“GENETIC VARIABILITY, CORRELATION AND PATH ANALYSIS IN RED RICE GENOTYPES (*Oryza sativa* L.)”

A

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IN

GENETICS AND PLANT BREEDING

BY

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B.Sc. (Hort.)

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B. A. COLLEGE OF AGRICULTURE,

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CERTIFICATE

This is to certify that the thesis entitled **"GENETIC VARIABILITY, CORRELATION AND PATH ANALYSIS IN RED RICE GENOTYPES (*O. sativa* L.)"** submitted by **MR. PATIL ABHIJIT SURESHRAO (Reg. No. 04-1315-2010)** in partial fulfillment of the requirements for the award of the degree of **MASTER OF SCIENCE** in **GENETICS AND PLANT BREEDING** of the Anand Agricultural University, Anand is a record of bonafide research work carried out by him under my guidance and supervision and the thesis has not previously formed the basis for the award of any degree, diploma or other similar title.

Place: Anand **(M. G. MAKWANA)**

Date: /08/2014 **Major Advisor**

DECLARATION

This is to declare that the whole of the research work reported herein for the partial fulfillment of the requirement for the degree of **Master of Science in Genetics and Plant Breeding** by the undersigned is the result of investigation done by me under the guidance and supervision of **Dr. M. G. Makwana,** Research Scientist, Bidi Tobacco Research Station, Anand Agricultural University, Anand and no part of work has been submitted for any other degree so far.

Place: Anand

Date: /08/2014 **(Patil Abhijit Sureshrao)**

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ABSTRACT

Genetic variability, correlation and path coefficients, were studied in 59 red and 4 white rice genotypes during Kharif - 2011 at Main Rice Research Station, Anand Agricultural University, Nawagam.

The analysis of variance revealed significant differences for all the characters under study. Characters like grain yield per plant, plant height, number of productive tillers per plant, number of grains per panicle, number of filled grains per panicle, 1000 grain weight, grain breadth, grain L:B ratio and harvest index had high genotypic coefficient of variances, high heritability and moderate to high genetic advance expressed as percentage of mean indicating that phenotypic selection could be effective in improvement of these characters. Iron and zinc content had high genotypic coefficient of variation, high heritability and low to moderate genetic advance as percentage of mean. The estimates of genotypic coefficient of variation and genetic advance were low to moderate for days to 50% flowering, panicle length, number of total tillers per plant, grain length, hulling and milling percentage.

Grain yield per plant exhibited significant positive correlation with panicle length, number of total tillers per plant, number of productive tillers per plant, number of filled grains

per panicle, 1000 grain weight, hulling percentage and harvest index at phenotypic as well as genotypic levels, while with grains per panicle at phenotypic level and with milling percentage at genotypic level.

The path coefficient analysis, studying sixteen characters as causal variable indicated that grain length had high positive direct effect on grain yield per plant followed by 1000 grain weight, number of filled grains per panicle, plant height, number of productive tillers per plant and hulling percentage, whereas, harvest index and days to 50% flowering indicated moderate and low positive direct effect respectively. Indirect effect of grain L:B ratio through plant height, grain breadth *via* number of productive tillers per plant and number of filled grains per panicle, grain L:B ratio *via* 1000 grain weight, grain breadth *via* grain length, 1000 grain weight and grain L:B ratio *via* hulling percentage were also positive and high.

Results revealed that the importance of yield components like number of productive tillers per plant, number of filled grains per panicle, 1000 grain weight, grain length and harvest index in selection programme aiming to improve grain yield per plant of red rice, since, these characters had high heritability, moderate to high genotypic coefficient of variation and moderate to high genetic advance as percent of mean. These characters also had significant positive correlation at genotypic and phenotypic levels and high positive direct effects on grain yield.

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Place : Anand

DATE : /08/2014 ***(Patil Abhijit Sureshrao)***

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I. INTRODUCTION

Rice (*Oryza sativa* L.) is life and princess among the *cereals* and the most important food crop of the world. It is the second largest cereal crop after wheat, which is a staple food for one half to two third of the world's population. It belongs to the genus *Oryza*, sub tribe *Oryzineae* of the family Poaceae. The genus includes 24 species of which 22 are wild and 2 viz., *O. Sativa* L. (Asian rice), *O. Glaberrima* Steaud (African rice) are cultivated. Both the species are diploid 2n=2x=24 in chromosome number respectively cultivated in Asia and Africa. *O. sativa* (Asian rice) has 3 eco-geographical races viz., *indica, japonica* and *javanica.* The Asian cultivated rice (*O. sativa)* have been divided into two broad groups namely *japonica* and *indica.* The two groups show certain morphological, physiological and genetical differences. Later, a third group, *javanica*, has been recognized among Indonesian types (Takahashi, 1984). *Oryza sativa* evolved from an annual progenitor over a broad belt Gangenetic plains to the foot hills of Himalayas, across upper Burma, northern Thiland, Loas to Northern Vietnam and South China (Seetharaman, 1981). Besides the primary centers of origin, secondary centers are in Assam and adjoining areas and Jeypore tract in Koraput district of Odisha.

Among all the cereals, it occupies second position next to wheat (Anon., 2010 a). In 2010, globally per person rice consumption was 56.7 kilograms per year. It contains protein 7.3 g, carbohydrates 78 g, fat 3.6 g, crude fibre 0.4 g, thiamine 0.41 mg, riboflavin 0.02 mg, niacin equivalents 5.8 mg, sodium 4 mg, iron 0.5 mg, magnesium 32 mg, zinc 1.8 mg, calcium 51 mg and phosphorus 150 mg per 100 g. (Anon., 2002).

There is hardly any crop plant that grows under as diverse agroclimatic conditions as rice does. Rice is cultivated from 50^{o} N in central Czechoslovakia on the equator to 35^{o} S in Australia and it has adaptations to wide range of growing conditions, varying from below sea level in Kuttanad region of Kerala (India) to an altitude as high as 2000 m in Himalayas, extreme water regimes ranging from highly drought-prone uplands (<50 mm rainfall) to flood prone/ deep water lowlands(2-3 m depth), temperature in the range of 33^{o} C in West Pakistan to 17^{o} C in North Japan and soil types from acidic (pH<4) to alkaline/ saline soils(pH>11 and EC>4). Given its adaptation to such a wide range of growing conditions, defining of typical "rice climate" would not be easy. Nevertheless, conditions relatively optimal for high productivity and normal growth are deep non-injurious soils, enough water, high temperature and ample solar radiation throughout the growing season (Chopra, 2001).

It is grown extensively in the tropical and subtropical region of the world. Geographically, most of the rice area in the developing world is found in Asia about 90 per cent of world's rice area hence Asia is considered as "Rice Bowl". India ranks first position in area and second position in production. In India, rice covers the largest area of about 45 million hectares and producing 99.18 million tons with a productivity of 2178 kg/ha and extensively grown in most of states. In Gujarat most of the area under rice crop is confined in Middle to South Gujarat about 0.75 million hectares area with the production of 1.30 million tons and a productivity of 1744 kg/ha comprising the districts of Ahmedabad, Kheda, Anand, Vadodara, Dahod, Panchmahals, Surat, Valsad, Tapi, Dang and Navsari (Anon., 2010 b).

In traditional growing areas of Asia, rices of various colours as red, brown, purple, black, yellow and green have been known and grown. Coloured rices preffered in past for their special features such as medicinal value and exclusive taste. Rice with red bran layer is called red rice. The colour of the bran ranges from light to dark red. The red colour pigment in rice grains is due to the presence of proanthocynidins pigment (Oki *et al.,* 2002). Proanthocynidin pigment have shown important deterrant effect on pathogens and predators (Bate-Smith, 1973 and Scalbert, 1991). And also possesses several medicinal properties which promotes blood circulation and digestion. Bran layer contains polyphenols and anthocynin and possesses antioxidant properties. Anthocynin pigment system consists mainly of three basic genes : the *C* (chromogen), the *A* (activator) and the *P* (distributor) gene. The anthocynin is synthesized and regulated by structural and regulator genes respectively (Talukdar and Zhang, 2006).

Red rices occurs as a wild, weedy or cultivated type and red kernels are covered with dark or light coloured husk. Various species of wild red rices, *O. granulata, O. officinalis, O. rufipogan and O. nivara* occur in India. *O. rufipogan and O. nivara* have red grains and both are used as food and medicine. The male sterility in rice was first found in *O. rufipogan.* Off-type plants having a red pericarp or seeds are considered as weedy. These have awns of varying degree, high rate of out crossing, high seed shattering rate and dormancy (Oka,1988). Wild rices have been utilized in rice varietal improvement programme to impart resistance against many diseases and pests.

Red rices has more Vitamin B1, Vitamin B2, Vitamin C, N, P, K, Ca, Mg, S (Jing *et al.,* 2000). The zinc and iron contain of red rices is 2-3 times higher than white rices (Ramaiah and Rao, 1953). Regardless the problem associated with red rice as weed, the red pigment is of intrest for nutritional reasons and importantly “Biofortification” which has emerged as a new strategy to address micronutrient malnutrition.

Before the advent of high-yeilding varieties, which are mostly white, red rices formed an important group in Asian countries such as India, Srilanka, Philipines, Korea, China, Japan. Few red varieties were reported from the plains of Gujarat, Haryana, Rajasthan, Punjab, Western Uttar Pradesh. The main emphasis of rice varietal improvement in all countries and International Institutes has been on increasing rice production per unit area followed by imparting resistance against biotic stresses and finally on cooking and grain quality. Most varieties released have been white, due to market demand that has resulted in the reduction and depletion of red rice varieties from Asia and Africa (Ahuja *et al.,* 2007).

The agricultural food production must continue to meet the demands of growing population. It is estimated that by the year 2025 the global population is expected to reach 8.5 billion and agricultural land availability will decline appreciably. The scarcity of productive agricultural land may force us to grow agricultural crops in harsher environments (Khush, 2005).

In any crop improvement programme, existence of variability and selection of genotypes with due selection pressure on yield component characters is of prime importance. The efficiency of selection depends on the existence of genetic variability in the base population. However, assessment of genetic variability in the base population is the first step in any breeding programme. The extent of success further depends on degree to which these components are heritable. The yield and yield contributing characters are generally polygenic in nature and influenced by environment. Sometimes it is difficult to judge whether observed variation for a particular character is heritable or due to environmental influence. Therefore heritability estimates are important. Burton (1952) and Johnson *et al.* (1955) reported that to arrive at a reliable conclusion, genetic variability and heritability should jointly be considered in totality so as to bring an effective improvement in yield and other yield related characters.

The yield is a complex character resulting from interplay of various yield contributing characters, which have positive or negative association with yield and among themselves. Thus, selection directly based on the performance of seed yield may not be very effective but selection based on its component characters would prove more effective as reported in other plants (Fisher, 1918). Correlation studies would provide estimates of degree of association between seed yield and its various components and also among the components.

The study of character association has been suggested to be an important strategy designed to break negative genetic barriers to yield. Although studies on correlation are helpful in determining the components of complex characters like seed yield, these estimates do not provide an exact picture of the relative magnitude of direct and indirect influences of each of the component character on seed yield. In these context Wright (1921) proposed estimation of path coefficient analysis as an important tool in partitioning the correlation coefficient into direct and indirect effects which will be useful in identifying important biometrical characters to achieve desirable goal.

Therefore, keeping all these facts in view the proposed investigation is undertaken using 59 red and 4 white genotypes of rice.

1. To ascertain the extent of variability in quantitative and qualitative traits, and partitioning it into heritable and non-heritable components.
2. To estimate heritability and genetic advance of various phenotypic traits.
3. To study the extent of genotypic and phenotypic correlations between grain yield and other characters, and
4. To estimate direct and indirect effect of various grain yield components by partitioning total components through path coefficient analysis.

II. REVIEW OF LITERATURE

The present literature pertaining to the rice (*Oryza sativa* L.) has been reviewed as follows :

2.1 Variance components

2.2 Correlation coefficient

2.3 Path analysis

2.1 VARIANCE COMPONENTS

The progress of any breeding programme depends on the information regarding genetic variability present in a population. In 1918, Fisher partitioned the genetic variance into following three components.

(a) Additive genetic variance

(b) Dominance components

(c) Epistatic components

Amongst the, additive genetic variance is the variance of breeding values, which can be exploited for genetic advance through selection. This together with information on heritability and genetic advance would be rewarding and designing an effective breeding programme. The genetic variability is determined with the help of certain genetic parameters such as genotypic coefficient of variation (GCV), phenotypic coefficient of variation (PCV), heritability estimates and their partitioning them into heritable and non-heritable components. The knowledge of heritability helps the plant breeder in pre-assesing the results of selection for a particular character. However, for predicting the effects of selection, heritability estimates along with genetic advance are more useful than the heritability estimates alone (Johnson *et al,* 1955). A brief review on variability parameters in rice presented here under :

Johnson *et al.* (1955) indicated that heritability is the ratio of the genotypic variance to the phenotypic variance. In the strict sense, it is a fraction of the total variance that is due to additive effect of genes. If heritability of the character is high, the phenotypic value provides a fairly close measure of the genotypic value and thus, breeder could base his selection on phenotypic performance. However, for predicting the effective selection heritability estimates along with genetic advance are more useful than heritability estimate alone.

Panse (1957) postulated the necessity for partitioning the phenotypic variability into heritable and non heritable components. He also suggested that selection based on heritable characters would be more effective rather than non heritable characters because highly heritable character show least effects of environments.

Allard (1960) proposed that genotypic variance must be measured with reference to some particular group of environments. He also reported that genotypic variance estimated from a single test in one environment contains interaction variance in addition to the genotypic variance.

Chaudhary *et al.* (1973) studied genetic variability in 23 rice varieties and found high genotypic coefficient of variation for panicle weight, panicle number and yield per plant. They also reported high heritability and high genetic advance for panicle weight, single plant yield, number of panicles, grains per panicle and 1000-grain weight.

Das and Borthakur (1974) studied ten tall and sixteen semi-dwarf *indica* rice varieties of diverse origin for variability in 19 quantitative characters, traditional tall varieties were found greater genetic variability and genetic advance for most of the traits. High GCV was observed for panicle weight, panicle number per hill, spikelet per panicle, 1000-grain weight and grain yield per plant in both the parents. Days to 50% flowering and plant height showed low PCV and GCV values. Further, high heritability coupled with high genetic advance was observed for 1000-grain weight, panicle weight and panicle number per hill; while moderate heritability was found for grain yield per plant with high genetic advance.

Paramasivam (1981) reported that heritability ranged from 16.20 per cent for number of productive tillers to 94.60 per cent for length of panicle. Number of spikelet showed very high value of heritability (93.23%) along with high genetic advance (51.38%). The high value of heritability and genetic advance for number of grains per panicle was attributed to high degree of additive effect.

Amirthadevarathinam (1983) obtained high estimate of genetic coefficient of variation, heritability and genetic advance expressed as per cent of mean for grain yield, productive tillers, total tillers and days for first flowering.

Maurya *et al.* (1986) evaluated 48 lowland rice cultivars for assessing variability, heritability and genetic advance. A wide range of variation was found for characters like test weight, grains per panicle, tillers per plant, grain yield per plant and leaf angle. Where as, panicle length and days to 50% flowering noted narrow range of variation. High heritability with high genetic advance was observed for kernel length. Length:breadth ratio, plant height, test weight and grains per panicle.

Singh *et al.* (1986) studied variability, heritability and genetic advance in 98 upland rice cultivars. They reported all the characters except sheath length showed wide range of phenotypic variation. They also found that phenotypic coefficient of variation was higher than genotypic coefficient of variation. Heritability was highest for days to 50% flowering followed by plant height, seedling height and test weight.

Hussain *et al.* (1987) reported high GCV, PCV, heritability and genetic advance for grain breadth and length:breadth ratio in indigenous upland rice. But variation was low for grain length with moderate genetic advance. Test weight had high GCV and PCV coupled with (GA%), but low heritability.

Sundaram *et al.* (1988) studied genetic variability and correlation coefficient in early rice varieties and reported higher estimates of phenotypic and genotypic variance for grains per panicle, plant height and dry matter, where as, lowest for productive tillers. They also reported moderate to high heritability coupled with genetic gains for straw yield, grains per panicle, dry matter and productive tillers indicating presence of additive gene effects for these characters.

Deoskar *et al.* (1989) investigated 30 breeding lines of upland rice and observed high coefficient of variation for characters *viz.,* plant height, grain yield per plant, number of grains per panicle and 1000-grain weight. High values of heritability coupled with high to moderate expected genetic advance was observed for plant height, days to 50% flowering, days to maturity and 1000-grain weight.

Amirthadevarathinum (1990) observed highest genotypic coefficient of variation for grains per panicle followed by number of tillers and plant yield in both early maturing *indica* and *japonica* rice genotypes. Expected genetic advance and heritability estimates were higher for Days to 50% flowering, panicle length and grains per panicle.

Singh *et al.* (1990) measured 16 yield components in 56 genotypes sown in sodic soil and reported high value of both GCV and PCV for tillers per plant, panicles per plant, filled grains per panicle, spikelets per panicle, grain yield per plant and harvest index. Days to 50% flowering, days to maturity and panicle length showed low PCV and GCV values. Further, heritability of all the traits was high except for grain yield per plant. Grain sterility, spikelet per panicle, filled grains per panicle and harvest index showed high values for genetic advance.

Chauhan *et al.* (1993) studied genetic variation and character association in rainfed upland rice and reported that straw yield per plant exhibited highest genetic variation followed by harvest index. They further reported that straw yield per plant, harvest index, 1000 grain weight, days to 50 per cent flowering, panicle length and per cent filled spikelets possessed high heritability coupled with high to moderate expected genetic advance in 21 advance breeding lines in rice.

Kannan Babu and Soundrapandian (1993) studied 25 F3 family progenies for variability analysis and revealed that grain yield per plant exhibited highest PCV and GCV followed by number of productive tillers and total number of tillers. High heritability was observed in all the traits i.e., plant height total number of tillers grain yield per plant and 1000-grain weight except panicle length. High genetic advance per cent of mean together with high heritability was recorded for grain yield per plant, total and productive tillers per plant.

Patil *et al.* (1993) observed that the characters grain yield per m^2, straw yield per m^2, and number of filled grains per panicle showed high GCV, high heritability was observed for all the characters studied in 37 cultures of upland rice during wet season. The considerable range of genetic advance was exhibited (8.96 to 73.83). However, straw yield per m^2 expressed maximum genetic gain (73.83) followed by grain yield per m^2 (73.60) and number of filled grains per panicle (38.02).

Chooker *et al.* (1994) observed maximum range of variation for plant height, effective tillers per meter length, 1000 grain weight, number of grains per panicle, days to 50% flowering, days to maturity and grain yield per plot. The significant variability was observed for days to 50% flowering, effective tillers per meter length and days to maturity and also appreciable amount of genotypic coefficient of variation, heritability and expected genetic advance was for quantative characters *viz.,* length of panicle, number of grains per panicle and 1000 grain weight, which indicated additive gene action in these characters.

Sawant *et al.* (1994) studied 55 breeding lines of low land rice and revealed that grains per panicle, plant height, ear bearing tillers per plant, 100 seed weight and seed yield per plant had considerable amount of variation. Plant height and grains per panicle exhibited high heritability with high genetic advance but seed yield had low heritability indicating that this trait was under the influence of environmental factors.

Ganesan *et al.* (1995) evaluated 28 rice hybrids and their seven very early and four early maturing parents. They reported that characters viz., grains per panicle, grain yield, dry matter production and panicles per plant had high GCV, heritability and genetic advance as per cent of mean.

Sawant and Patil (1995) assessed 75 diverse genotypes of rice for variability studies and found out that high GCV and PCV were observed for grain yield per plant and plant height, panicle length, days to 50% flowering had high heritability with low genetic advance.

Ravindra Babu (1996) studied the nature and magnitude of variation of 22 advanced generation saline tolerance genotypes. They found that GCV and PCV were high for productive tillers per plant, plant height, panicle length, 1000 grain weight, and grain yield per plant. High heritability observed for productive tillers per plant, plant height, panicle length and grain yield per plant coupled with high genetic gain.

Marekar and Siddiqui (1996) studied genetic variability and heritability in 73 rice varieties and reported considerable genotypic and phenotypic coefficient of variation for grain length and L:B ratio. High estimates of heritability with genetic gain were also observed for these traits.

Reddy and De (1996) studied 36 rice genotypes with water depth of up to 61 and 65 c. respectively. They observed that grain yield per hill, grains per panicle, 1000 grain weight, plant height and tillers per plant had the highest estimates of genotypic and phenotypic variability; where as these estimates were low in magnitude for panicle length, grain length and grain breadth. High heritability estimates were observed for grain length followed by 1000-grain weight, grain breadth, plant height, grain yield and grains per panicle.

Sarma *et al.* (1996) studied 39 early maturing upland cultivars from Madhya Pradesh and revealed that high GCV for effective tillers m^{-1} row length followed by grain yield m^{-1} row length and spikelets per panicle, where as low was recorded for days to 50% flowering, days to maturity and panicle length. Broad sense heritability estimates ranged from 42.2% for grain yield

m^{-1} row length to 99.9% for grain length. Genetic advance was highest for effective tillers m^{-1} row length coupled with high heritability.

Mani *et al.* (1997) studied 24 Basmati rice genotypes for 6 panicle characters and reported that number of filled grains par panicle, 100-grain weight and grain yield per panicle showed wide range of variation and high heritability. High estimates of heritability coupled with high genetic advance found in filled grains per panicle.

Sharma and Dubey (1997) reported moderately high GCV for grains per panicle, grain weight per panicle and productive tillers per plant with higher to moderate broad sense heritability in 60 advanced breeding lines.

Anand *et al.* (1998) studied 40 F_1 hybrids and their parents under cold stress condition and revealed that number of chaffy grains, number of filled grains and grain yield per plant showed high variability, heritability and high genetic advance as percentage of mean. Number of productive tillers was highly influenced by the environment as revealed by high differences between PCV and GCV. Higher heritability estimates were obtained for the characters viz., days to 50% flowering, plant height and grain yield per plant while total number of tillers per plant had moderate.

Balan *et al.* (1999) evaluated 15 salt tolerant rice genotypes under rainfed condition and revealed that highest GCV and PCV for grain yield and harvest index while lowest for days to maturity. High heritability was recorded for days to 50% flowering, grain yield and days to maturity with high genetic advance.

Verma *et al.* (2000) studied variability in 49 rice genotypes developed by 7 parents in half diallel and found high magnitude of GCV and PCV for number of sterile and total spikelets per panicle, grain and biological yield, number of productive and total tillers per plant. But these values were low for panicle length and harvest index. Moderate narrow sense heritability coupled with high genetic advance were recorded for plant height, days to 50% flowering and 100-grain weight.

Prasad *et al.* (2001) studied 8 genotypes and reported genotypic coefficient of variation ranged from 3.23 to 20.81 and phenotypic coefficient of variation ranged from 3.25 to 21.29. Highest genotypic coefficient of variation, high heritability along with high genetic advance was observed in 1000 grain weight, number of fertile grains per panicle, number of effective tillers per plant, plant height and yield per plant. Among them 1000 grain weight, number of effective tillers per plant, number of fertile grains per panicle and yield per plant showed more than 10% variation at phenotypic and genotypic levels. Whereas, plant height, panicle length and days to maturity had less than 10% variation at phenotypic and genotypic levels.

Vanaja and Babu (2006) studied 56 genotypes of diverse origin and observed that the phenotypic coefficient of variation and genotypic coefficient of variation revealed the existence of large variability in grain length, grain breadth and moderate variability in L/B ratio of grain, hulling percentage, milling percentage. High genotypic coefficient of variation and phenotypic coefficient of variation reported for grain breadth, L/B ratio of grain and milling percentage. High degree of broad sense heritability were exhibited by grain length, grain breadth, L/B ratio, hulling percentage and milling percentage.

Karim *et al.* (2007) in a study of aromatic rices reported that phenotypic variance was higher than the corresponding genotypic variance for the characters. Considering genetic parameters high genotypic coefficient of variation value was observed for 1000-grain weight followed by spikelet sterility %, grain yield per hill and number of filled grains per panicle, number of primary branches and harvest index showed moderate GCV and PCV, whereas days to maturity showed very low genotypic coefficient of variation.

Mustafa and Elsheikh (2007) studied variability for yield and its components in fourteen rice genotypes at Gezira Research Station Farm, Sudan. The highest genotypic coefficient of variation was found in grain yield, number of grains per panicle, number of filled grains per panicle and percent unfilled grain per panicle. High heritability estimates in broad sense were exhibited by plant height, days to fifty percent flowering, days to fifty percent maturity, number of grains per panicle and 1000 seed weight but had low genotypic coefficient of variation.

Bisne *et al.* (2009) observed low, moderate, high genotypic and phenotypic coefficient of variations. High genotypic and phenotypic coefficient of variations were expressed by harvest index, total number of filled spikelets 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 spikelets per panicle, grain yield per plant, total number of filled spikelets per panicle, spikelet fertility percentage, panicle length, plant height, tillers per plant, spikelet length and spikelet breadth, further they suggested that selection may be effective for these characters.

Jamal *et al.* (2009) reported existence of significant genetic variation among the genotypes for days to 50 % flowering (ranged from 59.7-85.7), days to maturity (ranged from 96.7-110.7), plant height (ranged between 82.2-124.9 cm), panicle length (ranged from 19.2-24.1 cm) for productive tillers per plant (ranged from 10 to 13.1 %), for primary branches (ranged between 9.3-11.3), number of grains per panicle (ranged from 10.0-13.1), for 1000 grain weight (ranged between 10.2-14.7 g), grain yield per plant (ranged from 82.2 -124.9).

Khan *et al.* (2009) studied genetic variability for grain yield and component characters *viz.* Days to 50% flowering, plant height, days to maturity, panicle length, tillers per plant and grains per panicle in rice using 25 genotypes. In the study analysis of variance indicated highly significant differences among the twenty five genotypes for all the morphological traits. Grains per panicle had high GCV and PCV followed by plant height and tillers per plant. High heritability estimates were observed over sixty seven percent in all the characters.

Akter *et al.* (2010) reported that highest genotypic variance and phenotypic variance were found for pollen sterility and filled grains per panicle. High heritability and genetic advance were recorded for days to 50%

flowering, filled grains per panicle, grain length, grain breadth and grain yield per hill.

Chakraborty and Chakraborty (2010) reported very small difference between genotypic coefficient variation and phenotypic coefficient variation for days to fifty percent flowering and wide difference between genotypic coefficient variation and phenotypic coefficient variation for plant height, effective branch per tillers, panicle length, sterility percentage and yield per plant. They observed that high heritability was associated with high genetic advance in grain yield per hill, sterility percentage, high heritability with moderate genetic advance was associated with plant height, high heritability with low genetic advance for days to fifty percent flowering, moderate heritability with moderate genetic advance for effective branch tillers per hill, flag leaf length, flag leaf breadth.

Akinwale *et al.* (2011) reported that panicles per plant and grains per panicle had high PCV and GCV. Genotypic coefficient of variation were lower than phenotypic coefficient of variation in all traits. High to medium broad sense heritability estimates observed on days to 50% flowering, plant height and number of grains per panicle. Low broad sense heritability observed for number of tillers per plant and 1000 grain weight. High to medium heritability and genetic advance were recorded for number of grains per panicle and number of panicles per plant suggests that these traits are under genetic control.

Chaudhary *et al.* (2011) concluded significant variation among the genotypes for morphological traits *viz.,* plant height (ranged from 101 cm to 222.67 cm); all wild, red cultivated and weedy rices were tall whereas both cultivated white entries were semi-dwarf in stature, panicle length (ranged from 27cm to 17.16 cm), yield per plant (ranged from 22.16 to 3.72). Highest yield per plant was observed in cultivated white followed by cultivated red, weedy rice and wild types. Also found cultivated white and cultivated red were awnless while awns of different length in weedy rice. Both wild possessed black hulls and both cultivated white possessed straw hull. Grain colour ranged from white to red.

Selvaraj *et al.* (2011) studied the genetic parameters of variability for grain yield and other yield attributes among rice blast disease resistant genotypes of rice. All the twenty one genotypes and sixty four hybrids were evaluated for nine traits in randomized block design over five replications. They reported that considerable variability among the genotypes for days to 50% flowering, plant height, number of tillers per plant, number of productive tillers per plant, panicle length, days to maturity, test weight and grain yield per plant and high heritability coupled with high genetic advance and high genotypic coefficient of variation days to 50% flowering, plant height, number of tillers per plant, number of productive tillers per plant, filled grains per panicle, test weight and grain yield.

Tiwari *et al.* (2011) conducted experiment with three CMS lines *viz.,* IR 58025, NMS 4A, PMS 10A and 20 diverse genotypes. The crosses were evaluated in Line x Tester mating design. The highest magnitude of phenotypic coefficient of variation and genotypic coefficient of variation was recorded for 100 grain weight, grain yield per plant, number of fertile spikelets, spikelet fertility percent, pollen fertility percent, effective tillers per plant, panicle length, number of spikelets per panicle, harvest index and biological yield. High broad sense heritability were observed for all the characters *viz.* days to 50% flowering, plant height, effective tillers per plant, panicle length, number of spikelets per panicle, 100 grain weight, yield per plant and harvest index. High heritability with high genetic advance was recorded for number of spikelet per panicle, number of fertile spikelet, spikelet fertility percent, pollen fertility, grain yield per plant and harvest index.

Idris *et al.* (2012) reported close relationship between GCV and PCV in all the characters. The PCV values were slightly greater than GCV, revealing very little influence of environment for their expression. High GCV were observed for grain yield kg/ha followed by number of filled grain per panicle, number of grains per panicle. Characters under study *viz.* panicle length, grain length, number of grains per panicle, 100 grain weight and harvest index exhibited high broad sense heritability of more than 50%, except panicle length (<50%).

Ravindra Babu *et al.* (2012) study the genetic parameters for yield, yield attributing, quality and nutritional characters in twenty one rice hybrids and reported high genotypic coefficient of variation (GCV) and phenotypic coefficient of variation (PCV) for number of filled grains per panicle, number of chaffy grains per panicle and iron content. Moderate GCV and PCV for days to 50% flowering, productive tillers per plant, 1000 grain weight, kernel length and kernel breadth. Low to high heritability estimates ranging from 25.5 to 98.4 percent was reported. The characters *viz.,* number of filled grains per panicle days to 50% flowering, plant height, panicle length, 1000 grain weight, kernel length, kernel breadth and zinc content exhibited high heritability coupled with high genetic advance. Low GCV and PCV for plant height, panicle length, grain yield per plant, milling percentage, kernel breadth. Number of productive tillers per plant, grain yield per plant and iron content showed low to moderate heritability coupled with low to moderate GA as per cent of mean.

2.2 CORRELATION COEFFICIENT

Amongst all the quantitative characters of economic importance showed correlated responses. Hence, the knowledge of character association would be useful to plant breeder for designing effective breeding programme.

In plant breeding, correlation coefficient analysis measures the mutual relationship between various plant characters and determines the component characters on which selection can be based for genetic improvement in yield and other yield attributes and thus helps in selection of superior genotypes from diverse genetic populations (Singh and Narayanan, 2000).

The concept of correlation was given by Galton (1889), which was further elaborated by Fisher (1918) in order to initiate effective selection programme aimed at genetic improvement in economic yield of crop. It is an index of cause in the genesis of two variables and not to causes themselves. The degree of association between yield and component traits might vary with environment of material under study or both. Hence, it is essential to measure the correlations at genotypic and phenotypic levels.

Some of the important research on correlation coefficients studies on various characters in red rice is presented here.

Sr. No.	Experimental material	Correlation with	Type of correlation	Author and Year
1.	2.	3.	4.	5.
Grain yield per plant (gm)				
1	23 varieties from national germplasm collection	1000-grain weight	Highly significant, Positive	Chaudhary *et al.* (1973)
2	49 dwarf strains of rice	Grains per panicle	Highly significant, Positive (p)	Mishra *et al.* (1973)
3	7 late maturing varieties of rice	Ear bearing tillers, Number of grains per panicle, 100-grain weight	Highly significant, Positive	Rao *et al.* (1980)
4	32 rice genotypes of diverse origin	Ear bearing tillers per plant	Highly significant, Negative	Singh *et al.* (1980)

5	13 varieties of rice	Plant height, Number of productive tillers per plant, Number of grains per panicle and panicle length	Significant, Positive	Paramasivam (1981)
6	162 breeding lines	Total tillers per plant, Productive tillers per plant	Significant, Positive	Amirthadevarathinam (1983)
		Days to maturity, plant height	Significant, Negative	
7	Early rice genotypes	Productive tillers per plant, Grains per panicle, Straw yield per plant	Highly significant, high to moderate (g) and (p)	Sundaram *et al.* (1988)
		Plant height	Highly significant, Negative	
8	30 rice genotypes	Number of grains per panicle	Significant positive	Deoskar *et al.* (1989)

9	50 newly developed lines from diverse crosses and 10 varieties	Plant height and panicle length and Number of grains per panicle	Significant positive	Panwar and Bansal (1989)
10	60 fixed cultures of rice	Plant height	Negative non significant	Sardana *et al.* (1989)
		panicle length	Significant	
11	40 early maturing rice genotypes	Days to fifty percent flowering and panicle length	Highly significant, positive	Amirthadevarathinam (1990)
12	6 parents and their 30 hybrids obtained by diallel crosses	Days to 50% flowering, Plant height, Panicle length, Productive tillers per plant	Highly significant, Positive	Arumugachamy *et al.* (1993)
13	80 rice varieties	Plant height	Highly significant positive	Chaubey and Richaria (1993)
14	25 F_3 family progeny of cross ADT 31 x IET 7281	Panicle length, Total tillers per plant, Productive tillers per plant	Highly significant, Positive	Kanan Babu and Soundrapandian (1993)
		Plant height	Significant, Negative	

15	99 genotypes of rice	Days to fifty percent flowering and panicle length,	Highly significant, Positive	Roy *et al.* (1993)
		1000 grain weight	Significant negative (p) and highly significant (g)	
16	20 rice varieties	Ear bearing tillers, Plant height	Highly significant, Positive (p)	Choubey and Singh (1994)
17	27 short duration rice under alkaline condition	Panicle length, Straw yield per plant, Grains per panicle, 100-grain weight	Significant, Positive	Ramalingam *et al.* (1995)
18	10 drilled upland paddy	Tillers per plant, Grains per panicle, Panicle length, 1000-grain weight	Significant, Positive (p & g)	Rathod *et al.* (1995)
19	49 medium duration rice genotypes	Productive tillers per hill, 1000-seed weight	Significant, Positive	Reddy *et al.* (1995)
		Seeds per panicle, Harvest index	Highly significant, Positive	

20	52 late duration pure lines of low land rice	Ear bearing tillers, Grains per panicle	Highly significant, Positive (p & g)	Sawant and Jadhav (1995)
21	22 advance generations	Number of productive tillers per plant	Highly significant, Positive	Ravindra Babu (1996)
22	44 very early elite breeding lines and 2 rainfed upland cultivars	Harvest index, Straw yield, biological yield	Significant, Positive (p)	Chauhan (1996)
23	8 parents (3 CMS and 5 restorers) and 15 F1's obtained by L x T design	Number of tillers per plant, Panicles per plant, Panicle length, 1000-grain weight	Highly significant, Positive	Padmavathi *et al.* (1996)
24	40 drought tolerant rice genotypes studied under semi-dry condition	Number of productive tillers, Harvest index, Plant height	Highly significant, Positive	Rao *et al.* (1996)
25	128 accessions of *indica* rice along with 4 standard cultivars	Grain breadth, harvest index, 100 grain weight	Highly significant, Positive (p & g)	Sarawgi *et al.* (1997)
		Grain length	Significant,	

			Positive (g)	
		Number of tillers per plant, number of productive tillers per plant and panicle length	Significant, Positive (p)	
26	75 land races of rice grouped into 3 sets based on test weight	Plant height, Panicle bearing tillers per plant, Grains per panicle	Highly significant, Positive	Verma *et al.* (1997)
27	40 F_1 hybrids and their parents under cold condition	Number of grains per panicle	Highly significant, Positive (p & g)	Anand *et al.* (1998)
28	11 deep water rice varieties	Plant height	Significant, Positive	Deb Chaudhary and Das (1998)
29	121 elite homozygous lines of rice	Grain length	Significant, Negative	Dhananjaya *et al.* (1998)
30	25 genotypes of rice with diverse origin	Days to fifty percent flowering, panicle length	Highly significant, Positive	Mokate *et al.* (1998)
31	F_2 population of cross IR 50 x TNAU 901793	Days to flowering, Number of productive tillers per plant, Harvest index	Highly significant, Positive (p)	Selvarani and Rengasamy (1998)

.32	21 hybrid obtained by L x T	Productive tillers, Dry matter production, Grains per panicle, Harvest index	Highly significant, Positive	Meenakshi *et al.* (1999)
33	24 early maturing upland rice	Fertile grains per panicle, Biological yield	Highly significant, Positive	Rao and Saxena (1999)
34	29 boro rice genotypes	Harvest index, Panicles per plant, Panicle length	Highly significant, Positive (p & g)	Chakraborty *et al.* (2001)
		100 grain weight	Highly significant, negative (g)	
35	8 fine rice genotypes	Days to 50% flowering, number of effective tillers per plant, Number of fertile grains per panicle, 1000 grain weight	Positive (p & g)	Prasad *et al.* (2001)
		Panicle length	Negative (p & g)	
		Plant height	Significant, Negative (g)	

36	481 scented germplasm of rice	Plant height	Highly significant, Negative	Shobha Rani *et al.* (2001)
		Tillers per plant, Days to 50% flowering and maturity	Significant, Positive	
37	80 breeding lines derived from 11 different cross population in F_6 generation and their 10 parents	Number of filled grains per panicle, Harvest index and Biological yield	Significant	Surek and Beser (2003)
		Days to fifty percent flowering	Significant negative	
38	F_1 population of 12 crosses combination and their parents	Plant height	Significant, Positive	Hasib and Kole (2004)
39	Induced mutants of "Taraori" basmati	Plant height, Days to 50% flowering, Test weight	Highly positive	Singh and Singh (2004)
40	20 double haploid lines from cross between IR-64 - an *indica* variety	Plant height, number of panicles per plant,	Significant, positive (p & g)	Shashidhar *et al.* (2005)

	and Azucena-a traditional *japonica* variety developed	Number of grains per panicle	Significant, positive (g)	
		Days to 50 % flowering, plant height	Significant, Positive (g)	
		Harvest index	Significant, Positive (p)	
41	10 hybrids and their 14 parents	Number of grains per panicle	Significant, Positive	Ramkrishnan *et al.* (2006)
42	25 genotypes of rice	Number of grains per panicle, total filled grains per plant and number of effective tillers per plant	Significant, Positive	Aghai *et al.* (2007)
		Plant height	Significant, Negative (p)	
		Plant height	Significant, Positive (g)	
43	25 indigenous aromatic rice genotypes	Days to fifty percent flowering and number of productive tillers per plant	Positive association	Jaiswal *et al.* (2007)

44	100 rice genotypes	Days to fifty percent flowering and number of productive tillers per plant, number of filled grains per panicle	Significant positive	Patil and Sahu (2009)
45	14 rice genotypes	Number of tillers per plant	Negative	Mustafa and Elsheikh (2007)
46	44 extra early and early maturing rice genotypes	Grains per panicle, panicle length, 1000 grain weight	Highly significant, Positive (p)	Sharma and Sharma (2007)
47	25 genotypes of rice	Plant height	Significant positive (g)	Khan *et al.* (2009)
		Panicle length, number of grains per panicle	Significant positive (p & g)	
		Total tillers per plant	Non significant negative (p & g)	
48	50 exotic rice genotypes and 2 variety	Filled grains per panicle	Significant, Positive (p & g)	Akter (2010)

49	47 bold grain genotypes of rice and 2 checks Ranjit and Manoharsali	Plant height,	Significant negative (p & g)	Chakraborty and Chakraborty (2010)
		Number of effective tillers per plant	Significant positive (g)	
		Panicle length	Significant positive (g)	
		Days to fifty percent flowering	Significant, negative (p & g)	
50	33 genotypes of rice	Days to 50% flowering, Plant height, Number of grains per panicle	Significant, Positive (p & g)	Nandan *et al.* (2010)
		1000 grain weight	Negative (p & g)	
		Hulling	Negative	
51	30 rice genotypes	Plant height, number of total tillers per plant, number of grains per panicle	Significant to highly significant positive (p & g)	Wattoo *et al.* (2010)
52	150 rice genotypes including 5	Total tillers per plant, Productive	Significant, Positive	Padmaja *et al.* (2011)

	checks	tillers per plant, Number of grains per panicle, Panicle length and days to fifty percent flowering		
53	21 rice genotypes	Days to fifty percent flowering and plant height	Significant, negative	Selveraj *et al.* (2011)
		Panicle length, number of filled grains per panicle	Significant positive (p & g)	
54	21 rice genotypes	Number of tillers per plant, Number of grains per panicle	Significant, Positive	Akinwale *et al.* (2011)
55	8 genotypes of rice	Number of grains per panicle, Number of filled grains per panicle, panicle length, Harvest index	Positive	Idris *et al.* (2012)

Days to 50 % flowering				
1	50 newly developed lines from diverse crosses and 10 varieties	Panicle length, Panicle number	Significant, Positive	Panwar and Bansal (1989)
2	40 early maturing rice genotypes	Panicle length, grains per panicle	Highly significant, positive	Amirthadevarathinam (1990)
3	21 advanced breeding lines of rice	Straw yield	Highly significant, positive (p)	Chauhan *et al.* (1993)
4	99 genotypes of rice	Plant height	Significant, positive (g)	Roy *et al.* (1993)
		Panicle length, Hulling %, Milling %	Highly significant, Positive	
5	52 late duration pure lines of low land rice	Days to maturity, ear bearing tillers per plant	Significant, Positive (p & g)	Sawant and Jadhav (1995)
6	44 very early elite breeding lines and two rainfed upland cultivars	Panicle length, straw yield	Highly significant, positive	Chauhan (1996)
7	40 F_1 hybrid with parents under cold condition	Total number of tillers per plant, Productive tillers per plant	Significant, Negative (p & g)	Anand *et al.* (1998)

8	11deep water rice varieties	Panicle length	Significant, Positive (g)	Deb Chaudhary and Das (1998)
9	121 elite homozygous lines of rice	Harvest index, Grain length	Significant, Positive	Dhananjaya *et al.* (1998)
10	25 genotypes of rice with diverse origin	Plant height	Significant, Positive (g)	Mokate *et al.* (1998)
		Panicle length	Highly significant (g)	
11	F_2 population of cross IR-50 x TNAU- 801793	Number of productive tillers per plant, Harvest index	Highly significant, Positive (p)	Selvarani and Rengasamy (1998)
12	21 Hybrids developed by L x T	Plant height	Highly significant, Positive	Meenakshi *et al.* (1999)
13	481 scented germplasm of rice	Test weight	Highly significant, Negative	Shobha Rani *et al.* (2001)
14	41 aromatic rice genotypes	Plant height	High, significant, positive	Tavisha (2005)
		Hulling percentage	Negative	
15	10 hybrids and their 14 parents	Plant height, L:B ratio, 1000 grain weight	Positive	Ramakrishnan *et al.* (2006)
		Panicle length, number of grains per panicle	Negative	

16	25 indigenous aromatic rice genotypes	Yield per plant	Positive association	Jaiswal *et al.* (2007)
17	25 genotypes of rice	Days to maturity, panicle length	Significant positive (p & g)	Khan *et al.* (2009)
18	100 rice genotypes	Grain yield per plant	Significant, Positive	Patil and Sahu (2009)
19	150 rice genotypes including 5 checks	Productive tillers per plant, panicle length	Significant, Positive	Padmaja *et al.* (2011)
20	21 rice genotypes	Number of filled grains per panicle	Strong significant, Positive (p & g)	Selvaraj *et al.* (2011)
		Number of tillers per plant, plant height, 1000 grain weight, grain yield per plant	Significant, Negative	
Plant height				
1	32 genotypes of rice with diverse origin	Panicle length	Highly significant, Positive	Singh *et al.* (1980)
2	18 genotypes of upland rice with diverse origin	Panicle length, 1000-grain weight	Highly significant, Positive	Pathak and Patel (1989)

3	25 F_3 family progeny of cross ADT 31 x IET 7281	Panicle length	Significant Negative	Kanan Babu and Soundrapandian (1993)
4	21 advanced breeding lines of rice	Panicle length, 1000-grain weight, straw yield	Highly significant, Positive	Chauhan *et al.* (1993)
5	80 rice varieties	Panicle length	Highly significant, Positive	Choubey and Riccharia (1993)
		Productive tillers, Harvest index, Test weight	Highly significant, Negative	
6	20 rice varieties	Panicle length	Highly significant, Positive (p)	Choubey and Singh (1994)
7	99 rice genotypes	Panicle length	Highly significant, Positive (g)	Roy *et al.* (1993)
		Panicle length	Significant, Positive (p)	
8	22 advanced saline tolerant rice genotypes	Panicle length	Highly significant, Positive (g)	Ravindra Babu (1996)
9	44 very early elite breeding lines and two rainfed upland cultivars	Harvest index	Highly significant, Negative	Chauhan (1996)

10	73 rice varieties	Panicle length. Grain length, G L/B ratio, 1000-Grain weight	Highly significant and significant, Positive	Marekar and Siddiqui (1996)
11	3 high yielding vavieties and 5 F_4 populations	Grain yield per plant	Highly significant, Negative (e)	Nath and Talukdar (1997)
12	40 F1 hybrid and their parents under cold condition	Total tillers per plant, Productive tillers per plant	Highly significant, Positive (p & g)	Anand *et al.* (1998)
13	121 elite homozygous lines of rice	Panicle length	Highly significant, Positive	Dhananjaya *et al.* (1998)
14	94 rice genotypes	Panicle length	Highly significant, Positive	Kaw *et al.* (1999)
15	24 early maturing upland rice	Number of grains per panicle	Highly significant, Positive	Rao and Saxena (1999)
16	16 hybrids developed by L x T	Panicle length, Productive tillers per plant	Significant, Positive	Janardhanam *et al.* (2001)
17	29 boro rice genotypes	Fertile grains per panicle, panicle per plant, Harvest index	Highly significant, Positive (p & g)	Chakraborty *et al.* (2001)
		100-Grain weight	Positive (p) Negative (g)	

18	8 fine rice genotypes	Panicle length	Significant, Positive (g)	Prasad *et al.* (2001)
19	481 scented germplasm of rice	Panicle length, days to 50% flowering	Highly significant, Positive	Shobha Rani *et al.* (2001)
		Test weight	Highly significant, Negative	
20	30 rice cultivars and advanced lines	1000 grain weight, number of panicles per plant, panicle length	Non significant	Oad *et al.* (2002)
		Ratoon grain yield	Positive significant	
21	F_1 population of 12 crosses combination and their parents	Test weight	Significant, Positive	Hasib and Kole (2004)
22	41 aromatic rice genotypes	Panicle length	Significant, positive	Tavisha (2005)
23	10 hybrids and their 14 parents	1000 grain weight	Positive significant	Ramakrishnan *et al.* (2006)
		Number of grains per panicle, Number of panicles per plant	Negative	

24	25 genotypes of rice	Days to 50% flowering, panicle length,	Significant positive (p & g)	Khan *et al.* (2009)
		Tillers per plant, grains per panicle	Significant positive (g)	
25	30 rice genotypes	Number of tillers per plant	Positive (g), Significant positive (p)	Wattoo *et al.* (2010)
		Number of grains per panicle	Negative (g)	
		Test weight	Positive (p & g)	
26	150 rice genotypes including 5 checks	Total tillers per plant, productive tillers per plant, panicle length,	Negative	Padmaja *et al.* (2011)
27	21 rice genotypes	Number of tillers per plant, Number of productive tillers per plant, Panicle length	Significant, Positive (p & g)	Selvaraj *et al.* (2011)
Panicle length (cm)				
1	18 diverse genotypes of upland rice	Plant height, number of grains per panicle, 1000-grain weight	Significant, Positive (p & g)	Pathak and Patel (1989)

2	25 F_3 family progeny of cross ADT 31 x IET 7281	Productive tillers per plant	Significant, Negative	Kanan Babu and Soundrapandian (1993)
3	27 short duration rice under alkaline condition	Plant height, Grains per panicle, Straw yield per plant	Highly significant, Positive	Ramalingam *et al.* (1995)
4	73 rice varieties	Grain length, Grain length/breadth ratio	Highly significant, Positive	Marekar and Siddiqui (1996)
5	36 low land rice genotypes	Grain length	Highly significant, Positive (g)	Reddy *et al.* (1997)
		Grain length, Grains per panicle	Significant, Positive (p)	
6	128 accessions of *indica* rice along with 4 standard cultivars	Effective tillers per plant	Significant, Positive (g), Significant, negative (p)	Sarawgi *et al.* (1997)
7	121 elite homozygous lines of rice	Grain length/breadth ratio	Highly significant, Positive	Dhananjaya *et al.* (1998)
8	10 scented rice genotypes under rainfed transplanted condition	1000-grain weight	Highly significant, Positive	Chandra and Das (2000)

9	42 saline and alkaline tolerant rice	Days to 50% flowering, Plant height	Significant, Positive	Bala (2001)
10	29 boro rice genotypes	100 grain weight, harvest index	Significant, Positive (p & g)	Chakraborty *et al.* (2001)
11	11 hybrids and five high yielding rice varieties	Panicle number, Harvest index	Highly significant, Negative	Pradhan and Das (2001)
12	10 hybrids and their 14 parents	1000 grain weight	Significant, positive (g)	Ramakrishnan *et al.* (2006)
13	150 rice genotypes including 5 checks	Number of grains per panicle	Significant, Positive	Padmaja *et al.* (2011)
Number of total tillers per plant				
1	30 rice genotypes	Plant height	Significant, Negative	Deoskar *et al.* (1989)
2	16 early maturing japonica rice genotypes	Panicle length	Significant, Positive	Amirthadevarathinum (1990)
		Plant height	Highly significant, Positive	
3	8 parents (3 CMS and 5 restorers) and 15 F_1's obtained by L x T design	Panicle length, 1000-Grain weight	Significant, Positive	Padmavathi *et al.* (1996)

4	40 F_1 hybrids and their parents under cold condition	Productive tillers per plant	Highly significant, Positive (p & g)	Anand *et al.* (1998)
		Filled grains per panicle	Highly significant, Negative (p & g)	
5	24 early maturing upland rice cultures	Plant height	Significant, Negative	Rao and Saxena (1999)
6	482 scented germplasm of rice	Panicle length	Highly significant, Positive	Shobha Rani *et al.* (2001)
7	25 genotypes of rice	Number of grains per panicle	Significant, Negative (g)	Khan *et al.* (2009)
8	21 rice genotypes	Number of productive tillers per plant, Panicle length, Filled grains per panicle, Grain yield per plant	Significant, Positive (p & g)	Selvaraj *et al.* (2011)
Number of productive tillers per plant				
1	18 diverse genotypes of upland rice	Grain yield	Positive significant (p& g),	Pathak and Patel (1989)

		Plant height	Negative significant (g)	
2	80 varieties of rice	Plant height	Highly significant, Negative	Chaubey and Richharia (1993)
		Panicle length	Highly significant, Positive	
3	10 drilled upland paddy cultures	Panicle length, Number of grains per panicle, 1000-grain weight	Highly significant, Positive (p & g)	Rathod *et al.* (1995)
4	52 late duration pure lines of low land rice	Days to 50% flowering, Number of grains per panicle	Significant, Positive	Sawant and Jadhav (1995)
		Plant height	Highly significant, Negative	
5	121 elite homozygous lines of rice	Harvest index	Highly significant, Positive	Dhananjaya *et al.* (1998)
6	F_2 population of IR 53 x TNAU 801793	Days to flowering, Harvest index	Highly significant, Positive (p)	Selverani and Rengasamy (1998)
7	10 parents and	Dry matter	Highly	Meenakshi *et al.*

	21 hybrids developed by L x T	production, Harvest index	significant, Positive	(1999)
8	150 rice genotypes including 5 checks	Days to 50 % flowering, panicle length	Significant, Positive	Padmaja *et al.* (2011)
9	21 rice genotypes	Panicle length, Filled grains per panicle, Grain yield per plant	Significant, Positive (g)	Selvaraj *et al.* (2011)
Number of grains per panicle				
1	32 rice genotypes of diverse origin	Panicle length	Highly significant, Positive	Singh *et al.* (1980)
2	27 short duration rice under alkaline condition	Panicle length, Straw yield per plant	Highly significant, Positive	Ramalingam *et al.* (1995)
3	10 drilled upland paddy genotypes	Tillers per plant, panicle length, 1000-grain weight	Highly significant, Positive (p & g)	Rathod *et al.* (1995)
4	49 medium duration rice genotypes	Tillers per hill	Significant, Negative	Reddy *et al.* (1995)
5	73 rice varieties	Length of panicle, Filled grains per	Highly significant, Positive	Marekar and Siddiqui (1996)

		panicle		
6	8 parents (3 CMS and 5 restorers) and 15 F1's obtained by L x T design	Plant height, Number of spikelets per panicle	Highly significant, Positive	Padmavathi *et al.* (1996)
7	10 scented rice genotypes under rainfed transplanted condition	Panicle length, Harvest index, 1000-grain weight	Highly significant, Positive	Chandra and Das (2000)
8	10 hybrids and their 14 parents	Grain yield per plant	Significant, Positive	Ramakrishnan *et al.* (2006)
		Kernel length	Significant, negative	
9	14 rice genotypes	Panicle length	Significant, Positive	Mustafa and Elsheikh (2007)
10	25 genotypes of rice	Panicle length	Significant Positive (p & g)	Khan *et al.* (2009)
11	30 rice genotypes	1000 grain weight	Significant to highly significant, positive (g)	Wattoo *et al.* (2010)
Number of filled grains per panicle				
1	23 varieties from national germplasm collection	Panicle length, Panicle weight	Highly significant, Positive	Chaudhary *et al.* (1973)
2	29 boro rice	Harvest index,	Highly	Chakraborty *et al.*

	genotypes	100-grain weight, Panicle length, Plant height	significant, Positive	(2001)
1000-grain weight (gm)				
1	49 dwarf strains of rice	Number of ear bearing tiller per plant	Significant, Negative	Mishra *et al.* (1973)
2	30 genotypes of rice	Number of tillers per plant	Highly significant, Positive	Deoskar *et al.* (1989)
		Plant height	Significant, Negative	
3	18 diverse genotypes of upland rice	Plant height, Panicle length, number of grains per panicle, grain yield per plant	Highly significant, Positive (p & g)	Pathak and Patel (1989)
4	6 parents and their 30 hybrids obtained by diallele crosses	Grains per panicle,	Highly significant, Positive	Arumugachamy *et al.* (1993)
		days to 50% flowering	Highly significant, Negative	
5	73 rice varieties	Grain length	Highly significant, Positive	Marekar and Siddiqui (1996)
		Grain breadth	Significant, Positive	

6	8 parents (3 CMS and 5 restorers) and 15 $F_{1's}$ obtained by L x T design	Days to 50% flowering, Number of tiller per plant	Highly significant, Positive	Padmavathi *et al.* (1996)
7	128 accessions of indica rice along with 4 standard cultivars	Panicle length	Significant, Positive (g)	Sarawgi *et al.* (1997)
8	29 boro rice genotypes	Plant height, Panicles per plant, Harvest index	Highly significant, Negative	Chakraborty *et al.* (2001)
9	30 cultivars of rice and advanced lines	Panicle length	Positive	Oad *et al.* (2002)
10	41 aromatic rice genotypes	Grain length, grain breadth and grain L/B ratio	Significant positive	Tavisha (2005)
11	30 rice genotypes	Number of grains per panicle	Significant to highly significant, positive (g)	Wattoo *et al.* (2010)
Grain length (mm)				
1	100 indigenous upland rice	Grain breadth	Significant, Negative (g)	Hussain *et al.* (1987)
		L:B ratio, test weight	Positive (p & g)	

2	73 varieties of rice	Grain L:B ratio	Highly significant, Negative	Marekar and Siddiqui (1996)
3	128 accessions of *indica* rice along with 4 standard cultivars	100 grain weight	Significant, Positive (p & g)	Sarawgi *et al.* (1997)
4	121 elite homozygous lines of rice	Grain L:B ratio	Highly significant, Positive	Dhananjaya *et al.* (1998)
		Grain breadth	Highly significant, Negative	
5	F_1 population of 12 cross combination and their parents	Grain L:B ratio	Significant, Positive	Hasib and Kole (2004)
6	41 aromatic rice genotypes	Hulling (%) and milling (%)	Highly significant , positive	Tavisha. (2005)
7	50 exotic rice genotypes and 2 variety	Filled grains per panicle	Significant, Negative (p & g)	Akter (2010)
Grain breadth (mm)				
1	100 indigenous upland rice	Grain L:B ratio	Highly significant, Negative	Hussain *et al.* (1987)

2	73 rice varieties	Grain L:B ratio	Highly significant, Negative	Marekar and Siddiqui (1996)
3	128 accessions of *indica* rice along with 4 standard cultivars	Grain yield per plant, 100 grain weight	Significant, Positive (p & g)	Sarawgi *et al.* (1997)
4	20 varieties (10 high yielding and 10 local varieties)	1000-grain weight	Highly significant, Positive	Sarwar *et al.* (1999)
		Grain L:B ratio	Highly significant, Negative	
5	50 exotic rice genotypes and 2 variety	Grain length	Significant, Negative (p & g)	Akter (2010)
Grain length : Grain breadth ratio				
1	100 indigenous upland rice	1000-grain weight	Significant, positive (p & g)	Hussain *et al.* (1987)
2	F_2 population of two crosses *viz.,* Prabhavati x IET 8573 and Prabhavati x Basmati 370 by using P_1, P_2, F_1, F_2, BC_1, BC_2	Kernel elongation	Highly significant positive	Deosarkar and Nerker (1994)
3	20 varieties (10 high yielding and 10 local varieties)	1000-grain weight	Highly significant, Negative	Sarwar *et al.* (1999)

4	41 aromatic rice genotypes	Hulling (%), Milling (%)	Significant, negative	Tavisha. (2005)
Hulling (%)				
1	100 indigenous upland rice	Milling (%)	Highly significant, Positive	Hussain *et al.* (1987)
2	99 genotypes of rice	Milling (%)	Highly significant, Positive	Roy *et al.* (1993)
3	41 aromatic rice genotypes	Milling (%),	Highly significant, Positive	Tavisha (2005)
Milling (%)				
1	99 genotypes of rice	Grain yield per plant	Significant, positive	Roy *et al.* (1993)
Harvest index				
1	128 accessions of *indica* rice along with 4 standard cultivars	Number of effective tillers per plant, grain length, grain breadth, 100 grain weight	Positive and significant (p & g)	Sarawgi *et al.* (1997)
2	121 elite homozygous lines of rice	Grain breadth	Highly significant, Positive	Dhananjaya *et al.* (1998)
		Grain L:B ratio	Highly significant, Negative	

3	10 rice genotypes screened under rainfed transplanted condition	Panicle per m^2, panicle length	Highly significant, Positive	Chandra and Das (2000)
		1000-grain weight	Highly significant, Negative	
4	11 rice hybrids and 5 high yielding rice varieties	Panicle number, plot yield	Highly significant, Positive	Pradhan and Das (2001)
		Panicle length	Highly significant, Negative	

2.3 PATH ANALYSIS

The path analysis developed by Wright (1921), but it was first used for plant selection by Dewey and Lu in 1959. Path analysis measures the direct and indirect contribution of various independent characters on dependent character and is based on all possible simple correlation among various characters (Singh and Narayanan, 2000)

Sr. No.	Experimental material	Type of contribution by independent traits in dependent trait (Grain yield)	Indirect effect through	Author and Year
1.	2.	3.	4.	5.
Days to 50 % flowering				
1	60 fixed cultures of rice	Maximum positive, direct	-	Sardana *et al.* (1989)
2	24 early Indica rice	High negative, direct	-	Amirthadevarathanam (1990)
	16 early Japonica rice	High positive, direct	-	
3	11 deep water rice	Negative, direct	-	Deb Chaudhary and Das (1998)
4	80 breeding lines derived from 11 different cross population in F_6 generation and their 10 parents	Negative, direct	-	Surek and Beser (2003)
5	41 aromatic rice genotypes	Negative, direct	-	Tavisha (2005)
6	4 lines and 5 testers along with 20 crosses obtained by crossing between these parents	Positive indirect	Plant height	Manomani and Ranganathan (2006)

7	25 indigenous aromatic rice genotypes	Highest positive, direct	-	Jaiswal *et al.* (2007)
8	25 rice genotypes	Direct, positive Indirect, positive	Plant height, panicle length	Khan *et al.* (2009)
9	100 rice genotypes	Positive, direct	-	Patil and Sahu (2009)
10	33 genotypes of rice	Direct positive, Indirect	- Days to maturity	Nandan *et al.* (2010)
11	30 rice genotypes	Direct, negative	-	Wattoo *et al.* (2010)
12	150 rice genotypes including 5 checks	Positive, direct	-	Padmaja *et al.* (2011)
13	21 rice genotypes	Positive, direct & indirect	Plant height, Panicle length, Filled grains per panicle	Selveraj *et al.* (2011)
Plant height (cm)				
1	32 rice genotypes with diverse origin	High positive, direct	-	Singh *et al.* (1980)
2	11 upland rice breeding lines	High positive, direct	-	Reuben and Katuli (1989)
3	60 fixed cultures of rice	Negative direct	-	Sardana *et al.* (1989)
4	18 diverse genotypes of rice	Negative, direct	-	Pathak and Patel (1989)

5	50 newly developed lines from diverse crosses and 10 varieties	Positive direct	-	Panwar and Bansal (1989)
6	14 drought tolerant lines of rice	Low, negative direct	-	Ibrahim *et al.* (1990)
7	6 parents and their 30 hybrids obtained through diallel crosses	High negative, direct and moderate negative, indirect	Grains per panicle, Days to 50% flowering	Arumugachamy *et al.* (1993)
8	20 rice varieties	High positive, direct	-	Chaubey and Singh (1994)
9	F_4 and F_5 generation of Zhen Shan 97 and A/IR 50 cross	Low direct	-	Rejeshwari and Nadarajan (1995)
		Indirect	Panicle length	
10	36 low land rice	Moderate positive, direct	-	Reddy *et al.* (1997)
11	11 deep water rice	High positive, direct	-	Deb Chaudhary and Das (1998)
12	16 hybrids obtained by L x T	High positive, direct	-	Janardhanam *et al.* (2001)
13	8 fine rice genotypes	Highest negative, direct	-	Prasad *et al.* (2001)

14	10 hybrids and their 14 parents	Negative, direct	-	Ramakrishnan *et al.* (2006)
15	25 indigenous aromatic rice genotypes	Highest positive, indirect	Number of panicle bearing tillers	Jaiswal *et al.* (2007)
16	25 genotypes of rice	Positive, direct	-	Khan *et al.* (2009)
17	100 rice genotypes	Positive, direct	-	Patil and Sahu. (2009)
18	33 genotypes of rice	Maximum Positive, direct	-	Nandan *et al.* (2010)
19	30 rice genotypes	Positive, direct	-	Wattoo *et al.* (2010)
		Indirect	Days to maturity	
		Negative, indirect	Days to heading	
20	150 rice genotypes including 5 checks	Positive, direct	-	Padmaja *et al.* (2011)
21	21 rice genotypes	Positive, direct	-	Selveraj *et al.* (2011)
		Negative, indirect	Days to 50% flowering, Panicle length, Number of total tillers per plant, Number of productive tillers per plant, filled grains per panicle, 1000 grain weight	

Panicle length (cm)				
1	32 diverse origin rice	Negative, direct	-	Singh *et al.* (1980)
2	11 upland rice breeding lines	Negative, direct	-	Reuben and Katuli (1989)
3	18 diverse genotypes of rice	High, positive, direct	-	Pathak and Patel (1989)
4	60 fixed cultures of rice	Low magnitude, direct	-	Sardana *et al.* (1989)
5	50 newly developed lines from diverse crosses and 10 varieties	Low negative direct	-	Panwar and Bansal (1989)
6	14 drought tolerant lines of rice	Moderate, direct	-	Ibrahim *et al.* (1990)
7	80 varieties of rice	Positive indirect and low, positive, direct	Panicle weight	Chaubey and Richaria (1993)
8	F4 and F5 generation of cross Zhen Shan 97 x A/IR 50	High, positive, direct	-	Rajeshwari and Nadarajan (1995)
9	22 advance generations of rice	Positive direct	-	Ravindra Babu (1996)

10	30 F_1 and their parents	Moderate direct	-	Gopalkrishnan and Ganapathy (1996)
11	8 parents (3 CMS and 5 restorers) and their 15 F_1 obtained by L x T design	High positive, direct	-	Padmavathi *et al.* (1996)
12	36 low land rice	Moderate direct positive	-	Reddy *et al.* (1997)
13	60 advanced breeding lines	High direct	Productive tillers per plant, Grains per panicle	Sharma and Dubey (1997)
14	11 deep water rice	High positive, direct	-	Deb Chaudhary and Das (1998)
15	25 rice genotypes	Positive, direct	-	Mokate *et al.* (1998)
16	29 boro rice genotypes	Positive, direct	Harvest index	Chakraborty *et al.* (2001)
17	8 fine rice genotypes	Positive direct, Negative indirect	Plant height	Prasad *et al.* (2001)
18	16 hybrids obtained by L x T	Negative, direct	Plant height	Janardhan *et al.* (2001)
19	200 scented and 1 non scented rice genotypes	Negative, direct	-	Nayak *et al.* (2001)

20	4 lines and 5 testers along with 20 crosses obtained by crossing between these parents	Negative direct	-	Manomani and Ranganathan (2006)
21	10 hybrids and their 14 parents	High direct, negative	-	Ramakrishnan *et al.* (2006)
22	100 rice genotypes	Positive, direct	-	Patil and Sahu (2009)
23	21 rice genotypes	Positive, direct	-	Selveraj *et al.* (2011)
		Positive, indirect	Days to 50% flowering, plant height, Number of total tillers per plant, Number of productive tillers per plant, 1000 grain weight	
Number of total tillers per plant				
1	32 diverse origin rice	High positive, direct and low negative indirect	Plant height, Number of grains per panicle	Singh *et al.* (1980)
2	162 breeding lines	Positive, direct	-	Amirthadevarathinam (1983)

3	60 fixed cultures of rice	Low magnitude, direct	-	Sardana *et al.* (1989)
4	16 early duration japonica genotypes	High negative, direct	-	Amirthadevarathinam (1990)
	24 early duration indica genotypes	High positive, direct	-	
5	8 parents (3 CMS and 5 restorers) and their 15 F1's obtained by L x T design	Negative, direct	-	Padmavathi *et al.* (1996)
6	25 genotypes of rice	Negative, direct	-	Khan *et al.* (2009)
		and Positive, indirect	Plant height	
7	30 rice genotypes	Positive, direct	-	Wattoo *et al.* (2010)
		Negative, indirect	Plant height	
8	150 rice genotypes including 5 checks	Negative, direct,	-	Padmaja *et al.* (2011)
9	21 rice genotypes	Positive, direct & indirect	Plant height, Panicle length, Number of total tillers per plant, Filled grains per panicle, 1000 grain weight	Selveraj *et al.* (2011)
		Negative, indirect	Days to 50% flowering	

Number of productive tillers per plant				
1	14 drought tolerant lines of rice	Negative direct	-	Ibrahim *et al.* (1990)
2	20 rice varieties	High positive, direct	-	Chaubey and Singh (1994)
3	27 short duration rice under alkaline condition	Low positive, direct	-	Ramalingam *et al.* (1995)
4	22 advance generations of rice	Positive direct	-	Ravindra Babu (1996)
5	128 accessions of rice	Negative direct, Positive indirect	Panicle length	Sarawgi *et al.* (1997)
6	75 land races of rice grouped into 3 set based on test weight	High positive, direct	-	Verma *et al.* (1997)
7	16 hybrids obtained by L x T	Positive, direct	Plant height, Grains per panicle	Janardhanam *et al.* (2001)
8	8 fine rice genotypes	Highest negative, direct	-	Prasad *et al.* (2001)
		High positive, indirect	Plant height, Number of fertile grains per panicle, Panicle length, 1000-grain weight	

9	20 double haploid lines from cross between IR-64 – an *indica* variety and Azucena-a traditional *japonica* variety developed	Low Positive direct	-	Shashidhar *et al.* (2005)
10	4 lines and 5 testers along with 20 crosses obtained by crossing between these parents	High positive direct	-	Manomani and Ranganathan (2006)
		Negative indirect	Panicle length, number of grain per panicle	
11	1o hybrid and their 14 parents	Positive direct	-	Ramakrishnan *et al.* (2006)
12	25 genotypes of rice	Highest positive, direct	-	Aghai *et al.* (2007)
13	25 indigenous aromatic rice genotypes	Highest positive, direct	-	Jaiswal*et al.* (2007)
14	100 rice genotypes	Positive, direct	-	Patil and Sahu (2009)
15	33 genotypes of rice	Negative, direct	-	Nandan *et al.* (2010)
16	150 rice genotypes including 5 checks	Positive, direct	-	Padmaja *et al.* (2011)

17	21 rice genotypes	Positive, direct & indirect	Days to 50% flowering	Selveraj *et al.* (2011)
		Negative, indirect	Plant height, Panicle length, Number of total tillers per plant, Filled grains per panicle, 1000 grain weight	
Number of grains per panicle				
1	49 dwarf strains of rice	High positive direct and negative indirect	Number of ear bearing tillers, 1000-grain weight	Mishra *et al.* (1973)
2	50 newly developed lines from diverse crosses and 10 varieties	High negative direct	-	Panwar and Bansal (1989)
3	6 parents and their 30 hybrids obtained by diallele crosses	High positive, direct	Days to 50% flowering	Arumugachamy *et al.* (1993)

4	Early rice genotypes	Highest positive direct and positive indirect	Productive tillers, panicle weight, grain weight	Sundaram *et al.* (1988)
		Highest negative indirect	Dry matter	
5	27 short duration rice under alkaline condition	Low positive, direct	-	Ramalingam *et al.* (1995)
6	30 F_1 and their parents	Moderate direct	-	Gopalkrishnan and Ganapathy (1996)
7	60 advanced breeding lines	High positive direct	Productive tillers per plant	Sharma and Dubey (1997)
8	16 hybrids developed by L x T	Maximum direct, positive	-	Janardhanam *et al.* (2001)
9	200 scented and 1 non scented rice genotypes	Maximum direct, positive	-	Nayak *et al.* (2001)
10	20 double haploid lines from cross between IR-64 -an *indica* variety and Azucena-a traditional *japonica* variety developed	Positive, Low direct	-	Shashidhar *et al.* (2005)

11	4 lines and 5 testers along with 20 crosses obtained by crossing between these parents	Positive indirect	Days to 50% flowering, Plant height, Number productive tillers per plant	Manomani and Ranganathan (2006)
12	10 hybrids and their 14 parents	High, direct	-	Ramakrishnan *et al.* (2006)
13	25 genotypes of rice	Positive, direct	-	Aghai *et al.* (2007)
14	25 genotypes of rice	Highest positive, direct	-	Khan *et al.* (2009)
15	33 genotypes of rice	High positive, direct	-	Nandan *et al.* (2010)
16	30 rice genotypes	Positive, direct	-	Wattoo *et al.* (2010)
		Positive, indirect	Number of tillers per plant, 1000 grain weight	
		Negative, indirect	Plant height	
17	150 rice genotypes including 5 checks	Positive, direct	-	Padmaja *et al.* (2011)

Number of filled grains per panicle				
1	19 promising lines from 7 crosses studied under saline condition	Largest direct, positive	-	Buu and Truong (1988)
2	29 boro rice genotypes	Negative, direct	Most characters	Chakraborty *et al.* (2001)
3	8 fine rice genotypes	Highest positive, direct	-	Prasad *et al.* (2001)
4	80 breeding lines derived from 11 different cross population in F_6 generation and their 10 parents	Positive, direct	-	Surek and Beser (2003)
5	14 rice genotypes	Negative, direct	Grain yield per ha.	Mustafa and Elsheikh (2007)
		Positive, indirect	Number of grains per panicle	
		Negative, indirect	Number of tillers per plant	
6	100 rice genotypes	Positive, direct	-	Patil and Sahu (2009)

7	50 exotic rice genotypes and 2 variety	Maximum positive, direct	-	Akter (2010)
8	21 rice genotypes	Positive, direct	-	Selveraj *et al.* (2011)
		Positive, indirect	Days to 50% flowering, plant height, Number of total tillers per plant, Number of productive tillers per plant, 1000 grain weight	
1000-grain weight (gm)				
1	19 promising lines from 7 crosses	Negative, direct	-	Buu and Truong (1988)
2	188 diverse genotypes of rice	High positive, direct	-	Pathak and Patel (1989)
3	6 parents and their 30 hybrids obtained through diallel crosses	Direct, positive low effect and moderate negative indirect	Grains per panicle, Days to 50% flowering, Productive tillers per plant	Arumugachamy *et al.* (1993)
4	99 genotypes of rice	High positive, direct	-	Roy *et al.* (1993)

5	30 F_1 and their parents	Positive moderate, direct	Harvest index	Gopalkrishnan and Ganapathy (1996)
6	8 fine rice genotypes	Highest positive, indirect	Plant height	Prasad *et al.* (2001)
7	80 breeding lines derived from 11 different cross population in F_6 generation and their 10 parents	Positive, direct	-	Surek and Beser (2003)
		Positive, indirect	Harvest index	
		Negative, indirect	Number of filled grains per panicle	
8	41 aromatic rice genotypes	Positive, direct	-	Tavisha (2005)
9	10 hybrids and their 14 parents	Low direct	-	Ramakrishnan *et al.* (2006)
10	25 genotypes of rice	Positive direct	-	Aghai *et al.* (2007)
11	33 genotypes of rice	Negative, direct	-	Nandan *et al.* (2010)
12	30 rice genotypes	Negative, indirect	Plant height, Number of tillers per plant, Number of grains per panicle	Wattoo *et al.* (2010)

13	21 rice genotypes	Maximum positive, direct	-	Selveraj *et al.* (2011)
		Positive indirect	Plant height, Number of tillers per plant, number of productive tillers per plant, Panicle length, Filled grains per panicle	
Grain length (mm)				
1	128 accessions of *indica* rice along with 4 standard cultivars	Low negative, direct	-	Sarawgi *et al.* (1997)
		Positive, indirect	Harvest index	
2	41 aromatic rice genotypes	Positive, direct	-	Tavisha (2005)
3	50 exotic rice genotypes and 2 variety	Positive, direct	-	Akter (2010)
Grain breadth (mm)				
1	128 accessions of *indica* rice along with 4 standard cultivars	Low negative, direct	-	Sarawgi *et al.* (1997)
		Positive, indirect	Harvest index	

2	41 aromatic rice genotypes	Positive, direct	-	Tavisha (2005)
3	50 exotic rice genotypes and 2 variety	Direct	-	Akter (2010)
Grain length : Grain breadth ratio				
1	41 aromatic rice genotypes	Positive, direct	-	Tavisha (2005)
2	10 hybrids and 14 parents	Positive direct	-	Ramakrishnan *et al.* (2006)
Hulling (%)				
1	33 genotypes of rice	Positive, direct	-	Nandan *et al.* (2010)
Harvest index				
1	26 indica rice genotypes	Highest positive, direct	Grains per panicle, effective tillers, Panicle length	Katoch *et al.* (1993)
2	40 drought tolerant rice genotypes	Highest positive, direct	-	Rao *et al.* (1996)
3	128 accessions of *indica* rice along with 4 standard cultivars	Positive, direct	-	Sarawgi *et al.* (1997)
4	F_2 population of IR 52 x TNAU 801793	Moderate positive, direct	-	Selvarani and Rengasamy (1998)

5	10 parents and 21 hybrids obtained by L x T	High positive, direct	-	Meenakshi *et al.* (1999)
6	29 boro rice genotypes	High positive, direct	-	Chakraborty *et al.* (2001)
7	80 breeding lines derived from 11 different cross population in F_6 generation and their 10 parents	Positive, indirect	1000 grain weight, number of filled grains per panicle	Surek and Beser (2003)
8	20 double haploid lines from cross between IR-64 -an *indica* variety and Azucena-a traditional *japonica* variety developed	High positive, direct	-	Shashidhar *et al.* (2005)
9	33 genotypes of rice	Maximum direct, positive	-	Nandan *et al.* (2010)

III. MATERIAL AND METHODS

3.1 LOCATION AND CLIMATIC CONDITION

The present study entitled “Genetic variability, correlation and path analysis in red rice (*Oryza sativa* L.) genotypes” was carried out at Main Rice Research Station (MRRS), Anand Agricultural University, Nawagam during *Kharif*, 2011. The rice research centre is located in the Middle Gujarat agro-climatic Zone-III in the outside of Kheda district and lies at 22^0 48^0 N latitude and 71^0 38^0 E longitude at an altitude of 32.4 meters above mean sea level. The average rainfall of the zone is around 800 mm. Rainy season begins in mid June and extends through September. Details of some of the weather parameters for the year 2011 during which the experimental research was conducted are presented in Appendix – I.

3.2 SOIL AND WATER CONDITION

The soil of the station and its surrounding is medium black deep to very deep, poorly drained and salt affected. Soil samples were collected from the plot before sowing, during the growth period and after harvesting of the crop for determination of pH and EC of the soil. Electrical conductivity of the saturated extract (EC_e) in the soil was found in the range of 4.5 to 5.8 mmhos/cm approximately, and pH of the soil was recorded in the range of 7.3 to 8.5 during crop growth period. The irrigation water is of medium quality and electrical conductivity was found in the range of 2.38 to 4.28 mmhos/cm and pH was recorded in the range of 7.4 to 7.8.

3.3 EXPERIMENTAL MATERIAL AND DESIGN

The material comprised of fifty-nine red and four (non red) white rice genotypes. These 63 genotypes were sown in an individual small plot under suitable nursery condition on June 21, 2011. After the development of seedling up to suitable height, healthy selected seedling were transplanted under three replications, with 20 x 15 cm spacing, 3m x 0.60m gross plot size in Rndomized Block Design on August 4, 2011. List of 63 genotypes studied and presented in Table 3.3.1.

3.4 CULTURAL PRACTICES APPLIED

All the necessary and important agronomic and entomological practices were uniformly applied to the crop from sowing to transplanting and transplanting to harvesting stage. Fertilizers were applied at the rate of 100 kg N and 25 kg P_2O_5 per hectare. To control pests Furadan and Caldan were applied at the rate of 25 and 20 kg per hectare, respectively. The crop growth was healthy and satisfactory.

Table 3.3.1 List of Genotypes :

Sr. No.	Genotype	Pedigree / Source
1	Baska-1	Local
2	Choria Chettari	Local
3	Dabhoda local	Local
4	Dang futia local	Local
5	Dang hario local	Local
6	HB-1	-
7	Kada local	Local
8	Kalo vankalo	Kharedi, Dahod
9	Kolorado	-
10	Lal vankalo	Kharedi, Dahod
11	Lal fotari local	Local
12	Mane deshi utavari	Local
13	Mehsana sutarsal	Local
14	IET-18940	-
15	Mehsana vani	Local
16	Nawagam-5	Local
17	Niriya-5	Local
18	Panchmahal dabhoda	Local
19	Pataniu	Local
20	Saria	Local
21	SKL-5-11-1-62	-
22	Surat bhadaravi	Local
23	Surat futia	Local
24	Tapkhira	Local
25	Tuljapur-1	Local
26	Vadodara ankali	Local
27	Vankvel	Local
28	ARC-5752	-
29	ARC-10239	-
30	BTS-24	-
31	LST-77	-
32	Mudgo	-

33	Pokali	-
34	Setail	IIRON-M2(2010, No.410)
35	IET-21224	-
36	IET-21617	UPR3281-9-1-1
37	IET-22094	NDR-2105
38	IET-22127	KAU-PTB Samyuktha
39	IET-22128	KAU-PTB Vaisakh
40	IET-22129	KAUM 166-2
41	IET-22130	KAUM 168-1
42	IET-22131	KAUM 172-1
43	IR 68652-3B-81	ST-2925
44	IR 68652-3B-11-2	ST-2926
45	IR 68652-3B-22-3	ST-2931
46	IR 68652-3B-10-3	-
47	IR 68654-3B-1-2	ST-2934
48	IR 68654-3B-2-3	ST-2935
49	IR 68654-3B-6-1	ST-2936
50	IR 68654-3B-9-1	ST-2937
51	IR 68657-3B-15-2	ST-2940
52	IR 70868-B-P-14-1	T-36470
53	IR 70868-B-P-19-2	T-35484
54	IR 70868-B-P-30-3	T-36500
55	IR 70869-B-P-10-2	T-36511
56	IR 70869-B-P-16-2	T-36523
57	IR 70869-B-P-18-2	T-36526
58	IR 70870-B-P-3-2	T-36545
59	IR 81429-B-31	IR-78908-44 × IR-78908-86
60	GR-7 (White)	GR-3 × Basmati-370
61	GR-12 (White)	GR-4 × IR-64
62	GAR-13 (White)	GR-11 × IET-14726
63	Gurjari (White)	Asha × Kranti

3.5 CHARACTER STUDIED

To record observation, five competitive plants from middle row were randomly selected and tagged from each plot in all the three replications. The following agro-morphological, yield and grain characters were recorded.

3.5.1 Grain yield per plant (gm)

Weight of mature grains harvested from five samples plants were recorded in grams and the mean was calculated.

3.5.2 Days to 50 per cent flowering

The date of flowering in 50 % plants for each plot were noted and then number of days was worked out from the date of sowing in nursery to that of 50 % flowering and recorded as number of days to 50% flowering (DFF).

3.5.3 Plant height (cm)

Height of the five plants in each plot was measured in centimeter from soil level to the apical tip of the top panicle at the time of harvesting and mean plant height for each entry was computed.

3.5.4 Panicle length (cm)

The length of the main panicle of five plants from the ciliate ring (panicle base) to the tip of the panicle in centimeter was measured at the time of harvesting and average panicle length computed.

3.5.5 Number of total tillers per plant

Number of productive and non productive tillers of the selected plants in each plot were counted at the time of harvesting and averaged out for number of tillers per plant.

3.5.6 Number of productive tillers per plant

The tillers producing panicle with seed set were considered as productive tillers. Number of productive tillers of the selected plants in each plot were counted at the time of harvesting and mean values were worked out.

3.5.7 Number of grains per panicle

The grains of main panicle per plant were counted for each selected plant and mean recorded/calculated.

3.5.8 Number of filled grains per panicle

The filled grains of main panicle per plant were counted for each selected plant as filled grains per panicle and mean recorded /calculated.

3.5.9 1000-grain weight (Test weight) (g)

Thousand seed were randomly collected from whole seed lot per sample and weighted in gram.

3.5.10 Grain length (mm)

From each sample of genotypes ten healthy grains were selected and length was measured by gauge meter in mm as the distance from the base of lowermost sterile lemma to the tip (apiculus) of the fertile lemma or palea, whichever was longer. In case of awned varieties grain length was measured to a point comparable to the tip of the apiculus. And average was computed.

3.5.11 Grain breadth (mm)

Grain breadth was measured through gauge meter as the distance across the fertile lemma and palea at the widest point. Ten grains were measured per sample and average was computed.

3.5.12 Grain length : breadth ratio

The length : breadth ratio was computed from the length and breadth dimension.

Khush *et al.* (1979) used to classify the grains for shape as follows

L/B ratio	Shape
Over 3.0	Slender (Long)
2.1 to 3.0	Medium
1.1 to 2.0	Bold
Less than 1.1	Round (Short)

3.5.13 Hulling (%) :

From the paddy sample 300 gm paddy weighed separately for each genotype. The samples were dehusked with the help of satake dehusker. The dehusked kernels were weighed & percentage was determined by the following formula,

$$\text{Hulling (\%)} = \frac{\text{Weight of dehusked paddy}}{\text{Weight of paddy}}$$

3.5.14 Milling (%) :

Dehusked kernels were then put into a kett polisher. The time of the polisher was applied in such a way that per cent polishing is 5% (approximately). Total polished kernels were weighed and then milling percentage was calculated by the following formula,

$$\text{Milling \%} = \frac{\text{Total polished kernels}}{\text{Weight of paddy}} \text{x100}$$

3.5.15 Harvest index (%)

Harvest index is the ratio of economic yield to total biological yield (Donald, 1962). It is expressed in percentage.

$$\text{Harvest Index } \% = \frac{\text{Grain yield in gram}}{\text{Total dry matter in gram}} \text{ x100}$$

(Total dry matter constituted the dry weight of haulms and grain weight of the individual plant).

3.5.16 & 17 Iron and Zinc

Chemical required : 1) Concentrated Nitric Acid

2) Concentrated Perchloric Acid

3) Double Distilled Water

Procedure :

1 gm rice grain powder in 250 ml conical flask.

10 ml Di-acid mixture at ratio of 2:1 was added.

Kept incubation overnight.

Hot plate for digestion until colourless.

Filter the sample and make up the volume upto 50 ml by double distilled water.

These sample were used for the estimated for Fe and Zn.

3.6 STATISTICAL ANALYSIS

For all the characters under study, the mean values of five randomly selected plants were used for statistical analysis. The data recorded for different characters were subjected to analysis of variance. Different components of variance *viz.,* phenotypic, genotypic and environmental variance were estimated. Different parameters of genetic variability were computed by standard statistical procedure. The phenotypic and genotypic correlations were also estimated. The genotypic correlation subjected to path analysis.

3.6.1 Analysis of variance

The data recorded for all the characters were subjected to analysis of variance with the formula suggested by Panse and Sukhatme (1978). The following linear model for randomized block design was used.

$$y_{ij} = m + r_i + g_j + e_{ij}$$

where,

y_{ij} = Observation on j^{th} genotype in i^{th} replication,

i = 1,2,3,.....r

j = 1,2,3,.....g

m = General mean

r_i = Effect due to i^{th} replication

g_i = Effect due to j^{th} genotypes

e_{ij} = Uncontrolled variation associated with j^{th} genotype in i^{th} replication.

Analysis of variance tables were prepared separately for all the characters under study, based on above model

ANOVA

Sr. No.	Source of variation	Degree of freedom	Sum of Squares	Mean sum squares	Expected mean squares (EMS)
1	Replication	(r-1)	SS_1	Mr	$\sigma_e^2 + g\ \sigma_r^2$
2	Treatment	(g-1)	SS_2	Mg	$\sigma_e^2 + r\ \sigma_g^2$
3	Error	(r-1) (g-1)	SS_3	Me	σ_e^2
4	Total	(rg-1)			

Where,

r = Number of replications

g = Number of genotypes

$\sigma_e^2, \sigma_r^2, \sigma_g^2$ = Variance due to error, replications and genotypes, respectively.

Mr, Mg, Me = Mean sum of squares for replications, genotypes and error, respectively.

The useful 'F' test was done to test the significance of differences among replications and among genotypes. The standard error, standard error of differences, critical differences and coefficient of variation were calculated as under.

S. E. = $\sqrt{Me/r}$

C. D. = S.E. x $\sqrt{2}$ X table 't' value at 0.05 level of significances and error degree of freedom.

C. V.% = $\frac{\sqrt{Me}}{\overline{X}}$ x 100

3.6.2 Estimation of Variance

The following estimates were worked out to asses the variability.

3.6.2.1 Mean

The mean values for each character was worked out by dividing the grand total by corresponding number of observations.

Mean = $\overline{X}$ = $\sum_{i,j}^{r,g}$ Xij/n

Where,

$\overline{X}$ = mean of the character

Xij = observation on i^{th} replication and in j^{th} genotype

n = total number of observation

3.6.2.2 Phenotypic range

It is a differences between the lowest and the highest mean values for each character.

3.6.2.3 Components of variance

The phenotypic (σ_p^{2}), genotypic (σ_g^{2}) and environmental (σ_e^{2}) components of variances based on analysis of variance were estimated by using the following relation (Johnson *et al.,* 1955).

i) $\pounds^{2}e$ = me = Environmental variance

ii) $\pounds^{2}g = = \frac{Mg-Me}{r}$ = Genotypic variance

iii) $\pounds^{2}p = \sigma_g^{2} + \sigma_e^{2}$ = Phenotypic variance

Where,

$\pounds^{2}$e = expected environmental variance

$\pounds^{2}$g = expected genotypic variance

$\pounds^{2}$p = expected phenotypic variance

3.6.2.4 Heritability in broad sense (H^2)

It is the proportion of phenotypic variability that is due to genetic reasons. It was computed in percentage using following formula given by Allard (1960).

$$H^{2}(\%) = \frac{\pounds^{2}g}{\pounds^{2}p} \times 100$$

Where,

H = heritability in broad sense

$\pounds^{2}$g = genotypic variance

$£^2 p$ = phenotypic variance

3.6.2.5 Expected genetic advance

The expected genetic advance (G.A.) under selection was estimated by adopting the formula suggested by Allard (1960).

i) G.A. =K x $£^2 p$ x H

Where,

G.A. = genetic advance

K = selection differential value of K at 5 % selection deviation

$£^2 p$ = phenotypic standard deviation

H = heritability in broad sense

ii) Genetic advance expressed as percentage of mean (G.A.% of mean)

$$\text{G.A. \% of mean} = \frac{\text{G. A.}}{\overline{\text{X}}} \times 100$$

Where,

G. A. = Genetic advance

$\overline{\text{X}}$ = General mean of the character under study

3.6.2.6. Coefficient of variation

The relative amount of genotypic and phenotypic variation for different traits were calculated as per procedure outlined by Burton (1952).

3.6.2.6.1 Genotypic coefficient of variation (GCV %)

It was computed using the following formula given Burton (1952).

$$\text{GCV (\%)} = \frac{\sqrt{£^2 g}}{\overline{\text{X}}} \times 100$$

Where,

GCV = Genotypic coefficient of variation

$£^2 g$ = Genotypic variance

$\overline{X}$ = General mean of the character under study

3.6.2.6.2 Phenotypic coefficient of variation (PCV %)

It was computed using the following formula given Burton (1952).

$$PCV(\%) = \frac{\sqrt{£^2 p}}{\overline{X}} \text{ x } 100$$

Where,

PCV = Phenotypic coefficient of variation

$£^2 p$ = Phenotypic variance

$\overline{X}$ = General mean of the character under study

3.6.2.7 Estimation of correlation coefficients

For this purpose, analysis of covariance for all possible pairs of seventeen characters were carried out as per Panse and Sukhatme (1978) by using mean values.

The analysis of covariance had the following formula.

Source of variation	Degree of freedom	Sum of cross products	Mean sum of cross products	Expectation of mean sum of cross products
Replication	(r-1)	SP_1	MSP_1	$Cov_{exy} + {}_{g}Cov_{rxy}$
Genotypes	(g-1)	SP_2	MSP_2	$Cov_{exy} + {}_{r}Cov_{gxy}$
Error	(r-1) (g-1)	SP_3	MSP_3	Cov_{exy}

The components of variation were determined by adopting following relationships.

$$Cov_{pxy} = Cov_{gxy} + Cov_{exy}$$

$$Cov_{gxy} = \frac{MSP2 - MSP3}{r}$$

$Cov_{exy} = MSP_3$

Where,

Cov_{pxy} = Phenotypic component of covariance

Cov_{gxy} = Genotypic component of covariance

Cov_{exy} = Environmental component of covariance

The genotypic (rg) and phenotypic (rp) correlation coefficients were calaulated as under (Miller *et al.,* 1958).

$r_p = Cov_{pxy} / (\sigma_{px} . \sigma_{py})$

$r_g = Cov_{gxy} / (\sigma_{gx} . \sigma_{gy})$

$r_e = Cov_{exy} / (\sigma_{ex} . \sigma_{ey})$

All the narrations used, have the same meaning as explained earlier. The phenotypic correlations were tested as per procedure of Fisher and Yates (1963).

3.6.3 Path coefficient analysis

The path coefficient analysis permits the separation of correlation coefficients of grain yield with component characters into direct and indirect effects in a system of cause and effect relationship. This analysis was performed according to the method suggested by Dewey and Lu (1959) using sixteen causal characters.

The above equations written in a matrix form are as under :

$$\overset{\textbf{A}}{\begin{pmatrix} 1 & r_{12} & r_{13}\ldots\ldots\ldots\ldots r_{1i} \\ r_{21} & 1 & r_{23}\ldots\ldots\ldots\ldots r_{2i} \\ r_{31} & r_{32} & 1\ \ldots\ldots\ldots\ldots r_{3i} \\ \vdots & \vdots & \\ \vdots & \vdots & \\ \vdots & \vdots & \\ r_{i1} & r_{i2} & r_{i3}\ \ldots\ldots\ldots\ldots r_{in} \\ \vdots & \vdots & \\ \vdots & \vdots & \\ \vdots & \vdots & \\ r_{n1} & r_{n2} & r_{n3}\ \ldots\ldots\ldots r_{nn} \end{pmatrix}} \text{ X } \overset{\textbf{B}}{\begin{pmatrix} P_{1y} \\ P_{2y} \\ P_{3y} \\ \vdots \\ \vdots \\ \vdots \\ P_{iy} \\ \vdots \\ \vdots \\ \vdots \\ P_{ny} \end{pmatrix}} = \overset{\textbf{C}}{\begin{pmatrix} r_1y \\ r_2y \\ r_3y \\ \vdots \\ \vdots \\ \vdots \\ r_iy \\ \vdots \\ \vdots \\ \vdots \\ r_ny \end{pmatrix}}$$

With the help of matrix inversion (Goulden, 1962) the following form of inverted 'C' matrix was obtained.

$[C] = [A]^{-1}\ [B]$

The indirect effects were calculated by taking the products of genotypic correlation coefficients between corresponding two characters and the path coefficient (direct effect) connecting the causal effect with yield.

The residual effect measures the contribution of the characters which are not considered in the causal sheme and was obtained as under.

Residual effect (R) = $1 - R^2$

All the statistical and genetical analysis were carried out on electronic computer at Anand Agricultural University, Anand.

IV. EXPERIMENTAL RESULT

The results of present investigation on the parameters of variability, correlation and path analysis for quantitative characters of red rice (*Oryza sativa* L.) are presented here.

4.1 Analysis of variance

The Analysis of variance for seventeen characters is presented in table 4.2. The mean square due to genotypes were highly significant except hulling and milling percentage, where it was significant suggesting the existence of significant genetic variability among tested genotypes for all the characters under study.

4.2 Mean performance and genotypic variability

Mean performance of sixty three genotypes for seventeen polygenic characters along with standard error of mean, critical difference (C.D.) and coefficient of variation (C.V.%) and range of phenotypic variability are presented in table 4.1.

4.2.1 Grain yield

Grain yield exhibited wide range (10.37 to 26.38 g) of phenotypic variability with general mean 18.27g. The highest grain yield was recorded by genotype G_{50} (26.38 g) which was followed by G_{49} (25.92 g), G_{63} (25.59 g), G_{32} (25.44 g), G_{58} (23.66 g) and G_{33} (23.26 g). Low grain yield was observed by G_{16} (10.37 g) followed by G_{37} (12.35 g), G_{40} (12.99 g), G_{17} (13.40 g), G_{35} (13.47 g), G_{13} (13.50 g) and G_{34} (13.57 g).

Table 4.1

Table 4.1

Table 4.1

Table 4.1

Table 4.2

4.2.2 Days to 50% flowering

Days to fifty percent flowering showed high range of phenotypic variability (87.33 to 118.67) with general mean 102.24. The late fifty percent flowering was exhibited by G_{42} (118.67) followed by G_{40} (117.33), G_{43} (117.33), G_{33} (116.00), G_{41} (116.00), G_{45} (116.00), G_{50} (116.00), G_{54} (115.67), G_{2} (115.33), G_{35} (115.00), G_{34} (114.67) and G_{14} (113.00). Moderate days to fifty percent flowering was G_{16} (105.33), G_{11} (104.00), G_{4} (103.00), G_{31} (103.00), G_{32} (103.00), G_{61} (103.00), G_{29} (102.33), G_{39} (101.67) and G_{63} (101.67). G_{8} (87.33), G_{13} (87.33) and G_{28} (87.33) was earliest for fifty percent flowering which was followed by G_{1} (90.67), G_{5} (90.67), G_{6} (92.00) and G_{10} (92.00).

4.2.3 Plant Height

The high range of phenotypic variability was observed for plant height (84.33 to 188.73 cm) with general mean (123.60 cm). G_{33} (188.73 cm), G_{2} (184.00), G_{32} (166.27 cm), G_{29} (161.67 cm), G_{38} (155.87 cm), G_{14} (151.80 cm), G_{24} (145.93 cm), G_{4} (145.80 cm) and G_{9} (140.00 cm) were the taller genotypes. The dwarf genotypes were G_{6} (84.13 cm), G_{53} (92.93 cm), G_{34} (95.07 cm), G_{49} (97.53 cm), G_{54} (100.53 cm) and G_{11} (100.67 cm).

4.2.4 Panicle length

Panicle length had exhibited high range of phenotypic variability (20.54 to 30.41 cm) with general mean 24.98 cm. The long panicle length was exhibited by G_{50} (30.41 cm) followed by G_{57} (29.25 cm), G_{4} (29.23 cm), G_{2} (28.95 cm), G_{56} (28.93 cm), G_{58} (28.83 cm) and G_{32} (28.79 cm). The short panicle length was observed by G_{13} (20.54 cm) followed by G_{41} (21.11 cm), G_{36} (21.23 cm) and G_{8} (22.06 cm).

4.2.5 Number of total tillers per plant

Number of total tillers per plant had exhibited narrow range of phenotypic variability (8.27 to 11.53) with general mean 9.89. The genotype G_{15} (11.53) had the maximum number of total tillers and followed by G_{55} (11.20), G_{62} (11.13), G_{14} (11.00) G_{19} (10.67), G_{29} (10.67) and G_{31} (10.67). Genotypes G_{21} (8.40), G_{22} (8.87), G_{33} (8.87), G_{37} (8.93), G_{23} (9.00), G_{40} (9.07), G_{8} (9.13), G_{41} (9.13) and G_{53} (9.13) recorded less number of total tillers per plant.

4.2.6 Number of productive tillers per plant

Number of productive tillers per plant showed high range of phenotypic variability (4.93 to 9.80) with general mean (7.25). Genotype G_{15} (9.80) recorded maximum number of productive tillers per plant followed by G_{55} (8.93) and G_{62} (9.13). Low number of productive tillers per plant were recorded for G_{41} (4.93), G_{37} (5.20), G_{8} (5.47), G_{20} (5.53), G_{13} (5.73) and G_{21} (5.87). The rest of the genotypes showed moderate number of productive tillers per plant.

4.2.7 Number of grains per panicle

The wide range of phenotypic variability was observed for number of grains per panicle (124.73 to 248.26) with general mean (163.36). The maximum number of grains per panicle was recorded for G_{41} (248.26). G_{17} (124.73), G_{18} (134.97) and G_{16} (139.33) recorded less number of grains per panicle. The remaining genotypes showed moderate number of grains per panicle.

4.2.8 Number of filled grains per panicle

The wide range of phenotypic variability was observed for number of filled grains per panicle (91.33 to 178.52) with general mean (121.97). The maximum number of filled grains per panicle was recorded for G_{41} (178.52). G_{17} (91.33), G_{57} (97.88), G_{18} (97.93), G_{31} (99.03), G_{43} (104.85) and G_{16} (105.21) recorded less number of filled grains per panicle. The remaining genotypes showed moderate number of filled grains per panicle.

4.2.9 1000 grain weight

High range of phenotypic variability was observed for 1000 grain weight (14.8 to 30.73 g) with general mean (23.81 g). The maximum 1000 grain weight was observed for G_{33} (30.73 g) which was followed by G_{63} (29.40 g) and G_{32} (29.13 g). The low 1000 grain weight was recorded by G_{61} (14.80 g). Moderate 1000 grain weight was showed by the remaining genotypes.

4.2.10 Grain length

Grain length exhibited moderate range of phenotypic variability (7.38 to 10.44 mm) with general mean (8.77 mm). The maximum grain length was recorded for G_{14} (10.44 mm) followed by G_{34} (10.35 mm) and G_{6} (10.34 mm), where as G_{41} (7.38 mm) recorded minimum grain length followed by G_{36} (7.40 mm), G_{29} (7.60 mm), G_{17} (7.63 mm), G_{30} (7.63 mm), G_{35} (7.67 mm), G_{40} (7.65 mm) and G_{53} (7.85 mm). The moderate grain length was recorded by rest of the genotypes.

4.2.11 Grain breadth

Low range of phenotypic variability was observed for grain breadth (1.98 to 3.44 mm) with general mean (2.78 mm). The maximum grain breadth was recorded for G_{33} (3.44 mm) followed by G_{2} (3.36 mm) and G_{32} (3.33 mm). Low grain breadth was observed for G_{61} (1.98 mm) followed by G_{62} (2.01 mm) and G_{14} (2.06 mm). The rest of the genotypes showed moderate grain breadth.

4.2.12 Grain L:B ratio

Grain L:B ratio exhibited low range of phenotypic variability (2.39 to 5.08 mm) with general mean (3.21 mm). The maximum grain L:B ratio was recorded for G_{14} (5.08 mm), whereas G_{40} (2.39 mm), G_{33} (2.48 mm), G_{17} (2.50 mm), G_{29} (2.57 mm) and G_{2} (2.58 mm) recorded low grain L:B ratio. The moderate grain L:B ratio was recorded by rest of the genotypes.

4.2.13 Hulling percent

Hulling percent exhibited moderate range of phenotypic variability (71.00 to 80.30%) with general mean (75.67%). The maximum hulling percent was recorded for G_{51} (80.30 %) followed by G_{3} (79.57%), G_{18} (78.77%), G_{4} (78.76%), G_{49} (78.75%), G_{2} (78.09%), G_{6} (77.61%), G_{63} (77.42%), G_{19} (77.39%), G_{5} (77.33%), G_{50} (77.33%) and G_{32} (77.30%). Whereas G_{9} (71.00%) recorded low hulling percent followed by G_{25} (71.48%), G_{14} (71.73%), G_{22} (71.78%), G_{13} (72.39%), G_{20} (72.47%), G_{24} (72.63%), G_{10} (72.93%) and G_{1} (73.12%). The moderate hulling percent was recorded by rest of the genotypes.

4.2.14 Milling percent

Moderate range of phenotypic variability was observed for milling percent (58.89 to 68.76%) with general mean (64.03%). G_{18} (68.76%) recorded maximum milling percent followed by G_{4} (68.67%), G_{8} (68.34%), G_{51} (68.12%), G_{49} (67.64%), G_{63} (67.41%), G_{55} (67.21%), G_{47} (66.45%), G_{53} (66.42%), G_{54}

(66.41%) and G_{59} (66.03%). Genotype G_{9} (58.89%), G_{13} (59.53%), G_{10} (61.08%), G_{27} (61.53%), G_{30} (61.56%), G_{35} (61.65%) and G_{42} (61.90%) recorded was less milling percent.

4.2.15 Harvest Index

Harvest index exhibited wide range of phenotypic variability (35.84 to 58.34%) with general mean (46.34%). G_{50} (58.34%) had maximum harvest index which was followed by G_{49} (56.67%), G_{47} (56.42%), G_{28} (55.70%), G_{30} (55.11%), G_{39} (54.81%) and G_{53} (46.17%). Low harvest index was recorded by G_{62} (35.84%), G_{37} (36.20%), G_{16} (37.73%), G_{18} (38.43%), G_{17} (38.98%), G_{35} (39.18%), G_{41} (39.60%), G_{9} (39.90%), G_{21} (39.95%) and G_{2} (40.31%). The rest of the genotypes showed moderate harvest index.

4.2.16 Iron content

High range of variability was observed for iron content (7.67 to 109.67) with general mean (32.91). The maximum iron content was observed for G_{22} (109.67) which was followed by G_{16} (96.67), G_{8} (78.67), G_{57} (70.33), G_{7} (62.83), G_{52} (60.50) and G_{23} (59.50). The low iron content was recorded by G_{29} (7.67), G_{39} (10.17), G_{47} (11.17), G_{4} (12.17), G_{48} (12.50), G_{42} (12.67), G_{56} (14.33), G_{30} (15.00), G_{32} (16.83) and G_{43} (18.50). Moderate iron content was showed by the remaining genotypes.

4.2.17 Zinc content

Moderate range of variability was observed for zinc content (2.33 to 14.17) with general mean (7.88). The high zinc content was observed for G_{7} (14.17) followed by G_{10} (13.67), G_{25} (13.50), G_{19} (13.17), G_{43} (13.00), G_{22}

(12.33), G_{18} (11.83), G_{21} (11.83), G_{24} (11.67), G_{23} (10.83), G_{44} (10.33) and G_{16} (10.17). G_{17} (2.33) had minimum zinc content followed by G_{62} (3.33), G_{39} (4.67), G_{42} (4.67), G_{45} (4.67), G_{40} (4.83), G_{47} (4.83), G_{5} (5.50), G_{40} (5.50), G_{31} (5.67) and G_{35} (5.83). The remaining genotypes showed moderate zinc content.

4.3 Variance components

The phenotypic, genotypic and environmental variances calculated for all the characters are presented in table 4.3. The phenotypic variances were higher than corresponding genotypic variances. The maximum genotypic variance and phenotypic variance were observed for plant height (V.G. = 407.04, VP = 438.81). Both values were moderate for number of filled grains per panicle (V.G. = 214.29, VP = 288.63). Whereas low values of genotypic and phenotypic variances were observed for grain breadth (V.G. = 0.09, VP = 0.10).

The highest environmental variance was observed for number of grains per panicle (VE = 105.19) medium for number of filled grains per panicle (VE = 74.34) and low for grain breadth (VE = 0.006)

4.4 Genotypic and phenotypic coefficient of variation

The genotypic coefficient of variation (GCV), phenotypic coefficient of variation (PCV) and environmental coefficient of variation (ECV) of seventeen quantitative characters are presented in table 4.3.

Table 4.3

4.4.1 Genotypic coefficient of variation (GCV)

Genotypic coefficient of variation for various characters varied from 1.52 for hulling percent to 58.23 for iron content. Most of the characters were found to have moderate to high genotypic coefficient of variation *viz.*, days to 50% flowering (8.22), number of total tillers per plant (5.78), panicle length (8.59), grain length (8.01), grain yield per plant (18.75), plant height (16.32), number of productive tillers per plant (13.46), number of grains per panicle (11.01), number of filled grains per panicle (12.00), 1000 grain weight (13.09), grain breadth (11.05), harvest index (11.03), L:B ratio (17.37), zinc content (34.49) and iron content (58.23), where as hulling percentage (1.52) and milling percentage (1.89) had lower value of GCV.

4.4.2 Phenotypic coefficient of variation (PCV)

The estimate of phenotypic coefficient of variation were high for iron content (58.38) and zinc content (34.78), where as grain yield per plant (21.75), days to 50% flowering (8.98), plant height (16.95), panicle length (9.74), total tillers per panicle (8.17), productive tillers per plant (15.67), number of grains per panicle (12.68), number of filled grains per panicle (13.93), 1000 grain weight (13.74), grain length (8.67), grain breadth (11.39), L:B ratio (17.82) and harvest index (13.43) showed moderate values of pcv. Hulling percentage (4.27) and milling percentage (5.26) had low pcv.

4.5 Heritability

The estimate of heritability in broadsense for all the characters under study are presented in table 4.3. High heritability values were recorded for grain yield (74.3), days to 50% flowering (83.90), plant height (92.8), panicle length (77.7), productive tillers per plant (73.8), total grains per panicle (75.5), filled grains per panicle (74.2), 1000 grain weight (90.8), grain length (85.3), grain breadth (94.1), L:B ratio (95.1), harvest index (67.5), iron content (99.5) and zinc content (98.4). Total grains (49.9) showed moderate heritability values. However, hulling percentage (12.6) and milling percentage (12.9) showed low heritability values.

4.6 Genetic advance

The genetic advance with respect to seventeen characters was estimated to determine the expected response of selection at 5 percent selection intensity (K=2.06). The estimated genetic advance has been presented in table 4.3. High genetic advance was observed for days to 50% flowering (15.86), plant height (40.03), number of grains per panicle (32.19), number of filled grains per panicle (25.98) and iron content (39.38), while it was moderate for grain yield (6.08), 1000 grain weight (6.12), harvest index (8.65) and zinc content (5.56). The rest of the characters showed low genetic advance.

Genetic advance expressed as percentage of mean (GAM) was observed high for grain yield (33.3), plant height (32.4), productive tillers per plant (23.9), filled grains per panicle (21.3), 1000 grain weight (25.7), grain breadth (21.9) and L:B ratio (34.9). The moderate values were observed for days to 50% flowering (15.5), panicle length (15.6), number of grains per panicle (19.7), grain length (15.3), harvest index (18.7) and iron content (11.9). Whereas number of total grains per panicle (8.4), hulling percentage (1.11), milling percentage (1.40) and zinc content (7.06) had low genetic advance as percentage of mean.

4.7 CORRELATION COEFFICIENT ANALYSIS

In estimating the association between characters, correlation analysis has often been used to determine the type and magnitude of association between a pair of characters. These association provide a better understanding of the contributing one trait in building up the genetic make up of the other trait of a crop. The knowledge about correlation between economically important traits and characters contributing to that in all combinations can be of help to decide the parameters for selection, so that improvement in the associated characters can be done. Genotypic correlation in particular are helpful in the construction of selection indices and permit the prediction of correlated response.

The genotypic and phenotypic correlation coefficients were estimated among 17 characters of 59 red and 4 white rice genotypes to find out the association of grain yield and other yield related characters (Table 4.4).

It is evident from the data that the correlation at the genotypic and phenotypic levels has the same trend. In general, the magnitude of genotypic correlation coefficients were relatively higher than the corresponding phenotypic correlation coefficient in almost all the characters paired; suggesting that although there was inherent association between various characters, the phenotypic expression of the correlation was influenced by environments.

Table 4.4

4.7.1 Grain yield per plant

Grain yield per plant had significant and positive correlation with panicle length (r_g = 0.261, r_p = 0.180), total tillers per plant (r_g = 0.412, r_p = 0.350), productive tillers per plant (r_g = 0.456, r_p = 0.434), filled grains per panicle (r_g 0.258, r_p = 0.239), 1000 grain weight (r_g = 0.471, r_p = 0.393), hulling percent (r_g = 0.609, r_p = 0.184) and harvest index (r_g = 0.569, r_p = 0.475) at both genotypic and phenotypic levels. It had significant and positive association with number of grains per panicle (r_p = 0.194) and milling percent (r_g = 0.604) at phenotypic and genotypic level respectively. Iron content (r_g = -0.424, r_p = -0.362) was significantly and negatively correlated with grain yield at both levels. It had positive but non significant correlation with days to 50% flowering (r_g = 0.061, r_p = 0.057), plant height (r_g = 0.129, r_p = 0.115), grain length (r_g = 0.194, r_p = 0.163), grain breadth (r_g = 0.033, r_p = 0.028), L:B ratio (r_g = 0.054, r_p = 0.047) and grains per panicle (r_g = 0.216). Zinc content (r_g = -0.077, r_p = -0.070) had negative but non significant correlation with grain yield.

4.7.2 Days to 50% flowering

Days to 50% flowering showed significant and positive correlation with panicle length (r_g = 0.394, r_p = 0.324) at genotypic and phenotypic levels. Total tillers per plant (r_p = 0.020), total grains per panicle (r_g = 0.193, r_p = 0.147), filled grains per panicle (r_g = 0.109, r_p = 0.105) showed non significant and positive correlation with days to fifty percent flowering. Zinc content (r_g = -0.271, r_p = -0.250) exhibited significant but negative correlation with days to fifty percent flowering at genotypic and phenotypic levels. It had non significant and negative correlation with plant height (r_g = -0.058, r_p = -0.036), productive tillers per plant (r_g = -0.031, r_p = -0.040), 1000 grain weight (r_g = -0.146, r_p = -0.136), grain length (r_g = -0.128, r_p = -0.119), grain breadth (r_g = -0.021, r_p = -0.024), L:B ratio (r_g = -0.025, r_p = -0.024), hulling percent (r_g = -0.082, r_p = -0.053), milling percent (r_g = -0.048, r_p = -0.030), harvest index (r_g = -0.128, r_p = -0.075) and iron content (r_g = -0.118, r_p = -0.103) at both the levels, while with total tillers per plant (r_g = -0.048) at genotypic levels only.

4.7.3 Plant height

Plant height had significant and positive correlation with 1000 grain weight (r_g = 0.361, r_p = 0.331) and grain breadth (r_g = 0.438, r_p = 0.142) at genotypic and phenotypic levels. It had positive but non significant correlation with panicle length (r_g = 0.154, r_p = 0.142), productive tillers per plant (r_g = 0.001, r_p = 0.012), filled grains per panicle (r_g = 0.110, r_p = 0.085) and zinc content (r_g = 0.121, r_p = 0.119). It showed significant and negative correlation with grain L:B ratio (r_g = -0.323, r_p = - 0.304) at both levels, hulling percent (r_g = -0.346), milling percent (r_g = - 0.370) at genotypic levels and harvest index (r_g = -250, r_p = -0.178) at phenotypic level only. Total tillers per plant (r_g = -0.068, r_p = -0.056), total grains per panicle (r_g = -0.099, r_p = -0.082), grain length (r_g = -0.149, r_p = -0.128), iron content (r_g = -0.078, r_p = -0.074) at both levels, hulling percent (r_p = -0.098) and milling percent (r_p = -0.102) at phenotypic level had non significant and negative correlation with plant height.

4.7.4. Panicle length

Panicle length was significantly and positively correlated with only hulling percent (r_g = 0.255) at genotypic level. It showed non significant and positive correlation with total tillers (r_g = 0.054, r_p = 0.014), productive tillers per plant (r_g = 0.063, r_p = 0.039), 1000 grain weight (r_g = 0.130, r_p = 0.113), grain length (r_g = 0.089, r_p = 0.091), grain breadth (r_g = 0.045, r_p = 0.035), grain L:B ratio (r_g = 0.010, r_p = 0.021), milling percent (r_g = 0.228, r_p = 0.118) and iron content (r_g = 0.008, r_p = 0.006) at genotypic and phenotypic levels and with hulling percent (r_p = 0.039) at phenotypic level. Panicle length had non significant and negative correlation with grains per panicle (r_g = -0.059, r_p = -0.049), filled grains per panicle (r_g = -0.113, r_p = -0.089), harvest index (r_g = -0.040, r_p = -0.012) and zinc content (r_g = -0.129, r_p = -0.100) at genotypic and phenotypic levels.

4.7.5 Number of total tillers per plant

Total tillers had significant and positive correlation with productive tillers per plant (r_g = 1.061, r_p = 0.711), grain L:B ratio (r_g = 0.319, r_p = 0.225) at genotypic and phenotypic levels and with hulling percent (r_g = 0.502) and milling (r_g = 0.409) at genotypic level. It showed non significant and positive correlation with grain breadth (r_g = 0.166, r_p = 0.112) and harvest index (r_g = 0.051, r_p = 0.118) at both levels, while with hulling percent (r_p = 0.077) and milling percent (r_p = 0.089) at phenotypic level only. Total grains per panicle (r_g = -0.328, r_p = -0.210), grain breadth (r_g = -0.296, r_p = -0.212), iron content (r_g = -0.352, r_p = -0.247) and zinc content (r_g = -0.355, r_p = -0.251) were significantly and negatively correlated with total tillers per plant at both levels, while 1000 grain weight (r_g = -0.263) at genotypic level. It had negative non significant correlation with filled grains per panicle (r_g = -0.210, r_p = -0.140) at genotypic and phenotypic levels and 1000 grain weight (r_p = -0.159) at phenotypic level.

4.7.6 Number of productive tillers per plant

Productive tillers showed significant and positive correlation with grain L:B ratio (r_g = 0.308, r_p = 0.265) at genotypic and phenotypic levels, while with hulling percentage (r_g = 0.403) and milling percentage (r_g = 0.354) at genotypic level only. It had non significant and positive correlation with grain length (r_g = 0.121, r_p = 0.121) and harvest index (r_g = 0.187, r_p = 0.170) at both levels, while with hulling percentage (r_g = 0.061) and milling percentage (r_p = 0.058) at phenotypic level. It showed significant and negative correlation with total grains per panicle (r_g = -0.359, r_p = -0.248), grain breadth (r_g = -0.297, r_p = -0.245), iron content (r_g = -0.339, r_p = -0.293) and zinc content (r_g = -0.323, r_p = -0.278) at genotypic and phenotypic levels. It had non significant negative correlation with filled grains (r_g = -0.153, r_p = -0.069), and 1000 grain weight (r_g = -0.211, r_p = -0.160).

4.7.7 Number of total grains per panicle

Total grains had significant and positive correlation with filled grains (r_g = 0.791, r_p = 0.767) at genotypic and phenotypic levels. It had non significant and positive correlation with milling (r_g = 0.107) at genoytypic level and with zinc content (r_g = 0.058, r_p = 0.044) at both levels. It showed non significant negative correlation with 1000 grain weight (r_g = -0.191, r_p = -0.165), grain length (r_g = -0.211, r_p = -0.164), grain breadth (r_g = -0.142, r_p = -0.127), grain L:B ratio (r_g = -0.028, r_p = -0.019), hulling percent (r_g = -0.092, r_p = -0.100), milling percent (r_g = 0.107, r_p = -0.050), harvest index (r_g = -0.012, r_p = -0.001) and iron content (r_g = -0.104, r_p = -0.091) at both levels.

4.7.8 Number of filled grains per panicle

Filled grains showed non significant and positive correlation with grain L:B ratio (r_g = 164, r_p = 144) and harvest index (r_g = 0.035, r_p = 0.059) at genotypic and phenotypic levels. It showed significant but negative correlation with 1000 grain weight (r_g = -0.300, r_p = -0.242), grain breadth (r_g = -0.316, r_p = -281) and hulling percent (r_g = -0.416, r_p = -0.188) at genotypic and phenotypic levels, while with Iron content (r_p = -0.177) at phenotypic level. Grain length (r_g = -0.134, r_p = -0.110), milling percent (r_g = -0.209, r_p = -0.142) and zinc content (r_g = - 0.002, r_p = -0.010) had non significant negative correlation with filled grains per panicle at genotypic and phenotypic levels.

4.7.9 1000 Grain weight

1000 grain weight had significant and positive correlation with grain breadth (r_g = 0.700, r_p = 0.645), hulling percent (r_g = 0.632, r_p = 0.182) and zinc content (r_g = 0.278, r_p = 0.265) at genotypic and phenotypic level respectively. It had positive but non significant correlation with grain length (r_g = 0.162, r_p = 0.142) at both levels while with milling percent (r_p = 0.161) and harvest index (r_g = 0.208) at phenotypic and genotypic levels respectively. It showed significant and negative correlation with grain L:B ratio (r_g = -0.429,

r_p = -0.398) and non significant and negative correlation with Iron content (r_g = -0.019, r_p = -0.018) at genotypic and phenotypic levels.

4.7.10 Grain length

Grain length had significant and positive correlation with grain L:B ratio (r_g = 0.735, r_p = 0.723) while non significant positive correlation with hulling (r_g = 0.151, r_p = 0.072), milling (r_g = 0.002, r_p = 0.062) and harvest index (r_g = 0.186, r_p = 0.166) at genotypic and phenotypic levels. It had significant but negative correlation with grain breadth (r_g = - 0.348, r_p = -0.298), while non significant negative correlation with iron content (r_g = -0.092, r_p = -0.081) and zinc content (r_g = -0.058, r_p = -0.041) at both levels.

4.7.11 Grain breadth

Grain breadth showed significant and positive correlation with hulling percentage (r_g = 0.320) and zinc content (r_p = 0.206) at genotypic and phenotypic level respectively. It had non significant and positive correlation with hulling percentage (r_p = 0.119) at phenotypic level, zinc content (r_g = 0.217) at genotypic level, milling percentage (r_g = 0.087, r_p = 0.023) and iron content (r_g = 0.126, r_p = 0.122) at genotypic and phenotypic levels. It had significant but negative correlation with grain L:B ratio (r_g = -0.878, r_p = -0.860) and non significant but negative correlation with harvest index (r_g = -0.065, r_p = -0.056) at genotypic and phenotypic levels.

4.7.12 Grain L:B ratio

Grain L:B ratio had non significant and positive correlation with milling percentage (r_p = 0.011) at phenotypic level and with harvest index (r_g = 0.107, r_p = 0.101) at both levels. It had non significant negative correlation with milling percentage (r_g = -0.093) at genotypic level and with hulling percentage (r_g = -0.190, r_p = -0.051), zinc content (r_g = -0.206, r_p = -0.193) at genotypic and phenotypic levels.

4.7.13 Hulling

Hulling percent showed significant and positive correlation with milling percent (r_g = 0.787, r_p = 0.750) at genotypic and phenotypic levels while with harvest index (r_g = 0.354) at genotypic level. It had non significant and positive correlation with harvest index (r_p = 0.104), iron content (r_g = -0.127, r_p = -0.038) and zinc content (r_g = -0.199, r_p = -0.084) had non significant and negative correlation with hulling percent.

4.7.14 Milling

Milling percent had significant and positive correlation with harvest index (r_g = 0.470, r_p = 0.181), where as it had non significant and negative correlation with iron content (r_g = -0.116, r_p = -0.036) and zinc content (r_g = -0.191, r_p =- 0.069) at genotypic and phenotypic levels.

4.7.15 Harvest index

Harvest index had non significant and positive correlation with zinc content (r_g = 0.106, r_p = 0.094), whereas it had non significant and negative correlation with iron content (r_g = -0.095, r_p = -0.076) at genotypic and phenotypic levels.

4.7.16 Iron content

Iron content showed significant and positive correlation with zinc content (r_g = 0.362, r_p = 0.359) at genotypic and phenotypic levels.

4.8 PATH ANALYSIS

The estimates of direct and indirect effect of path coefficients are presented in table 4.5.

4.8.1 Days to 50% flowering vs grain yield

The genotypic correlation between days to 50% flowering and grain yield per plant was positive and non significant (r_g = 0.061). The direct effect of days to 50% flowering on grain yield was low and positive (0.199). Its indirect effect through panicle length (0.006), number of grains per panicle (0.013), number of filled grains per panicle (0.045), grain breadth (0.030), grain L:B ratio (0.040) and iron content (0.002) were positive and negligible in magnitude. Whereas indirect effects of this trait via plant height (-0.021), total tillers per plant (-0.003), productive tillers per plant (-0.011), 1000 grain weight (-0.068), hulling percentage (-0.026), milling percentage (-0.004), harvest index (-0.036) and zinc (-0.003) were negative and negligible in magnitude, except grain length (-0.101) it was low.

4.8.2 Plant height vs grain yield per plant

Plant height showed non significant and positive correlation with grain yield per plant (r_g = 0.129). The direct effect of plant height on grain yield was positive and high in magnitude (0.354), also high indirect effect through grain L:B ratio (0.507). Its contribution via panicle length (0.002), productive tillers per plant (0.001), number of filled grains per panicle (0.046), iron content (0.001) and zinc content (0.002) were negligible except 1000 grain weight (0.167) where it was low. Indirect effects of plant height on grain yield via grain breadth (-0.602) was negative and high in magnitude.

Table 4.5

Its indirect effects via grain length (-0.118) and hulling were low. Its indirect effects through days to 50% flowering (-0.012), total tillers per plant (-0.005), number of grains per panicle (-0.007), milling (-0.031) and harvest index (-0.069) were negative and negligible.

4.8.3 Panicle length vs grain yield per plant

Panicle length showed significant and positive correlation with grain yield per plant (r_g = 0.261). The direct effect of panicle length on grain yield per plant was positive and negligible in magnitude (0.015). The indirect effects of panicle length on grain yield per plant via days to 50% flowering (0.078), grain length (0.070) and hulling percentage (0.080). Plant height (0.054), number of total tillers per plant (0.004), number of productive tillers per plant (0.022), 1000 grain weight (0.060), milling percentage (0.019) and iron content (0.001) were positive and negligible. Contribution of panicle length via number of grains per panicle (-0.004), number of filled grains per panicle (-0.047), grain breadth (-0.062), grain L:B ratio (-0.016), harvest index (-0.011) and zinc content (-0.002) were negative and negligible in magnitude.

4.8.4 Number of total tillers per plant vs grain yield per plant

The genotypic correlation between number of total tillers per plant and grain yield per plant was positive and significant (r_g = 0.412). The direct effect of total tillers per plant on grain yield per plant was negligible and positive (0.066). Its indirect effects through productive tillers per plant (0.366), grain breadth (0.406) was positive and of high magnitude. It had exhibited low indirect positive effects on grain yield per plant via grain length (0.131) and hulling (0.158). The indirect effects via panicle length (0.001), milling (0.034), harvest index (0.014) and iron content (0.006) were also positive but of negligible in magnitude.

The indirect effects of total tillers per plant on grain yield via grain L:B ratio (-0.502) and 1000 grain weight (-0.122) were negative and high and low in magnitude respectively, while through days to 50% flowering (-0.009), plant height (-0.024), number of grains per panicle (-0.022), number of filled grains per panicle (-0.087) and zinc content (-0.005) were also negative and negligible in magnitude.

4.8.5 Number of productive tillers per plant vs grain yield per plant

Number of productive tillers per plant had highly significant and positive correlation with grain yield per plant (r_g =0.456). Its direct effects on grain yield per plant was positive and high (0.345). Indirect effects of grain breadth was positive and high (0.408) and via hulling percentage (0.127) positive and low, negligible through plant height (0.001), panicle length (0.001), total tillers per plant (0.070), grain length (0.096), milling percentage (0.030), harvest index (0.053) and iron content (0.005). Indirect effect via grain L:B ratio was negative and high (-0.484), while it was negligible via days to 50% flowering (-0.006), number of grains per panicle (-0.024), number of filled grains per panicle (-0.064), 1000 grain weight (-0.098) and zinc content (-0.004).

4.8.6 Number of grains per panicle vs grain yield per plant

Number of grains per panicle showed positive correlation with grain yield per plant (r_g = 0.216). Number of grains per panicle had positive and negligible direct effect (0.066) on as compared to high positive indirect effects through number of filled grains per panicle (0.329), and it was low for grain breadth (0.195). Its contribution via days to 50% flowering (0.038), grain L:B ratio (0.044), milling percentage (0.009), iron content (0.002) and zinc content (0.001) were positive and negligible.

Indirect effects of number of grains per panicle on grain yield per plant via number of productive tillers per plant (-0.124) and grain length (-0.166) were negative and of low magnitude. Its indirect effects through plant height (-0.035), panicle length (-0.001), total tillers per plant (-0.022), 1000 grain weight (-0.088), hulling percentage (-0.029) and harvest index (-0.003) were negligible.

4.8.7 Number of filled grains per panicle vs grain yield per plant

Number of filled grains per panicle showed significant and positive correlation with grain yield per plant (r_g = 0.258). It had showed high positive direct effect (0.417) towards grain yield per plant. Its contribution through grain breadth (0.434) was also positive and high. It has negligible positive effects via days to 50% flowering (0.022), plant height (0.039), number of grains per panicle (0.052), harvest index (0.010), iron content (0.003) and zinc content (0.001). Its indirect effects through 1000 grain weight (-0.139), grain length (-0.105) and hulling percentage (-0.131) were negative and of low in magnitude. It was moderate for grain L:B ratio (-0.258), while through panicle length (-0.002), number of total tillers per plant (-0.014), number of productive tillers per plant (-0.053) and milling percentage (-0.017) had negligible negative indirect effects.

4.8.8 1000 grain weight vs grain yield per plant

1000 grain weight showed highly significant and positive correlation with grain yield per plant (r_g = 0.471). Its direct effects on grain yield per plant was positive and of high magnitude (0.464). Its contribution via grain L:B ratio (0.674) was also positive and of high magnitude. Indirect effects through plant height (0.128), grain length (0.128), hulling percentage (0.200) were also positive and of low magnitude, while through panicle length (0.002), milling percentage (0.032), harvest index (0.059), iron content (0.001) and zinc content (0.004) were also positive and negligible. Its indirect effects through grain breadth (-0.962) was negative and of high magnitude, while through days to 50% flowering (-0.029), number of total tillers per plant (-0.017), number of productive tillers per plant (-0.073), number of grains per panicle (-0.013) and number of filled grains per panicle (-0.125) were negative and of negligible / low magnitude.

4.8.9 Grain length vs grain yield per plant

Grain length showed non significant and positive correlation with grain yield per plant (r_g = 0.194). It showed high direct positive contribution (0.788) towards grain yield per plant. Its contribution through grain breadth (0.479) was positive and of high magnitude, while through panicle length (0.001), number of total tillers per plant (0.011), number of productive tillers per plant (0.042), 1000 grain weight (0.075), hulling percentage (0.048), milling percentage (0.001), harvest index (0.052) and zinc content (0.001) were also positive but negligible. Its indirect effects through grain L:B ratio (-1.155) was negative and of very high magnitude, while its indirect effects via days to 50% flowering (-0.025), plant height (-0.053), number of grains per panicle (-0.056) and zinc content (-0.001) were also negative but negligible.

4.8.10 Grain breadth vs grain yield per plant

Grain breadth showed non significant positive correlation with grain yield per plant (r_g = 0.033). Its direct effect on grain yield per plant was negative and of very high magnitude (-1.375). Its contribution through grain length (-0.275), number of productive tillers per plant (-0.102), number of filled grains per panicle (-0.132) were negative and moderate/low, while through days to 50% flowering (-0.004), number of total tillers per plant (-0.020), number of grains per panicle (-0.009), harvest index (-0.018) and iron content (-0.002) it was negative and negligible. Its indirect effects through grain L:B ratio (1.379) was positive and of very high magnitude, while through 1000 grain weight (0.324) was positive and of high magnitude. Its indirect effects through plant height (0.155), panicle length (0.001), hulling percentage (0.101) milling percentage (0.007) and zinc content (0.003) were positive and low/negligible.

4.8.11 Grain L:B ratio vs grain yield per plant

Grain L:B ratio showed non significant and positive correlation (r_g = 0.054) with grain yield per plant. It had very high negative direct effect

(-1.571). Its contribution via plant height (-0.114), 1000 grain weight (-0.199) were negative and low. Its indirect effects through days to 50% flowering (-0.005), number of grains per panicle (-0.002), hulling percentage (-0.060), milling percentage (-0.008) and zinc content (-0.003) were negative and negligible. Its indirect effects on grain yield per plant via grain breadth (1.207), grain length (0.580) were positive and very high. Indirect effects through panicle length (0.001), number of total tillers per plant (0.021), number of productive tillers per plant (0.106), number of filled grains per panicle (0.068), harvest index (0.030) and iron content (0.002) were also positive but of negligible magnitude.

4.8.12 Hulling vs grain yield per plant

Hulling showed highly significant and positive correlation with grain yield per plant (r_g = 609). Its direct effect on grain yield was positive and of high magnitude (0.316). Its contribution via 1000 grain weight (0.293), grain L:B ratio (0.298) were positive and moderate. Number of productive tillers per plant (0.139) and grain length (0.119) were also positive and low. Indirect effects through panicle length (0.004), number of total tillers per plant (0.033), milling percentage (0.066), harvest index (0.100) and iron content (0.002) were positive but of negligible magnitude. Whereas its indirect effect through grain breadth (-0.440) was negative and of high magnitude. Plant height (-0.123) and number of filled grains per panicle (-0.173) were negative and low. Its indirect effects through days to 50% flowering (-0.016), number of grains per panicle (-0.006) and zinc content (-0.003) were negative and negligible.

4.8.13 Milling vs grain yield per plant

Milling exhibited highly significant and positive correlation with grain yield (r_g = 0.604). It had showed negligible direct contribution (0.084) towards grain yield per plant. Its contribution through number of productive tillers per plant (0.122), 1000 grain weight (0.180), grain L:B ratio (0.145), hulling percentage (0.248) and harvest index (0.133) were also positive but low/moderate. Its contribution via panicle length (0.003), number of total tillers per plant (0.027), number of grains per panicle (0.007), grain length (0.002) and iron content (0.002) were negligible. Its indirect effects through plant height (-0.131) and grain breadth (-0.120) were negative and of low magnitude, while through days to 50% flowering (-0.009), number of filled grains per panicle (-0.087) and zinc content (-0.002) were negative and negligible.

4.8.14 Harvest index vs grain yield per plant

The genotypic correlation between harvest index and grain yield per plant was positive and highly significant (r_g g = 0.569). The direct effect of harvest index on grain yield per plant was positive and moderate (0.282). Its indirect effects through grain length (0.147) and hulling percentage (0.112) were positive and of low magnitude. It had showed negligible indirect positive effects on grain yield per plant via number of total tillers per plant (0.003), number of productive tillers per plant (0.065), 1000 grain weight (0.096), grain breadth (0.090), milling percentage (0.039), iron content (0.002) and zinc content (0.001). The indirect effect of this trait via grain L:B ratio was negative and of low magnitude (-0.168). It had negative and negligible indirect effects through days to 50% flowering (-0.025), plant height (-0.087), panicle length (-0.001) and number of grains per panicle (-0.001)

4.8.15 Iron content vs grain yield per plant

Iron content showed significant and negative correlation with grain yield per plant (r_g = -0.424). The direct effect of iron content on grain yield per plant was negative and negligible (-0.016). The indirect effects of iron content on grain yield per plant via number of productive tillers per plant (-0.117) grain breadth (-0.173) were negative and low, while through days to 50% flowering (-0.023), plant height (-0.028), number of total tillers per plant (-0.023), number of grains per panicle (-0.007), number of filled grains per panicle (-0.087), 1000 grain weight (-0.009), grain length (-0.072), hulling percentage (-0.040), milling percentage (-0.010) and harvest index (-0.027) were negative and negligible. Contribution of iron content via grain L:B ratio (0.203) was positive and moderate. The indirect effects via panicle length (0.001) and zinc content (0.005) were also positive and negligible.

4.8.16 Zinc content vs grain yield per plant

Zinc content showed non significant and negative correlation with grain yield per plant (r_g = -0.077). The direct effect of zinc content on grain yield per plant was positive and negligible (0.013). The indirect effect of zinc content on grain yield per plant via grain L:B ratio (0.324) was positive and of high magnitude and 1000 grain weight (0.129) had positive and low, while through plant height (0.043), number of total grains per panicle (0.004), number of filled grains per panicle (0.001) and harvest index (0.030) were positive and negligible. The indirect effect via grain breadth (-0.298) was negative and moderate, while it was low for number of productive tillers per plant (-0.111). The indirect effects via days to 50% flowering (-0.054), panicle length (-0.002), number of total tillers per plant (-0.024), grain length (-0.046), hulling percentage (-0.063), milling percentage (-0.016) and iron content (-0.006) were also negative but negligible.

V. DISCUSSION

The aim of present investigation was to find out superior genotypes from germplasm to be included in future breeding programme. The knowledge regarding variability, heritability and genetic advance is of great importance to plant breeding in order to identify superior genotype. Further the knowledge of interrelationships of quantitative characters with grain yield per plant and among themselves is essential for making improvement in a complex character like yield through selection. The correlation coefficient provides measure of association between two characters and is helpful in selection programme. Though, the practical utility of correlation is restricted in selection programme as, they do not take into consideration the cause and effect of relationship.

The technique of path coefficient analysis originally developed by Wright (1921) and utilized by Dewey and Lu (1959) in creasted wheat grass is capable of providing a measure of direct and indirect effects of component characters influencing the yield. In order to generate the information on these aspects on red rice, sixty three genotypes were studied in respect of seventeen characters.

5.1 Variability

The knowledge of nature and magnitude of variation present in base population are of great importance for making effective selection of superior genotypes from a breeding material. Since greater the genetic diversity, wider the scope for selection. Hence it is essential that base population should posses a large amount of heritable variation.

Since differences among the genotypes for all the characters in present study indicated considerable amount of variability in the population for further estimation of genetic parameters. The range of variability was more wide in case of the characters *viz*; grain yield per plant, days to 50% flowering, plant height, panicle length, number of total tillers per plant, number of productive tillers per plant, number of total grains per panicle, number of filled grains per panicle, 1000 grain weight, grain length, grain breadth, L:B ratio, harvest index, iron content and zinc content. This indicate that there is enough opportunity for improving these characters. Das and Barthurkar (1974), Maurya *et al.* (1986), Singh *et al.* (1986), Chooker *et al.* (1994), Sawant *et al.* (1994), Reddy and De (1996), Mani *et al.* (1997), Anand *et al.* (1998), Jamal *et al.* (2009), Chaudhary *et al.* (2011) and Selvaraj *et al.* (2011) had also observed a wide range of variability for various characters.

The phenotypic range of variation is not a precise criterion of judging the amount of genetic variation in population. The genetic parameters such as variance components, genotypic coefficient of variation, heritability and genetic advance were worked out because they are important in studying the amount of genetic variability more accurately.

The breeding potential of an experimental material depends almost exclusively on the amount of genetic variability which is prerequisite for response to selection. The phenotypic variance was partitioned into its genotypic and environmental components to know the extent of genetic variability present in each character.

The genotypic variance and phenotypic variances were of similar magnitude and greater than environmental variance for all the characters under study except hulling per cent and milling per cent indicating that phenotypic variability may be considered as reliable measure of genotypic variability.

With a view to compare different quantitative characters in respect of genotypic variability, coefficient of genotypic variation were estimated. High amount of genotypic coefficient of variation were observed for grain yield per plant, plant height, number of productive tillers per plant, number of grains per panicle, number of filled grains per panicle, 1000 grain weight, grain breadth, L:B ratio, harvest index, iron content and zinc content, whereas it was low for days to 50% flowering, panicle length, number of total tillers per plant, grain length, hulling and milling.

High genotypic and phenotypic coefficient of variation for panicle number per hill, spikelet per panicle, 1000 grain weight and grain yield per plant were also reported by Das and Borthakur (1974); for grain breadth, 1000 grain weight and L:B ratio by Hussain *et al.* (1987); for plant height, grain yield per plant, number of grains per panicle, 1000 grain weight by Deoskar *et al.* (1989); for number of total tillers per plant, number of panicles per plant, number of filled grains per panicle, grain yield per plant and harvest index by Singh *et al.* (1990); number of total tillers per plant, number of productive tillers per plant and grain yield per plant by Kanan babu and Soundrapandian (1993); for number of productive tillers per plant, plant height, 1000 grain weight and grain yield per plant by Ravindra Babu (1996); for number of effective tillers per plant, plant height, 1000 grain weight and grain yield per plant by Prasad *et al.* (2001); for grain breadth, grain L:B ratio and milling per cent by Vanaja and Babu (2006); for 1000 grain weight, grain yield per hill and number of filled grains per panicle by Karim *et al.* (2007); for number of filled grains per panicle, 100 grain weight and harvest index by Bisne *et al.* (2009); for number of total tillers per plant, plant height and grain yield per plant by Khan *et al.* (2009); for number of effective tillers per plant, 100 grain weight, grain yield per plant and harvest index by Tiwari *et al.* (2011) and number of filled grains per panicle, number of productive tillers per plant, 1000 grain weight and iron content by Ravindra Babu *et al.* (2012) in rice.

5.2 Heritability and genetic advance

Genotypic coefficient of variation measures the amount of variation present in particular character. However, it does not decide the proportion of heritable variation in the total variation. Therefore, heritability representing heritable variation present in the character was calculated. The characters having high heritability values could be improved directly through selection as they less affected by environment. The knowledge of heritability along with genotypic coefficient of variation estimates provide a better picture of genetic improvement through selection.

The heritability estimates were quite high for grain yield per plant, days to 50% flowering, plant height, panicle length, number of total tillers per plant, number of productive tillers per plant, number of grains per panicle, number of filled grains per panicle, 1000 grain weight, grain length, grain breadth, L:B ratio, harvest index, iron content and zinc content.

A number of workers have also observed high heritability estimates for number of panicles per plant, number of grains per panicle, 1000 grain weight and grain yield per plant (Chaudhary *et al;* 1973); 1000 grain weight and number of panicles per hill (Das and Borthakur, 1974); days to 50% flowering, number of total tillers per plant, number of productive tillers per plant and grain yield per plant (Amirthadevarathinum, 1983); number of grains per panicle, plant height, test weight, kernel length and grain L:B ratio (Maurya *et al;* 1986); days to 50% flowering, plant height and 1000 grain weight (Singh *et al;* 1986); days to 50% flowering, plant height and 1000 grain weight (Deoskar *et al;* 1989); days to 50% flowering, panicle length and number of grains per panicle (Amirthadevarathinum, 1990); number of total tillers per plant, number of panicles per plant, number of filled grains per panicle and harvest index (Singh *et al;* 1990); days to 50% flowering, panicle length, 1000 grain weight and harvest index (Chauhan *et al;* 1993); plant height, number of total tillers per plant, grain yield per plant and 1000 grain weight (Kanan babu and Soundrapandian, 1993); number of panicles per plant, number of grains per panicle and grain yield per plant (Ganesan *et al;* 1995); number of productive tillers per plant, plant height, panicle length and grain yield per plant (Ravindra Babu, 1996); plant height, number of grains per panicle, grain length, grain breadth, 1000 grain weight and grain yield per plant (Reddy and De, 1996); number of filled grains per panicle, 100 grain weight and grain yield per plant (Mani *et al;* 1997); days to 50% flowering, plant height, number of filled grains per panicle and grain yield per plant (Anand *et al;* 1998); number of effective tillers per plant, plant height, number of filled grains per panicle, 1000 grain weight and grain yield per plant (Prasad *et al;* 2001); grain length, grain breadth and grain L:B ratio (Vanaja and Babu, 2006); days to 50% flowering, plant height, number of grains per panicle and 1000 grain weight (Mustafa and Elsheikh, 2007); plant height, number of total tillers per plant, panicle length, harvest index and grain yield per plant (Bisne *et al;* 2009); days to 50% flowering, plant height, panicle length, number of total tillers per plant, number of grains per panicle and grain yield per plant (Khan *et al;* 2009); days to 50% flowering, number of filled grains per panicle, grain length, grain breadth and grain yield per hill (Akter *et al;* 2010); days to 50% flowering, plant height and grain yield per plant (Chakraborty and Chakraborty, 2010); days to 50 % flowering, plant height, number of grains per panicle (Akinwale *et al;* 2011); days to 50% flowering, plant height, number of total tillers per plant, number of productive tillers per plant, number of filled grains per panicle, 1000 grain weight and grain yield per plant (Selvaraj *et al;* 2011); days to 50% flowering, plant height, number of effective tillers per plant, panicle length, 100 grain weight, grain yield per plant and harvest index (Tiwari *et* *al;* 2011) and days to 50% flowering, plant height, panicle length, number of filled grains per panicle, 1000 grain weight, kernel length, kernel breadth and zinc content (Ravindra Babu *et al;* 2012).

The high estimate of heritability indicates that a large portion of phenotypic variability in the concerned character was heritable, hence phenotypic selection could be effective. It further suggests effectiveness with which selection of genotype can be done on phenotypic performance. If heritability is 100 percent ($\sigma^2g = \sigma^2p$) then phenotypic performance would be a perfect indication of genetic progress that would result from selecting the best individual. Since, genetic advance is the ultimate objective and genetic progress would increase with increase in genetic variance. The heritability value itself has not much significance as it include both additive as well as epistatic gene effects. It is therefore, necessary to utilize the heritability estimates in conjuction with expected genetic advance because genetic advance is commonly predicted by the product of heritability ratio and the selection differential. (Johnson *et al;* 1955). In the present study, expected genetic advance was estimated for different characters. Expected genetic advance expressed in percentage of mean were high for grain yield per plant, plant height, number of productive tillers per plant, number of filled grains per panicle, 1000 grain weight, grain breadth and grain L:B ratio, whereas for days to 50 % flowering, panicle length, number of grains per panicle, grain length, harvest index and iron content expected genetic advance expressed in percentage of mean were medium. Number of total tillers per plant, hulling percent, milling percent and zinc content had low genetic advance expressed in percentage of mean. High genetic advance was reported by Chaudhary *et al;* (1973) for number of grains per panicle, 1000 grain weight and grain yield per plant; Amirthadevarathinum (1983) for days to 50% flowering, number of productive tillers per plant, number of total tillers per plant and grain yield per plant; Maurya *et al;* (1986) for plant height, number of grains per panicle, 1000 grain weight, kernel length and grain L:B ratio; Deoskar *et al;* (1989) for days to 50 % flowering, plant height and 1000 grain weight; Amirthadevarathinum (1990) for days to 50 % flowering, panicle length and number of grains per panicle; Singh *et al;* (1990) for number of filled grains per panicle and harvest index; Chauhan *et al;* (1993) for days to 50 % flowering, panicle length, harvest index and 1000 grain weight; Soundrapandian (1993) for number of total tillers per plant, number of productive tillers per plant and grain yield per plant; Chooker *et al;* (1994) for panicle length, number of grains per panicle and 1000 grain weight; Ganesan *et al;* (1995) for number of panicles per plant, number of grains per panicle and grain yield per plant; Ravindra Babu (1996) for number of productive tillers per plant, plant height, panicle length and grain yield per plant; Anand *et al;* (1998) for number of filled grains per panicle and grain yield per plant; Balan *et al;* (1999) for days to 50 % flowering and grain yield per plant; Prasad *et al;* (2001) for plant height, number of effective tillers per plant, number of filled grains per panicle, 1000 grain weight and grain yield per plant; Bisne *et al;* (2009) for plant height, number of total tillers per plant, panicle length, harvest index and grain yield per plant; Akter *et al;* (2010) for days to 50 % flowering, number of filled grains per panicle, grain length, grain breadth and grain yield per hill; Akinwale *et al;* (2011) for number of panicles per plant and number of grains per panicle; Selvaraj *et al;* (2011) for days to 50 % flowering, plant height, number of total tillers per plant, number of productive tillers per plant, number of filled grains per panicle, 1000 grain weight and grain yield per plant; Tiwari *et al.* (2011) for grain yield per plant and harvest index; Ravindra Babu *et al.* (2012) for days to 50 % flowering, plant height, panicle length, number of filled grains per panicle, 1000 grain weight and zinc content. Low to moderate genetic advance as percent of mean reported by Ravindra Babu *et al.* (2012) for number of productive tillers per plant, grain yield per plant and iron content.

5.3 Correlation Coefficient

Prior to breeding crops for higher yield, it is imperative to obtain information regarding the interrelationships of different plant characters with yield, because, it facilitates the quicker assessment of high yielding genotypes in selection programme. Estimates of total correlation is not sufficient to fully evaluate the correlation between two variables, because it is the result of interaction between genotypes and environment. The real or true correlation could be known only through genotypic correlation which estimates the environmental influence.

In the present study, correlation between grain yield per plant and its sixteen characters and among themselves at phenotypic and genotypic levels were worked out so as to understand association of various characters.

In general, the value of genotypic correlations were slightly higher than their phenotypic correlations suggested the existence of strong inherent association among various traits; the phenotypic expression was reduced under the influence of the environment. In few cases phenotypic correlations were slightly higher than their genotypic counterparts indicated that non genetic causes inflated the values of genotypic correlation. The results are in agreement with the earlier findings of sawant and Jadhav (1995), Ravindra Babu (1996), Sharma and Dubey (1997), Shashidhar *et al.* (2005), Wattoo *et al.* (2010) and Selvaraj *et al.* (2011). Genotypic correlation provides a measure of genetic association between traits and helps in identifying the more important as well as lesser important characters to be included in breeding programme.

In the present study, panicle length, number of total tillers per plant, number of productive tillers per plant, number of filled grains per panicle, 1000 grain weight, hulling percent and harvest index showed significant and positive correlation at phenotypic and genotypic levels with grain yield per plant, while number of total grains per panicle and milling percent had significant positive correlation at phenotypic and genotypic level respectively with grain yield per plant. Iron content showed significant negative correlation at phenotypic and genotypic levels with grain yield per plant. Similar results have also reported by Chaudhary *et al.* (1973) for 1000 grain weight; Mishra *et al.* (1973) for number of grains per panicle; Rao *et al.* (1980) for number of ear bearing tillers per plant, number of grains per panicle and 100 grain weight; Paramasivam (1981) for number of productive tillers per plant and number of grains per panicle; Amirthadevarathinam (1983) for number of total tillers per plant and number of productive tillers per plant; Sundaram *et al.* (1988) for productive tillers per plant and number of grains per panicle; Arumugachamy *et al.* (1993) for panicle length and number of productive tillers per plant; Kanan babu and Soundrapandian (1993) for panicle length, number of total tillers per plant and number of productive tillers per plant; Ramalingam *et al.* (1995) for panicle length, number of grains per panicle and 100 grain weight; Rathod *et al.* (1995) for number of total tillers per plant, number of grains per panicle, panicle length and 1000 grain weight; Reddy *et al.* (1995) for number of productive tillers per hill and 1000 seed weight; Sawant and Jadhav (1995) for number of ear bearing tillers per plant and number of grains per panicle; Ravindra Babu (1996) for number of productive tillers per plant; Padmavathi *et al.* (1996) for number of total tillers per plant, number of panicles per plant, panicle length and 1000 grain weight; Rao *et al.* (1996) for number of productive tillers per plant and harvest index; Sarawgi *et al.* (1997) for harvest index, 100 grain weight, grain length, number of total tillers per plant and panicle length; Verma *et al.* (1997) for number of effective tillers per plant and number of grains per panicle; Selvarani and Rengasamy (1998) for number of productive tillers per plant and harvest index; Meenakshi *et al.* (1999) for number of productive tillers per plant, number of grains per panicle and harvest index; Chakraborty *et al.* (2001) for harvest index and number of panicles per plant; Prasad *et al.* (2001) for number of effective tillers per plant, number of fertile grains per panicle and 1000 grain weight; Shobha Rani *et al.* (2001) for number of total tillers per plant; Surek and Beser (2003) for number of filled grains per panicle and harvest index; Aghai *et al.* (2007) for number of grains per panicle; Sharma and Sharma (2007) for number of grains per panicle, panicle length and 1000 grain weight; Khan *et al.* (2009) for panicle length and number of grains per panicle; Akter *et al.* (2010) for number of filled grains per panicle, Chakraborty and Chakraborty (2010) for number of effective tillers per plant and panicle length; Padmaja *et al.* (2011) for number of total tillers per plant, number of productive tillers per plant, number of grains per panicle and panicle length; Akinwale *et al.* (2011) for number of total tillers per plant and number of grains per panicle and Idris *et al.* (2012) for number of grains per panicle, number of filled grains per panicle, panicle length and harvest index.

Grain yield per plant showed significant but negative correlation with iron content at both phenotypic and genotypic levels, while it showed non significant negative correlation with zinc content. A negative correlation between iron content and zinc content with grain yield per plant indicated that as yield attributing traits increases grain yield per plant increases and zinc content decreases.

Days to 50% flowering exhibited significant and positive correlation with panicle length at phenotypic and genotypic levels. It showed significant negative correlation with zinc content and non significant negative correlation with number of total tillers per plant, number of productive tillers per plant, 1000 grain weight, grain length, grain breadth, grain L:B ratio, hulling percentage, milling percentage, harvest index and iron content at phenotypic and genotypic levels. This showed that selection of early flowering improve the characters like number of total tillers per plant, number of productive tillers per plant, 1000 grain weight, grain length, grain breadth, grain L:B ratio, hulling, milling, harvest index, iron and zinc content. The results were in agreement with those reported by Panwar and Bansal (1989) for panicle length and number of panicles per plant; Amirthadevarathinam (1990) for panicle length and number of grains per panicle; Roy *et al.* (1993) for panicle length; Chauhan (1996) for panicle length; Anand *et al.* (1998) for number of total tillers per plant and number of productive tillers per plant; Deb Chaudhary and Das (1998) for panicle length; Shobha Rani *et al.* (2001) for test weight, Tavisha (2005) for hulling percent; Khan *et al.* (2009) for panicle length; Padmaja *et al.* (2011) for panicle length and Selvaraj *et al.* (2011) for number of total tillers pre plant, plant height and 1000 grain weight.

Plant height had significant and positive association with 1000 grain weight and grain breadth at genotypic and phenotypic levels. It had non significant and positive correlation with panicle length, number of filled grains per panicle and zinc content at both levels. Whereas, it had significant negative correlation with grain L:B ratio and harvest index at genotypic and phenotypic levels. It had significant negative correlation with hulling and milling at genotypic level. It had non significant negative correlation with number of total tillers per plant, number of grains per panicle, grain length and iron content at both levels. So, it is suggested that taller plants have more panicle length, more number of filled grains per panicle, 1000 grain weight, grain breadth and more zinc content. Reduce the number of total tillers per plant, number of total grains per panicle, grain length, grain L:B ratio, hulling percentage, milling percentage and harvest index. So, it is suggested that shorter plants found to be good selection criteria for development of high yielding strains. Singh *et al.* (1980) for panicle length; Pathak and Patel (1989) for panicle length and 1000 grain weight; Kanan babu and Soundrapandian (1993) for panicle length; Chauhan *et al.* (1993) for panicle length and 1000 grain weight; Chaubey and Richaria (1993) for panicle length and harvest index; Ravindra Babu (1996) for panicle length; Chauhan (1996) for harvest index; Marekar and Siddiqui (1996) for panicle length and grain weight; Anand *et al.* (1998) for productive tillers per plant; Rao and Saxena (1999) for number of grains per panicle; Janardhanam *et al.* (2001) for panicle length and number of productive tillers per plant; Oad *et al.* (2002) for for 1000 grain weight, number of panicles per plant and panicle length; Hasib and Kole (2004) for test weight; Ramkrishnan *et al.* (2006) for 1000 grain weight, number of grains per panicle and number of panicles per plant; Khan *et al.* (2009) for days to 50 % flowering and panicle length; Wattoo *et al.* (2010) for number of total tillers per plant and number of grains per panicle; Padmaja *et al.* (2011) for number of total tillers per plant and Selvaraj *et al.* (2011) for number of productive tillers per plant and panicle length have also reported similar results.

Panicle length had significant positive correlation with hulling percentage at genotypic level and non significant positive correlation at phenotypic level. It had non significant positive correlation with number of total tillers per plant, number of productive tillers per plant, 1000 grain weight, grain length, grain breadth, grain L:B ratio and milling percent. It had negative correlation with number of grains per panicle, number of filled grains per panicle and zinc content. Hence intensive selection on the positive side of number of total tillers per plant, number of productive tillers per plant, 1000 grain weight, grain length, grain breadth and grain L:B ratio since these characters showed positive correlation with panicle length. Similar results have also reported by Pathak and Patel (1989) for 1000 grain weight; Marekar and Siddiqui (1996) for grain length and grain L:B ratio; Reddy *et al.* (1997) for grain length; Sarawgi *et al.* (1997) for number of effective tillers per plant; Dhananjaya *et al.* (1998) for grain L:B ratio; Chandra and Das (2000) for 1000 grain weight; Chakraborty *et al.* (2001) for 1000 grain weight and Ramakrishnan *et al.* (2006) for 1000 grain weight.

Number of total tillers per plant exhibited significant and positive correlation with number of productive tillers per plant, grain L:B ratio at genotypic and phenotypic levels, while it had significant positive correlation with hulling and milling at genotypic level. It had non significant positive correlation with grain length and harvest index. It had significant negative correlation with number of grains per panicle, 1000 grain weight, grain breadth, iron content and zinc content, while it had non significant negative correlation with number of filled grains per panicle.

Number of total tillers per plant had significant positive correlation with number of productive tillers per plant; grain L:B ratio, hulling and milling. The close positive association of these traits with number of total tillers per plant indicated an increase in these components would result in corresponding increase number of total tillers per plant there by increase in grain yield per plant. Similar results had reported by Anand *et al.* (1998) for number of productive tillers per plant and number of filled grains per panicle; Khan *et al.* (2009) for number of grains per panicle and Selvaraj *et al.* (2011) for number of productive tillers per plant.

In the present investigation number of productive tillers per plant exhibited significant and positive association with grain L:B ratio at genotypic and phenotypic levels, while with hulling and milling at genotypic level. It had non significant positive correlation with grain length and harvest index. So, it should be considered as an important index of yielding potentially, since as number of productive tillers increases, grain L:B ratio, hulling, milling, grain length and harvest index also increases. It had significant negative correlation with number of grains per panicle, grain breadth, iron and zinc content, showed that as number of productive tillers per plant increases number of grains per panicle, grain breadth, iron and zinc content decreases. Dhananjaya *et al.* (1998) for harvest index; Selvarani and Rengasamy (1998) for harvest index; Meenakshi *et al.* (1999) for harvest index had also reported similar results.

Number of grains per panicle had significant and positive correlation with number of filled grains per panicle at genotypic and phenotypic levels. It had non significant positive association with zinc content. Whereas, it had non significant negative association with 1000 grain weight, grain length, grain breadth, grain L:B ratio, hulling, milling, harvest index and iron content. A significant and positive association between number of grains per panicle and number of filled grains per panicle clearly shows that number of grains per panicle improvement could be achieved more effectively though selection for filled grains per panicle.

Number of filled grains per panicle had significant negative correlation with 1000 grain weight, grain breadth and harvest index at genotypic and phenotypic levels, while with iron content at phenotypic level only. It indicates that as number of filled grains per panicle increases 1000 grain weight, grain breadth and hulling decreases.

In the present investigation 1000 grain weight exhibited significant and positive correlation with grain breadth, hulling and zinc content at genotypic and phenotypic levels, while with milling percentage and harvest index at genotypic and phenotypic level respectively. It had significant negative correlation with grain L:B ratio. This indicated that selection for more 1000 grain weight would increase the grain breadth, hulling percentage, milling percentage, harvest index and zinc content. Similar type results had reported by Marekar and Siddiqui (1996) for grain length and grain breadth; Chakraborty *et al.* (2001) for harvest index and Tavisha (2005) for grain length and grain breadth.

Grain length had significant negative correlation with grain breadth and significant positive correlation with grain L:B ratio at both genotypic and phenotypic levels. It indicates grain length increases grain breadth decreases and grain L:B ratio increases. The results are in agreement with the earlier findings of Hussain *et al.* (1987) for grain breadth and grain L:B ratio; Dhananjaya *et al.* (1998) for grain breadth and grain L:B ratio; Hasib and Kole (2004) for grain L:B ratio and Tavisha (2005) for hulling percentage and milling percentage.

Significant and negative genotypic and phenotypic correlation between grain breadth and grain L:B ratio indicate that selection for broad grain could adversely affect the grain L:B ratio. It had significant positive correlation with hulling percentage and zinc content at genotypic and phenotypic levels respectively. Similar type of results had also reported by Hussain *et al.* (1987) for grain L:B ratio; Marekar and Siddiqui (1996) for grain L:B ratio and Sarwar *et al.* (1999) for grain L:B ratio.

Grain L:B ratio had non significant positive correlation with harvest index and non significant negative correlation with hulling percentage, milling percentage, zinc and iron content. These implied that an increase in L:B ratio corresponding increase in harvest index and decrease in hulling percentage, milling percentage, iron and zinc content. The results are in agreement with earlier findings of Tavisha (2005).

Hulling percentage had significant positive association with milling percentage at genotypic and phenotypic levels, while with harvest index at genotypic level. It indicates that as hulling percent increases milling percent also increases. It had non significant negative correlation with iron content and zinc content. These implied that as hulling percentage increases iron and zinc content decreases. Similar type of results had also reported by Hussain *et al.* (1987), Roy *et al.* (1993) and Tavisha (2005) for milling percentage.

Milling percentage had significant positive correlation with harvest index and non significant negative correlation with iron content and zinc content. So harvest index and milling percentage is important index of yielding potentiality. Whereas milling percentage increases iron content and zinc content decreases.

Harvest index had non significant negative correlation with iron content and non significant positive correlation with zinc content at genotypic and phenotypic levels.

Iron content showed significant positive association with zinc content. As iron content increases zinc content also increases.

5.4 Path coefficient analysis

Information about the contribution made by each character to grain yield is a greater importance in planning a breeding programme for developing high yielding varieties through correlations of agronomical and morphological characters with yield. Though, these correlations reflects the extent of association between a particular character and yield but they do not provide a complete picture of how there components affect the yield. Path coefficient analysis provides an indication of the direct as well as indirect effects through other interrelated variable on yield.

In view of the difficulty of unveiling the causal relationship by a study of correlation only and also in view of possibility that negative as well as low correlations among the variables might be masking the real contribution of the different components to grain yield, it was decided to undertake path coefficient analysis.

In present study, sixteen characters were considered as causal variables of grain yield. The high positive direct effects on grain yield were recorded by plant height, number of total tillers per plant, number of productive tillers per plant, number of filled grains per panicle, 1000 grain weight, grain length and hulling. Moderate positive direct effect on grain yield was recorded by harvest index. Number of total tillers per plant, number of productive tillers per plant, number of filled grains pr panicle, 1000 grain weight, hulling percentage and harvest index had positive significant genotypic correlation with grain yield.

The finding are in agreement with the results of Singh *et al.* (1980), Bau and Troung (1988), Amirthadevarathinam (1990), Singh (1994), Ravindra Babu (1996), Verma *et al.* (1997), Manomani and Ranganathan (2006), Aghai *et al.* (2007), Jaiswal *et al.* (2007), Prasad *et al.* (2001), Wattoo *et al.* (2010) and Selvaraj *et al.* (2011).

This study suggested that the characters like number of total tillers per plant, number of productive tillers per plant, number of filled grains per panicle, 1000 grain weight, grain length and harvest index are important yield contributing characters as they have high direct effect except number of total tillers per plant and number of total grains per panicle. Number of total tillers per plant had high positive indirect effect through number of productive tillers per plant and number of grains per panicle had high positive indirect effect through number of filled grains per panicle. Hence, the number of total tillers per plant, number of productive tillers per plant, number of filled grains per panicle, 1000 grain weight, grain length and harvest index should be given due importance in selection in genotypes for higher grain yield. These characters also had moderate to high heritability, moderate to high genotypic coefficient of variation, moderate to high expected genetic advance as percent of mean and high direct effect on grain yield.

VI. SUMMARY AND CONCLUSION

Rice is one of the significant cereal commodities. Rice fulfills the nutritional requirements of half of the world population. It accounts for about 43% of food grain production in the country. A great quantity of germplasm of red rice available in the country. But a little work had been done on genetic variability, heritability and correlation of economic characters. There is a sufficient variability among the genotypes with respect to iron and zinc content, so it is easy to breed the varieties with higher iron and zinc content. For this correlation and path coefficient studies are useful to breeders. Therefore, in the present study, sixty three genotypes of (59 red and 4 white) rice representing a germplasm collection maintained at Main Rice Research Station, Anand Agricultural University, Nawagam were accessed with a view to generate information on polygenic variation, correlation and path analysis. This experiment was conducted at Main Rice Research Station, A.A.U., Nawagam during Kharif – 2011.

The analysis of variances revealed significant differences among the genotypes for all the seventeen polygenic traits studied, indicating the presence of sufficient variation among genotypes tested. Thus, selection could be practiced with success for these attributes.

A wide range of phenotypic variability was observed for grain yield per plant, days to 50 % flowering, plant height, panicle length, number of total tillers per plant, number of productive tillers per plant, number of grains per panicle, number of filled grains per panicle, 1000 grain weight, grain length, grain breadth, harvest index, iron content and zinc content. Hulling percentage and milling percentage showed narrow range of phenotypic variability suggesting that selected strains were appropriate for further estimation of genetic parameters of variation.

A high phenotypic and genotypic variances were showed by days to 50 % flowering, plant height, number of grains per panicle, harvest index and iron content indicating that selection should be carried on for these characters.

Characters viz., grain yield per plant, plant height, number of productive tillers per plant, number of grains per panicle, number of filled grains per panicle, 1000 grain weight, grain breadth, grain length, harvest index, iron content and zinc content had moderate to high genotypic coefficient of variation and phenotypic coefficient of variation. Days to 50 % flowering, panicle length, number of total tillers per plant, grain length, hulling percentage and milling percentage had lower values of GCV and PCV.

Broad sense heritability estimates were obtained high for grain yield per plant, days to 50 % flowering, plant height, panicle length, number of productive tillers per plant, number of grains per panicle, 1000 grain weight, grain length, grain breadth, grain L:B ratio, harvest index iron content and zinc content. It was moderate for total tillers per plant and low for hulling percentage and milling percentage.

High genetic advance expressed as percentage of mean was observed for grain yield per plant, plant height, number of productive tillers per plant, number of filled grains per panicle, 1000 grain weight, grain breadth and grain L:B ratio. Moderate values were observed for days to 50 % flowering, panicle length, number of grains per panicle, grain length, harvest index and iron content. Whereas number of total tillers per plant, hulling percentage, milling percentage and zinc content showed low genetic advance percentage of mean.

The traits grain yield per plant, plant height, number of grains per panicle, number of filled grains per panicle, 1000 grain weight, grain breadth, grain L:B ratio and harvest index showed high values of GCV, PCV, heritability and genetic advance as percentage of mean. It suggested that possibility of selection response based on their phenotypic expression.

The genotypic correlations tended to be higher than the phenotypic correlations in most of the traits pairs, indicating strong inherant association between the characters.

Grain yield per plant showed significant positive correlation at phenotypic as well as genotypic levels with panicle length, number of total tillers per plant, number of productive tillers per plant, number of filled grains per panicle, 1000 grain weight, hulling percentage and harvest index and at genotypic level with milling and phenotypic level with number of total grains per panicle. Whereas, it had significant negative correlation with iron content at phenotypic and genotypic levels.

Days to 50% flowering with panicle length, panicle length with 1000 grain weight and grain breadth, panicle length with hulling percentage, number of total tillers per plant with number of productive tillers per plant, grain L:B ratio, hulling percentage and milling percentage, number of productive tillers per plant with grain L:B ratio, hulling percentage and milling percentage, number of total grains per panicle with number of filled grains per panicle, 1000 grain weight with grain breadth, hulling percentage, milling percentage, harvest index and zinc content, grain breadth with hulling percentage and zinc content, hulling percentage with milling percentage and harvest index, milling percentage with harvest index and iron content with zinc content showed significant positive correlations. Whereas, days to 50% flowering with zinc content, plant height with grain L:B ratio, hulling percentage, milling percentage and harvest index, number of total tillers per plant with number of total grains per panicle, 1000 grain weight, grain breadth, iron content and zinc content, number of productive tillers per plant with number of total grains per panicle, grain breadth, iron content and zinc content, number of filled grains per panicle with 1000 grain weight, grain breadth, hulling percentage and iron content, 1000 grain weight with grain L:B ratio; grain length with grain breadth and grain breadth with grain L:B ratio exhibited significant negative correlations.

Maximum direct positive effect on grain yield per plant was exhibited by grain length followed by 1000 grain weight, number of filled grains per panicle, plant height, number of productive tillers per plant and hulling percentage. Whereas, harvest index indicated moderate positive direct effect.

The direct effect of days to 50% flowering, plant height, number of filled grains per panicle, 1000 grain weight and grain length were of higher magnitude than their correlation with grain yield per plant. The indirect effects of plant height via grain L:B ratio; number of total tillers per plant via number of productive tillers per plant and grain breadth; number of productive tillers per plant via grain breadth; number of filled grains per panicle via grain breadth; 1000 grain weight via grain L:B ratio; grain length via grain breadth; hulling percentage via 1000 grain weight and grain L:B ratio were also positive and high.

Based on these findings, it was indicated that more pressure should be given on number of total tillers per plant, number of productive tillers per plant, number of filled grains per panicle, 1000 grain weight and harvest index in selection programme aiming to improve grain yield in red rice.

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Appendix

Appendix I: Mean weekly meteorological data during *kharif* - 2011.

Standard Week No.	Temperature (^0C)		Rainfall (mm)	RH (%)		Sun shine hours	Mean wind speed in 24 hrs (km/hr)
	Max.	Min.		Morning	Evening		
24	38.0	27.3	0.0	73.2	47.4	8.4	11.5
25	37.4	28.4	0.0	70.1	46.3	2.8	13.5
26	36.5	28.0	0.0	67.5	44.9	0.7	14.4
27	35.0	26.7	47.5	76.6	42.3	0.8	9.1
28	30.3	27.0	20.9	94.2	32.6	1.4	13.7
29	32.2	27.9	36.5	92.0	36.0	1.5	7.7
30	31.6	27.6	29.7	90.8	34.9	2.4	0.7
31	32.0	27.4	33.9	90.5	35.6	3.1	0.2
32	29.1	26.3	22.3	90.3	30.5	3.2	13.4
33	29.5	27.5	19.1	91.8	30.8	3.2	12.4
34	29.0	27.1	28.1	93.8	30.1	3.2	12.3
35	30.4	27.5	15.3	94.9	32.6	2.7	7.6
36	30.3	25.5	16.2	93.1	31.9	2.2	6.1
37	30.7	25.3	30.2	91.5	32.7	1.4	3.8
38	31.6	24.3	5.4	97.1	34.4	2.0	4.4
39	32.0	23.8	0.0	92.3	35.3	1.9	2.5
40	33.0	22.5	0.0	90.2	37.6	1.8	2.6
41	34.8	23.0	0.0	96.0	41.7	2.4	3.4
42	36.3	21.9	0.0	85.8	44.0	2.7	1.7
43	35.0	18.1	0.0	77.0	41.3	2.9	2.1
44	34.4	18.6	0.0	70.8	40.2	2.9	2.8
45	35.2	19.3	0.0	80.2	42.4	2.0	1.7
46	34.8	17.6	0.0	74.4	40.3	2.6	1.9
47	33.4	15.8	0.0	68.9	37.2	2.9	3.7
48	31.7	18.7	0.0	62.3	34.7	2.2	5.7
49	35.0	16.2	0.0	82.7	37.1	1.9	2.3
50	34.4	13.3	0.0	62.2	29.5	1.9	5.7
51	35.2	12.7	0.0	73.8	31.2	2.0	3.6
52	34.8	11.1	0.0	74.3	27.4	2.5	3.8
Total	-	-	305.1	-			-

Source: Main Rice Research Station, Anand Agricultural University, Nawagam.

Photographs of 59 red and 4 white rice genotypes before hulling and after hulling

(G_1) Baska-1

(G_2) Choria Chettari

(G_3) Dabhoda local

(G_4) Dang futia local

(G_5) Dang hario local

(G_6) HB-1

(G_7) Kada local

(G_8) Kalo vankalo

(G_9) Kolorado

(G_{10}) Lal vankalo

(G_{11}) Lal fotari local

(G_{12}) Manedeshi utavari

(G_{13}) Mehsana sutarsal

(G_{14}) IET-18940

(G_{15}) Mehsana vani

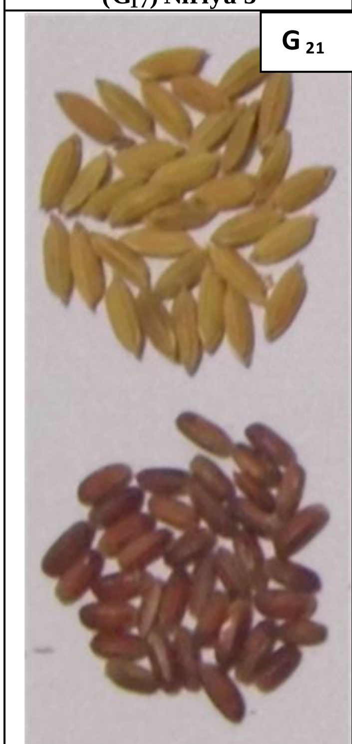
(G_{16}) Nawagam-5

(G_{17}) Niriya-5

(G_{18}) Panchmahal dabhoda

(G_{19}) Pataniu

(G_{20}) Saria



(G_{21}) SKL-5-11-1-62

(G_{22}) Surat bhadaravi

(G_{23}) Surat futia

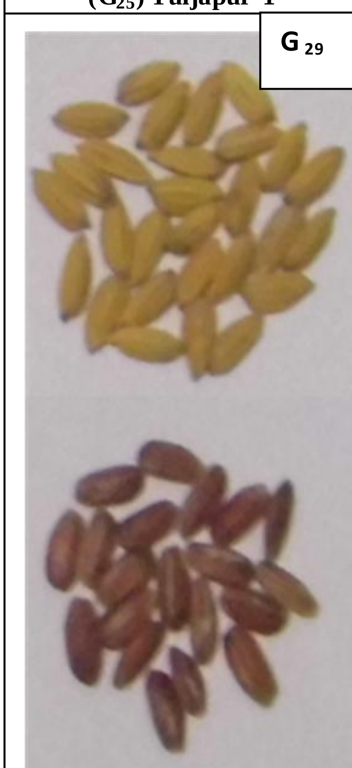
(G_{24}) Tapkhira

(G25) Tuljapur-1

(G26) Vadodara ankali

(G27) Vankvel

(G28) ARC-5752



(G29) ARC-10239

(G30) BTS-24

(G31) LST-77

(G32) Mudgo

			
(G_{33}) Pokali	**(G_{34}) Setail**	**(G_{35}) IET-21224**	**(G_{36}) IET-21617**
			
(G_{37}) IET-22094	**(G_{38}) IET-22127**	**(G_{39}) IET-22128**	**(G_{40}) IET-22129**

(G_{41}) IET-22130

(G_{42}) IET-22131

(G_{43}) IR 68652-3B-81

(G_{44}) IR 68652-3B-11-2

(G_{45}) IR 68652-3B-22-3

(G_{46}) IR 68652-3B-10-3

(G_{47}) IR 68654-3B-1-2

(G_{48}) IR 68654-3B-2-3

(G_{49}) IR 68654-3B-6-1

(G_{50}) IR 68654-3B-9-1

(G_{51}) IR 68657-3B-15-2

(G_{52}) IR 70868-B-P-14-1

(G_{53}) IR 70868-B-P-19-2

(G_{54}) IR 70868-B-P-30-3

(G_{55}) IR 70869-B-P-10-2

(G_{56}) IR 70869-B-P-16-2

(G_{57}) IR 70869-B-P-18-2

(G_{58}) IR 70870-B-P-3-2

(G_{59}) IR 81429-B-31

(G_{60}) GR-7 (White)

(G_{61}) GR-12 (White)

(G_{62}) GAR-13 (White)

(G_{63}) Gurjari (White)

Table 4.1a. Mean values of 59 red & 4 white rice genotypes for seventeen characters.

Sr. No.	Genotypes		Grain yield/ plant (g)	Days to 50 % flowering	Plant height (cm)	Panicle length (cm)	No. of total tillers/ plant	No. of productive tillers/ plant	No. of grains/ panicle
1	Baska-1	G_1	18.01	90.67	120.07	25.02	9.40	6.40	207.48
2	Choria Chettari	G_2	20.79	115.33	184.00	28.95	9.93	7.27	174.65
3	Dabhoda local	G_3	18.44	87.67	131.27	22.44	9.80	6.87	142.70
4	Dang futia local	G_4	20.71	103.00	145.80	29.23	10.07	7.67	155.26
5	Dang hario local	G_5	22.46	90.67	126.47	25.25	10.00	7.20	171.97
6	HB-1	G_6	15.24	92.00	**84.13**	23.87	10.07	7.27	157.61
7	Kada local	G_7	18.96	95.33	120.33	22.68	10.13	7.67	146.90
8	Kalo vankalo	G_8	15.77	87.33	130.13	22.06	9.13	5.47	161.37
9	Kolorado	G_9	17.49	106.33	140.00	26.77	10.53	8.60	144.20
10	Lal vankalo	G_{10}	15.97	92.00	124.53	23.37	9.73	6.00	147.13
11	Lal fotari local	G_{11}	19.58	104.00	100.67	25.03	10.40	8.40	168.20
12	Manedeshi utavari	G_{12}	18.80	96.00	136.13	24.63	10.53	7.67	164.27
13	Mehsana sutarsal	G_{13}	13.50	87.33	126.60	**20.54**	9.67	5.73	152.73
14	IET-18940	G_{14}	15.87	113.00	151.80	24.85	11.00	8.40	153.40
15	Mehsana vani	G_{15}	21.42	95.33	135.33	25.09	**11.53**	**9.80**	146.80
16	Nawagam-5	G_{16}	**10.37**	105.33	138.13	28.21	9.40	6.40	139.33
17	Niriya-5	G_{17}	13.40	98.33	116.27	22.48	10.27	7.87	**124.73**
18	Panchmahal dabhoda	G_{18}	14.01	97.67	127.00	25.03	10.07	7.20	134.97
19	Pataniu	G_{19}	17.83	97.33	119.93	23.99	10.67	8.47	144.50
20	Saria	G_{20}	16.28	93.67	133.87	24.12	**8.27**	5.53	173.57
21	SKL-5-11-1-62	G_{21}	17.27	97.00	129.53	24.39	8.40	5.87	163.33
22	Surat bhadaravi	G_{22}	13.79	98.00	124.87	23.04	8.87	6.00	152.83
23	Surat futia	G_{23}	18.24	96.00	129.40	23.93	9.00	6.40	176.00
24	Tapkhira	G_{24}	16.30	95.00	145.93	24.44	9.20	6.47	161.30
25	Tuljapur-1	G_{25}	14.73	96.00	137.80	23.83	9.27	6.67	177.60
26	Vadodara ankali	G_{26}	18.13	96.00	135.87	22.65	10.20	8.07	144.43
27	Vankvel	G_{27}	22.85	96.00	132.73	26.67	10.20	7.87	150.97
28	ARC-5752	G_{28}	21.38	**87.33**	128.53	24.85	10.20	8.47	173.00
29	ARC-10239	G_{29}	23.03	102.33	161.67	23.25	10.67	8.40	179.40
30	BTS-24	G_{30}	17.83	96.00	137.20	23.17	9.93	7.33	165.90

31	LST-77	G_{31}	16.20	103.00	137.47	27.45	10.67	8.33	144.48
32	Mudgo	G_{32}	25.44	103.00	166.27	28.79	10.53	8.47	150.12
33	Pokali	G_{33}	23.26	116.00	**188.73**	25.05	8.87	6.60	179.55
34	Setail	G_{34}	13.57	114.67	95.07	22.85	9.40	7.13	149.84
35	IET-21224	G_{35}	13.47	115.00	115.33	27.11	9.87	6.93	146.12
36	IET-21617	G_{36}	19.18	105.67	118.13	21.23	10.40	8.27	183.04
37	IET-22094	G_{37}	12.35	109.67	126.80	27.13	8.93	5.20	167.28
38	IET-22127	G_{38}	15.98	101.67	155.87	24.81	9.33	6.67	166.78
39	IET-22128	G_{39}	20.01	101.67	130.80	23.78	9.60	7.60	146.37
40	IET-22129	G_{40}	12.99	117.33	109.47	26.91	9.07	6.33	143.84
41	IET-22130	G_{41}	17.95	116.00	111.47	21.11	9.13	**4.93**	**248.26**
42	IET-22131	G_{42}	19.92	**118.67**	109.93	23.57	10.60	7.73	174.44
43	IR 68652-3B-81	G_{43}	18.85	117.33	120.00	24.60	9.60	6.53	161.14
44	IR 68652-3B-11-2	G_{44}	17.18	104.67	102.93	26.94	9.47	6.73	170.52
45	IR 68652-3B-22-3	G_{45}	16.04	116.00	102.80	24.69	10.00	7.20	152.65
46	IR 68652-3B-10-3	G_{46}	20.59	104.67	108.80	29.22	9.67	6.13	186.88
47	IR 68654-3B-1-2	G_{47}	20.36	107.67	107.13	22.49	9.67	7.07	149.38
48	IR 68654-3B-2-3	G_{48}	20.67	105.67	119.40	26.13	9.67	6.73	186.81
49	IR 68654-3B-6-1	G_{49}	25.92	96.00	97.53	25.97	10.47	8.80	167.74
50	IR 68654-3B-9-1	G_{50}	**26.38**	116.00	105.60	**30.41**	9.80	6.87	176.67
51	IR 68657-3B-15-2	G_{51}	17.32	96.00	107.27	23.86	9.87	7.07	167.89
52	IR 70868-B-P-14-1	G_{52}	15.62	105.00	102.53	23.98	9.87	7.53	182.64
53	IR 70868-B-P-19-2	G_{53}	14.26	104.00	92.93	23.67	9.13	6.20	195.98
54	IR 70868-B-P-30-3	G_{54}	21.45	115.67	100.53	26.31	9.80	7.07	171.13
55	IR 70869-B-P-10-2	G_{55}	23.04	107.00	102.40	24.71	11.20	8.93	162.61
56	IR 70869-B-P-16-2	G_{56}	18.48	103.67	116.00	28.93	10.00	7.20	158.77
57	IR 70869-B-P-18-2	G_{57}	14.32	105.33	115.00	29.25	9.53	6.27	159.65
58	IR 70870-B-P-3-2	G_{58}	23.66	112.00	116.67	28.83	10.07	7.87	173.82
59	IR 81429-B-31	G_{59}	20.25	94.00	118.33	24.89	10.07	7.40	156.05
60	GR-7 (White)	G_{60}	20.29	98.00	105.47	23.97	10.00	7.60	166.10
61	GR-12 (White)	G_{61}	16.45	103.00	111.53	24.68	10.33	8.40	175.75
62	GAR-13 (White)	G_{62}	15.55	97.67	104.73	23.35	11.13	9.13	164.99
63	Gurjari (White)	G_{63}	25.52	101.67	107.80	23.30	10.80	8.47	148.10
S.Em.			1.16	2.13	3.25	0.66	0.33	0.34	5.92
C.D. (5%)			3.25	5.96	9.11	1.86	0.92	0.94	16.58
C. V. %			11.02	3.60	4.56	4.60	5.78	8.02	6.28
Mean			18.27	102.24	123.60	24.98	9.89	7.25	163.36
Range			10.37 - 26.38	87.33 - 118.67	84.13 - 188.73	20.54 - 30.41	8.27 - 11.53	4.93 - 9.8	124.73 - 248.26

Table 4.1 b. Mean values of 59 red & 4 white rice genotypes for seventeen characters.

Sr. No.	No. of filled grains/ panicle	1000-grain weight (g)	Grain length (mm)	Grain breadth (mm)	L:B ratio	Hulling (%)	Milling (%)	Harvest index (%)	Iron (ppm)	Zinc (ppm)
1	132.09	23.83	8.24	2.66	3.10	73.12	62.94	42.54	38.67	10.67
2	120.04	28.60	8.64	3.36	2.58	78.09	65.94	40.31	24.33	8.33
3	111.58	28.00	9.30	2.93	3.17	79.57	64.12	41.67	28.00	9.17
4	124.08	25.70	9.54	2.61	3.65	78.76	68.67	41.86	12.17	3.00
5	127.13	28.63	9.69	3.15	3.08	77.33	65.73	44.86	29.17	5.50
6	111.45	20.47	10.34	2.39	4.33	77.61	63.78	52.47	28.83	8.33
7	119.06	25.03	8.33	2.95	2.82	75.51	63.88	50.73	62.83	**14.17**
8	108.95	28.33	8.69	3.21	2.70	79.72	68.34	50.36	78.67	8.33
9	119.25	20.40	9.28	2.18	4.26	**71.00**	**58.89**	39.90	29.33	6.50
10	108.17	26.03	9.49	2.80	3.39	72.93	61.08	47.88	38.17	13.67
11	130.79	22.47	9.51	2.65	3.59	76.44	62.96	48.19	22.50	7.33
12	135.64	22.70	9.20	2.93	3.14	75.16	63.45	42.50	26.17	8.67
13	116.63	25.30	9.35	3.08	3.04	72.39	59.53	42.44	22.50	6.67
14	127.30	**19.03**	**10.44**	2.06	**5.08**	71.73	63.07	42.93	34.00	5.50
15	110.64	25.90	8.35	3.16	2.65	76.39	63.39	41.85	26.67	7.50
16	105.21	21.10	8.40	2.82	2.98	76.00	63.49	37.73	96.67	10.17
17	**91.33**	24.50	7.63	3.05	2.50	75.92	62.97	38.98	34.00	**2.33**
18	97.93	24.90	8.36	2.91	2.87	78.77	**68.76**	38.43	50.67	11.83
19	108.19	25.97	8.24	2.98	2.77	77.39	65.91	50.82	28.00	13.17
20	141.15	23.53	8.71	2.63	3.31	72.47	62.57	49.29	30.83	8.33
21	113.05	29.47	9.31	3.02	3.09	75.54	62.67	39.95	33.17	11.83
22	117.22	23.57	8.69	3.00	2.90	71.78	60.72	46.14	**109.67**	12.33
23	126.85	27.00	8.77	3.07	2.86	76.35	63.34	44.62	59.50	10.83
24	127.31	24.53	8.38	2.94	2.86	72.63	63.78	48.91	23.17	11.67
25	137.02	22.53	8.41	2.96	2.85	71.48	62.23	46.25	39.17	13.50
26	109.73	24.57	8.55	2.79	3.07	77.61	64.81	52.84	45.17	7.33
27	126.18	24.93	8.78	2.48	3.54	75.11	61.53	46.54	21.50	8.50
28	140.03	21.27	9.36	2.28	4.11	75.42	63.39	55.70	24.00	9.50
29	134.52	22.77	7.60	2.96	2.57	75.82	64.80	43.96	**7.67**	6.17
30	134.34	20.33	7.63	2.71	2.82	75.76	61.56	55.11	15.00	9.67
31	99.03	21.83	9.79	3.07	3.19	74.76	62.79	45.81	30.50	5.67
32	118.08	29.13	8.75	3.33	2.63	77.30	62.66	49.04	16.83	8.00
33	156.16	**30.73**	8.54	**3.44**	2.48	75.80	63.06	48.70	21.83	7.50
34	119.85	22.40	10.35	2.27	4.56	74.74	60.49	40.65	29.17	7.83
35	115.06	19.53	7.67	2.67	2.88	73.11	61.65	39.18	22.83	5.83
36	131.68	19.93	7.40	2.65	2.79	74.36	63.19	42.83	32.00	6.67
37	126.04	21.27	8.64	2.76	3.13	76.84	62.92	36.20	26.83	6.67
38	124.66	23.27	8.12	2.90	2.80	72.19	62.11	40.79	26.33	7.17
39	108.52	24.90	8.28	2.98	2.78	73.21	62.64	54.81	10.17	4.67
40	106.19	22.23	7.65	3.20	**2.39**	75.39	62.99	43.00	45.50	4.83
41	**178.52**	20.37	**7.38**	2.61	2.83	74.74	62.26	39.60	34.00	9.33
42	115.91	22.87	9.11	2.90	3.14	75.16	61.90	46.27	12.67	4.67
43	104.85	26.00	8.50	2.89	2.94	75.86	65.30	47.66	18.50	13.00
44	111.79	24.07	8.65	2.85	3.04	76.87	65.91	46.87	30.00	10.33
45	106.66	23.63	8.49	2.96	2.86	76.98	65.57	47.49	26.00	4.67
46	128.04	24.17	9.35	2.56	3.65	75.42	64.91	46.91	44.17	5.67
47	114.81	25.63	9.91	2.61	3.80	76.66	66.45	56.42	11.17	4.83
18	136.75	24.77	9.48	2.68	3.54	74.52	63.97	41.92	12.50	8.17

Table 4.2 Analysis of variance for seventeen characters in 59 red and 4 white rice genotypes.

Sr. No.	Characters	Mean squares		
		Replication	Treatment	Error
1	Grain yield / plant (g)	1.25	39.25**	4.05
2	Days to 50 % flowering	25.75	225.59**	13.58
3	Plant height (cm)	19.62	1252.90**	31.77
4	Panicle length (cm)	0.81	15.13**	1.32
5	No. of total tillers / plant	0.63	1.31**	0.33
6	No. of productive tillers / plant	0.29	3.20**	0.34
7	No. of grains / panicle	108.00	1075.92**	105.19
8	No. of filled grains / panicle	118.38	717.20**	74.34
9	1000-grain weight (g)	1.66	30.11**	0.98
10	Grain length (mm)	0.007	1.57**	0.085
11	Grain breadth (mm)	0.003	0.29**	0.006
12	Grain L:B ratio	0.012	0.95**	0.016
13	Hulling (%)	15.25	13.08*	9.12
14	Milling (%)	1.87	14.29*	9.89
15	Harvest index (%)	20.60	90.99**	12.59
16	Iron (ppm)	0.76	1103.67**	1.82
17	Zinc (ppm)	0.20	22.31**	0.12

Table 4.3 The estimates of genotypic ($\sigma^{\wedge 2}_g$) and phenotypic ($\sigma^{\wedge 2}_p$) variances and other genetic parameters for seventeen characters in 59 red and 4 white rice genotypes.

Sr. No.	Characters	Mean	$\sigma^{\wedge 2}_g$	$\sigma^{\wedge 2}_p$	GCV (%)	PCV (%)	H^2 (b) (%)	GA	GA (% of mean)
1	**Grain yield / plant (g)**	18.27	11.73	15.78	18.75	21.75	74.3	6.08	33.3
2	**Days to 50 % flowering**	102.24	70.67	84.25	8.22	8.98	83.9	15.86	15.5
3	**Plant height (cm)**	123.60	407.04	438.81	16.32	16.95	92.8	40.03	32.4
4	**Panicle length (cm)**	24.98	4.60	5.92	8.59	9.74	77.7	3.90	15.6
5	**No. of total tillers / plant**	9.89	0.33	0.66	5.78	8.17	49.9	0.83	8.4
6	**No. of productive tillers /plant**	7.25	0.95	1.29	13.46	15.67	73.8	1.73	23.9
7	**No. of grains / panicle**	163.36	323.58	428.77	11.01	12.68	75.5	32.19	19.7
8	**No. of filled grains / panicle**	121.97	214.29	288.63	12.00	13.93	74.2	25.98	21.3
9	**1000-grain weight (g)**	23.81	9.71	10.69	13.09	13.74	90.8	6.12	25.7
10	**Grain length (mm)**	8.77	0.50	0.58	8.01	8.67	85.3	1.34	15.3
11	**Grain breadth (mm)**	2.78	0.09	0.10	11.05	11.39	94.1	0.61	21.9
12	**Grain L:B ratio**	3.21	0.31	0.33	17.37	17.82	95.1	1.12	34.9
13	**Hulling (%)**	75.67	1.32	10.44	1.52	4.27	12.6	0.84	1.11
14	**Milling (%)**	64.03	1.47	11.36	1.89	5.26	12.9	0.90	1.40
15	**Harvest index (%)**	46.34	26.13	38.72	11.03	13.43	67.5	8.65	18.7
16	**Iron (ppm)**	32.91	367.28	369.10	58.23	58.38	99.5	39.38	11.9
17	**Zinc (ppm)**	7.88	7.40	7.52	34.49	34.78	98.4	5.56	7.06

Table 4.4 Genotypic (r_g) and Phenotypic (r_p) correlations between grain yield/plant and other quantitative and qualitative characters of 59 red and 4 white rice genotypes.

		D.F.F.	Pl. Ht.	P.L.	Total T.	P.Ti.	Gr/P	F/P	1000	Len.	Br.	L:B	H	M	HI	Fe	Zn
		2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17
1	r_g r_p	0.061 0.057	0.129 0.115	0.261* 0.180**	0.412** 0.350**	0.456** 0.434**	0.216 0.194**	0.258* 0.239**	0.471** 0.393**	0.194 0.163	0.033 0.028	0.054 0.047	0.609** 0.184**	0.604** 0.169	0.569** 0.475**	-0.424** -0.362**	-0.077 -0.070
2	r_g r_p	1.000	-0.058 -0.036	0.394** 0.324**	-0.048 0.020	-0.031 -0.040	0.193 0.147	0.109 0.105	-0.146 -0.136	-0.128 -0.119	-0.021 -0.024	-0.025 -0.024	-0.082 -0.053	-0.048 -0.030	-0.128 -0.075	-0.118 -0.103	-0.271** -0.250**
3	r_g r_p		1.000	0.154 0.142	-0.068 -0.056	0.001 0.012	-0.099 -0.082	0.110 0.085	0.361** 0.331**	-0.149 -0.128	0.438** 0.412**	-0.323* -0.304**	-0.346** -0.098	-0.370** -0.102	-0.250* -0.178*	-0.078 -0.074	0.121 0.119
4	r_g r_p			1.000	0.054 0.014	0.063 0.039	-0.059 -0.049	-0.113 -0.089	0.130 0.113	0.089 0.091	0.045 0.035	0.010 0.021	0.255* 0.039	0.228 0.118	-0.040 -0.012	0.008 0.006	-0.129 -0.100
5	r_g r_p				1.000	1.061** 0.711**	-0.328** -0.210*	-0.210 -0.140	-0.263* -0.159	0.166 0.112	-0.296* -0.212*	0.319* 0.225*	0.502** 0.077	0.409** 0.089	0.051 0.118	-0.352** -0.247**	-0.355** -0.251**
6	r_g r_p					1.000	-0.359** -0.248**	-0.153 -0.069	-0.211 -0.160	0.121 0.121	-0.297* -0.245**	0.308* 0.265**	0.403** 0.061	0.354** 0.058	0.187 0.170	-0.339** -0.293**	-0.323** -0.278**
7	r_g r_p						1.000	0.791** 0.767**	-0.191 -0.165	-0.211 -0.164	-0.142 -0.127	-0.028 -0.019	-0.092 -0.100	0.107 -0.050	-0.012 -0.001	-0.104 -0.091	0.058 0.044
8	r_g r_p							1.000	-0.300* -0.242**	-0.134 -0.110	-0.316* -0.281**	0.164 0.144	-0.416** -0.188**	-0.209 -0.142	0.035 0.059	-0.209 -0.177*	-0.002 -0.010
9	r_g r_p								1.000	0.162 0.142	0.700** 0.645**	-0.429** -0.398**	0.632** 0.182*	0.389** 0.161	0.208 0.179*	-0.019 -0.018	0.278* 0.265**
10	r_g r_p									1.000	-0.348** -0.298**	0.735** 0.723**	0.151 0.072	0.002 0.062	0.186 0.166	-0.092 -0.081	-0.058 -0.041
11	r_g r_p										1.000	-0.878** -0.860**	0.320* 0.119	0.087 0.023	-0.065 -0.056	0.126 0.122	0.217 0.206*

12	r_g											1.000	-0.190	-0.093	0.107	-0.129	-0.206
	r_p												-0.051	0.011	0.101	-0.124	-0.193
13	r_g												1.000	0.787**	0.354**	-0.127	-0.199
	r_p													0.750**	0.104	-0.038	-0.084
14	r_g													1.000	0.470**	-0.116	-0.191
	r_p														0.181*	-0.036	-0.069
15	r_g														1.000	-0.095	0.106
	r_p															-0.076	0.094
16	r_g															1.000	0.362**
	r_p																0.359**
17	r_g																1.000
	r_p																

Note : * and ** indicate significance at 5% and 1% respectively.

1: G.Y. : Grain yield per plant; **2**: D.F.F : Days to 50% flowering; **3**: Pl. Ht : Plant height; **4**: P.L. : Panicle length; **5**: Total T. : Number of total tillers per plant; **6**: P.Ti. : Number of productive tillers per plant; **7**: Gr/P : Number of grains per panicle; **8**: F/P :Number of filled grains per panicle; **9** : 1000 : 1000 grain weight; **10**: Len. : Grain length; **11**: Br. : Grain breadth; **12**: L:B : Grain L:B ratio; **13**: H : Hulling; **14**: M : Milling; **15**: H.I. : Harvest index; **16**: Fe : Iron; **17**: Zn : Zinc.

Table 4.5 Path coefficient analysis showing direct and indirect effects of various characters on grain yield in 59 red and 4 white rice genotypes.

Sr. No.	Characters	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	Genotypic correlation with GY/plant
2	**Days to 50 % flowering**	**0.199**	-0.021	0.006	-0.003	-0.011	0.013	0.045	-0.068	-0.101	0.030	0.040	-0.026	-0.004	-0.036	0.002	-0.003	0.061
3	**Plant height (cm)**	-0.012	**0.354**	0.002	-0.005	0.001	-0.007	0.046	0.167	-0.118	-0.602	0.507	-0.109	-0.031	-0.069	0.001	0.002	0.129
4	**Panicle length (cm)**	0.078	0.054	**0.015**	0.004	0.022	-0.004	-0.047	0.060	0.070	-0.062	-0.016	0.080	0.019	-0.011	0.001	-0.002	0.261*
5	**No. Total tillers/plant**	-0.009	-0.024	0.001	**0.066**	0.366	-0.022	-0.087	-0.122	0.131	0.406	-0.502	0.158	0.034	0.014	0.006	-0.005	0.412*
6	**No. productive tillers/plant**	-0.006	0.001	0.001	0.070	**0.345**	-0.024	-0.064	-0.098	0.096	0.408	-0.484	0.127	0.030	0.053	0.005	-0.004	0.456**
7	**No. of grains/panicle**	0.038	-0.035	-0.001	-0.022	-0.124	**0.066**	0.329	-0.088	-0.166	0.195	0.044	-0.029	0.009	-0.003	0.002	0.001	0.216
8	**No. of filled grains/panicle**	0.022	0.039	-0.002	-0.014	-0.053	0.052	**0.417**	-0.139	-0.105	0.434	-0.258	-0.131	-0.017	0.010	0.003	0.001	0.258*
9	**1000 grain weight (g)**	-0.029	0.128	0.002	-0.017	-0.073	-0.013	-0.125	**0.464**	0.128	-0.962	0.674	0.200	0.032	0.059	0.001	0.004	0.471**
10	**Grain length (mm)**	-0.025	-0.053	0.001	0.011	0.042	-0.014	-0.056	0.075	**0.788**	0.479	-1.155	0.048	0.001	0.052	0.001	-0.001	0.194
11	**Grain breadth (mm)**	-0.004	0.155	0.001	-0.020	-0.102	-0.009	-0.132	0.324	-0.275	**-1.375**	1.379	0.101	0.007	-0.018	-0.002	0.003	0.033
12	**L:B ratio**	-0.005	-0.114	0.001	0.021	0.106	-0.002	0.068	-0.199	0.580	1.207	**-1.571**	-0.060	-0.008	0.030	0.002	-0.003	0.054
13	**Hulling (%)**	-0.016	-0.123	0.004	0.033	0.139	-0.006	-0.173	0.293	0.119	-0.440	0.298	**0.316**	0.066	0.100	0.002	-0.003	0.609**
14	**Milling (%)**	-0.009	-0.131	0.003	0.027	0.122	0.007	-0.087	0.180	0.002	-0.120	0.145	0.248	**0.084**	0.133	0.002	-0.002	0.604**
15	**Harvest index (%)**	-0.025	-0.087	-0.001	0.003	0.065	-0.001	0.014	0.096	0.147	0.090	-0.168	0.112	0.039	**0.282**	0.002	0.001	0.569**
16	**Iorn (ppm)**	-0.023	-0.028	0.001	-0.023	-0.117	-0.007	-0.087	-0.009	-0.072	-0.173	0.203	-0.040	-0.010	-0.027	**-0.016**	0.005	-0.424**
17	**Zinc (ppm)**	-0.054	0.043	-0.002	-0.024	-0.111	0.004	0.001	0.129	-0.046	-0.298	0.324	-0.063	-0.016	0.030	-0.006	**0.013**	-0.077

Residual effect = 0.0869

0.0 to 0.09 = Negligible; **0.10 to 0.19 =** Low; **0.20 to 0.29** = Moderate; **0.30 to 0.99** = High; **> 1.0** = Very High