998) studied 36 genotypes and concluded that heritability estimates revealed plant height, number of filled grains per panicle and grain weight to be highly heritable characters.

Mehetre *et al.* (1996) concluded that information on heritability, yield correlations and genetic variability is derived from data on 8 characters in M_2 generation of 8 upland rice varieties with gamma radiation (10, 20, 30, 40 or 50 kR). Significant differences occurred among genotypes for all characters. Estimates of heritability ranged from 91.2 (plant height) to 35.6% (sterility). Expected genetic advance ranged from 6.9 (panicle length) to 54.9% (grain yield/plant).

Mishra *et al.* (1996) studied genetic parameters in some rice genotypes and found high value of heritability and genetic advance for 1000-grain weight.

Sawant and Patil (1995) evaluated 75 genotypes of rice and found high coefficient of variation for spikelet yield per plant. High value of heritability coupled with high expected genetic advance was observed for spikelet yield per plant.

Chaubey and Singh (1994) evaluated 20 rice varieties and reported high heritability for total number of spikelet followed by grain yield per plant and 1000-grain weight. Genetic advance in percent of mean were higher for grain yield per plant followed by panicle weight and total number of spikelet.

A study was conducted by Yadav (1992) on 11 plant characters in 16 rice genotypes and revealed that heritability estimate was high for days to 50% flowering and for yield/plant.

Vishwakarme *et al.* (1989) estimates moderate heritability and moderate genetic advance for grain yield per plant in 82 population of rice.

Singh *et al.* (1986) studied genetic variability and extend of heritability of this trait was assessed in 98 upland cultivars and showed a wide range of phenotypic variation and high heritability along with high estimated genetic advance for 1000-grain weight. 1000-grain weight has been reported as high heritable character by Sarathe *et al.* (1969) and Majumder *et al.* (1971).

Jangale *et al.* (1985) studied variability, heritability and genetic advance for some quantitative characters in upland rice and reported that plant height had high heritability. They also found that grain yield had maximum genetic advance by plant height.

2.2 Correlation coefficient

Rangare *et al.* (2012) evaluated forty exotic and Indian rice germplasm including one local check for their efficiency with respect to eleven yield and yield contributing characters from *Kharif*, 2009 under normal conditions. Associated studies have indicated that for an improvement in grain yield the intensive selection should be positive for biological yield per plant, number of fertile tillers per plant, number of spikelet per panicle, test weight, panicle length and days to maturity as these traits showed significantly strong positive association with grain yield, but days to 50% flowering, days to initial flowering, harvest index and plant height through had positively non significant association with grain yield.

Satheeshkumar *et al.* (2012) estimated correlation in fifty three genotypes of rice for fifteen characters. It revealed grain yield per plant exhibited high significant and positive genotypic correlation with number of productive tillers per plant, filled grains per panicle and total number of grains.

Seyoum *et al.* (2012) conducted a field experiments using fourteen rice genotypes during the main rainy seasons of 2009 and 2010 at three rain fed upland locations of Southwest Ethiopia to estimate the correlation coefficient of grain yield and yield contributing traits in upland rice. Grains per panicle had highly significant (r = 0.906**) genotypic correlation coefficient with grain yield.

Akinwale *et al.* (2011) evaluated twenty rice genotypes in the International Institute of Tropical Agriculture, Ibadan, Nigeria during 2008/2009 cropping season. They concluded that grain yield exhibited significantly positive correlation with the number of tillers per plant (r = 0.58**), panicle weight (r =0.60*) and number of grains per panicle (r= 0.52*). Therefore, the results suggest that these traits can be used for grain yield selection.

Sadeghi (2011) used 49 rice varieties (*Oryza sativa* L.) in an experiment to determine variability, heritability and correlation between yield and yield components for 2 years. Grain yield was found to be positively and significantly correlated with grains per panicle, days to maturity, panicle weight, number of productive tillers, days to flowering, plant height, panicle length indicating the importance of these characters for yield improvement in this population.

Selvaraj *et al.* (2011) studied variability, correlation and path coefficient on 21 rice genotypes for grain yield and other yield attributes. Result of correlation analysis revealed that characters like plant height, number of tillers/plant, number of productive tillers/plant, panicle length, filled grains per panicle and test weight had significant positive association with grain yield.

Ullah *et al.* (2011) studied ten traditional fine Biroin rice and found that genotypic correlations were higher than the phenotypic correlations in most of the cases. Grains per panicle, panicle length, leaf area index, harvest index and chlorophyll content were the major characters contributing to grain yield as these traits were significantly and positively associated with grain yield per plant.

Ghosal *et al.* (2010) evaluated eighteen advanced breeding lines for yield and yield contributing characters to observe their variability, associations and direct and indirect effect on yield during *boro* season, 2009. Effective tillers/m^2, panicle length (cm), thousand grain weight (g) and growth duration (days) showed significant positive correlation with grain yield.

Nandeshwar *et al.* (2010) evaluated twenty five F_2 progenies derived from the crosses involving HYV and quality rice during *kharif*, 2005. Grain yield plant $^{-1}$ possessed significant positive correlation with panicle number plant $^{-1}$, panicle weight and grain number panicle $^{-1}$ while it had significant negative correlation with plant height.

Nandan *et al.* (2010) made an experiment to evaluate thirty three genotypes for identifying their efficiency with respect to 20 yield and quality traits. The correlation studies revealed strong positive association of yield with days to 50 % flowering, plant height, number of grains per panicle, number of spikelet per panicle and spikelet fertility.

In a genetic study conducted by Jayasudha *et al.* (2010) the results indicated that spikelet fertility (%) and harvest index showed positive and significant correlation with seed yield per plant both at genotypic and phenotypic levels.

Yadav *et al.* (2010) carried out a field experiment was to establish the extent of association between yield and yield components and others characters in rice. They found that the correlation coefficient between seed yield per plant and other quantitative attributing to yield showed that grain yield was significantly and positively associated with harvest index, number of tillers per hill, number of panicle per plant, panicle length, number of spikelet's per panicle and test weight at both genotypic and phenotypic levels.

Wattoo *et al.* (2010) conducted an experiment in order to determine the associations among yield components and their direct and indirect influence on grain yield of rice. For this purpose, 30 genotypes collected from different sources were tested. The phenotypic correlations among the yield traits were estimated. Grain yield was significantly correlated with its component characters; number of productive tillers per plant, number of grains per panicle and flag leaf area.

Kumar *et al.* (2009) carried out an experiment to study the selection criteria for selecting high yielding genotypes in two different early segregating F_2 and F_3 populations by estimating heritability and genetic correlation between yield and its main economic traits in their subsequent F_3 and F_4 generations of two crosses in rice. Correlation analysis revealed that grain yield/plant had significant and positive associations with spikelet/main panicle but non-significant and positive association with 100-grain weight.

Sabesan *et al.* (2009) evaluated 54 rice varieties of diverse origin for correlation analysis under coastal saline low lands. The 100 grain weight was positively significantly correlated with plant height, grains per panicle and grain breadth.

Vange (2009) conducted a field experiments in 2005 in the Experimental Farm Station of the University of Agriculture, Makurdi, Nigeria to evaluate the performance and genetic diversity of some upland rice accessions. Genotypic correlation analysis of yield with other traits revealed that yield had a significantly positive correlation with flag leaf area, number of tillers, number of panicles, panicle weight, panicle length, number of branches/panicle, number of seeds/panicle and seed weigh/panicle, grain length and 1000 seed weight.

Karad *et al.* (2008) observed a wide range of variability in yield and yield contributing characters. The grain yield was positively correlated with almost all the characters except 1000-grain weight at both genotypic and phenotypic levels. Genotypic correlation estimates were higher than phenotypic correlation with grain yield plot^{-1}.

Kole *et al.* (2008) studied correlation for twelve morphological characters were studied on 18 morphologically distinct mutants in M_4 generation along with their two mother genotypes (IET 14142 and IET 14143), which were developed from Tulaipanja, an aromatic non-basmati rice cultivar of West Bengal. Grain yield was found to be positively and significantly correlated with plant height, panicle number per plant, straw weight and harvest index at both genotypic and phenotypic levels indicating the importance of these characters for yield improvement in this population.

Twenty modern *boro* rice varieties were evaluated with a view to find variability and genetic association for grain yield and yield components characters by Rokonuzzaman *et al.* (2008). The experiment was conducted at BRRI farm during the Boro season of 2004. Genotypic and Phenotypic correlation among these characters were computed. Both genotypic and phenotypic correlation coefficients were significant between plant height and number of effective tillers per plant followed by panicle length. There was a positive significant correlation between yield and number of effective tillers per plant followed by percent filled grain per panicle.

Agahi *et al.* (2007) conducted an experiment to investigate correlation coefficient of grain yield and sixteen yield-related traits among 25 lines. The results showed that grain yield was significantly correlated with days to heading, total tillers, number of productive tillers, days to maturity, number of grain per panicle, flag leaf length, flag leaf width and plant height.

Mustafa *et al.* (2007) evaluated 14 rice (*Oryza sativa* L.) genotypes at the Gezira Research Station Farm (GRSF), Sudan for correlation coefficient between yield and yield components among phenotypic markers and polygenic trait analysis. Phenotypic correlations between grain yield and number of filled grain panicle^{-1}, number of panicle m^{-2} and 1000 grain weight were 0.52, 0.36 and 0.27, respectively. These results suggested that improvement in yield could be attained by selecting rice plants for higher number of filled grain panicle^{-1}, number of panicle m^{-2}, and 1000 grain weight.

Ramakrishnan *et al.* (2006) studied correlation which indicated that for improvement in rice grain yield, the intensive selection on the positive side should be made for grains per panicle and spikelet fertility since these traits showed significantly positive correlation with seed yield and also among themselves. Panicles per plant, panicle length and grain weight though had positively non-significant correlation with grain yield also be utilized for improvement of yield.

Sankar *et al.* (2006) studied on correlation on single plant yield and its components in 34 rice genotypes. They concluded that single plant yield was positively and significantly correlated with days to 50 per cent flowering, productive tillers/plant, panicle length and grains/panicle and hence can be taken as indices for improving yield in rice.

Agbo and Obi (2005) carried out an experiment on eleven rice genotypes obtained from National Cereals Research Institute, Badeggi, Nigeria, and a local variety were evaluated under field culture in Nsukka for a period of two years (1998 and 1999).

showed significant positive correlation with plant height, panicle length, spikelet per panicle, panicle weight, and test weight.

Bai *et al.* (1992) reported that spikelet yield per plant positively correlated with numbers of positively tillers and number of spikelet per/plant.

Dhaliwal *et al.* (1992) revealed that number of grains per panicle, number of panicles per plant, panicle length and 100-grain weight showed positive and significant correlation with grain yield.

2.3 Path coefficient

When more characters are involved in correlation study it becomes difficult to ascertain the traits which really contribute towards the yield. The path analysis under such situation helps to determine the direct and indirect contribution of these traits towards the yield.

Rangare *et al.* (2012) evaluated forty exotic and Indian rice germplasm including one local check for their efficiency with respect to eleven yield and yield contributing characters from *kharif*, 2009 under normal conditions. This study for improvement of yield was used through path coefficient analysis, and results revealed that biological yield per plant, harvest index, number of fertile tiller per plant, days to 50% flowering, test weight, days to maturity and panicle length all had important role in the improvement of grain yield in rice at genotypic and phenotypic levels.

Seyoum *et al.* (2012) conducted a field experiments using fourteen rice genotypes during the main rainy seasons of 2009 and 2010 at three rain fed upland locations of Southwest Ethiopia to estimate the path coefficient of grain yield and yield contributing traits in upland rice. They showed that grains per panicle had maximum positive direct effect.

In order to estimate genetic variability and relationships among some agronomic traits of rice an experiment were conducted with 30 varieties of rice under two irrigation regimes by Abarshahr *et al.* (2011). Path analysis for paddy yield indicated that the number of spikelet per panicle and flag leaf length had positive direct effects and days to complete maturity and plant height had negative direct effects on paddy yield under optimum irrigation condition, while flag leaf width and number of filled grains per panicle had positive direct effects and days to 50% flowering had negative direct effect on paddy yield under drought stress condition.

Hairmansis *et al.* (2010) evaluated agronomic characters and grain yield of nine advanced rice breeding lines and two rice varieties in a series of experiments in tidal swamp areas, Karang Agung Ulu Village, Banyuasin, South Sumatra, for four cropping seasons in dry season (DS) 2005, wet season (WS) 2005/2006, DS 2006, and DS 2007. Result from path analysis revealed that the following characters had positive direct effect on grain yield, i.e. number of productive tillers per hill ($p = 0.356$), number of filled grains per panicle ($p = 0.544$), and spikelet fertility ($p = 0.215$). Plant height had negative direct effect ($p = -0.332$) on grain yield, while maturity, number of spikelet per panicle, and 1000-grain weight showed negligible effect on rice grain yield.

Sadeghi (2011) used 49 rice varieties (*Oryza sativa* L.) in an experiment to determine variability, heritability and correlation between yield and yield components for 2 years. Result of the phenotypic path analysis revealed that the numbers of productive tillers had the highest positive direct effect followed by days to maturity, grains per panicle and 1000-grain weight.

Selvaraj *et al.* (2011) studied variability, correlation and path coefficient on 21 rice genotypes for grain yield and other yield attributes. Results of path-coefficient analysis revealed that, test weight exhibited maximum positive direct effect on grain yield / plant followed by filled grains / panicle, plant height, panicle length, number of tillers / plant and days to 50% flowering and they contributed primarily to yield and could be relied upon for selection of genotypes to improve genetic yield potential of rice.

Ullah *et al.* (2011) studied ten traditional fine Biroin rice and found that maximum contribution of more chlorophyll content to grain yield was observed in path analysis, which was followed by higher harvest index and grains per panicle through higher direct effect. Leaf area index, panicle length, days to maturity, grains per panicle, harvest index, 1000-grain weight and plant height had positive but indirect effect on grain yield through chlorophyll content.

Studies on genetic variability, character association and path-coefficient analysis were conducted on forty seven (47) rice genotypes by Jayasudha *et al.* (2010). Results of path-coefficient analysis revealed that productive tillers per plant had the highest positive direct effect on grain yield followed by harvest index, spikelet fertility (%), pollen fertility (%) and plant height.

Ghosal *et al.* (2010) evaluated 18 advanced breeding lines for yield and yield contributing characters to observe their variability, associations and direct and indirect effect on yield during Boro season, 2009. Path coefficient analysis revealed that effective tillers/m^2, thousand grain weight (g) and growth duration (days) had higher direct effects on yield (t/ha).

Nandeshwar *et al.* (2010) evaluated twenty five F_2 progenies derived from the crosses involving HYV and quality rices during kharif 2005. Panicle number plant $^{-1}$ imparted maximum direct effect on grain yield followed by grain number panicle $^{-1}$, 1000 grain weight and panicle length in this regard.

Nandan *et al.* (2010) made an experiment to evaluate thirty three genotypes for identifying their efficiency with respect to 20 yield and quality traits. The result of path analysis indicated that the number of grains per panicle had maximum direct effect on grain yield per plant followed by kernel length after cooking (KLAC), days to 50 % flowering, hulling percentage, plant height, harvest index and kernel breadth after cooking (KBAC).

Yadav *et al.* (2010) carried out a field experiment was to establish the extent of association between yield and yield components and others characters in rice. They found that the path coefficient at genotypic level revealed that harvest index, biological yield, number of tillers per hill, panicle length, number of spikelet per panicle, plant height and test weight had direct positive effect on seed yield per hill, indicating these are the main contributors to yield.

Wattoo *et al.* (2010) conducted an experiment in order to determine the associations among yield components and their direct and indirect influence on grain yield of rice. For this purpose, 30 genotypes collected from different sources were tested. Path analysis revealed that days to maturity had the highest direct effect (0.751) on grain yield per plant. In addition, the yield components had positive direct effect on grain yield except the days to heading (-0.834). The order of yield components was the number of productive tillers per plant, flag leaf area and 1000 grain weight.

Kumar *et al.* (2009) carried out an experiment to study the selection criteria for selecting high yielding genotypes in two different early segregating F2 and F3 populations by estimating heritability and genetic correlation between yield and its main economic traits in their subsequent F_3 and F_4 generations of two crosses in rice. Path coefficients analysis confirmed that spikelet/main panicle was important yield determinants followed by 100-grain weight as evident from their magnitude of direct contribution to grain yield.

Kole *et al.* (2008) studied path coefficient for 12 morphological characters were studied on 18 morphologically distinct mutants in M_4 generation along with their two mother genotypes (IET 14142 and IET 14143), which were developed from Tulaipanja, an aromatic non-basmati rice cultivar of West Bengal. The results of genotypic path analysis revealed that panicle number had the highest positive direct effect followed by grain number, test weight, plant height, days to flower and straw weight.

Karad *et al.* (2008) observed a wide range of variability in yield and yield contributing characters. Path coefficient analysis revealed that length of panicle had the highest positive direct effect followed by number of panicles, number of tillers plant^{-1} and number of mature panicles whereas the characters plant height, number of immature panicles and 1000 grain weight had the negative direct effect via indirect effect on grain yield plot^{-1}.

Rokonuzzaman *et al.* (2008) evaluated 20 modern *boro* rice varieties with a view to find variability and genetic association for grain yield and yield components characters. The experiment was conducted at BRRI farm during the *boro* season of

2004. Path coefficient showed that number of effective tiller per plant and plant height are the characters that contribute largely to grain yield.

Agahi *et al.* (2007) investigated path coefficient of grain yield and 16 yield-related traits among 25 lines. Genotypic and phenotypic path coefficient analysis revealed that the number of productive tillers had the highest positive direct effect on grain yield (p_p = 1.034, p_g = 1.196). The second and third traits were the number of grain per panicle (p_p = 0.665, p_g = 0.813) and 100-grain weight (p_p = 0.440, p_g = 0.425) respectively.

From a study of Ramakrishnan *et al.* (2006) partitioning through path coefficient analysis revealed that grains per panicle played an important role in the improvement of grain yield in rice.

Jaiswal *et al.* (2007) investigated the path coefficient for yield and quality traits in 25 indigenous aromatic rice genotypes. Number of panicle bearing tillers and days to 50% flowering exhibited highest positive direct effect along with positive association with yield plant-1. Kernel length after cooking quality showed highest positive direct effect on kernel length.

Mustafa *et al.* (2007) evaluated 40 rice (*Oryza sativa* L.) genotypes at the Gezira Research Station Farm (GRSF), Sudan for path coefficient between yield and yield components among phenotypic markers and polygenic trait analysis. The path analysis revealed that number of filled grains panicle^{-1} had direct positive (0.87) contribution to the grain yield ha^{-1} and positive (0.33) indirect effect on grain yield ha^{-1} through days to 50% maturity and number of grains panicle^{-1} (0.089); while number of filled grains per particle had negative (-0.30) and (-0.21) indirect effect on grain yield ha^{-1} through number of tillers plant^{-1} and number of panicles m^{-2}, respectively.

Sankar *et al.* (2006) studied on path-coefficients on single plant yield and its components in 34 rice genotypes. They showed that the correlated traits except panicle length exhibited high positive direct effects towards single plant yield.

Agbo and Obi (2005) carried out an experiment on eleven rice genotypes obtained from National Cereals Research Institute, Badeggi, Nigeria, and a local variety were evaluated under field culture in Nsukka for a period of two years (1998 and 1999). The direct effect of percentage fertile spikelet on yield was positive and of higher magnitude than the direct effects of tiller number, panicle number, spikelet number and 1000 grain weight. Selecting upland rice genotypes with stable and high number of filled grains would sustain high yields in such genotypes especially as the yield components are complementary in action.

Zia-Ul-Qamar *et al.* (2005) conducted an experiment involving nine genotypes of aromatic group and eight genotypes of non-aromatic group separately to study yield and yield components in rice. Association and path analysis suggested that productive tillers per hill, days to maturity and days to 50% flowering may be considered important for the improvement of grain yield in the nonaromatic group whereas productive tillers per hill, spikelet per panicle, fertility % and plant height may be considered as the selection criteria for the direct improvement of grain yield in the aromatic group.

Iftekharuddaula *et al.* (2001) studied 24 modern rice varieties of irrigated ecosystem with a view to finding out variability and genetic association for grain yield and its component characters. Path analysis revealed that higher number of grains/panicle, bold grains, more panicles/m^2 and higher harvest index had positive and higher direct effect on grain yield. Moreover, days to maturity, days to flowering, plant height and spikelet/panicle had positive and higher indirect effect on grain yield though grains/panicle.

Prasad *et al.* (2001) conducted an experiment where eight fine rice genotypes were studied. Path coefficient analysis revealed maximum contribution of fertile grains/panicle to grain yield.

Tomar *et al.* (2000) found that the path coefficient analysis at phenotypic level revealed that 1000-grain weight had the maximum direct effect on the grain yield followed by number of primary branches, harvest index, number of effective tillers and flag leaf length. Plant height though showed the positive correlation with grain yield but had negative direct effect and contributed indirectly through harvest index. At the genotypic level, panicle length had maximum direct effect on the grain yield followed by number of grain/panicle, 1000-grain weight, harvest index and flag leaf width.

Ashura (1998) studied 36 genotypes and results from path analysis identified number of filled grains per panicle, number of panicles per plant and 1000 grain weight to be important characters that influence grain yield. However, number of filled grains per panicle had a significant negative indirect effect through number of panicles per plant and 1000 grain weight.

Mehetre *et al.* (1996) concluded in their experiment that path analyses showed that filled grains/panicle, plant height and panicle length are important characters for selection in breeding programs.

Chaubey and Richharia (1993) studied path coefficient on eight quantitative characters in 80 *Indica* rice varieties, including HYV and indigenous high quality rice in two environments each at two locations during rainy season. Path-analysis indicated a greater contribution of panicle weight to grain yield.

Dhaliwal *et al.* (1992) studied 28 diverse rice genotypes and concluded that number of grains per panicle, number of panicles per plant, panicle length and 100-grain weight had high direct positive effect on grain yield. Indirect effect of panicle length via number of grain per panicle was also high.

CHAPTER III

MATERIALS AND METHODS

CHAPTER III

MATERIALS AND METHODS

The experiment was conducted during the period from December 2013 to May 2014, to study the variability of yield attributes and to select high yielding and short duration rice (*Oryza sativa* L.) from different crosses. The materials and methods that were used and followed for conducting the experiment presented under the following headings-

3.1 Experimental site

The experiment was conducted at the experimental field of Sher-e-Bangla Agricultural University, Dhaka-1207. The location of the experimental site was situated at $23^0 45'$ N latitude and $90^0 23'$ E longitude with an elevation of 8.45 meter from the sea level. Photograph showing experimental sites (Appendix I).

3.2 Soil and climate

The experimental site was situated in the subtropical zone. The soil of the experimental site belongs to Agro-ecological region of "Madhupur Tract" (AEZ No. 28). The soil was clay loam in texture and olive gray with common fine to medium distinct dark yellowish brown mottles. The pH was 5.47 to 5.63 and organic carbon content is 0.82% (Appendix II). The records of air temperature, humidity and rainfall during the period of experiment were noted from the Bangladesh Meteorological Department, Agargaon, Dhaka (Appendix III).

3.3 Experimental materials

The healthy seeds of 25 F_4 and four parent materials of *Oryza sativa* L. collected from the Department of Genetics and Plant Breeding, Sher-e-Bangla Agricultural University and BRRI respectively, which were used as experimental materials. The materials used in that experiment is shown in Table 1.

Table 1. Materials used for the experiment

Sign	Genotypes	Source
G1	BR 26	BRRI
G2	BRRI dhan 28	BRRI
G3	BRRI dhan 29	BRRI
G4	BRRI dhan 36	BRRI
G5	BR 26×BRRI dhan 29, S1P3	SAU
G6	BR 26×BRRI dhan 29, S1P4	SAU
G7	BR 26×BRRI dhan 29, S1P7	SAU
G8	BR 26 ×BRRI dhan29, S1P8	SAU
G9	BR 26×BRRI dhan 29, S1P10	SAU
G10	BR 26×BRRI dhan 36, S7P1	SAU
G11	BR 26×BRRI dhan 36, S7P2	SAU
G12	BR 26×BRRI dhan 36, S7P3	SAU
G13	BR 26×BRRI dhan 36, S7P4	SAU
G14	BR 26×BRRI dhan 36, S7P6	SAU
G15	BRRI dhan 28×BRRI dhan 29, S2P2	SAU
G16	BRRI dhan 28×BRRI dhan 29, S2P3	SAU
G17	BRRI dhan 28×BRRI dhan 29, S2P4	SAU
G18	BRRI dhan 28×BRRI dhan 29, S2P5	SAU
G19	BRRI dhan 28×BRRI dhan 29, S2P6	SAU
G20	BRRI dhan 28×BRRI dhan 36, S7P1	SAU
G21	BRRI dhan 28×BRRI dhan 36, S7P2	SAU
G22	BRRI dhan 28×BRRI dhan 36, S7P6	SAU
G23	BRRI dhan 28×BRRI dhan 36, S7P8	SAU
G24	BRRI dhan 28×BRRI dhan 36, S7P9	SAU
G25	BRRI dhan 29×BRRI dhan 36, S5P2	SAU
G26	BRRI dhan 29×BRRI dhan 36, S5P5	SAU
G27	BRRI dhan 29×BRRI dhan 36, S5P7	SAU
G28	BRRI dhan 29×BRRI dhan 36, S5P9	SAU
G29	BRRI dhan 29×BRRI dhan 36, S5P10	SAU

3.4 Methods

The following precise methods have been followed to carry out the experiment:

3.4.1 Germination of seed

Seed of all collected rice genotypes soaked separately for 24 hours in clothes bag. Soaked seeds were picked out from water and wrapped with straw and gunny bag to increase the temperature for facilitating germination. After 72 hours seeds were sprouted properly.

3.4.2 Seedbed preparation and seedling rising

The seed bed was prepared well by puddling the wetland with repeated ploghing following by laddering. Sprouted seeds were sown seperately in the previously wet seed bed on 5 December, 2013. Proper care was taken so that there was no infestation of pest and diseases and no damage by birds.

3.4.3 Land preparation for transplanting

The experimental plot was prepared by several ploughing and cross ploughing followed by laddering and harrowing with tractor and power tiller to bring about good tilth. Weeds and other stubbles were removed carefully from the experimental plot and leveled properly.

3.4.4 Application of manure and fertilizer

The fertilizers N, P, K, S and B in the form of urea, TSP, MP, Gypsum and Borax respectively were applied. The entire amount of TSP, MP, Gypsum, Zinc Sulphate and Borax were applied during final preparation of field. Urea was applied in two equal installments before sowing and flowering (Appendix IV).

3.4.5 Experimental design and layout

Field lay out was done after final land preparation. The experiment was laid out in Randomized Complete Block Design (RCBD) with three replications. The total area of the experiment was 30 m $\times$ 12.2 m = 366 m^2. Each replication size was 30m $\times$ 3.4m, and the distance between replication to replication was 50 cm. The spacing between lines to line was 20cm. Seeds were sown in lines in the experimental plots on 5 December, 2013.

3.4.6 Transplanting

The check varieties were first transplanted randomly in each block. Then experimental genotypes (25 F_4 cross materials) were tranplanted randomly to the remaining plots. Each entry was grown as single seedling per hill in the rows on January 11, 2014 with a spacing of 20 cm between rows and 20 cm between plants.

3.4.7 Intercultural operations and after care

After establishment of seedlings, various intercultural operations were accomplished for better gowth and development of the rice seedlings.

i. **Irrigation and drainage**

   Flood irrigation was given to maintain a constant level of standing water upto 6 cm in the early stages to enhance tillering, proper growth and development of the seedlings and 10-12 cm in the later stage to discourge late tillering. The field was finally dried out 15 days before harvesting.

ii. **Gap filling**

   First gap filling was done for all of the plots at 10 Days after transplanting (DAT).

iii. **Weeding**

   Weeding was done to keep the plots free from weeds, which ultimately ensured better growth and development. The newly emerged weeds were uprooted carefully at tillering stage and at panicle initiation stage by mechanical means.

iv. **Top dressing**

   After basal dose, the remaining doses of urea were top-dressed in 2 equal installments. The fertilizers were applied on both sides of seedlings rows with the soil.

v. **Plant Protection**

   Diazinon 57 EC was applied at the time of final land preparation and later on other insecticides were applied as and when necessary.

3.4.8 Crop harvesting

Harvesting was done from 25th April to 6th May, 2014 depending upon the maturity. When 80% of the plants showed symptoms of maturity i.e. straw color of panicles, leaves, stems desirable seed color, the crop was assessed to attain maturity. Ten plants were selected at random from F_4 progenies in each replication. The plants were harvested by uprooting and then they were tagged properly. Data were recorded on different parameters from these plants. Variation at flowering and ripening stage of different genotypes are presented in Plate 1.

3.4.9 Data collection

For studying different genetic parameters and inter-relationships, fourteen characters were taken into consideration. The data were recorded on ten selected plants for each cross and ten selected plants for each parent on the following traits-

i. **Days to flowering**

   Difference between the dates of transplanting to the date of 50% flowering of a plot was counted and was recorded when 50% plant of a plot were at the flowering stage. Plate 1(a) showing variation at days to flowering.

ii. **Days to maturity**

   Maturities of the crops of different combination were recorded considering the symptom such as moisture content of rice, color changing of the plant from greenish to straw colored appearance. Plate 2(b) showing variation at maturity stage.

iii. **Plant height (cm)**

   The height of plant was recorded in centimeter (cm) at the time of harvesting. The height was measured from the ground level to the tip of the panicle.

iv. **Number of total tillers per plant**

   The total number of panicle bearing tillers were counted from each of the sample hills and average was taken.

v. **Number of effective tillers per plant**

   The number of effective tiller per plant was counted as the number of panicle bearing tillers per plant and average value was recorded.

vi. **Panicle length (cm)**

   The length of panicle was measured with a meter scale from 10 selected plants and the average value was recorded as per plant.

(a)

(b)

Plate 1. Photograph showing variation at (a) flowering stage and (b) ripening stage

vii. **Number of primary branches per panicle**

Primary branches were counted from one panicle of each of the randomly selected 10 plants and the average value was recorded.

viii. **Number of secondary branches per panicle**

Secondary branches were counted from one panicle of each of the randomly selected 10 plants and the average value was recorded.

ix. **Number of filled grains per panicle**

Presence of endosperm in spikelet was considered as filled grain and total number of filled grains present on main panicle was counted and average was taken.

x. **Number of unfilled grains per panicle**

Absence of endosperm in spikelet was considered as unfilled grain and total number of unfilled grains present on main panicle was counted and average was taken.

xi. **Total number of spikelet per panicle**

The total number of filled grains and unfilled grains were collected randomly from selected 10 plants of a plot and then average numbers of total spikelet per panicle was recorded.

xii. **Yield per plant (g)**

Grains obtained from each plant were sun dried and weighted carefully. The dry weight of gains per plant was then recorded.

xiii. **1000-seed weight (g)**

One thousand seeds were counted randomly from the total cleaned harvested seeds and then weighted in grams and recorded.

xiv. **Yield per hectare (t)**

Grains obtained from each unit plot were sun dried and weighted carefully and converted to ton per hectare.

3.4.10 Statistical analysis

All the collected data of the study were used to statistical analysis for each character, analysis of variance (ANOVA), mean, range were calculated by using MSTATC software program and then phenotypic and genotypic variance was estimated by the formula used by Johnson *et al.* (1955). Heritability and genetic advance were measured using the formula given by Singh and Chaudhary (1985) and Allard (1960).

Genotypic and phenotypic co-efficient of variation were calculated by the formula of Burton (1952). Genotypic and phenotypic correlation coefficient was obtained using the formula suggested by Miller *et al.* (1958) and Johnson *et al.* (1955); and path co-efficient analysis was done following the method outlined by Dewey and Lu (1959).

i. Estimation of genotypic and phenotypic variances

Genotypic and phenotypic variances were estimated according to the formula of Johnson *et al.* (1955).

a. **Genotypic variance,** $\delta^2 g = \frac{MSG - MSE}{r}$

Where, MSG = Mean sum of square for genotypes

MSE = Mean sum of square for error and

r = Number of replication

b. **Phenotypic variance,** $\delta^2 p = \delta^2 g + \delta^2 e$

Where, $\delta^2 g$ = Genotypic variance,

$\delta^2 g$ = Environmental variance = Mean square of error

ii. Estimation of genotypic and phenotypic co-efficient of variation

Genotypic and phenotypic co-efficient of variation were calculated by the following formula (Burton, 1952). The estimate of GCV and PCV were classified as low, medium and high (Sivasubramanian and Madhavamenon, 1973).

$$GCV = \frac{\delta_g \times 100}{\bar{x}}$$

$$PCV = \frac{\delta_p \times 100}{\bar{x}}$$

Where, GCV = Genotypic co-efficient of variation

PCV = Phenotypic co-efficient of variation

δ_g = Genotypic standard deviation

δ_p = Phenotypic standard deviation

$\bar{x}$ = Population mean

iii. **Estimation of heritability**

Broad sense heritability was estimated by the formula suggested by Singh and Chaudhary (1985). The heritability was categorized as suggested by Robinson *et al.* (1949).

$$h^2_b(\%) = \frac{\delta^2_g}{\delta^2_p} \times 100$$

Where, h^2_b = Heritability in broad sense

δ^2_g = Genotypic variance

δ^2_p = Genotypic variance

iv. **Estimation of genetic advance**

The following formula was used to estimate the expected genetic advance for different characters under selection as suggested by Allard (1960) and classified by adopting the method of Johnson *et al.* (1955).

$$GA = \frac{\delta^2_g}{\delta^2_p} . K . \delta_p$$

Where, GA = Genetic advance

δ^2_g = Genotypic variance

δ^2_p = Phenotypic variance

δ_p = Phenotypic standard deviation

K = Selection differential which is equal to 2.06 at 5% selection intensity.

v. **Estimation of genetic advance in percentage of mean**

Genetic advance in percentage of mean was calculated by the following formula given by Comstock and Robinson (1952).

$$\text{Genetic Advance in percentage of mean} = \frac{\text{Genetic advance}}{\bar{x}} \times 100$$

vi. Estimation of simple correlation co-efficient

Simple correlation co-efficient (r) was estimated with the following formula (Clarke, 1973; Singh and Chaudhary, 1985).

$$r = \frac{\sum xy - \frac{\sum x . \sum y}{N}}{\sqrt{[\{\sum x^2 - \frac{(\sum x)^2}{N}\}\{\sum y^2 - \frac{(\sum y)^2}{N}\}]}}$$

Where, $\sum$ = Summation

x and y are the two variables correlated

N = Number of observation

vii. Path co-efficient analysis

Path co-efficient analysis was done according to the procedure employed by Dewey and Lu (1959) also quoted in Singh and Chaudhary (1985), using simple correlation values. In path analysis, correlation co-efficient is partitioned into direct and indirect independent variables on the dependent variable.

In order to estimate direct & indirect effect of the correlated characters, say x1, x2 and x3 yield y, a set of simultaneous equations (three equations in this example) is required to be formulated as shown below:

$$r_{yx1} = P_{yx1} + P_{yx2}r_{x1x2} + P_{yx3}r_{x1x3}$$

$$r_{yx2} = P_{yx1}r_{x1x2} + P_{yx2} + P_{yx3}r_{x2x3}$$

$$r_{yx3} = P_{yx1}r_{x1x3} + P_{yx2}r_{x2x3} + P_{yx3}$$

Where, r's denotes simple correlation co-efficient and P's denote path co-efficient (Unknown). P's in the above equations may be conveniently solved by arranging them in matrix from.

Total correlation, say between x1 and y is thus partitioned as follows:

P_{yx1} = The direct effect of x1 on y.

$P_{yx2}r_{x1x2}$ = The indirect effect of x1 via x2 on y.

$P_{yx3}r_{x1x3}$ = The indirect effect of x1 via x3 on y.

After calculating the direct and indirect effect of the characters, residual effect (R) was calculated by using the formula given below (Singh and Chaudhary, 1985).

$$P^2_{RY} = 1 - \sum P_{iy} \cdot riy$$

Where, $P^2_{RY} = (R^2)$; and hence residual effect, $R = (P^2_{RY})^{1/2}$

P_{iy} = Direct effect of the character on yield

Riy = Correlation of the character with yield.

CHAPTER IV

RESULTS AND DISCUSSION

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The present study was conducted to determine the variability among 25 populations (F_4 generation) with their 4 checks of rice (*Oryza sativa* L.) and also to study the correlation and path co-efficient for seed yield and different yield contributing characters. The data were recorded on different characters such as days to flowering, days to maturity, plant height (cm), number of total tillers per plant, number of effective tillers per plant, panicle length (cm), number of primary branches per panicle, number of secondary branches per panicle, number of filled grains per panicle, number of unfilled grains per panicle, total number of spikelet per panicle, yield per plant (g), 1000-seed weight (g), yield per hectare (t). The data were statistically analyzed and thus obtained results are described below under the following heads:

- Variation of 25 populations and their 4 checks
- Genetic parameters
- Correlations
- Path co-efficient analysis

4.1 Variation of 25 populations and their 4 checks

The analysis of variance of 25 populations (F_4 generation) with their 4 checks of rice for yield related different characters are shown in Table 2. The analysis of variance for the characters indicated the existence of significant differences among the genotypes studied revealing that sufficient variability was present and selection would be effective to develop the varieties. Mean performance of those characters of individual genotypes with Duncan's Multiple Range Test (DMRT) are presented in Table 3.

Table 2. ANOVA for different characters of 4 checks and 25 populations (F_4 generation) of *Oryza sativa* L.

Source of Variation	df	Mean sum of squares												
		DF	DM	PH	NTT	NET	PL	NPB	NSB	NFG	NUFG	TNSP	YP	TSW
Replication	2	509.39	682.79	3965.35	83.3	88.6	205.18	50.72	322.08	13647.4	3.04	13568.4	419.12	51.12
Genotype	28	47.85**	215.11**	189.32**	8.44**	10.39**	8.67**	6.66**	265.57**	1031.20**	278.69**	1714.03**	42.00**	19.65**
Error	56	1.37	1.25	15.53	0.42	0.44	1.52	0.39	5.81	25.8	37.45	51.42	7.12	0.79
CV%		0.97	0.75	3.78	4.84	5.29	5.09	5.8	6.82	3.19	23.91	3.88	7.37	4.12

**** = Significant at 1% level of probability**

DF= Days to flowering, DM= Days to maturity, PH= Plant height (cm), NTT= Number of total tillers per plant, NET= Number of effective tillers per plant, PL=, Panicle length (cm) , NPB= Number of primary branches per panicle, NSB= Number of secondary branches per panicle, NFB= Number of filled grains per panicle, NUFB= Number of unfilled grains of per panicle, TNSP= Total number of spikelet per panicle, YP= Yield per plant (g), TSW=1000-seed weight (g), Y= Yield per hectare (t), CV (%) = Co-efficient of Variation, df=Degrees of freedom

Table 3. Mean performance of various growth parameter of 25 populations and 4 checks of *Oryza sativa* L.

Genotypes	DF	DM	PH	NTT	NET	PL	NPB
G1	118.00	145.70	119.90	13.37	12.80	23.35	13.30
G2	122.70	141.70	87.22	15.70	15.07	21.58	10.73
G3	125.30	160.70	101.40	13.50	12.90	27.29	11.77
G4	119.30	145.30	104.20	12.13	11.30	23.10	9.80
G5	123.30	150.30	106.30	13.80	12.63	23.23	10.60
G6	120.70	148.00	107.60	13.37	12.40	25.38	10.47
G7	123.00	150.30	108.90	15.80	14.67	26.28	11.27
G8	121.70	149.30	106.10	14.10	13.10	23.39	9.63
G9	123.00	148.30	113.70	12.23	11.67	26.72	9.83
G10	120.70	150.00	114.00	12.40	11.77	23.13	9.73
G11	119.00	151.30	112.20	12.20	11.13	23.70	10.20
G12	124.30	153.00	123.20	11.40	10.27	27.34	9.27
G13	121.00	147.00	112.40	13.07	12.70	24.10	11.03
G14	128.00	151.00	110.20	11.60	10.80	25.61	10.40
G15	117.30	145.70	94.39	13.53	12.63	26.29	11.77
G16	115.30	146.70	93.91	13.23	11.80	23.69	10.30
G17	116.70	147.00	104.60	11.17	10.70	25.32	10.23
G18	118.30	146.00	100.40	12.43	11.53	27.44	10.13
G19	120.70	146.30	99.48	13.37	12.57	24.40	11.27
G20	118.70	146.70	98.02	14.53	13.67	22.08	10.97
G21	116.70	147.30	96.73	13.17	12.53	21.92	9.43
G22	116.00	146.30	99.73	13.37	12.60	24.39	9.57
G23	120.30	146.70	102.30	12.77	12.23	22.40	10.47
G24	119.70	146.70	95.06	12.97	12.00	23.42	12.53
G25	116.00	147.30	101.30	15.10	14.23	23.37	9.30
G26	117.70	144.00	100.80	15.27	14.37	24.08	12.13
G27	119.00	144.70	102.80	13.37	12.57	22.70	12.60
G28	120.70	147.00	102.70	15.07	14.43	22.62	11.63
G29	117.30	147.70	104.00	13.27	12.43	23.67	12.40
Max	128.00	160.70	123.20	15.80	15.07	27.44	13.30
Min	115.30	141.70	87.22	11.17	10.27	21.58	9.27
Mean	120.01	147.86	104.26	13.35	12.53	24.21	10.79
SD	3.63	3.47	12.25	2.01	2.06	3.83	1.95
SE	0.68	0.64	2.28	0.37	0.38	0.71	0.36

DF= Days to flowering, DM= Days to maturity, PH= Plant height (cm), NTT= Number of total tillers per plant, NET= Number of effective tillers per plant, PL=, Panicle length (cm), NPB= Number of primary branches per panicle

Table 3 (Cont'd). Mean performance of various growth parameter of 25 populations and 4 checks of *Oryza sativa* L.

Genotypes	NSB	NFG	NUFG	TNSP	YP	TSW	Y
G1	30.77	146.10	20.13	166.20	35.65	23.00	7.44
G2	23.10	119.40	18.60	138.00	34.04	23.33	7.48
G3	39.93	158.80	36.13	194.90	34.20	19.00	7.03
G4	30.20	147.60	16.43	164.00	29.58	22.00	7.72
G5	32.53	152.60	21.63	174.20	35.79	20.33	7.99
G6	39.43	176.20	18.07	194.20	39.23	20.67	8.29
G7	35.80	160.60	21.87	182.50	37.06	19.00	7.59
G8	35.03	163.20	11.73	174.90	38.43	19.33	8.84
G9	38.83	182.80	21.97	204.80	36.47	19.33	8.78
G10	29.50	151.00	10.93	162.00	35.75	24.00	8.15
G11	31.87	153.70	13.47	167.10	35.43	23.67	8.28
G12	31.33	151.70	17.13	168.80	36.13	22.33	8.34
G13	28.57	153.80	11.00	164.80	40.76	26.00	7.83
G14	27.33	135.70	15.97	151.70	31.33	24.00	7.77
G15	37.50	173.00	30.77	203.80	38.81	22.67	8.72
G16	39.47	185.00	24.00	209.00	36.55	21.33	8.32
G17	38.70	163.60	33.93	197.50	30.26	21.33	8.28
G18	39.10	189.60	34.03	223.60	38.20	22.67	8.67
G19	40.03	176.80	29.47	206.20	40.22	19.33	8.60
G20	43.00	180.10	35.80	215.90	39.06	20.33	8.60
G21	33.07	146.20	29.30	175.50	33.79	22.00	8.09
G22	36.43	158.60	23.63	182.20	38.08	23.00	8.48
G23	36.67	150.40	35.60	186.00	32.79	22.00	8.71
G24	39.27	180.70	29.70	210.40	41.48	23.00	8.59
G25	36.53	139.70	38.80	178.50	32.85	21.00	8.18
G26	39.43	164.20	26.93	191.10	42.90	21.00	8.73
G27	36.33	144.90	43.87	188.70	36.26	21.67	8.87
G28	35.90	142.00	44.60	186.60	33.17	19.67	8.34
G29	39.02	167.30	26.83	194.10	35.32	19.33	9.62
Max	43.00	189.60	44.60	223.60	42.90	26.00	9.62
Min	23.10	119.40	10.93	138.00	29.58	19.00	7.03
Mean	35.33	159.15	25.60	184.73	36.19	21.60	8.29
SD	7.49	15.79	19.03	22.29	8.30	2.77	1.92
SE	1.39	2.93	3.53	4.14	1.54	0.51	0.36

NFB= Number of filled grains per panicle, NUFB= Number of unfilled grains of per panicle, TNSP= Total number of spikelet per panicle, YP= Yield per plant (g), TSW=1000-seed weight (g), Y= Yield per hectare (t)

4.1.1 Days to flowering

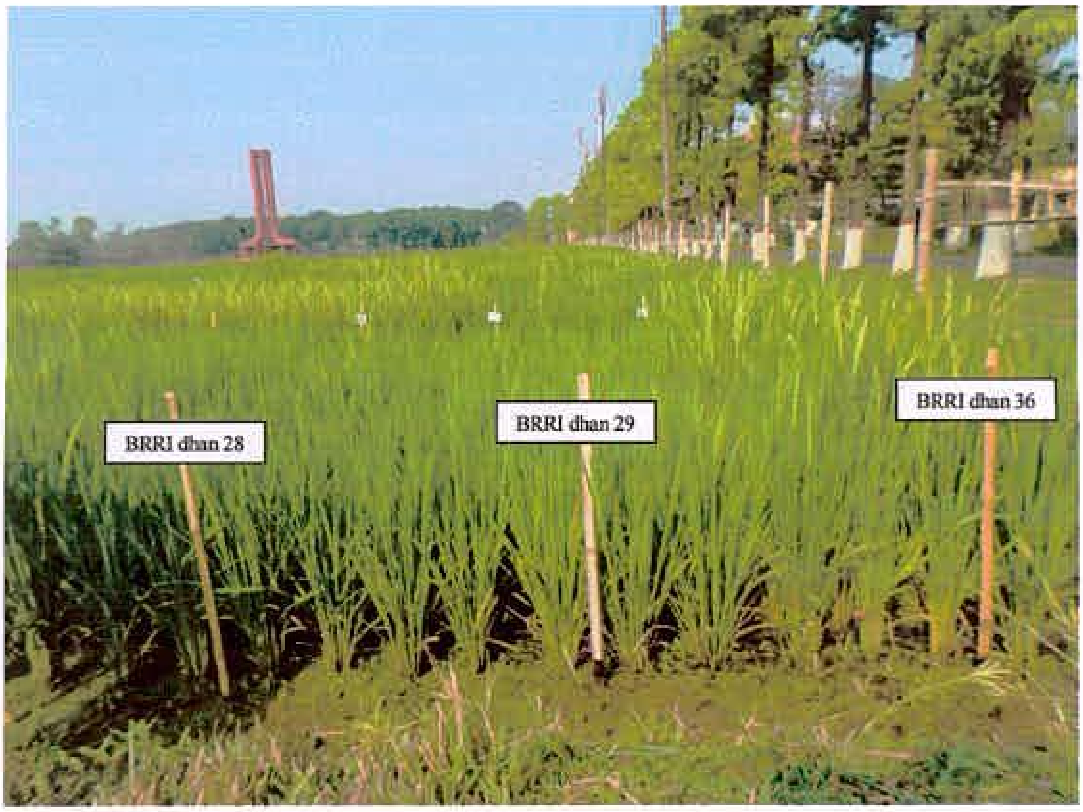
In this study out of 25 populations G14 (BR 26×BRRI dhan 36, S7P6) took the longest period (128 days) for days to flowering which was higher than their checks, as their checks BR 26 and BRRI dhan 36 took 118 days and 119.30 days for flowering respectively. G14 also took higher days to flowering than other two checks BRRI dhan 28 (122.70 days) and BRRI dhan 29 (125.30 days). G16 (BRRI dhan 28×BRRI dhan 29, S2P3) took minimum days (115.30 days) for flowering which was lower than all checks. G16, G17, G21, G22, G25, G26 and G29 also took lower days to flowering than all checks. G18 & G20 were close to BR 26, G9 was close to BRRI dhan 28 and G11, G24 & G27 were close to BRRI dhan 36. The rest of the populations are presented in Table 3. Variation at panicle initiation among check and between populations is presented in Plate 2.

4.1.2 Days to maturity

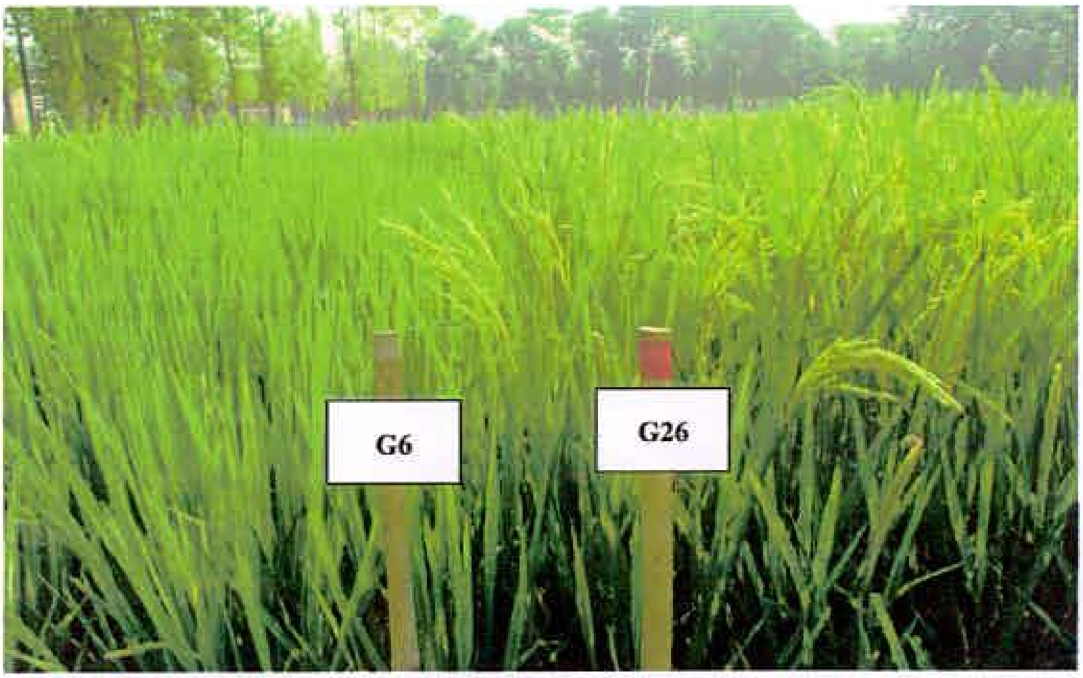
The study showed that the highest number of days to maturity (153.00 days) was recorded in G12 (BR 26×BRRI dhan 36, S7P3) which was higher than their checks, as their checks BR 26 and BRRI dhan 36 took 145.70 days and 145.30 days for maturity respectively. G12 was also higher than BRRI dhan 28 (141.70 days) but it was lower than BRRI dhan 29 (160.70 days) for days to maturity. G26 (BRRI dhan 29×BRRI dhan 36, S5P5) took minimum days (144.00 days) for maturity which was lower than BR 26, BRRI dhan 29 & BRRI dhan 36 but higher than BRRI dhan 28. G16, G18, G19, G20, G22, G23 and G24 were close to every other. The rest of the populations are presented in Figure 1 and Table 3.

4.1.3 Plant height (cm)

In this study the highest plant height (123.20 cm) was recorded in G12 (BR 26×BRRI dhan 36, s7 p3) which was longer than their checks, as their checks BR 26 and BRRI dhan 36 had 119.90 cm and 104.20 cm plant height respectively. G12 also took longer plant height than other two checks BRRI dhan 28 (87.28 cm) and BRRI dhan 29 (101.40 cm). The minimum plant height (93.91 cm) was recorded in G16 (BRRI dhan 28×BRRI dhan 29, s2 p3) which was shorter than BR 26, BRRI dhan 29 & BRRI dhan 36 but longer than BRRI dhan 28. G15, G19, G20, G21, G22 and G24 were also shorter than all checks studied here except BRRI dhan 28.



(a)



(b)

Plate 2. Photograph showing variation at panicle initiation (a) among check and (b) between populations in field

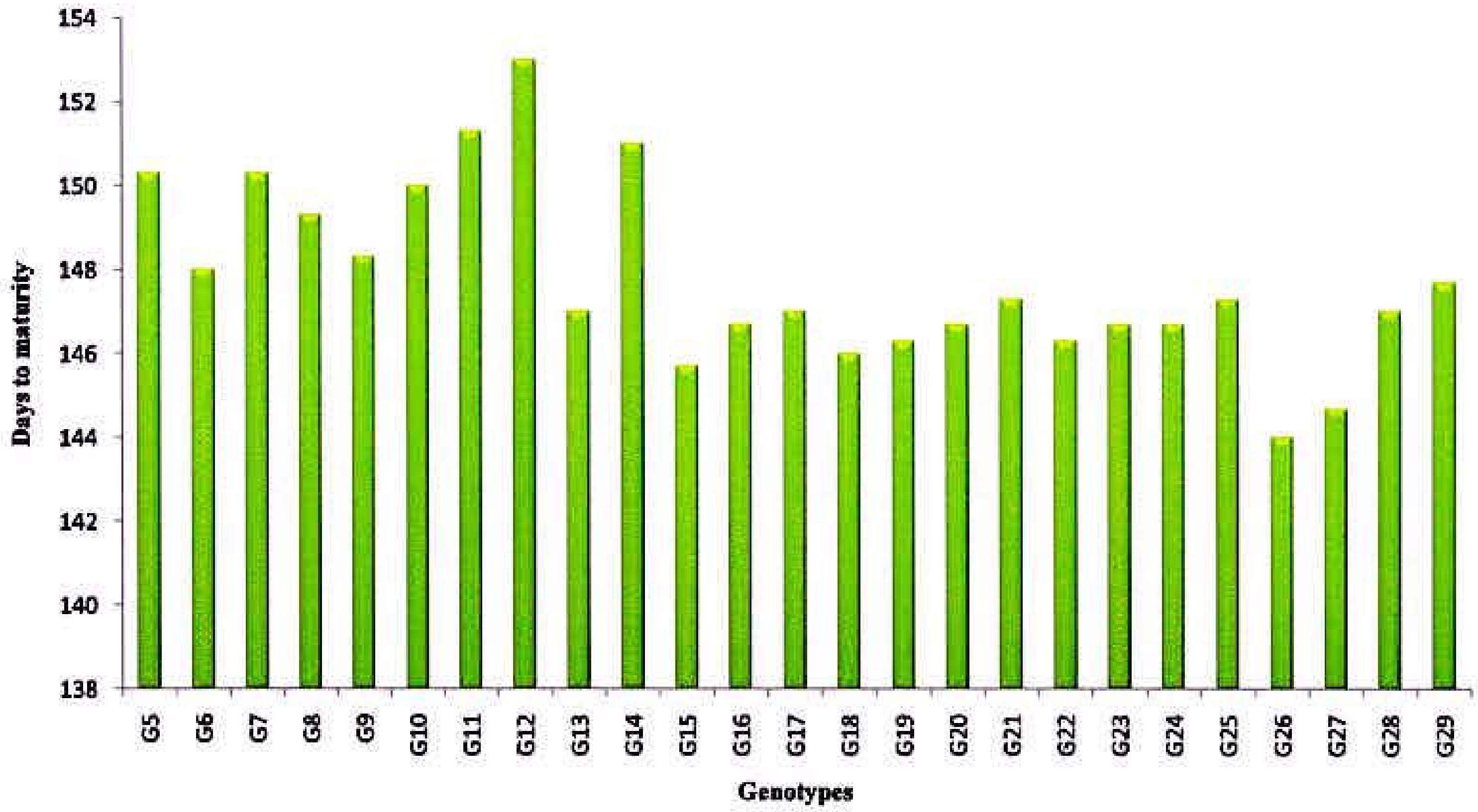


Figure 1. Mean performance of 25 populations on days to maturity

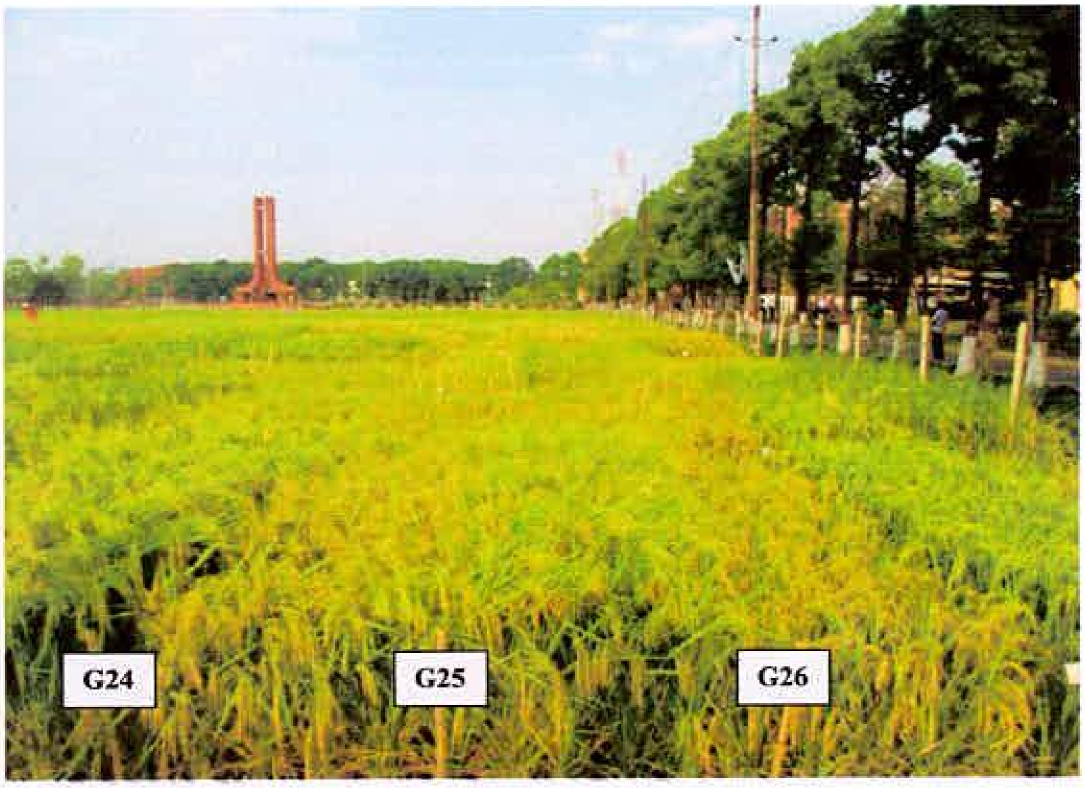


Plate 3. Photograph showing variation at maturity stage in experimental field

4.1.4 Number of total tillers per plant

In this study the highest number of total tillers per plant (15.80) was recorded in G7 (BR 26×BRRI dhan 29, S1P7) which was higher than their checks, as their checks BR 26 and BRRI dhan 29 had 13.37 and 13.50 total tillers per plant respectively. G7 also had higher number of total tillers per plant than other two checks BRRI dhan 28 (15.70) and BRRI dhan 36 (12.13). Minimum number of total tillers per plant (11.17) was recorded in G17 (BRRI dhan 28×BRRI dhan 29, S2P4) which was lower than all checks. G12, G14 and G17 had lower number of total tillers per plant than 4 checks studied here. G6, G19, G22, G27 and G29 were close to BR 26. The rest of the populations showed different number of tillers per plant (Table 3).

4.1.5 Number of effective tillers per plant

The highest number of effective tillers per plant (14.67) was recorded in G7 (BR 26×BRRI dhan 29, S1P7) which was higher than their checks, as their checks BR 26 and BRRI dhan 29 had 12.80and 12.90 number of effective tillers per plant respectively. G7 also had higher number of effective tillers per plant than BRRI dhan 36 (11.30) but lower than BRRI dhan 28 (15.07). Minimum number of effective tillers per plant (10.27) was recorded in G12 (BR 26×BRRI dhan 36, S7P3) which was lowerr than all checks. G12, G14 and G17 had lower number of total tillers per plant than 4 checks studied here. The rest of the populations showed different number of effective tillers per plant (Figure 2 and Table 3).

4.1.6 Panicle length (cm)

The highest panicle length (27.44 cm) was recorded in G18 (BRRI dhan 28×BRRI dhan 29, S2P5) which was higher than their checks, as their checks BRRI dhan 28 and BRRI dhan 29 had 21.58 cm and 27.29 cm panicle length respectively. G18 also had higher number of panicle length than BR 26 (23.35 cm) and BRRI dhan 36 (23.10 cm). Minimum panicle length (21.92 cm) was recorded in G21 (BRRI dhan 28×BRRI dhan 36, S7P2) which was lower than BR 26, BRRI dhan 29 & BRRI dhan 36 but higher than BRRI dhan 28. G12 and G18 had higher penicle length than 4 checks studied here. G8, G24 and G25 were close to BR 26. The rest of the populations showed different panicle length (Figure 3 and Table 3).

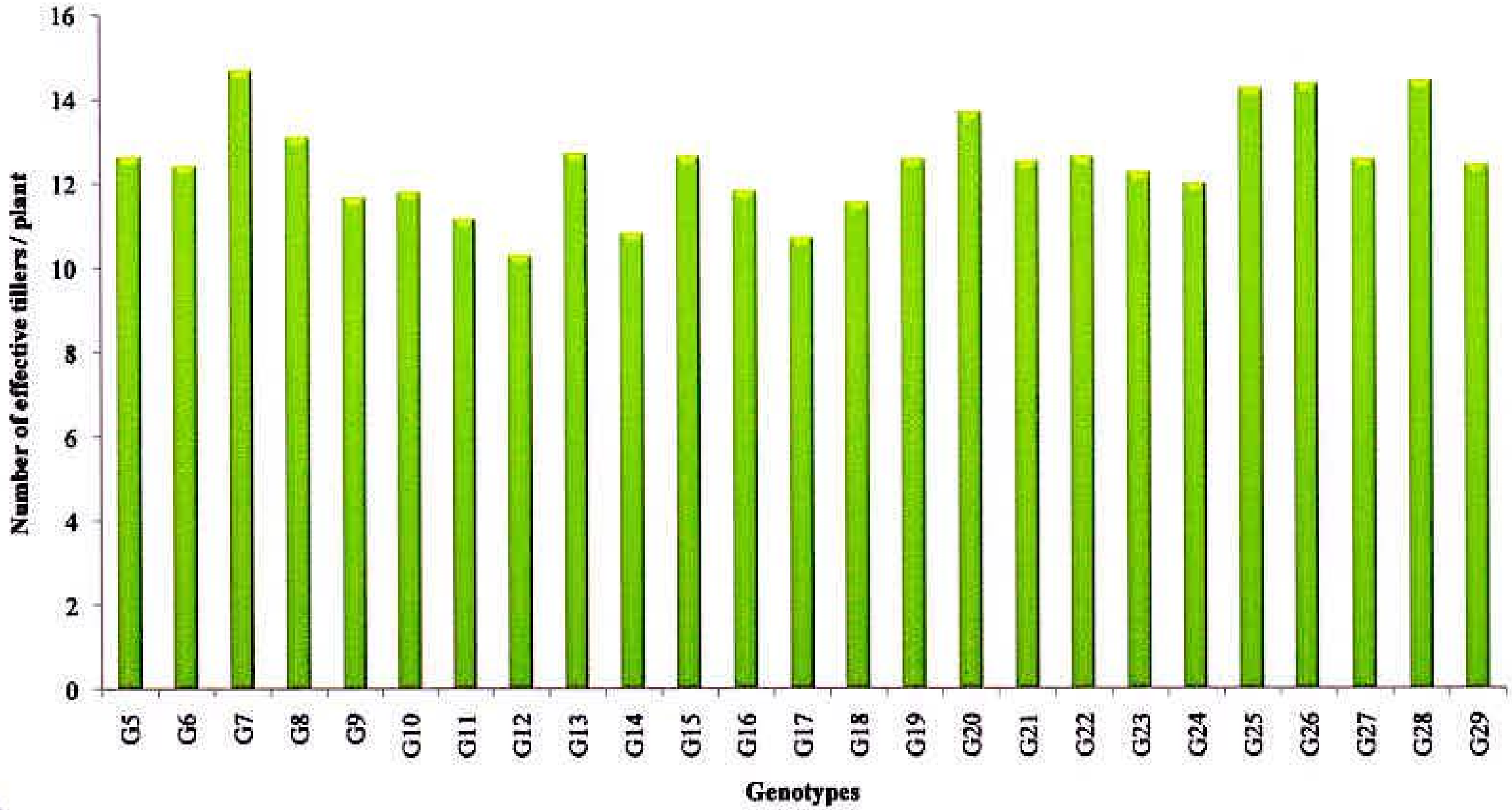


Figure 2. Mean performance of 25 populations on number of effective tillers per plant

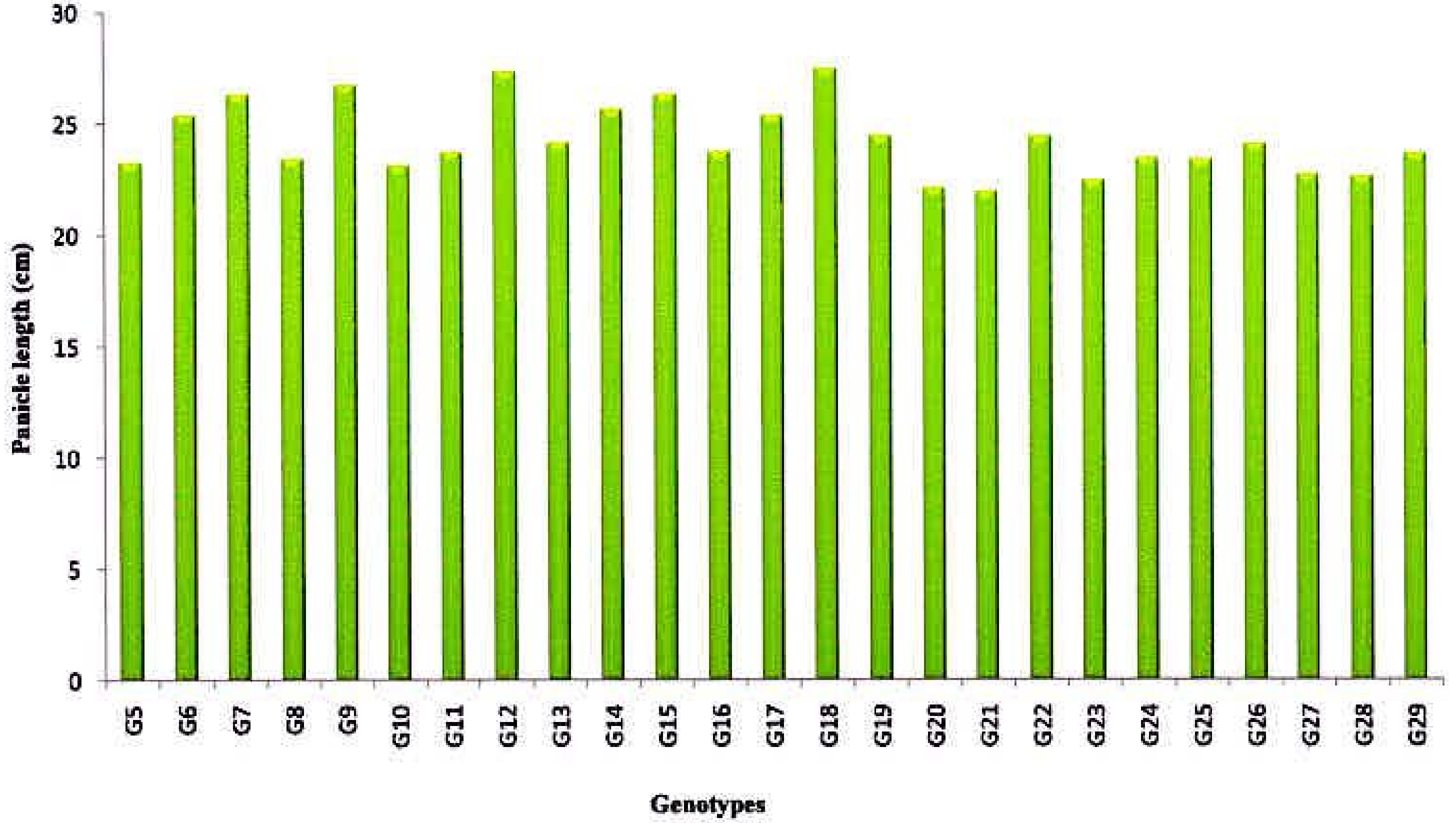


Figure 3. Mean performance of 25 populations on panicle length

4.1.7 Number of primary branches per panicle

The highest number of primary branches per panicle (12.60) was recorded in G27 (BRRI dhan 29×BRRI dhan 36, S5P7) which was higher than their checks, as their checks BRRI dhan 29 and BRRI dhan 36 had 11.77 and 9.80 number of primary branches per panicle respectively. G27 also had higher number of primary branches per panicle than BRRI dhan 28 (10.73) but lower number of primary branches per panicle than BR 26 (13.30). Minimum number of primary branches per panicle (9.27) was recorded in G12 (BR 26×BRRI dhan 36, S7P3) which was lower than all checks. G8, G10, G12, G21 and G25 had lower number of primary branches per panicle then all checks studied here. G5 &G20 close to BRRI dhan 28 and G15 & G28 were close to BRRI dhan 29 (Table 3).

4.1.8 Number of secondary branches per panicle

The highest number of secondary branches per panicle (43) was recorded in G20 (BRRI dhan 28×BRRI dhan 36, S7P1)) which was higher than their checks, as their checks BRRI dhan 28 and BRRI dhan 36 had 23.10 and 30.20 number of secondary branches per panicle respectively. G20 had higher number of secondary branches per panicle than BR 26 (30.77) & BRRI dhan 29 (39.93). Minimum number of secondary branches per panicle (27.33) was recorded in G14 (BR 26×BRRI dhan 36, S7P6) which was lower than all checks except BRRI dhan 28. G19 and G20 had higher secondary branches per panicle than all checks studied here. Except G5, G10, G13 & G14, rests were higher than BR 26, BRRI dhan 28 and BRRI dhan 36 (Table 3).

4.1.9 Number of filled grains per panicle

The highest number filled grains per panicle (189.60) was recorded in G18 (BRRI dhan 28×BRRI dhan 29, S2P5) which was higher than their checks, as their checks BRRI dhan 28 and BRRI dhan 29 had 119.40 and 158.80 number of filled grains per panicle respectively. G18 also had higher number of filled grains per panicle than BR 26 (146.10) & BRRI dhan 36 (147.60). Minimum number of filled grains per panicle (135.70) was recorded in G14 (BR 26×BRRI dhan 36, S7P6) which was lower than all checks except BRRI dhan 28. G7, G8, G9, G15, G16, G17, G18, G19, G20, G24, G26 and G29 had higher number of filled grains than all checks studied here (Figure 4 and Table 3).

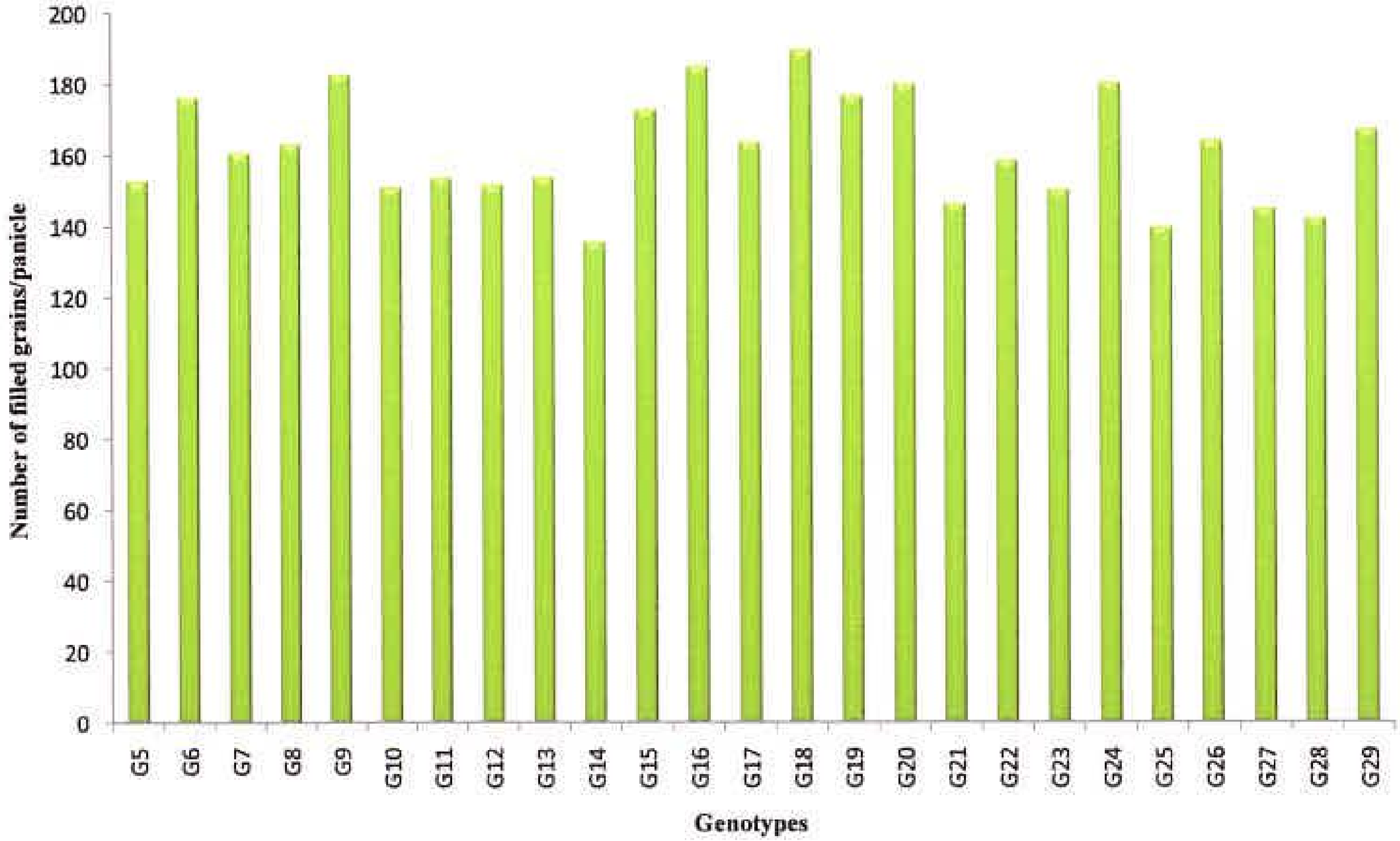


Figure 4. Mean performance of 25 populations on number of filled grains per panicle

4.1.10 Number of unfilled grains per panicle

The highest number unfilled grains of per panicle (44.60) was recorded in G28 (BRRI dhan 29×BRRI dhan 36, S5P9) which was higher than their checks, as their checks BRRI dhan 29 and BRRI dhan 36 had 36.13 and 16.43 number of unfilled grains per panicle respectively. G28 also had higher number of filled grains per panicle than BR 26 (20.13) & BRRI dhan 28 (18.60). Minimum number of unfilled grains per panicle (10.93) was recorded in G10 (BR 26×BRRI dhan 36, S7P1) which was lower than all checks. G10, G11 & G13 had lower and G25, G27 & G28 had higher number of unfilled grains per panicle then their checks. Rest of the populations showed different number of unfilled grains per panicle (Table 3).

4.1.11 Total number of spikelet per panicle

The highest number of total spikelet per panicle (223.60) was recorded in G18 (BRRI dhan 28×BRRI dhan 29, S2P5) which was higher than their checks, as their checks BRRI dhan 28 and BRRI dhan 29 had 138 and 194 number of total spikelet per panicle respectively. G18 also had higher number of total spikelet per panicle than BR 26 (166.20) & BRRI dhan 36 (164). Minimum number of spikelet per panicle (151.70) was recorded in G14 (BR 26×BRRI dhan 36, S7P6) which was lower than all checks except BRRI dhan 28. G9, G15, G16, G19 and G20 also had higher number of total spikelet per panicle than 4 checks studied here. Rest of the populations showed different number of total spikelet per panicle (Figure 5 and Table 3).

4.1.12 Yield per plant (g)

The highest number of yield per plant (42.90 g) was recorded in G26 (BRRI dhan 29×BRRI dhan 36, S5P5) which was higher than their checks, as their checks BRRI dhan 29 and BRRI dhan 36 had 34.20 g and 29.58 g yield per plant respectively. G26 also had higher yield per plant than BR 26 (35.65 g) & BRRI dhan 28 (34.04 g). Minimum number of yield per plant (30.26 g) was recorded in G17 (BRRI dhan 28×BRRI dhan 29, S2P4) which was lower than all checks except BRRI dhan 36. Most of the genotypes showed higher yield per plant than their checks (Figure 6 and Table 3).

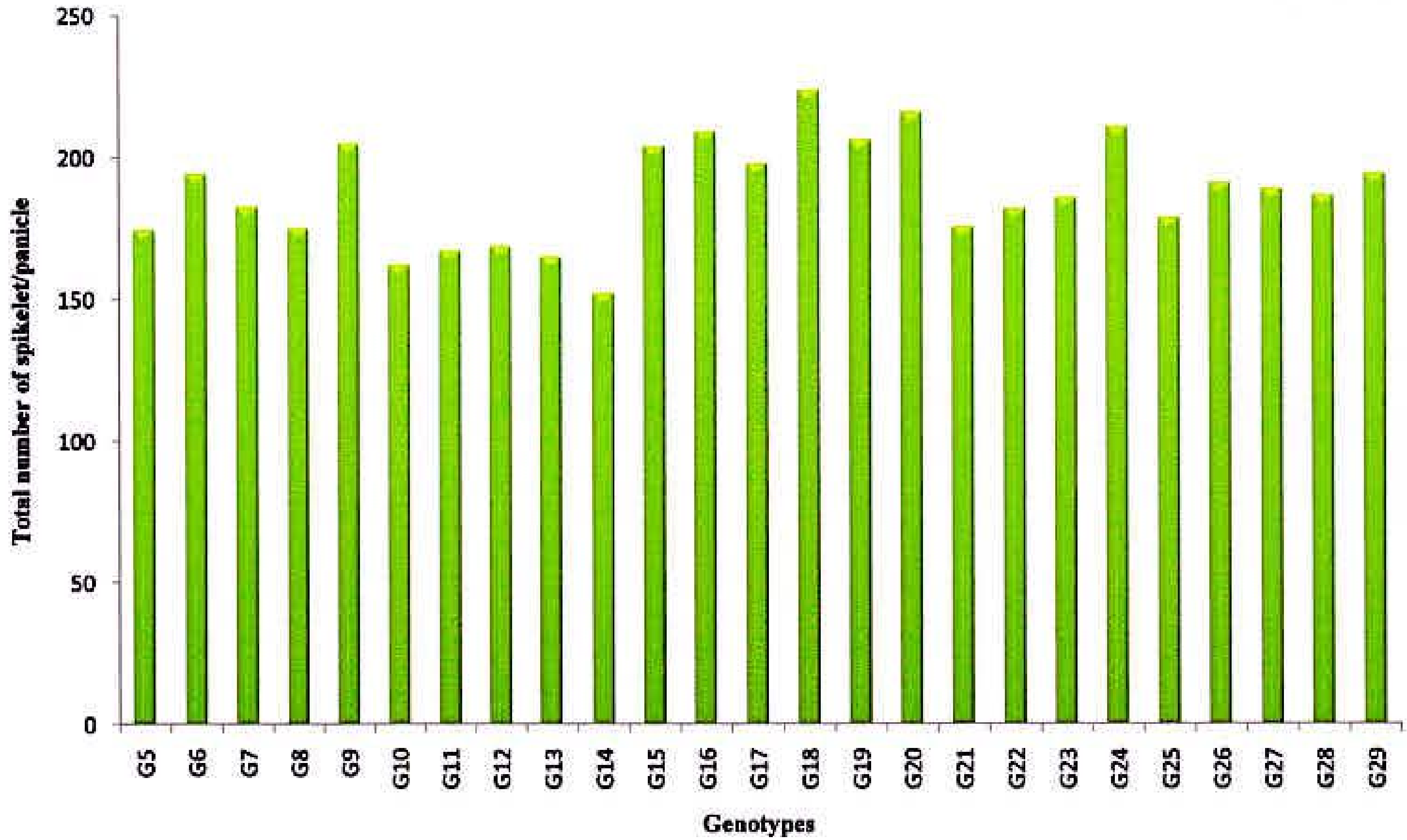


Figure 5. Mean performance of 25 populations on total number of spikelet per panicle

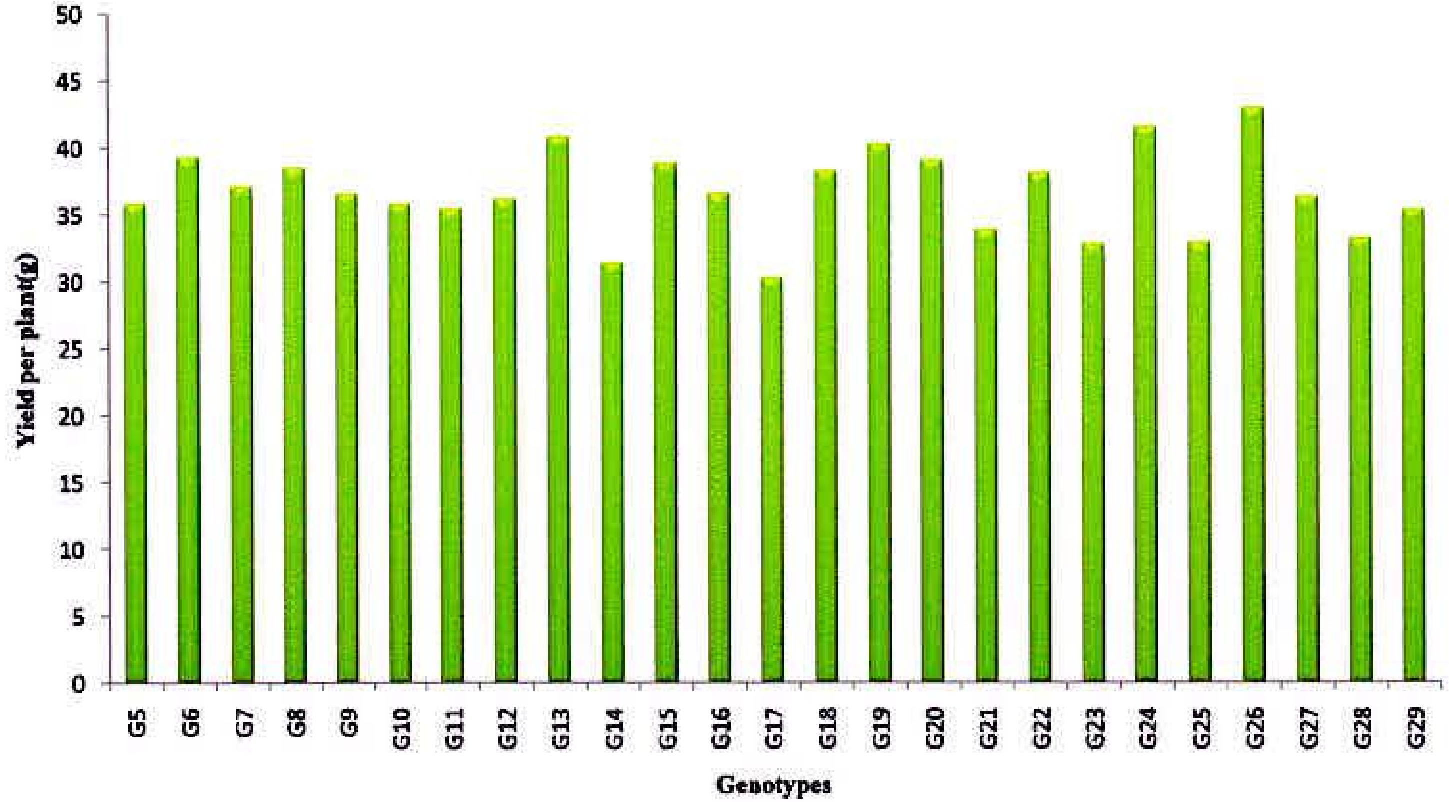


Figure 6. Mean performance of 25 populations on yield per plant (g)

4.1.13 1000-seed weight (g)

The highest number of 1000-seed weight (26 g) was recorded in G13 (BR 26×BRRI dhan 36, S7P4) which was higher than their checks, as their checks BR 26 and BRRI dhan 36 had 23 g and 22 g 1000-seed weight respectively. G13 also had higher 1000-seed weight than BRRI dhan 28 (23.33 g) & BRRI dhan 29 (19 g). Minimum number of 1000-seed weight (19.00 g) was recorded in G7 (BR 26×BRRI dhan 29, S1P7) which was same as BRRI dhan 29 but lower than other checks. G10, G11, G13 and G14 had higher 1000-seed weight than all their checks studied here. G22 & G24 close to BR 26, G7 close to BRRI dhan 29 and G21 & G23 close to BRRI dhan 36. Rest of the populations showed different number of 1000-seed weight (Figure 7 and Table 3).

4.1.14 Yield per hectare (t)

The highest number of yield per hectare (9.62 t) was recorded in G29 (BRRI dhan 29×BRRI dhan 36, S5P10)) which was higher than their checks, as their checks BRRI dhan 29 and BRRI dhan 36 had 7.03 t and 7.72 t yield per hectare respectively. G29 also had higher yield per hectare than BR 26 (7.44 t) & BRRI dhan 28 (7.48 t). Minimum number of yield per hectare (7.59 t) was recorded in G7 (BR 26×BRRI dhan 29, S1P7) which was lower than BRRI dhan 36 but higher than their checks. Except G7, all genotypes had higher yield per hectare than their checks. Rest of the populations showed different number yield (Figure 8 and Table 3).

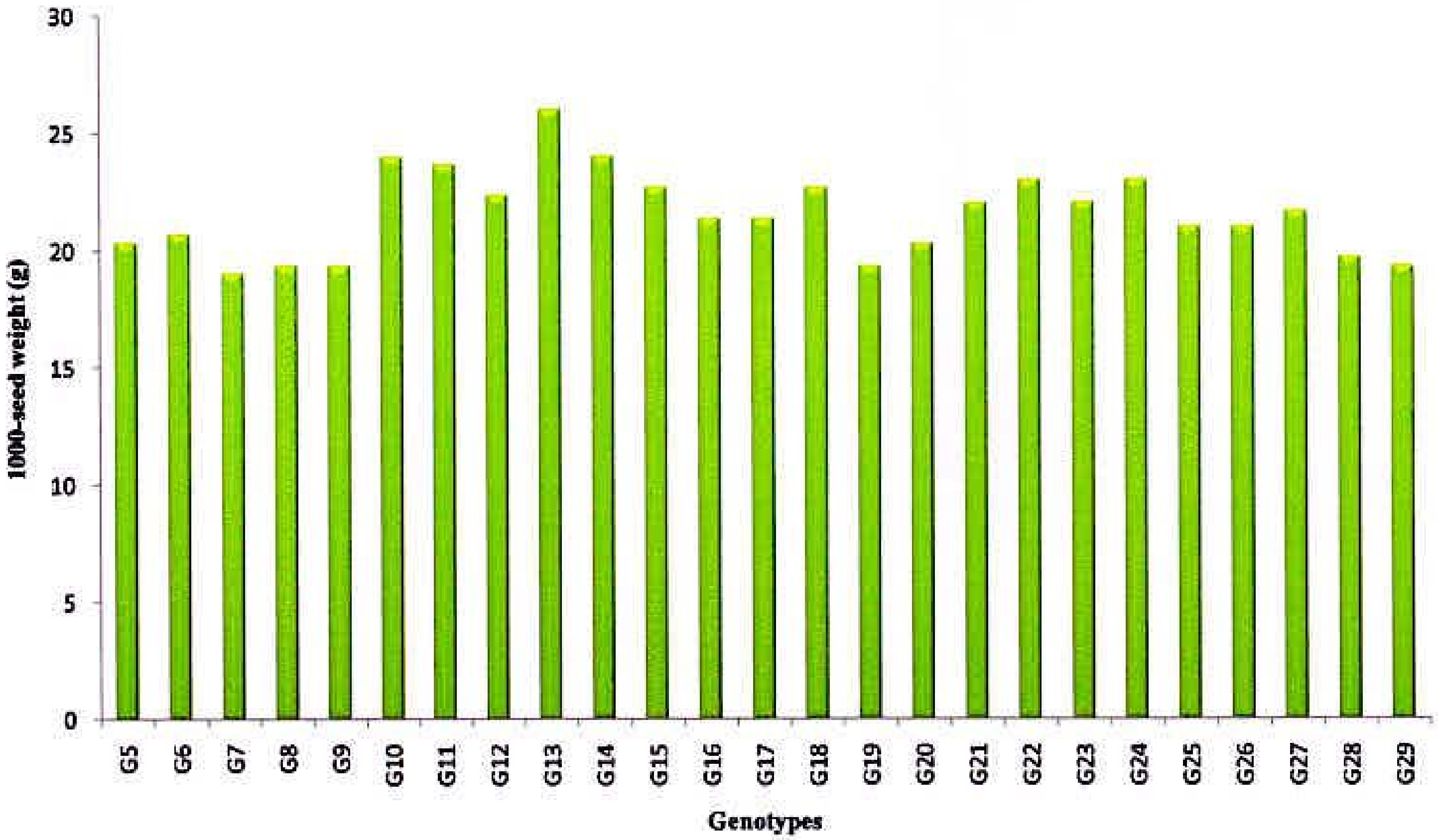


Figure 7. Mean performance of 25 populations on 1000-seed weight (g)

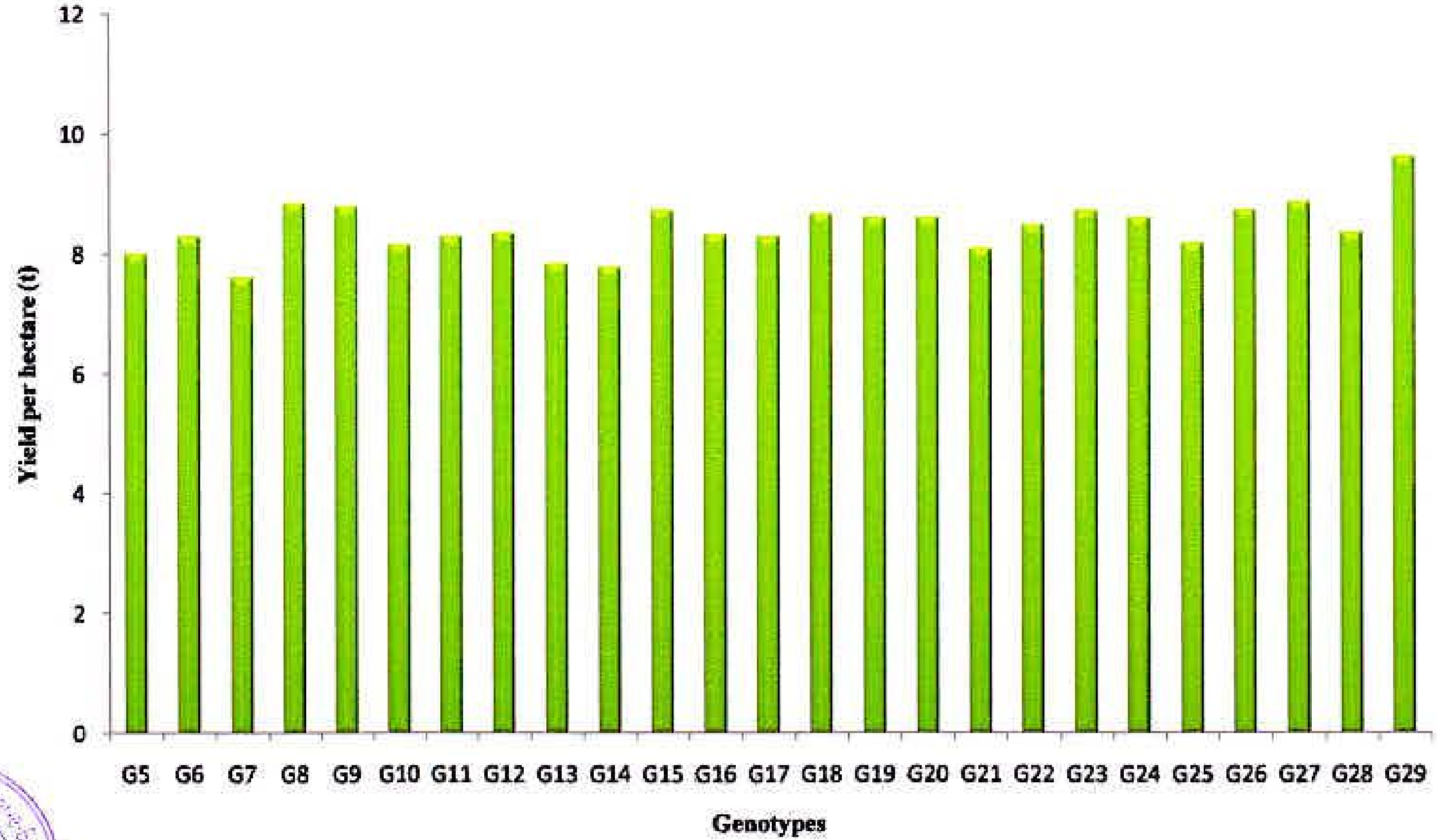


Figure 8. Mean performance of 25 populations on yield per hectare (t)

4.2 Genetic parameters

The genotypic variance (σ^2g), phenotypic variance (σ^2p) and environmental variance (σ^2e), genotypic co-efficient of variation (GCV), phenotypic co-efficient of variation (PCV), environmental co-efficient of variation (ECV), genetic advance and genetic advance in percent mean (GA %) for all the quantitative characters under study are presented in Table 4a & 4b and Figure 9 and 10. The difference between genotypic and phenotypic co-efficient of variation was less for all characters studied except panicle length and number of unfilled grains per panicle, indication of the more influence of the environment over this two characters. The slight difference between GCV and PCV was also reported by Mustafa and Elsheikh (2007), Kole *et al.* (2008) and Seyoum *et al.* (2012).

4.2.1 Days to flowering

The genotypic variance (15.49) and phenotypic variance (16.86) were close to each other, indicating least environmental effect for the expression of the character and genetic factor had significant expressivity on the days to flowering. GCV (3.28%) and PCV (3.42%) were low for days to flowering in the present study (Table 4a & Figure 9). There was a little difference between GCV and PCV on this character. Such values of GCV with least difference were also observed by Padmaja *et al.* (2008) for days to flowering. It showed high heritability (91.89%) and low genetic advance (6.48%) (Table 4b and Figure 10) suggesting that this trait had greater influence of non-additive gene action with a big role of non-genetic factors in their expression. High heritability also found by Sarma *et al.* (2004).

4.2.2 Days to maturity

The genotypic variance (12.54) and phenotypic variance (11.29) were close to each other, indicating least environmental effect for the expression of the character and genetic factor had significant expressivity on the days to maturity. GCV (2.27%) and PCV (2.39%) were low for days to flowering in the present study (Table 4a and Figure 9). There was a little difference between GCV and phenotypic co-efficient of variance on this character. Similar findings were reported by Balan *et al.* (1999) for days to maturity. It showed high heritability (90.03%) coupled with low genetic

Table 4a. Estimation of genetic parameters of 25 populations (F_4 generation) with their 4 checks in rice (*Oryza sativa* L.)

Parameters	Max	Min	Mean	MS	σ^2p	σ^2g	σ^2e
DF	128	115.3	120.01	47.85**	16.86	15.49	1.37
DM	160.7	141.7	147.86	35.107**	12.54	11.29	1.25
PH	123.2	87.22	104.26	189.32**	73.46	57.93	15.53
NTT	15.8	11.17	13.35	8.44**	3.09	2.68	0.42
NET	15.07	10.27	12.53	10.39**	3.76	3.32	0.44
PL	27.44	21.58	24.21	8.67**	3.90	2.39	1.52
NPB	13.3	9.27	10.79	6.66**	2.48	2.09	0.39
NSB	43	23.1	35.33	265.57**	92.39	86.59	5.81
NFG	189.6	119.4	159.15	1031.20**	360.93	335.13	25.80
NUFG	44.6	10.93	25.6	278.69**	117.86	80.41	37.45
TNSP	223.6	138	184.73	1714.03**	605.62	554.20	51.42
YP	42.9	29.58	36.19	42.00**	18.75	11.63	7.12
TSW	26	19	21.6	19.65**	7.08	6.29	0.79
Y	9.62	7.03	8.29	5.87**	2.21	1.83	0.38

**** Significant at 1% level of probability**

DF= Days to flowering, DM= Days to maturity, PH= Plant height (cm), NTT= Number of total tillers per plant, NET= Number of effective tillers per plant, PL=Panicle length (cm), NPB= Number of primary branches per panicle, NSB= Number of secondary branches per panicle, NFB= Number of filled grains per panicle, NUFB= Number of unfilled grains of per panicle, TNSP= Total number of spikelet per panicle, YP= Yield per plant (g), TSW=1000-seed weight (g), Y=Yield per hectare (t), MS= Mean sum of squire

Table 4b. Estimation of genetic parameters of 25 populations (F_4 generation) with their 4 checks in rice (*Oryza sativa* L.)

Parameters	PCV (%)	GCV (%)	ECV (%)	Heritability (%)	Genetic advance (5%)	Genetic advance (% mean)
DF	3.42	3.28	0.97	91.89	7.77	6.48
DM	2.39	2.27	0.76	90.03	6.57	4.44
PH	8.22	7.3	3.78	78.86	13.92	13.35
NTT	13.17	12.25	4.84	86.49	3.13	23.46
NET	15.46	14.53	5.29	88.31	3.53	28.13
PL	8.16	6.38	5.09	61.15	2.49	10.28
NPB	14.6	13.4	5.81	84.2	2.73	25.33
NSB	27.2	26.34	6.82	93.72	18.56	52.52
NFG	11.94	11.5	3.19	92.85	36.34	22.83
NUFG	42.41	35.03	23.91	68.23	15.26	59.61
TNSP	13.32	12.74	3.88	91.51	46.39	25.11
YP	11.96	9.42	7.37	62.01	5.53	15.28
TSW	12.32	11.61	4.13	88.79	4.87	22.53
Y	17.94	16.32	7.46	82.72	2.53	30.57

DF= Days to flowering, DM= Days to maturity, PH= Plant height (cm), NTT= Number of total tillers per plant, NET= Number of effective tillers per plant, PL=Panicle length (cm) , NPB= Number of primary branches per panicle, NSB= Number of secondary branches per panicle, NFB= Number of filled grains per panicle, NUFB= Number of unfilled grains of per panicle, TNSP= Total number of spikelet per panicle, YP= Yield per plant (g), TSW=1000-seed weight (g), Y= Yield per hectare (t)

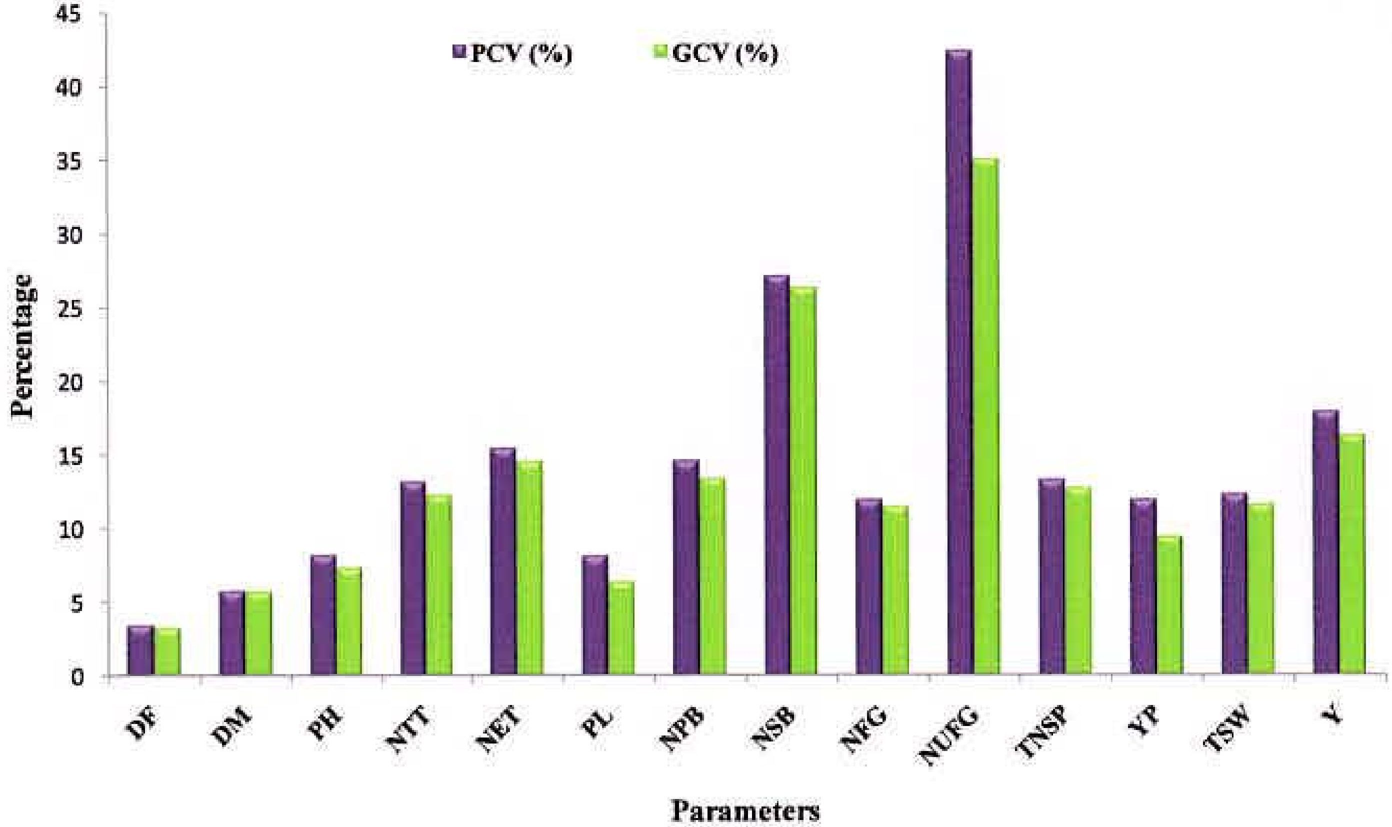


Figure 9. Genotypic and phenotypic co-efficient of variation in *Oryza sativa* L.

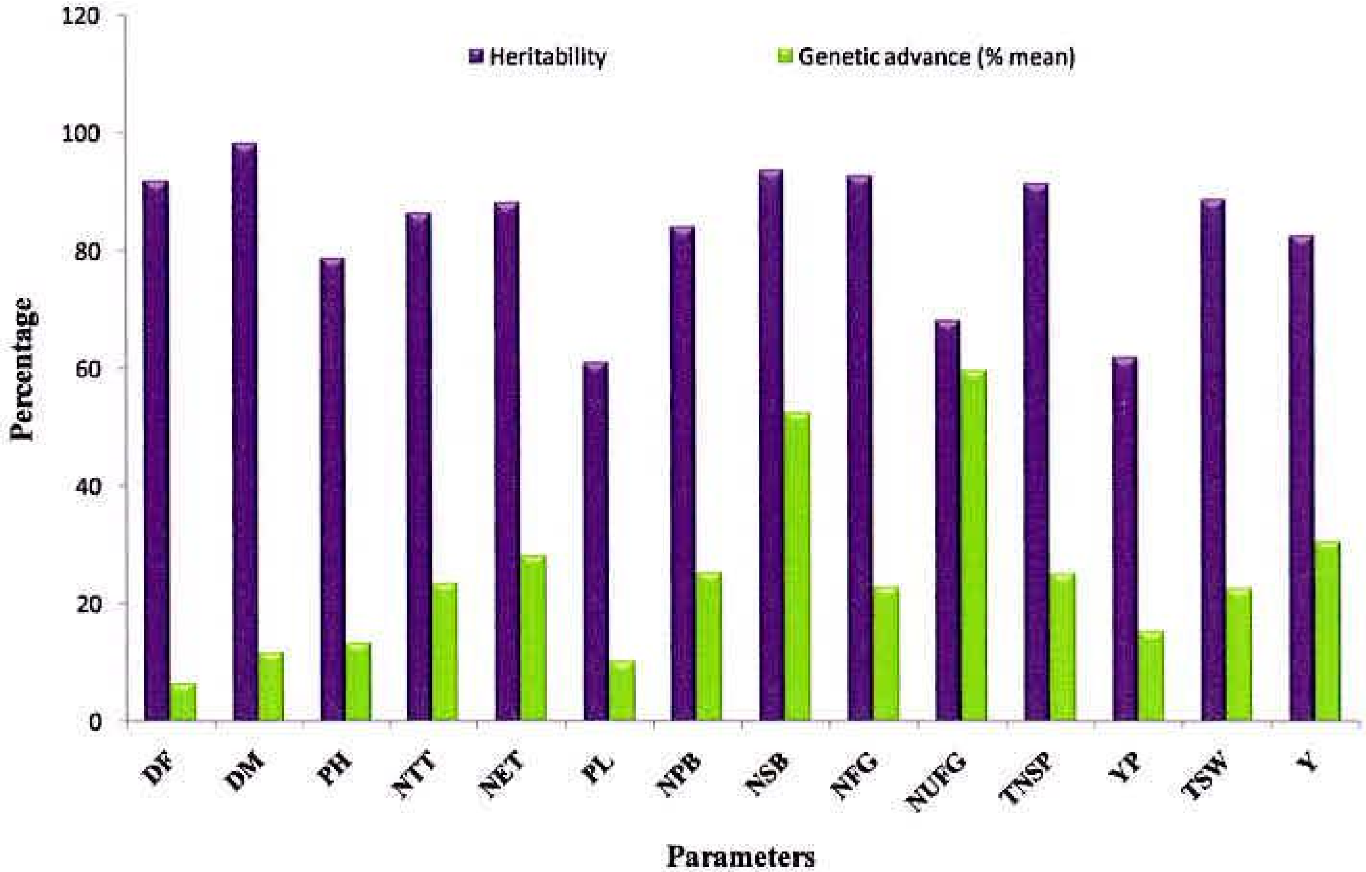


Figure 10. Heritability and genetic advance over mean in *Oryza sativa* L.

advance (4.44%) in percent mean (Table 4b and Figure 10) which indicated that the character was governed by non-additive gene action with a big role of non-genetic factors in their expression. So, there is a lot of scope for the improvement of this character through selection. Gomathinayagam *et al.* (1990) and Karim *et al.* (2007) showed high heritability and low genetic advance for days to maturity.

4.2.3 Plant height (cm)

The phenotypic variance (73.46) was higher than genotypic variance (57.93) indicating that environmental had played a significant role for the expression of the plant height. The low GCV (7.30%) and PCV (8.22%) with considerable difference between them indicated little environmental influence in the expression of this character (Table 4a and Figure 9). Kole *et al.* (2008) observed low GCV and PCV with little difference between them. But Seyoum *et al.* (2012) found high GCV and PCV for this trait. It showed high heritability (78.86%) coupled with moderate genetic advance (13.35%) in percent mean (Table 4b and Figure 10) which indicated that the character was governed by additive gene action. So selection based on this character could be effective. Kumari *et* al. (2003) found high heritability and moderate genetic advance for plant height. But Iftekharuddaula *et al.* (2001) and Bharadwaj *et al.* (2007) showed high heritability and high genetic advance for plant height.

4.2.4 Number of total tillers per plant

The phenotypic variance (3.09) was more or less similar to genotypic variance (2.68) indicating that least environmental effect for the expression of the character and genetic factor had significant expressivity on the number of total tillers per plant. The moderate GCV (12.25%) and PCV (13.17%) with this difference between them indicating that environment had less influence for the expression of this trait (Table 4a and Figure 9). Similar results for low to moderate values of GCV and PCV were also found by Sarkar *et al.* (2007); Prajapati *et al.* (2011) and Singh *et al.* (2011). It showed high heritability (86.49%) coupled with high genetic advance (23.46%) in percent mean (Table 4b and Figure 10) which indicated that the predominance of additive genes for controlling the number of total tillers per plant. Thus, selection based on this character will give positive response. High heritability and high genetic advance on this character was also found by Dutta *et* al. (2013); Subbaiah *et al.* (2011) and Prajapati *et al.* (2011).

4.2.5 Number of effective tillers per plant

The phenotypic variance (3.76) was more or less similar to genotypic variance (3.32) also indicating that least environmental effect for the expression of the character and genetic factor had significant expressivity on the number of total number of effective tillers per plant. The moderate GCV (15.46%) and PCV (14.53%) with this difference between them indicating that environment had less influence for the expression of this trait (Table 4a and Figure 9).The findings were supported by Subbaiah *et al.* (2011). It showed high heritability (88.31%) coupled with high genetic advance (28.13%) in percent mean (Table 4b and Figure 10) which indicated that the predominance of additive genes for controlling the number of effective tillers per plant. Thus, selection based on this character will give positive response. High heritability and high genetic advance on this character was also found by Dutta *et al.* (2013); Subbaiah *et al.* (2011); Sankar *et al.* (2006) and Bai *et al.* (1992).

4.2.6 Panicle length (cm)

The phenotypic variance (3.90) was slightly higher than genotypic variance (3.32) indicating that minor environmental effect for the expression of the panicle length. The low GCV (6.36%) and PCV (8.16%) with this difference between them also indicating that environment had minor influence for the expression of this trait (Table 4a and Figure 9). Therefore selection based upon phenotypic expression of this character would be effective for the improvement of this crop. Kole *et al.* (2008); Padmaja *et al.* (2008) and Shanthi and Singh (2001) found low GCV and PCV along with little difference between them. Panicle length showed high heritability (61.15%) coupled with moderate genetic advance (10.28%) in percent mean (Table 4b and Figure 10) which indicated that the character was governed by additive gene action. So selection based on this character could be effective. Sadhukhan and Chattopadhyay (2000) populations reported similar results.

4.2.7 Number of primary branches per panicle

The genotypic variance (2.20) and phenotypic variance (2.48) were close to each other, indicating least environmental effect for the expression of the character and genetic factor had significant expressivity on the days to maturity. GCV (13.40%) and PCV (14.60%) were moderate for number of primary branches per panicle (Table 4a and Figure 9).There was a little difference between GCV and PCV on this character. Karim *et al.* (2007) found higher differences between GCV and PCV for this trait. It showed high heritability (84.20%) coupled with high genetic advance (25.33%) in percent mean (Table 4b and Figure 10). Therefore selection based on this trait would be effective. These results matched with the findings of Reddy and Kumar (1996).

4.2.8 Number of secondary branches per panicle

The phenotypic variance (92.39) was higher than genotypic variance (86.59) indicating that there was environmental effect for the expression of the number of secondary branches per panicle and genetic factor had low expressivity on the trait. High GCV (26.20%) and PCV (27.20%) (Table 4a and Figure 9) with considerable difference between them indicating that environment had a significant role in the expression of this character. Number of secondary branches per panicle showed high heritability (93.72%) coupled with high genetic advance (52.52%) in percent mean (Table 4b and Figure 10) which indicating the roles of additive gene action and a good scope of selection using their phenotypic performance.

4.2.9 Number of filled grains per panicle

The phenotypic variance (360.93) was slightly higher than genotypic variance (335.13) indicating that there was environmental effect for the expression of the number of filled grains per panicle and genetic factor had low expressivity on the trait.. Moderate GCV (11.50%) and PCV (11.94%) (Table 4a and Figure 9) were present on this character. But Bisne (2009) *et al.* found high GCV and PCV for this trait. It showed high heritability (92.85%) coupled with high genetic advance (22.83%) in percent mean (Table 4b and Figure 10) which indicated the roles of additive gene action. Therefore, selection could be effective through this character. High heritability and high genetic advance on this character was also found by

Satyanaryan *et al.* (2005); Hasib (2005); Jaiswal *et al.* (2007); Bisne *et al.* (2009); Subbaiha *et al.* (2011) and Seyoum *et al.* (2012).

4.2.10 Number of unfilled grains per panicle

The phenotypic variance (117.86) was much higher than genotypic variance (80.41) indicating that there was environmental effect for the expression of the number of unfilled grains per panicle and genetic factor had low expressivity on the trait. High GCV (42.41%) and PCV (35.03%) (Table 4a and Figure 9) with high difference between them indicating that environment had a significant role in the expression of this character. Mustafa *et al.* (2007) also found high GCV and PCV on this character. Number of unfilled grains per panicle showed high heritability (68.23%) coupled with high genetic advance (59.61%) in percent mean (Table 4b and Figure 10) which indicating the roles of additive gene action. Therefore, selection could be effective through this character. Satyanaryan *et al.* (2005); Hasib (2005); Jaiswal *et al.* (2007); Subbaiha *et al.* (2011) and Seyoum *et al.* (2012) also found this result.

4.2.11 Total number of spikelet per panicle

The phenotypic variance (605.62) was higher than genotypic variance (554.20) indicating that there was environmental effect for the expression of the total number of spikelet per panicle and genetic factor had low expressivity on the trait. Moderate GCV (12.74%) and PCV (13.32%) (Table 4a and Figure 9) with considerable difference between them indicating that environment had a significant role in the expression of this character. Total number of spikelet per panicle showed high heritability (91.51%) coupled with high genetic advance (25.11%) in percent mean (Table 4b and Figure 10) which indicating the roles of additive gene action. Sawant and Patil (1995) and Bai *et al.* (1992) also found same result. Therefore, selection could be effective through this character.

4.2.12 Yield per plant (g)

The phenotypic variance (18.75) was higher than genotypic variance (11.63) indicating that there was environmental effect for the expression of the number of yield per plant (g). Moderate GCV (9.42%) and PCV (11.96%) (Table 4a and Figure 9) with high difference between them indicating that environment had a significant role in the expression of this character. Similar results were also found by Bisne *et al.* (2009). Prasad *et al.* (2001); Jaiswal *et al.* (2007) and Jayasudha *et al.* (2010) found high GCV and PCV. Yield per plant showed high heritability (62.01%) coupled with moderate genetic advance (15.28%) in percent mean (Table 4b and Figure 10) which indicating the roles of additive gene action. Therefore, selection could be effective through this character.

4.2.13 1000-seed weight (g)

The phenotypic variance (7.08) was slightly higher than genotypic variance (6.29) indicating that there was least environmental effect for the expression of the number of unfilled grains per panicle. Moderate GCV (11.61%) and PCV (12.32%) (Table 4a and Figure 9) with considerable difference between them indicating that environment had a significant role in the expression of this character. 1000-seed weight showed high heritability (88.79%) coupled with high genetic advance (22.53%) in percent mean (Table 4b and Figure 10) which indicating the roles of additive gene action. Therefore, selection could be effective through this character. Chand *et al.* (2004); Patil *et al.* (2003); Bidhan *et al.* (2001) and Mishra *et al.* (1996) found high heritability for 1000-seed weight.

4.2.14 Yield per hectare (t)

The phenotypic variance (2.21) was slightly higher than genotypic variance (1.83) indicating that there was least environmental effect for the expression of the number of unfilled grains per panicle and genetic factor had low expressivity on the trait.. Moderate GCV (16.32%) and PCV (17.94%) (Table 4a and Figure 9) with less difference between them indicating that environment had a significant role in the expression of this character. Yield per hectare showed high heritability (82.72%) coupled with high genetic advance (30.57%) in percent mean (Table 4b and Figure 10) which indicating the roles of additive gene action. Therefore, selection could be effective through this character. Vishwakarme *et al.* (1989) estimates moderate genetic advance for yield per plant.

4.3 Correlation co-efficient

Yield is a complex product being influenced by several inter-dependable quantitative characters. Thus selection for yield may not be effective unless the other yield components influence it directly or indirectly are taken in to consideration. Hence knowledge regarding association of character with yield and among themselves provides guideline to the plant breeder for making improvement through selection vis-à-vis provide a clear understanding about the contribution in respect of establishing the association by genetic and non-genetic factors (Dewey and Lu 1959). Genotypic and phenotypic correlation co-efficient of different characters of 25 populations and their checks are shown in (Table 5 and table 6). Most of the characters showed the genotypic correlation co-efficient higher than the corresponding phenotypic correlation co-efficient suggesting a strong inherent association between the characters under study and consequently lower. In few cases, phenotypic correlation co-efficient were higher than their corresponding genotypic correlation co-efficient suggesting that both environmental and genotypic correlation acted in the same direction and finally maximized their expression at phenotypic level.

4.3.1 Days to flowering

Days to flowering showed significant and positive correlation with days to maturity (G = 0.501, P = 0.452), plant height (G= 0.396, P= 0.346), number of effective tillers per panicle (G=0.295, phenotypically non-significant, 0.223) and number of unfilled grain per panicle (G= 0.368, P= 0.306) indicated that if days to flowering increased these characters also increased. It also exhibited non-significant and positive interaction with number of total tillers per panicle (G=0.113, P=0.081). However, it had significant and negative interaction with panicle length (G= -0.371, P= -0.315), number of secondary branches per panicle (G= -0.412, P= -0.352), number of filled grain per panicle (G= -0.276, P= -0.265), total number of spikelet (G= -0.398, P= -0.357), yield per plant(G= -0.129, phenotypically non-significant), yield per hectare (G= -0.576, P= -0.324). It also showed non-significant and negative association with 1000-seed weight (G=-.073, P= -.062) (Table 5 and table 6). Non-significant association of these traits indicated that the association between these traits is largely influenced by environmental factors. Ashura (1998) and Zia-Ul-Qamar *et al.* (2005) found negative correlation of this trait with yield.

Table 5. Genotypic correlation co-efficients among different pairs of yield and yield contributing characters for different genotype of *Oryza sativa* L.

	DM	PH	NTT	NET	PL	NPB	NSB	NFG	NUFG	TNSP	YP	TSW	Y
DF	0.501**	0.396**	0.221	0.295*	-0.371**	-0.340**	-0.412**	-0.276*	0.368**	-0.398**	-0.129*	-0.073	-0.576**
DM		0.449**	0.285*	0.305*	0.574**	0.296	0.040	0.005	0.135	-0.057	-0.195	0.255	0.596**
PH			-0.430**	-0.473**	0.374**	-0.412**	-0.304*	-0.120	0.324*	-0.346**	-0.093	0.109	-0.343**
NTT				0.608**	-0.416**	0.606**	0.090	-0.327*	-0.319*	-0.094	0.496**	-0.392**	-0.058
NET					-0.431**	0.355**	-0.058	0.253	-0.351**	0.081	0.301*	-0.351**	0.206
PL						-0.345**	0.296*	0.449**	-0.068	0.343**	0.203	-0.157	-0.379**
NPB							0.223	0.074	-0.273*	0.242	0.394**	-0.098	0.236
NSB								0.808**	-0.631**	0.800**	0.509**	-0.692**	0.722**
NFG									-0.132	0.557**	0.645**	-0.331*	0.655**
NUFG										-0.565**	-0.151	-0.370**	-0.302*
TNSP											0.468**	-0.599**	0.513**
YP												-0.112	0.566**
TSW													-0.361**

*** = Significant at 5% level of probability, ** = Significant at 1% level of probability**

DF= Days to flowering, DM= Days to maturity, PH= Plant height (cm), NTT= Number of total tillers per plant, NET= Number. of effective tillers per plant, PL=, Panicle length (cm) , NPB= Number of primary branches per panicle, NSB= Number of secondary branches per panicle, NFB= Number of filled grains per panicle, NUFB= Number of unfilled grains of per panicle, TNSP= Total number of spikelet per panicle, YP= Yield per plant (g), TSW=1000-seed weight (g), Y= Yield per hectare (t)

Table 6. Phenotypic correlation co-efficient among different pairs of yield and yield contributing characters for different genotype of *Oryza sativa* L.

	DM	PH	NTT	NET	PL	NPB	NSB	NFG	NUFG	TNSP	YP	TSW	Y
DF	0.452**	0.346**	0.174	0.223	-0.315*	-0.301*	-0.352**	-0.265	0.306*	-0.357**	-0.124	-0.062	-0.324*
DM		0.388**	0.232	0.257	0.452**	0.239	0.073	0.033	0.107	-0.033	-0.146	0.226	0.325*
PH			-0.317*	-0.386**	0.316*	-0.361**	-0.261	-0.108	0.286*	-0.295*	-0.089	0.145	-0.047
NTT				0.641**	-0.297*	0.529**	0.089	-0.282*	-0.308*	-0.105	0.329*	-0.343**	-0.014
NET					-0.335**	0.293*	-0.043	0.232	-0.331*	0.052	0.196	-0.296*	0.101
PL						-0.220	0.212	0.403**	-0.078	0.292*	0.079	-0.122	-0.111
NPB							0.201	0.076	-0.258	0.196	0.267*	-0.112	0.103
NSB								0.763**	-0.447**	0.775**	0.457**	-0.558**	0.421**
NFG									-0.124	0.554**	0.516**	-0.305*	0.403**
NUFG										-0.371**	-0.078	-0.241	-0.102
TNSP											0.386**	-0.508**	0.343**
YP												-0.066	0.339**
TSW													-0.150

*** = Significant at 5% level of probability, ** = Significant at 1% level of probability**

DF= Days to flowering, DM= Days to maturity, PH= Plant height (cm), NTT= Number of total tillers per plant, NET= Number of effective tillers per plant, PL=, Panicle length (cm) , NPB= Number of primary branches per panicle, NSB= Number of secondary branches per panicle, NFB= Number of filled grains per panicle, NUFB= Number of unfilled grains of per panicle, TNSP= Total number of spikelet per panicle, YP= Yield per plant (g), TSW=1000-seed weight (g), Y= Yield per hectare (t)

4.3.2 Days to maturity

Days to maturity showed significant and positive correlation with plant height (G= 0.449, P= 0.388), number of total tillers per panicle (G=0.285, phenotypically non-significant, 0.232), number of effective tillers per panicle (G=0.305, phenotypically non-significant, 0.257), panicle length (G= 0.574, P= 0.452), number of primary branches per panicle (G= 0.296, phenotypically non-significant,0.239), yield per hectare (G= 0.596, P= 0.325) indicated that if days to maturity increased then these characters also increased. It also exhibited non-significant and positive interaction with number of secondary branches per panicle (G= 0.040, P= 0.073), number of filled grain per panicle (G= 0.005, P= 0.033), number of unfilled grain per panicle (G= 0.135, P= 0.107), thousand seed weight (G= 0.255, P=0.226). But it had non-significant and negative interaction with total number of spikelet (G= -0.057, P= -0.033), yield per plant (G= -0.195, P= -0.146) (Table 5 and table 6). Non-significant association of these traits indicated that the association between these traits is largely influenced by environmental factors. Iftekharuddaula *et al.* (2001); Sadeghi (2011) and Rangare *et al.* (2012) reported positive and significant correlation with yield.

4.3.3 Plant height (cm)

Plant height showed significant and positive correlation with panicle length (G= 0.374, P= 0.316), number of unfilled grain per panicle (G= 0.324, P= 286), indicated that if plant height increased then panicle length also increased. It also exhibited non-significant and positive interaction with thousand seed weight (G= 0.109, P=0.145). But it had significant and negative interaction with number of total tillers per panicle (G= -0.430, P= -0.317), number of effective tillers per panicle (G= -0.473, P= -0.386), number of primary branches per panicle (G= -0.412, P= -0.361),number of secondary branches per panicle (G= -0.304, P= -0.267), total number of spikelet (G= -0.346, P= -0.295), yield per hectare (G= -0.343, phenotypically non-significant, -0.047). It had also non-significant negative relation with number of filled grain per panicle (G= -0.120, P= -0.108), yield per plant (G= -0.093, P= -0.089) (Table 5 and table 6). Insignificant association of these traits indicated that the association between these traits is largely influenced by environmental factors. Prasad *et al.* (2001); Zahid *et al.* (2005) and Nandeswar *et al.* (2010) found significant but negative correlation of plant height with yield.

4.3.4 Number of total tillers per plant

Number of total tillers per plant showed significant and positive correlation with number of effective tillers per panicle (G= 0.608, P= 0.641), number of primary branches per panicle (G= 0.606, P= 0.529), yield per plant (G= 0.496, P=0.329) indicated that if number of total tillers per plant increased then theses characters also increased. It also exhibited non-significant and positive interaction with number of secondary branches per panicle (G= 0.090, P= 0.089). It had significant and negative interaction with panicle length (G= -0.416, P= -0.297), number of filled grain per panicle (G= -0.327, P= -0.282), number of unfilled grain per panicle (G= 0.319, P= -0.308). 1000-seed weight (G= -0.392, P= -0.343). But it had also non-significant negative relation with total number of spikelet (G= -0.094, P= -0.105), yield per hectare (G= -0.058, P= -0.014) (Table 5 and table 6). Non-significant association of these traits indicated that the association between these traits is largely influenced by environmental factors.

4.3.5 Number of effective tillers per plant

Number of effective tillers per plant showed significant and positive correlation with number of primary branches per panicle (G= 0.355, P= 0.293), yield per plant (G= 0.301, phenotypically positive but non-significant, 0.196) indicated that if number of effective tillers per plant increased then theses characters also increased. It also exhibited non-significant and positive interaction with of filled grain per panicle (G= 0.253, P= 0.232), total number of spikelet (G= 0.081, P= 0.052), yield (G= 0.206, P= 0.101). It had significant and negative interaction with panicle length (G= -0.431, P= -0.335), number of unfilled grain per panicle (G= -0.351, P= -0.331), thousand seed weight (G= -0.351, P= -0.296). But it had non-significant negative relation with number of secondary branches per panicle (G= -0.058, P= -0.043) (Table 5 and table 6). Non-significant association of these traits indicated that the association between these traits is largely influenced by environmental factors. Tomar *et al.* (2000); Prasad *et al.* (2001); Zia-Ul-Qamar *et al.* (2005); Sankar *et.al.* (2006); Agahi *et al.* (2007); Rokonuzzaman *et al.* (2008); Ghosal *et al.* (2010); Watto *et al.* (2010) and Sadeghi *et al.* (2011) showed positive and significant correlation of yield with effective tillers per plant.

4.3.6 Panicle length (cm)

Panicle length showed significant and positive correlation with number of secondary branches per panicle (G= 0.296, phenotypically positive but non-significant, 0.212), number of filled grain per panicle (G= 0.449, P=0.403), total number of spikelet (G= 0.343, P= 0.292) indicated that if panicle length increased then theses characters also increased. It also exhibited non-significant and positive interaction with yield per plant (G= 0.203, P=0.079).). It had significant and negative interaction with number of primary branches per panicle (G= -0.345, phenotypically non-significant, -0.220), yield per hectare (G= -0.379, phenotypically non-significant, -0.111). It had also non-significant negative relation with number of unfilled grain per panicle (G= -0.068, P= -0.078), 1000-seed weight (G= -0.157, P= -0.122) (Table 5 and table 6). Insignificant association of these traits indicated that the association between these traits is largely influenced by environmental factors.

4.3.7 Number of primary branches per panicle

Number of primary branches per panicle showed significant and positive correlation with yield per plant (G= 0.394, P= 0.267) indicated that if number of primary branches per panicle increased then theses characters also increased. It also exhibited non-significant and positive interaction with number of secondary branches per panicle (G= 0.223, P= 0.201), number of filled grain per panicle (G= 0.074, P= 0.076), total number of spikelet (G= 0.242, P= 0.196), yield (G= 0.236, P= 0.103).). But it had significant negative relation with number of unfilled grain per panicle (G= -0.273, Phenotypically non-significant, -0.258) and non-significant negative interaction with thousand seed weight (G= -0.098, P= -0.112) (Table 5 and table 6). Non-significant association of these traits indicated that the association between these traits is largely influenced by environmental factors.

4.3.8 Number of secondary branches per panicle

Number of secondary branches per panicle showed significant and positive correlation with number of filled grain per panicle (G= 0.808, P= 0.763total number of spikelet (G= 0.800, P= 0.775), yield per plant (G= 0.509, P= 0.457), yield per hectare (G= 0.722, P= 0.421) indicated that if number of secondary branches per panicle increased then theses characters also increased. But it had significant negative relation with number of unfilled grain per panicle (G= -0.631, P= - 0.447), 1000-seed weight (G= -0.692, P= -0.558) (Table 5 and table 6).

4.3.9 Number of filled grains per panicle

Number of filled grains per panicle showed significant and positive correlation with total number of spikelet (G= 0.557, P= 0.554), yield per plant (G= 0.645, P= 0.516) yield (G= 0.655, P= 0.403) indicated that if number of effective tillers per plant increased then theses characters also increased. It also had significant negative relation with thousand seed weight (G= -0.331, P= -0.305) and non-significant negative interaction with number of unfilled grain per panicle (G= -0.132, P= -0.124) (Table 5 and table 6). Non-significant association of trait indicated that the association between these traits is largely influenced by environmental factors. Mehetre *et al.* (1996); Mustafa *et al.* (2007) and Satheeshkumar *et al.* (2012) showed positive and significant correlation of yield with number of filled grains per panicle.

4.3.10 Number of unfilled grains per panicle

Number of unfilled grains per panicle showed significant and negative correlation with total number of spikelet (G= -0.565, P= -0.371), 1000-seed weight (G= -0.370, Phenotypically non-significant, -0.241), yield per hectare (G= -0.302, Phenotypically non-significant -0.102) indicated that if number of unfilled grains per panicle increased then theses characters also decreased. It also had non-significant negative relation interaction with yield per plant (G= -0.151, P= -0.078) (Table 5 and table 6). Non-significant association of trait indicated that the association between these traits is largely influenced by environmental factors.

4.3.11 Total number of spikelet per panicle

Total number of spikelet per panicle showed significant and positive correlation with yield per plant (G= 0.468, P= 0.386), yield (G= 0.513, P= 0.343) indicated that if total number of spikelet per panicle increased then theses characters also increased. But it had significant negative relation with thousand seed weight (G= -0.599, P= -0.508) (Table 5 and table 6). Satheeshkumar *et al.* (2012) showed positive and significant correlation of yield with total number of spikelet per panicle.

4.3.12 Yield per plant (g)

Yield per plant showed significant and positive correlation with yield (G= 0.566, P=0.339) indicated that if yield per plant increased then yield also increased. But it had n0n-significant negative relation with thousand seed weight (G= -0.112, P= -0.066) (Table 5 and table 6). Insignificant association of this trait indicated that the association between these traits is largely influenced by environmental factors. Chaubey and Richharia (1993), Vange (2009), Nandeshwar *et al.*(2010); Sadeghi *et al.* (2011) and Akinwale *et al.* (2011) also reported that yield per was positively and significantly correlated with yield.

4.3.13 1000-seed weight (g)

1000-seed weight showed significant and negative correlation with yield (G= -0.361, Phenotypically negative but insignificant, -0.150) (Table 5 and table 6) indicated that if 1000-seed weight increased then yield decreased. Insignificant association of this trait indicated that the association between these traits was largely influenced by environmental factors. Karad *et al.* (2008) showed negatively and significantly correlation of 1000-seed weight with yield.

4.4 Path Co-efficient analysis

Genotypic correlation co-efficient were partitioned by using method of path analysis to find out the direct and indirect effects of yield contributing traits towards the yield per hectare. Path co-efficient analysis revealed that among the characters plant height (0.708), number of total tillers per plant (0.924), number of effective tillers per plant (0.542), number of secondary branches per panicle (0.997), number of filled grains per panicle (0.735), total number of spikelet per panicle (0.625), 1000-seed weight (0.940) showed positive direct effect indicating that among the independent variables, theses seven contributed maximum for yield per hectare (Table 7). Days to flowering (-0.529), days to maturity (-0.302), panicle length (-0.707), number of primary branches per panicle (-0.334), number of unfilled grains per panicle (0.324), yield per plant (-0.771) exerted negative direct effects towards yield per hectare. The maximum positive direct effect was exerted by number of secondary branches per panicle. Therefore, numbers of total tillers per plant, number of secondary branches per panicle, number of filled grains per panicle, 1000-seed weight were best contributors for increasing yield per hectare for rice.

4.4.1 Days to flowering

Days to flowering had positive indirect effect on plant height (0.316), number of total tillers per plant (0.204), number of effective tillers per plant (0.160), panicle length (0.262), number of primary branches per panicle (0.114), yield per plant (0.100), whereas, it had negative indirect effect on days to maturity (-0.151), number of secondary branch per panicle (-0.411), number of filled grains per panicle (-0.203), number of unfilled grains per panicle (-0.119), total number of spikelet per panicle (-0.248), 1000-seed weight (-0.069). Days to flowering finally made significant negative genotypic correlation with yield per hectare. These results indicated that if days to flowering increases then yield per hectare decreases mostly through the negative indirect effect of days to flowering with other characters (Table 7). Abarshahr *et al.* (2011) reported negative direct effect for this trait. But Iftekharuddaula *et al.* (2001); Zia-Ul-Qamar *et al.* (2005); Jaiswal *et al.* (2007) and Rangare *et al.* (2012) found positive direct effect for this trait.

4.4.2 Days to maturity

Days to maturity had positive indirect effect on days to flowering (0.265), plant height(0.359), number of total tillers per plan(0.263)t, number of effective tillers per plant(0.166), number of secondary branch per panicle(0.040), number of filled grains per panicle (0.004), yield per plant (0.150), 1000-seed weight (0.240) , whereas, it had negative indirect effect on panicle length (-0.406), number of primary branches per panicle (-0.099), number of unfilled grains per panicle (-0.044), total number of spikelet per panicle (-0.036). Days to maturity finally made significant positive genotypic correlation with yield per hectare. These results indicated that if days to maturity increases then yield per hectare increases mostly through the positive indirect effect of days to maturity with other characters (Table 7). Thus, selection for this trait may give positive response. Similar result was obtained by Sadeghi (2011); Abarshahr *et al.* (2011); Zia-Ul-Qamar *et al.* (2005) and Rangare *et al.* (2012).

4.4.3 Plant height (cm)

Plant height had positive indirect effect on days to flowering(0.209), number of primary branches per panicle (0.138), yield per plant (0.071), 1000-seed weight (0.103). It had negative indirect effect on days to maturity (-0.033), number of total tillers per plant (-0.305), number of effective tillers per plant (-0.256), panicle length (-0.264), number of secondary branches per panicle (-0.303), number of filled grains per panicle (-0.088), number of unfilled grains per panicle (-0.105), total number of spikelet per panicle (-0.218). Plant height finally made significant negative genotypic correlation with yield per hectare. These results indicated that if plant height increases then yield per hectare decreases mostly through the negative indirect effect of plant height with other characters (Table 7). It indicates that plant height would not be reliable criteria for improving yield per hectare. Yadav *et al.* (2010) and Kole *et al.* (2008) showed positive direct effect of plant height.

4.4.4 Number of total tillers per plant

Number of total tillers per plant had positive indirect effect on number of effective tillers per plant (0.330), panicle length (0.294), number of secondary branch per panicle (0.089), number of unfilled grains per panicle (0.103). Whereas, it had negative indirect effect on days to flowering (-0.060), days to maturity (-0.086), plant height (-0.399), number of primary branches per panicle (-0.203), number of filled grains per panicle (-0.241), total number of spikelet per panicle (-0.059), yield per plant (-0.383), 1000-seed weight (-0.369). Number of total tillers per plant finally made non-significant negative genotypic correlation with yield per hectare. These results indicated that if number of total tillers per plant increases then yield per hectare decreases mostly through the negative indirect effect of plant height with other characters (Table 7). It indicated that number of total tillers per plant would not be reliable criteria for improving yield per hectare. Karad *et al.* (2008) and Yadav *et al.* (2010) showed positive direct effect of total tillers per plant on yield.

Table 7. Path co-efficient analysis showing direct and indirect effects of different characters on yield of *Oryza sativa* L.

	Direct	Indirect effect													Genotypic
	effect	**DF**	**DM**	**PH**	**NTT**	**NET**	**PL**	**NPB**	**NSB**	**NFG**	**NUFG**	**TNSP**	**YP**	**TSW**	correlation
DF	**-0.529**	-	-0.151	0.316	0.204	0.16	0.262	0.114	-0.411	-0.203	-0.119	-0.248	0.1	-0.069	**-0.576****
DM	**-0.302**	0.265	-	0.359	0.263	0.166	-0.406	-0.099	0.04	0.004	-0.044	-0.036	0.15	0.24	**0.596****
PH	**0.708**	0.209	-0.033	-	-0.305	-0.256	-0.264	0.138	-0.303	-0.088	-0.105	-0.218	0.071	0.103	**-0.343****
NTT	**0.924**	-0.06	-0.086	-0.399	-	0.33	0.294	-0.203	0.089	-0.241	0.103	-0.059	-0.383	-0.369	**-0.058**
NET	**0.542**	-0.109	-0.199	-0.378	0.433	-	0.305	-0.119	-0.058	0.186	0.114	0.051	-0.232	-0.33	**0.206**
PL	**-0.707**	0.196	-0.174	0.298	-0.384	-0.237	-	0.115	0.296	0.33	-0.022	0.214	-0.157	-0.147	**-0.379****
NPB	**-0.334**	0.022	-0.053	-0.09	0.283	0.193	0.096	-	0.222	0.054	0.089	0.151	-0.304	-0.092	**0.236**
NSB	**0.997**	0.218	-0.072	-0.343	0.083	-0.132	-0.21	-0.074	-	0.594	0.204	0.5	-0.393	-0.65	**0.722****
NFG	**0.735**	0.146	-0.001	-0.096	-0.177	0.137	-0.348	-0.028	0.706	-	0.043	0.348	-0.498	-0.312	**0.655****
NUFG	**-0.324**	0.195	0.041	-0.425	0.294	-0.19	0.048	-0.133	0.63	0.147	-	-0.353	0.116	-0.348	**-0.302***
TNSP	**0.625**	0.11	0.017	-0.276	-0.043	0.044	-0.243	-0.181	0.846	0.527	0.011	-	-0.361	-0.563	**0.513****
YP	**-0.771**	0.068	0.059	-0.074	0.335	0.163	-0.144	-0.142	0.279	0.424	0.183	0.292	-	-0.106	**0.566****
TSW	**0.94**	0.139	-0.077	0.187	-0.361	-0.19	0.111	0.033	-0.69	-0.204	-0.049	-0.305	0.105	-	**-0.361****

Residual effect = 0.164

**, * Correlation is significant at the 0.01 and 0.05 level, respectively.

DF= Days to flowering, DM= Days to maturity, PH= Plant height (cm), NTT= Number of total tillers per plant, NET= Number of effective tillers per plant, PL= Panicle length (cm) , NPB= Number of primary branches per panicle, NSB= Number of secondary branches per panicle, NFB= Number of filled grains per panicle, NUFB= Number of unfilled grains of per panicle, TNSP= Total number of spikelet per panicle, YP= Yield per plant (g), TSW=1000-seed weight (g), Y= Yield per hectare (t)

4.4.5 Number of effective tillers per plant

Number of effective tillers per plant had positive indirect effect on number of total tillers per plant (0.433), panicle length (0.305), number of filled grains per panicle (0.186), number of unfilled grains per panicle (0.114), total number of spikelet per panicle (0.051). Whereas, it had negative indirect effect on days to flowering (-0.109), days to maturity (-0.199), plant height (-0.378), number of primary branches per panicle (-0.119), number of secondary branches per panicle (-0.058, yield per plant (-0.232), 1000-seed weight (-0.330). Number of effective tillers per plant finally made non-significant positive genotypic correlation with yield per hectare. These results indicated that if number of effective tillers per plant increases then yield per hectare increases mostly through the positive indirect effect of number of effective tillers per plant with other characters (Table 7).

4.4.6 Panicle length (cm)

Panicle length had positive indirect effect on days to flowering (0.196), plant height (0.298), number of primary branches per panicle (0.115), number of secondary branches per panicle (0.296), number of filled grains per panicle (0.330), total number of spikelet per panicle (0.214). Whereas, it had negative indirect effect on days to maturity (-0.174), number of total tillers per plant (-0.384), number of effective tillers per plant (-0.237), number of unfilled grains per panicle (-0.022), yield per plant (-0.157), 1000-seed weight (-0.147). Panicle length finally made significant negative genotypic correlation with yield per hectare. These results indicated that if panicle length increases then yield per hectare decreases mostly through the negative indirect effect of panicle length with other characters (Table 7). It indicated that panicle length would not be reliable criteria for improving yield per hectare.

4.4.7 Number of primary branches per panicle

Number of primary branches per panicle had positive indirect effect on days to flowering (0.022), number of total tillers per plant (0.283), number of effective tillers per plant (0.193), panicle length (0.096), number of secondary branch per panicle (0.222), number of filled grains per panicle (0.054), number of unfilled grains per panicle (0.089) and total number of spikelet per panicle (0.151). Whereas, it had negative indirect effect on days to maturity (-0.053), plant height (-0.090), yield per plant (-0.304), 1000-seeds weight (-0.092). Number of primary branches per panicle finally made non-significant positive genotypic correlation with yield per hectare. These results indicated that if number of total tillers per plant increases then yield per hectare increases mostly through the positive indirect effect of number of primary branches per panicle with other characters (Table 7).

4.4.8 Number of secondary branches per panicle

Number of secondary branches per panicle had positive indirect effect on days to flowering (0.218), number of total tiller per plant (0.083), number of filled grains per panicle (0.594), number of unfilled grains per panicle (0.204), total number of spikelet per panicle (0.500) Whereas, it had negative indirect effect on days to maturity (-0.072), plant height (-0.343), number of effective tillers per plant (-0.132), panicle length (-0.210), number of primary branches per panicle (-0.074), yield per plant (-0.393), 1000-seeds weight (-0.650). Number of secondary branches per panicle finally made significant positive genotypic correlation with yield per hectare. These results indicated that if number of secondary branches per panicle increases then yield per hectare increases mostly through the positive indirect effect number of secondary branches per panicle with other characters (Table 7). It indicated that selection based on this character would have greater chance to improve yield per hectare.

4.4.9 Number of filled grains per panicle

Number of filled grains per panicle had positive indirect effect on days to flowering (0.146), number of effective tillers per plant (0.137), number of secondary branches per panicle (0.706), number of unfilled grains per panicle (0.043), total number of spikelet per panicle (0.348). Whereas, it had negative indirect effect on days to maturity (-0.001), plant height (-0.096), number of total tillers per plant (-0.177), panicle length (-0.348), number of primary branches per panicle (-0.028), yield per plant (-0.498), 1000-seeds weight (-0.312). Number of filled grains per panicle finally made significant positive genotypic correlation with yield per hectare. These results indicated that if number of secondary branches per panicle increases then yield per hectare increases mostly through the positive indirect effect number of filled grains per panicle with other characters (Table 7). It indicated that selection based on this character would have greater chance to improve yield per hectare. Positive significant indirect effect also found by Ashura *et al.* (1998). Mehetre *et al.* (1996); Mustafa *et al.* (1998) and Abarshahr *et al.* (1998) obtained positive direct effect of filled grain per panicle on yield.

4.4.10 Number of unfilled grains per panicle

Number of unfilled grains per panicle had positive indirect effect on days to flowering (0.195), days to maturity (0.041), number of total tillers per plant (0.294), panicle length (0.048), number of secondary branch per panicle (0.630), number of filled grains per panicle (0.147), yield per plant (0.116). It had negative indirect effect on plant height (-0.425), number of effective tillers per plant (-0.190), number of primary branches per panicle (-0.133), total number of spikelet per panicle (-0.353), 1000-seeds weight (-0.348). Number of unfilled grains per panicle finally made significant negative genotypic correlation with yield per hectare. These results indicated that if number of unfilled grains per panicle increases then yield per hectare decreases mostly through the negative indirect effect of number of unfilled grains per panicle with other characters (Table 6). It indicated that number of unfilled grains per panicle would not be reliable criteria for improving yield per hectare.

4.4.11 Total number of spikelet per panicle

Total number of spikelet per panicle had positive indirect effect on days to flowering (0.110), days to maturity (0.017), number of effective tillers per plant (0.044), number of secondary branch per panicle (0.846), number of filled grains per panicle (0.527), number of unfilled grains per panicle (0.011). Whereas, it had negative indirect effect on plant height (-0.276), number of total tillers per plant (-0.043), panicle length (-0.243), number of primary branches per panicle (-0.181), yield per plant (-0.361), 1000-seeds weight (-0.563). Total number of spikelet per panicle finally made significant positive genotypic correlation with yield per hectare. These results indicated that if total number of spikelet per panicle increases then yield per hectare increases mostly through the positive indirect effect of total number of spikelet per panicle with other characters (Table 7). It indicated that selection based on this character would have greater chance for improving yield per hectare.

4.4.12 Yield per plant (g)

Yield per plant had positive indirect effect on days to flowering(0.068), days to maturity (0.059), number of total tillers per plant(0.335), number of effective tillers per plant (0.163), number of secondary branch per panicle (0.279), number of filled grains per panicle (0.424), number of unfilled grains per panicle (0.183), total number of spikelet per panicle(0.292), whereas, it had negative indirect effect on plant height (-0.074), panicle length (-0.144), number of primary branches per panicle (-0.142), 1000-seed weight (-0.106). Yield per plant finally made significant positive genotypic correlation with yield per hectare. These results indicated that if yield per plant increases then yield per hectare increases mostly through the positive indirect effect of yield per plant with other characters (Table 7). It indicated that selection based on this character would have greater chance for improving yield per hectare.

4.4.13 1000-seed weight (g)

1000-seed weight per plant had positive indirect effect on days to flowering (0.139), plant height (0.187), panicle length (0.111), number of primary branches per panicle (0.0330, yield per plant(0.105), whereas, it had negative indirect effect on days to maturity (-0.077), number of total tillers per plant (-0.361), number of effective tillers per plant (-0.190), number of secondary branch per panicle (-0.690), number of filled grains per panicle (-0.204), number of unfilled grains per panicle (-0.049), total number of spikelet per panicle (-0.305). 1000-seeds weight finally made significant negative genotypic correlation with yield per hectare. These results indicated that if 1000-seed weight increases then yield per hectare decreases mostly through the negative indirect effect of 1000-seed weight with other characters (Table 7). It indicated that 1000-seed weight would not be reliable criteria for improving yield per hectare. Similar result was obtained by Karad *et al.* (2008).

The residual effect was 0.164, indicated that contribution of component characters on yield per hectare was 83.6% by the thirteen characters studied in path analysis, the rest 16.4% was the contribution of other factors such as characters not studied and sampling error.

The correlation and path co-efficient studies revealed that days to maturity, number of secondary branches per panicle, number of filled grains per panicle and yield per plant are the most important yield component. Recent research has also emphasized the importance of these characters.

4.5 Selection of lines for further trial from F_4 populations

Data were recorded on ten selected plants and overall characters were taken from average. Individual data of selected plants are showed in Table 8. Yield contributing characters are given below only for selected populations.

BR 26 ×BRRI dhan29, S1P8

50% flowering was done within 119 to 125 days. Harvesting was done from 147 to 151 days on average. Number of effective tillers was 10-20, panicle length was 20-29.2 cm, total number of spikelet was 122-241, 1000-seed weight was 19-20 g, yield per plant varied from 20.7-57.1 g and yield per hectare was 8.29 to 9.44 t. Among all populations of this cross, S1P8 (6) from replication-3 was selected for further trial as it contributed higher yield (56.1 g) than average yield per plant of its checks BR 26 (35.65 g) and BRRI dhan 29 (34.20 g). S1P8 (6) took lower days to maturity (138 days) than BR 26 (145.70 days) and BRRI dhan 29 (160.70 days). Other high yielding plants were not selected either course grain or high duration for their maturity. Early mature plant from BR 26 × BRRI dhan 29 is presented in Plate 4, panicle length and grain size are presented in Plate 5.

BR 26 ×BRRI dhan29, S1P10

50% flowering was done within 119 to 126 days. Harvesting was done from 143 to 151 days. Number of effective tillers was 11-18, panicle length was 22.4-30.5 cm, total number of spikelet was 125-295, 1000-seed weight was 18-20 g, yield per plant varied from 23.9-52.4 gm and yield per hectare was 8.64 to 9.01 ton. Among all populations of this cross, S1P10 (3) from replication-1 was selected for further trial as it contributed higher yield (46.7 g) than average yield per plant of its checks BR 26 (35.65 g) and BRRI dhan 29 (34.20 g). Having total number of effective tiller 18 and total number of spikelet 252, this plant gave fewer yields than other selected materials, but its exceptionality was its fine grain. S1P10 (3) took lower days to maturity (138 days) than BR 26 (145.70 days) and BRRI dhan 29 (160.70 days). Other high yielding plants were not selected either course grain or high duration for their maturity.

Table 8. Selection of materials for future breeding program from F_4 materials

CROSS COMBINATIONS	r	PN	DM	NET	TNSP	YP(g)
BR 26 ×BRRI dhan29, S1P8	3	6	138	15	241	56.1
BR 26 ×BRRI dhan29, S1P10	1	3	138	18	252	46.7
BR 26×BRRI dhan 36, S7P1	2	1	137	19	206	51.3
BRRI dhan 28×BRRI dhan 29, S2P2	1	5	134	19	144	54.9
	3	8	134	13	254	51.1
BRRI dhan 28×BRRI dhan 29, S2P3	2	7	135	14	266	57.6
	2	2	135	14	321	44.5
BRRI dhan 28×BRRI dhan 29, S2P4	3	8	135	14	274	61.5
BRRI dhan 28×BRRI dhan 29, S2P5	1	7	134	14	184	53.9
	3	6	134	12	300	51
BRRI dhan 28×BRRI dhan 29, S2P6	1	7	134	18	185	50.1
	2	2	134	17	279	45.7
	3	8	134	15	256	58.9
BRRI dhan 28×BRRI dhan 36, S7P1	1	6	134	16	216	53.5
	1	8	134	13	127	52.8
	2	1	134	15	237	55.4
	2	2	134	17	241	52.3
BRRI dhan 28×BRRI dhan 36, S7P6	1	4	134	21	171	61.1
	2	2	134	15	198	58.9
	3	10	134	16	243	53.2
BRRI dhan 28×BRRI dhan 36, S7P8	1	10	134	13	296	50.8
BRRI dhan 28×BRRI dhan 36, S7P9	1	7	134	13	229	53.3
	2	10	134	17	271	62.5
BRRI dhan 29×BRRI dhan 36, S5P5	1	5	134	18	226	50.1
	3	4	134	17	247	59.5
	3	7	134	18	240	61.3

r= replication, PN= plant number, DM= days to maturity, NET= number of effective tillers per plant, TNSP= total number of spikelet per panicle, YP= yield per plant (g)

Plate 4 . Photograph showing selection of early mature plant (BR 26×BRRI dhan 29) in the field for further trial

(a)

(b)

Plate 5. Photograph showing (a) panicle length and (b) grain size of BR 26×BRRI dhan 29 with their checks

BR 26×BRRI dhan 36, S7P1

50% flowering was done within 117 to 121 days. Harvesting was done from 147 to 153 days. Number of effective tillers was 7-19, panicle length was 20.70-26.2 cm, total number of spikelet was 85-240, 1000-seed weight was 23-24 g, yield per plant varied from 19.7-56.4 g and yield per hectare was 7.47 to 9.35 t. Among all populations of this cross, S7P1 (6) from replication-2 was selected for further trial as it contributed higher yield (51.3 g) than average yield per plant of its checks BR 26 (35.65 g) and BRRI dhan 36 (29.58 g) as well as yield of other populations of this cross. S7P1 (6) took lower days to maturity (137 days) than BR 26 (145.70 days) and BRRI dhan 36 (145.30 days). Other high yielding plants were not selected either course grain or high duration for their maturity. Selected early maturity plant from BR 26 × BRRI dhan 36 is presented in Plate 6, panicle length and grain size are presented in Plate 7.

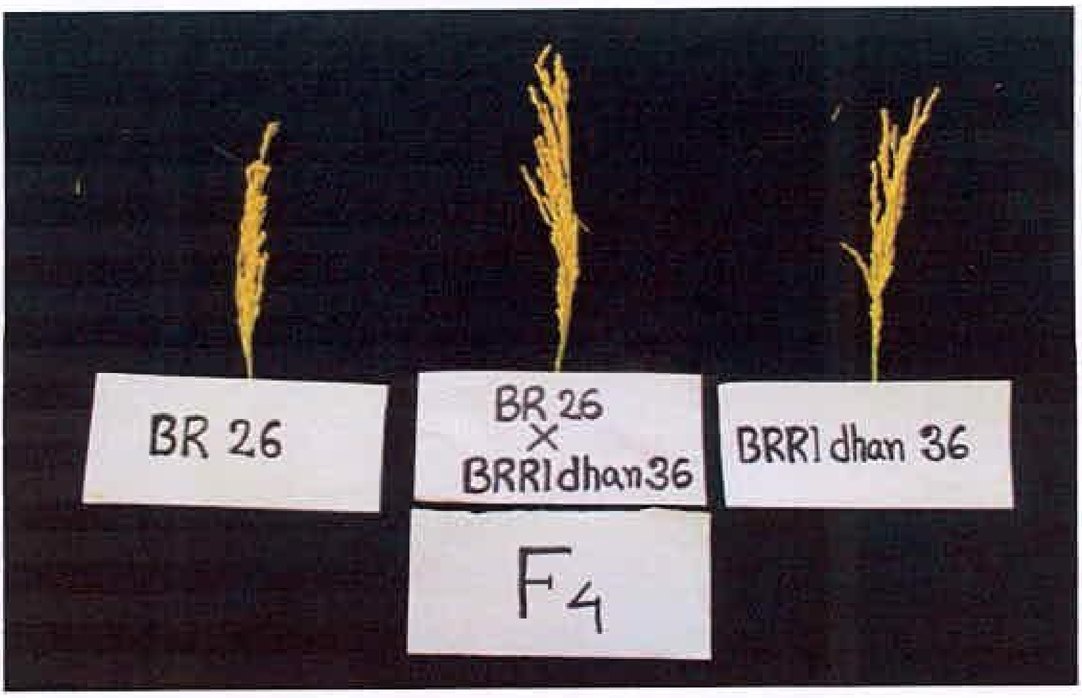
BRRI dhan 28×BRRI dhan 29, S2P2

50% flowering was done within 114 to 119 days. Harvesting was done from 145 to 147 days. Number of effective tillers was 9-16, panicle length was 22.50-30.50 cm, total number of spikelet was 118-285, 1000-seed weight was 21-24 g, yield per plant varied from 23-54.90g g and yield per hectare was 7.81 to 9.44 t. Among all populations of this cross, S2P2 (5) from replication-1 and S2P2 (8) from replication-3 were selected for further trial as they contributed higher yield (54.9g and5 1.1g respectively) than average yield per plant of its checks BRRI dhan 28 (34.04 g) and BRRI dhan 29 (34.20g). S2P2 (5) and S2P2 (8) took lower days to maturity (134days for both) than BRRI dhan 28 (141.70 days) and BRRI dhan 29 (160.70 days). Other high yielding plants were not selected either course grain or high duration for their maturity.

BRRI dhan 28×BRRI dhan 29, S2P3

50% flowering was done within 114 to 117 days. Harvesting was done from 147 to 148 days. Number of effective tillers was 8-16, panicle length was 20 -28.30 cm, total number of spikelet was 142-321, 1000-seed weight was 20-23 g, yield per plant varied from 19.4-57.60 g and yield per hectare was 7.25 to 10.38 t. Among all populations of this cross, S2P3 (2,7) from replication-2 were selected for further trial

Plate 6 . Photograph showing selection of early mature plant (BR 26×BRRI dhan 36) in the field for further trial



(a)

(b)

Plate 7. Photograph showing (a) panicle length and (b) grain size of BR 26×BRRI dhan 36 with their checks

as they contributed higher yield (44.5 g and 57.6 g respectively) than average yield per plant of its checks BRRI dhan 28 (34.04 g) and BRRI dhan 29 (34.20 g). S2P3 (2) had lower yield per plant than S2P3 (7) and others. But S2P3 (2) had 321 number of total spikelet and 14 number of effective tillers which indicated that its grain was fine and selected for further trial. They took lower days to maturity (135 days) than BRRI dhan 28 (141.70 days) and BRRI dhan 29 (160.70 days). Other high yielding plants were not selected either course grain or high duration for their maturity.

BRRI dhan 28×BRRI dhan 29, S2P4

50% flowering was done within 113 to 120 days. Harvesting was done from 146 to 147 days. Number of effective tillers was 9-16, panicle length was 22.50-29.40 cm, total number of spikelet was 76-294, 1000-seed weight was 20-23 g, yield per plant varied from 20.70-61.50 gm and yield per hectare was 6.62 to 10.69 t. Among all populations of this cross, S2P4 (8) from replication-3 was selected for further trial as it contributed higher yield (61.5 g) than average yield per plant of its checks BRRI dhan 28 (34.04 g) and BRRI dhan 29 (34.20 g). S2P4 (8) had also higher number of total spikelet (274) which was responsible for higher yield. S2P4 (8) took lower days to maturity (135 days) than BRRI dhan 28 (141.70 days) and BRRI dhan 29 (160.70 days). Considering above character S2P4 (8) was selected. Selected early maturity plant from BRRI dhan 28 × BRRI dhan 29 is presented in Plate 8, panicle length and grain size are presented in Plate 9.

BRRI dhan 28×BRRI dhan 29, S2P5

50% flowering was done within 116-121 days. Harvesting was done from 145 to 147 days. Number of effective tillers was 8-16, panicle length was 23-31.50 cm, total number of spikelet was 145-300, 1000-seed weight was 20-26 g, yield per plant varied from 22.50-53.90 g and yield per hectare was 7.33-9.83 t. Among all populations of this cross, S2P5 (7) from replication-1 and S2P5 (6) from replication-3 were selected for further trial as they contributed higher yield (53.9 g and 51 g respectively) than average yield per plant of their checks BRRI dhan 28 (34.04 g) and BRRI dhan 29 (34.20 g). S2P5 (7) and S2P5 (6) took lower days to maturity (134 days) than BRRI dhan 28 (141.70 days) and BRRI dhan 29 (160.70 days).

Plate 8 . Photograph showing selection of early mature plant (BRRI dhan 28×BRRI dhan 29) in the field for further trial

(a)

(b)

Plate 9. Photograph showing (a) panicle length and (b) grain size of BRRI dhan 28×BRRI dhan 29 with their checks

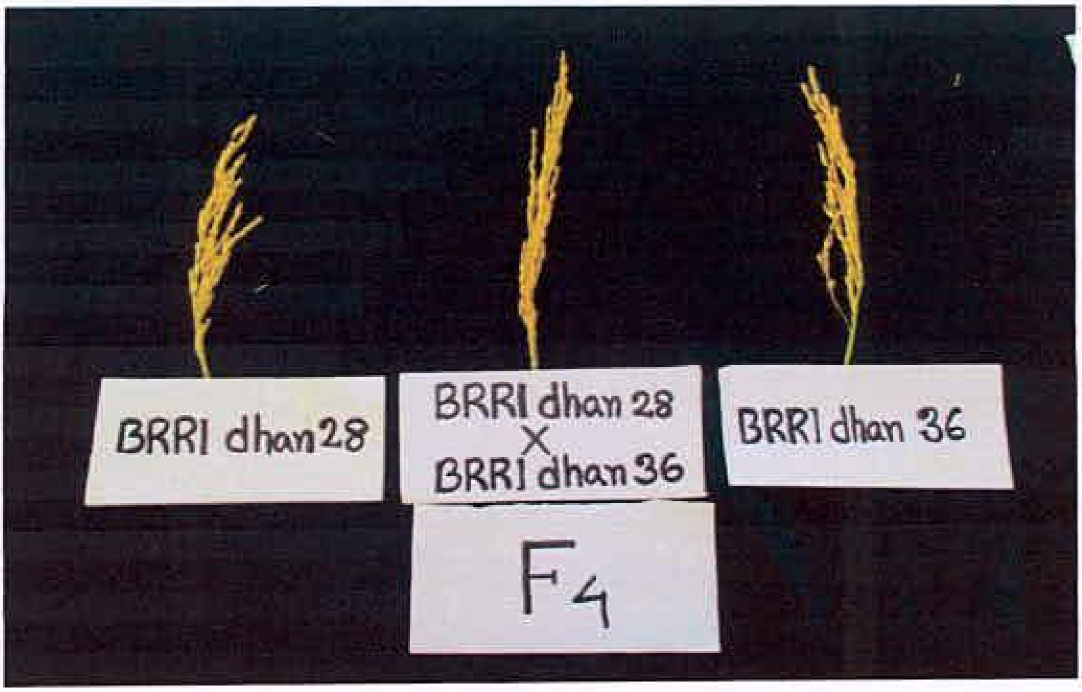
BRRI dhan 28×BRRI dhan 29, S2P6

50% flowering was done within 116-121 days. Harvesting was done from 145-147 days. Number of effective tillers was 8-18, panicle length was 16-27.5 cm, total number of spikelet was 112-277, 1000-seed weight was 18-20 g, yield per plant varied from 23.90-58.90 g and yield per hectare was 7.57-10.28 t. Among all populations of this cross, S2P6 (7) from replication-1, S2P6 (2) from replication-2 and S2P6 (8) from replication-3 were selected for further trial as they contributed higher yield (50.1 g, 45.7 gm and 58.9 g respectively) than average yield per plant of its checks BRRI dhan 28 (34.04 g) and BRRI dhan 29 (34.20 g). S2P6 (2) from replication-2 had lower yield than, S2P6 (7) from replication-1 and S2P6 (8) from replication-3 but selected for its higher number of effective tillers (17) and higher number of total spikelet (279), which gave it fine grains. They took lower days to maturity (134 days) than BRRI dhan 28 (141.70 days) and BRRI dhan 29 (160.70 days). Other high yielding plants were not selected either course grain or high duration for their maturity.

BRRI dhan 28×BRRI dhan 36, S7P1

50% flowering was done within 116-118 days. Harvesting was done from 145-148 days. Number of effective tillers was 9-20, panicle length was 19.50-28 cm, total number of spikelet was 125-283, 1000-seed weight was 19-21 g, yield per plant varied from 20.3-55.40 g and yield per hectare was 7.29-10.42 t. Among all populations of this cross, S7P1 (6, 8)) from replication-1 and S7P1 (1, 2)) from replication-2 were selected for further trial as they contributed higher yield (53.5 gm, 52.8 gm, 55.4 gm and 52.3 gm respectively) than average yield per plant of its checks BRRI dhan 28 (34.04 g) and BRRI dhan (34.20 g). They took lower days to maturity (134 days) than BRRI dhan 28 (141.70 days) and BRRI dhan 36 (145.30 days). Other high yielding plants were not selected either course grain or high duration for their maturity. Selected early maturity plant from BRRI dhan 28 × BRRI dhan 36 is presented in Plate 10, panicle length and grain size are presented in Plate 11.

Plate 10 . Photograph showing selection of early mature plant (BRRI dhan 28×BRRI dhan 36) in the field for further trial



(a)

(b)

Plate 11. Photograph showing (a) panicle length and (b) grain size of BRRI dhan 28×BRRI dhan 26 with their checks

BRRI dhan 28×BRRI dhan 36, S7P6

50% flowering was done within 114-121 days. Harvesting was done from 145-147 days. Number of effective tillers was 9-15, panicle length was 20.30-28 cm, total number of spikelet was 109-242, 1000-seed weight was 21-25 g, yield per plant varied from 24.90-61.10 g and yield per hectare was 7.93-9.19 t. Among all populations of this cross, S7P6 (4)) from replication-1, S7P6 (2)) from replication-2 and S7P6 (10) from replication-3 were selected for further trial as they contributed higher yield (61.1 gm, 58.9 gm and 53.2 gm respectively) than average yield per plant of their checks BRRI dhan 28 (34.04 g) and BRRI dhan (34.20 g). S7P6 (10) from replication-3 had lower yield than S7P6 (4)) from replication-1, S7P6 (2)) from replication-2 but having higher number of total spikelet (243) with fine grains. It also had higher yield than other selected materials. They took lower days to maturity (134 days) than BRRI dhan 28 (141.70 days) and BRRI dhan 36 (145.30 days). Other high yielding plants were not selected either course grain or high duration for their maturity.

BRRI dhan 28×BRRI dhan 36, S7P8

50% flowering was done within 116-119 days. Harvesting was done from 145-148 days. Number of effective tillers was 8-18, panicle length was 20.70-28.60 cm, total number of spikelet was 118-296, 1000-seed weight was 20-24 g, yield per plant varied from 21.80-50.80 g and yield per hectare was 7.17-10.85 t. Among all populations of this cross, S7P8 (10) from replication-1 was selected for further trial as it contributed higher yield (50.80 g) than average yield per plant of its checks BRRI dhan 28 (34.04 g) and BRRI dhan (34.20 g). S7P8 (10) had also fine grains and higher number of total spikelet (296). They took lower days to maturity (134 days) than BRRI dhan 28 (141.70 days) and BRRI dhan 36 (145.30 days). Other high yielding plants were not selected either course grain or high duration for their maturity.

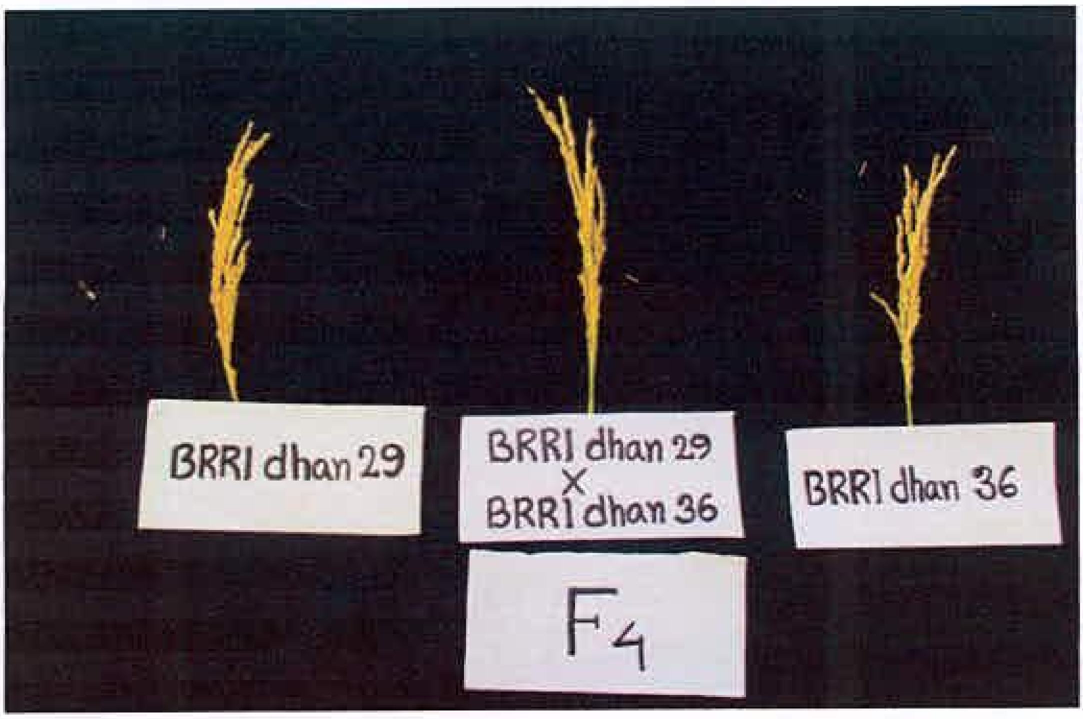
BRRI dhan 28×BRRI dhan 36, S7P9

50% flowering was done within 117-120 days. Harvesting was done from 145-148 days. Number of effective tillers was 8-17, panicle length was 22-25.6 cm, total number of spikelet was 138-271, 1000-seed weight was 22-24 g, yield per plant varied from 25.5-62.50 g and yield per hectare was 7.95-9.31 t. Among all populations of this cross, S7P9 (7) from replication-1 and S7P9 (10) from replication-2 were selected for further trial as they contributed higher yield (53.3 g and 62.5 g respectively) than average yield per plant of its checks BRRI dhan 28 (34.04 g) and BRRI dhan (34.20 g). S7P9 (10) had also fine grains. They took lower days to maturity (134 days) than BRRI dhan 28 (141.70 days) and BRRI dhan 36 (145.30 days). Other high yielding plants were not selected either course grain or high duration for their maturity.

BRRI dhan 29×BRRI dhan 36, S5 P5

50% flowering was done within 116-118 days. Harvesting was done at 145 days. Number of effective tillers was 8-21, panicle length was 21.80-26 cm, total number of spikelet was 120-266, 1000-seed weight was 20-21 g, yield per plant varied from 20.3-61.3 g and yield per hectare was 7.94-9.77 t. Among all populations of this cross, S5P5 (5) from replication-1 and S5P5 (4, 7) from replication-3 were selected for further trial as they contributed higher yield (59.5 g and 61.3 g respectively) than average yield per plant of its checks BRRI dhan 29 (34.20 g) and BRRI dhan (34.20 g). They had also fine grains and took lower days to maturity (134 days) than BRRI dhan 29 (160.70 days) and BRRI dhan 36 (145.30 days). Other high yielding plants were not selected either course grain or high duration for their maturity. Selected early maturity plant from BRRI dhan 29 × BRRI dhan 36 is presented in Plate 12, panicle length and grain size are presented in Plate 13.

Plate 12 . Photograph showing selection of early mature plant (BRRI dhan 29×BRRI dhan 36) in the field for further trial



(a)

(b)

Plate 13. Photograph showing (a) panicle length and (b) grain size of BRRI dhan 29×BRRI dhan 36 with their checks

CHAPTER V
SUMMARY AND CONCLUSION

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The present study was conducted in the experimental farm, Sher-e-Bangla Agricultural University (SAU), Dhaka during December 2013 to May 2014. This experiment involved four parents and twenty five F_4 cross materials of rice and was laid out in a Randomized Complete Block Design (RCBD) with three replications. Data on various yield attributing characters such as, days to flowering, days to maturity, plant height (cm), number of total tillers per plant, number of effective tillers per plant, panicle length (cm), number of primary branches per panicle, number of secondary branches per panicle, number of filled grains per panicle, number of unfilled grains per panicle, total number of spikelet per panicle, yield per plant (g), 1000 seed weight (g), yield per hectare (t) were recorded.

From variability analysis of F_4 progenies, it was observed that significant variation exist among all the genotypes used for most of the characters studied. In this study out of 25 cross materials G14 (BR 26×BRRI dhan 36, S7P6) took the longest period for days to flowering and G16 (BRRI dhan 28×BRRI dhan 29, S2P3) took minimum days for flowering. The highest number of days to maturity was recorded in G12 (BR 26×BRRI dhan 36, S7P3) and minimum days to maturity recorded in G26 (BRRI dhan 29×BRRI dhan 36, S5P5). The highest plant height was recorded in G12 (BR 26×BRRI dhan 36, S7 P3) and the minimum plant height was recorded in G16 (BRRI dhan 28×BRRI dhan 29, S2P3). The highest number of tillers per plant was recorded in G7 (BR 26×BRRI dhan 29, S1P7) and the minimum number of tillers per plant was recorded in G17 (BRRI dhan 28×BRRI dhan 29, S2P4). The highest number of effective tillers per plant was recorded in G7 (BR 26×BRRI dhan 29, S1P7) and the minimum number of effective tillers per plant was recorded in G12 (BR 26×BRRI dhan 36, S7P3). The highest number of panicle length was recorded in G18 (BRRI dhan 28×BRRI dhan 29, S2P5) and the minimum panicle length was recorded in G21 (BRRI dhan 28×BRRI dhan 36, S7P2). The highest number of primary branches per panicle was recorded in G27 (BRRI dhan 29×BRRI dhan 36, S5P7) and the minimum number of primary branches per panicle was recorded in G12 (BR 26×BRRI dhan 36, S7P3). The highest number of secondary branches per panicle was recorded in G20 (BRRI dhan 28×BRRI dhan 36, S7P1) and the minimum number of secondary branches per panicle was recorded in G14 (BR 26×BRRI dhan 36, S7P6). The highest number filled grains per panicle was recorded in G18 (BRRI dhan 28×BRRI dhan 29, s2 p5) and the minimum number of filled grains per panicle was recorded in G14 (BR 26×BRRI dhan 36, S7P6). The highest number unfilled grains of per panicle was recorded in G28 (BRRI dhan 29×BRRI dhan 36, S5P9) and the minimum number of unfilled grains per panicle was recorded in G10 (BR 26×BRRI dhan 36, S7P1). The highest number of spikelet per panicle was recorded in G18 (BRRI dhan 28×BRRI dhan 29, S2P5) and the minimum number of spikelet per panicle was recorded in G14 (BR 26×BRRI dhan 36, S7P6). The highest number of yield per plant was recorded in G26 (BRRI dhan 29×BRRI dhan 36, S5P5) and the minimum number of yield per plant was recorded in G17 (BRRI dhan 28×BRRI dhan 29, S2P4). The highest number of 1000-seed weight was recorded in G13 (BR 26×BRRI dhan 36, S7P4) and the minimum number of 1000-seed weight was recorded in G7 (BR 26×BRRI dhan 29, S1P7). The highest number of yield was recorded in G29 (BRRI dhan 29×BRRI dhan 36, S5P10) and the minimum number of yield was recorded in G7 (BR 26×BRRI dhan 29, S1P7).

However, the phenotypic variance and phenotype coefficient of variation were higher than the corresponding genotypic variance and genotypic coefficient of variation for all the characters under study. In case of number of filled grains per panicle, number of unfilled grains per panicle, total number of spikelet per panicle showed higher influence of environment for the expression of these characters.

On the other hand, days to flowering, days to maturity, number of total tillers per plant, number of effective tillers per plant, panicle length, number of primary branches per panicle, 1000-seed weight, yield per hector showed least difference phenotypic and genotypic variance suggesting additive gene action for the expression of the characters.

Number of secondary branches per panicle exhibits the highest value of heritability (93.72%) while panicle length exhibits the lowest value of heritability (61.15%). High heritability with high genetic advance in percent of mean was observed for number of tillers per plant, effective tillers per plant, number of primary branches per panicle, number of secondary branches per panicle, number of filled grains per panicle, number of unfilled grains per panicle, total number of spikelet per panicle, 1000-seed weight, yield per hector indicating that these traits were under additive gene control and selection for genetic improvement for these traits would be effective except number of unfilled grains per panicle.

High heritability with moderate genetic advance was observed for plant height, panicle length and yield per plant indicating medium possibility of selecting genotypes. High heritability with low genetic advance in percent of mean was observed for days to flowering and days to maturity indicating that non-additive gene effects were involved for the expression of these characters and selection for such traits might not be rewarding but there would be possibility for future selection.

Correlation coefficients among the characters were studied to determine the association between yield and yield components. In general, most of the characters showed the genotypic correlation co-efficient were higher than the corresponding phenotypic correlation co-efficient suggesting a strong inherent association between the characters under study and suppressive effect of the environment modified the phenotypic expression of these characters by reducing phenotypic correlation values. In few cases, phenotypic correlation co-efficient were higher than their corresponding genotypic correlation co-efficient suggesting that both environmental and genotypic correlation in these cases act in the same direction and finally maximize their expression at phenotypic level. The significant positive correlation with seed yield per hector were found in days to maturity (G=0.596, P=0.325), number of primary branches per panicle (G=0.722, P= 0.421), number of secondary branches per panicle (G=0.655, P=0.403) total number of spikelet per panicle (G= 0.513, P=0.343) and yield per plant (G=0.566, P=0.339)). In addition, there were non-significant positive correlation with yield per hector was also found in number of effective tillers per plant (G=0.206, P=0.101) and number of primary branches per panicle (G=0.236, P=0.103).

Path co-efficient analysis revealed that plant height, number of total tillers per plant, number of effective tillers per plant, number of secondary branches per panicle, number of filled grains per panicle, total number of spikelet per panicle and 1000-seed weight had the positive direct effect on yield per plant. Whereas, days to flowering, days to maturity, panicle length, number of primary branches per panicle, number of unfilled grains per panicle and yield per plant had the negative direct effect on yield per plant.

The genotypic correlation of days to maturity, number of secondary branches per panicle, number of filled grains per panicle, total number of spikelet per panicle and yield per plant were positive and considerably higher in magnitude. It is mainly due to high positive direct effect and positive indirect effects of others characters and selection would be effective for this trait. The path co-efficient studies indicated that effective tillers per plant, panicle length and 1000-seed weight were the most important contributors to yield per hector which could be taken in consideration for future hybridization program.

The residual effect was 0.164, indicated that contribution of component characters on yield per hectare was 83.6% by the thirteen characters studied in path analysis, the rest 16.4% was the contribution of other factors such as characters not studied and sampling error.

26 plants from G8 (BR 26 ×BRRI dhan29, S1P8), G9 (BR 26×BRRI dhan 29, S1P10), G10 (BR 26×BRRI dhan 36, S7P1), G15 (BRRI dhan 28×BRRI dhan 29, S2P2), G16 (BRRI dhan 28×BRRI dhan 29, S2P3), G17 (BRRI dhan 28×BRRI dhan 29, S2P4), G18 (BRRI dhan 28×BRRI dhan 29, S2P5), G19 (BRRI dhan 28×BRRI dhan 29, S2P6), G20 (BRRI dhan 28×BRRI dhan 36, S7P1), G22 (BRRI dhan 28×BRRI dhan 36, S7P6), G23 (BRRI dhan 28×BRRI dhan 36, S7P8), G24 (BRRI dhan 28×BRRI dhan 36, S7P9) and G26 (BRRI dhan 29×BRRI dhan 36, S5P5) on the basis of days to maturity, total number of spikelet and yield per plant.

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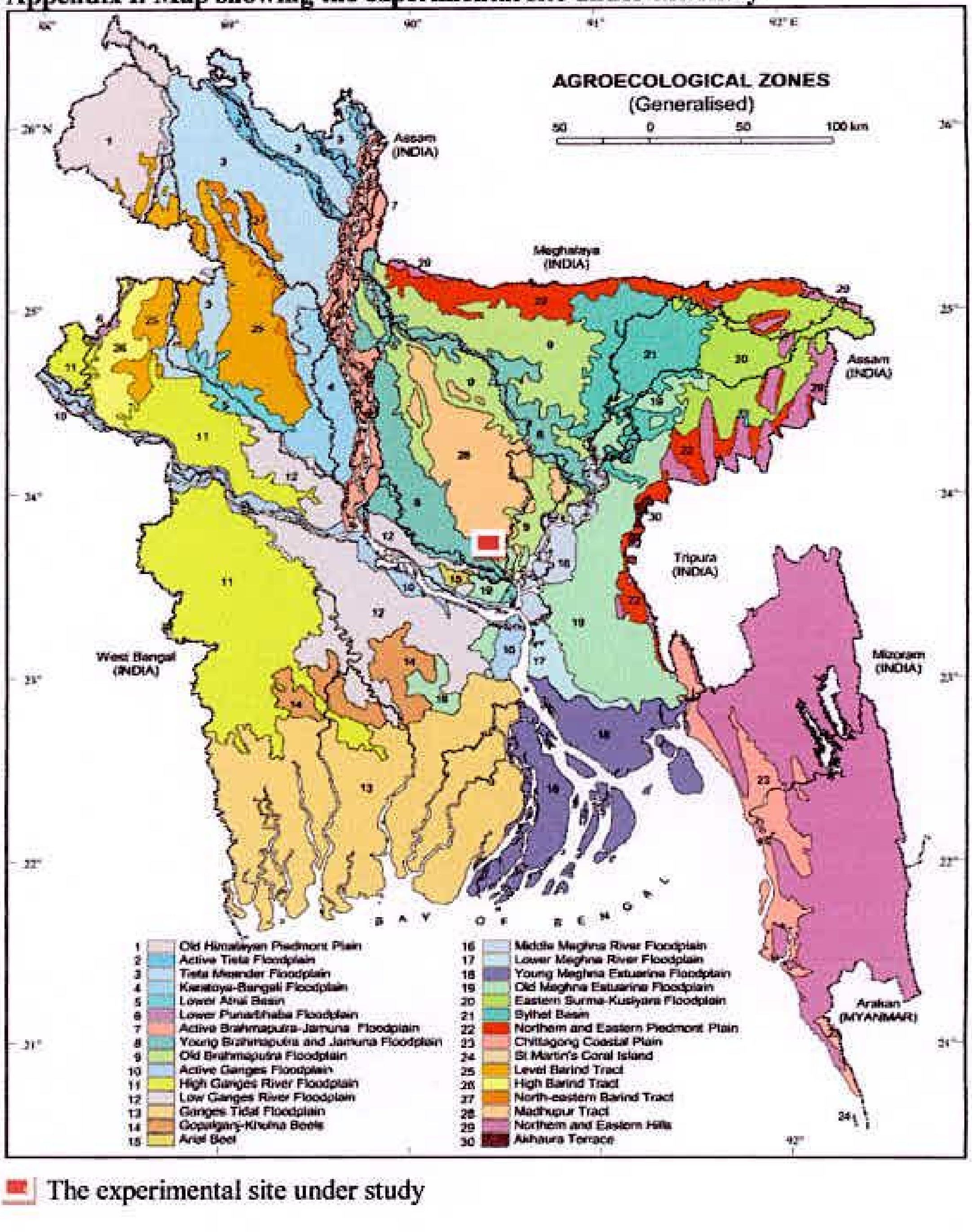
APPENDICES

APPENDICES

Appendix I. Map showing the experimental site under the study



The experimental site under study

Appendix II: Morphological, physical and chemical characteristics of initial soil (0-15 cm depth) of the experimental site

A. Physical composition of the soil

Soil separates	%	Methods employed
Sand	36.90	Hydrometer method (Day, 1915)
Silt	26.40	Do
Clay	36.66	Do
Texture class	Clay loam	Do

B. Chemical composition of the soil

Sl. No.	Soil characteristics	Analytical data	Methods employed
1	Organic carbon (%)	0.82	Walkley and Black, 1947
2	Total N (kg/ha)	1790.00	Bremner and Mulvaney, 1965
3	Total S (ppm)	225.00	Bardsley and Lanester, 1965
4	Total P (ppm)	840.00	Olsen and Sommers, 1982
5	Available N (kg/ha)	54.00	Bremner, 1965
6	Available P (kg/ha)	69.00	Olsen and Dean, 1965
7	Exchangeable K (kg/ha)	89.50	Pratt, 1965
8	Available S (ppm)	16.00	Hunter, 1984
9	pH (1:2.5 soil to water)	5.55	Jackson, 1958
10	CEC	11.23	Chapman, 1965

Source: Central library, Sher-e-Bangla Agricultural University, Dhaka.

Appendix III. Monthly average Temperature, Relative Humidity and Total Rainfall of the experimental site during the period from November, 2013 to March, 2014

Month	Air temperature (°c)		Relative humidity (%)	Rainfall (mm) (total)
	Maximum	Minimum		
November, 2013	28.10	6.88	58.18	1.56
December, 2013	25.35	5.21	54.30	0.63
January, 2014	21.17	15.46	64.02	0.00
February, 2014	24.30	19.12	53.07	2.34
March, 2014	29.78	22.37	48.66	0.12

Source: Weather station, Sher-e-Bangla Arricultural University, Dhaka - 1207

Appendix IV. Dose and method of application of fertilizers in rice field

Fertilizers	Dose(kg/ha)	Application (%)		
		Basal	Installment	
			1st	2nd
Urea	150	33.33	33.33	33.33
TSP	100	100	--	--
MP	100	100	--	--
Gypsum	60	100	--	--
Borax	10	100	--	--

Source: BRRI, 2013, Adhunik Dhaner Chash, Jodebpur, Gazipur.