

**GENETIC DIVERGENCE AND CHARACTER
ASSOCIATION OF RICE (*Oryza sativa* L.)
GENOTYPES SUITABLE FOR EARLY
KHARIF SEASON**

By

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B.Sc. (Ag.)

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CHAIRPERSON: Dr. P. RAMESH BABU



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2017

DECLARATION

I, **BONGI SUDHEER**, hereby declare that the thesis entitled “**GENETIC DIVERGENCE AND CHARACTER ASSOCIATION OF RICE (*Oryza sativa* L.) GENOTYPES SUITABLE FOR EARLY *KHARIF* SEASON**” submitted to the **Acharya N.G. Ranga Agricultural University** for the degree of **Master of Science in Agriculture** is the result of original research work done by me. I also declare that no material contained in the thesis has been published earlier in any manner.

Place: Bapatla
Date:

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CERTIFICATE

Mr. BONGI SUDHEER has satisfactorily prosecuted the course of research and that thesis entitled “**GENETIC DIVERGENCE AND CHARACTER ASSOCIATION OF RICE (*Oryza sativa* L.) GENOTYPES SUITABLE FOR EARLY *KHARIF* SEASON**” submitted is the result of original research work and is of sufficiently high standard to warrant its presentation to the examination. I also certify that neither the thesis nor its part thereof has been previously submitted by him for a degree of any university.

Date:

(P. RAMESH BABU)
Chairperson
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CERTIFICATE

This is to certify that the thesis entitled “**GENETIC DIVERGENCE AND CHARACTER OF ASSOCIATION RICE (*Oryza sativa* L.) GENOTYPES SUITABLE FOR EARLY *KHARIF* SEASON**” submitted in partial fulfillment of the requirements for the degree of ‘Master of science in Agriculture’ of the Acharya N. G. Ranga Agricultural University, Guntur is a record of the bonafide original research work carried out by **Mr. BONGI SUDHEER** under our guidance and supervision.

No part of the thesis has been submitted by the student for any other degree or diploma. The published part and all assistance received during the course of the investigations have been duly acknowledged by the author of the thesis.

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LIST OF SYMBOLS AND ABBREVIATIONS

%	:	Per cent
ANOVA	:	Analysis of Variance
CD	:	Critical Difference
cm	:	Centimeter
cm ²	:	Centimeter square
cm ² /g	:	Centimeter square per gram
CV	:	Coefficient of Variation
DAT	:	Days After Transplanting
DFP	:	Days to 50 % flowering
DM	:	Days to maturity
d.f	:	Degrees of Freedom
<i>et al.</i> ,	:	And co workers
FLA	:	flag leaf area
FLL	:	flag leaf length
FLW	:	flag leaf width
g	:	Grams
g/cm ²	:	Gram per centimeter square
GA	:	Genetic advance
GAM	:	Genetic Advance as per cent of mean
GCV	:	Genotypic Coefficient of Variation
GL	:	Grain length
GW	:	Grain width
G L/B ratio	:	Grain length /width ratio
GW	:	Grain Weight
GYP	:	Grain yield per plant
HI	:	Harvest index
i.e.	:	That is
<i>inter se</i>	:	Among themselves
kg/ha	:	Kilogram per hectare
m	:	Meter
m ²	:	Meter square
mm ²	:	Millimeter Square
MSL	:	Mean Sea Level
MSS	:	Mean Sum of Square

N	:	Nitrogen
NEBT	:	Number of ear bearing tillers per plant
NFGP	:	Number of filled grains per panicle
NIFGP	:	Number of ill-filled grains per panicle
No.	:	Number
NS	:	Non Significant
PCV	:	Phenotypic Coefficient of Variation
<i>per se</i>	:	As such with mean
PH	:	Plant height
PL	:	Panicle length
RBD	:	Randomized Block Design
S	:	Significant
SCMR	:	SPAD chlorophyll meter reading
SE	:	Standard Error
SEm	:	Standard Error mean
SPAD	:	Soil plant analytical development
SS	:	Sum of Square
viz.,	:	Namely
vs.	:	Against

ABSTRACT

Name of the Author : **BONGI SUDHEER**

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The present investigation was carried out during early *khari*f 2016 at Agricultural Research Station, Nellore, to study the variability, heritability, expected genetic advance, character association and path coefficient analysis involving 60 genotypes in rice for characters viz., days to 50 % flowering, days to maturity, plant height, number of ear bearing tillers per plant, panicle length, number of filled grains per panicle, number of ill-filled grains per panicle, 1000 grain weight, flag leaf length, flag leaf width, flag leaf area, SPAD chlorophyll meter reading, harvest index, grain length, grain width, grain L/B ratio and grain yield per plant.

Analysis of variance revealed significant differences among the genotypes for majority of the characters studied indicating a high degree of variability in the material.

The estimates of PCV and GCV were high for characters viz., Number of ill-filled grains per panicle. Moderate PCV and moderate GCV were observed for flag leaf length, ear bearing tillers per plant, grain yield per plant, 1000 grain weight, grain L/B ratio, flag leaf area and harvest index. While, low PCV and GCV were observed for days to 50 % flowering, days to maturity, plant height, panicle length, SCMR, grain length, and grain width.

The estimates of heritability coupled with genetic advance as per cent of mean were high for the characters viz., number of filled grains per panicle, number of ill-filled grains per panicle, 1000 grain weight, flag leaf length, flag leaf area and grain L/B ratio indicating the involvement of additive gene action in the inheritance of these traits.

The results of D^2 analysis indicated the presence of considerable genetic divergence among the 60 genotypes studied. The 60 genotypes were grouped into eight clusters. Out of 17 characters studied, flag leaf width, 1000 grain weight, days to maturity, flag leaf length and grain width contributed maximum towards divergence. Based upon the divergence studies, crosses may be made between genotypes of cluster III (IR 109A235) and VIII (JGL 11118) followed by cluster V (IR 11C208) and cluster

VIII (JGL 11118) to obtain desirable transgressive recombinants suitable for *kharif* situation.

Correlation studies at phenotypic and genotypic level revealed that the traits panicle length, flag leaf width, number of ear bearing tillers per plant, number of filled grains per panicle, 1000 grain weight, SCMR, and harvest index were found to possess significant association in desirable direction with grain yield per plant.

Path analysis revealed that number of ear bearing tillers per plant, number of filled grains per panicle, 1000 grain weight and harvest index showed true relationship by establishing positive association and positive direct effect on grain yield per plant.

Considering the nature and magnitude of character association and their direct and indirect effects, it can be inferred that under early *kharif* situation simultaneous improvement of grain yield per plant is possible through number of ear bearing tillers per plant, number of filled grains per panicle, 1000 grain weight and harvest index.

Chapter I

INTRODUCTION

Rice (*Oryza sativa* L.) is the most important crop providing food to over 75 % of Asian population and more than three billion of world population which represents 50 to 80 % of their daily calorie intake (Khush, 2005) and 55% of the protein intake in their average daily diet and aptly describes the slogan “Rice is life”. Rice is majorly grown in *kharif* and *rabi* seasons and in some areas it is also been grown in early *kharif* season. Early *kharif* rice crop is known by different names in different parts of India. viz., edagaru or mokeddugu in Nellore district of Andhra Pradesh, 'Aus' in West Bengal, 'Ahu' in Assam, 'Beali' in Orissa, 'Bhadai' in Bihar, 'Virippu' in Kerala and 'Kuruvai/Kar/March-April Sornavari' in Tamil Nadu (www.rkmp.drr on 24 june, 2011).

In India, rice grown area during early *kharif* season (Autumn) of 1.82 M ha with a production of 3.00 Mt and productivity 1645 kg ha⁻¹ and it was very low when compared to *kharif* and *rabi* productivity of 2295 and 3291 kg ha⁻¹ respectively (Ministry of Agriculture and Farmers Welfare, Government of India, 2014-15). In Nellore district of Andhra Pradesh, the rice is cultivated in an area of 60,000 ha in early *kharif* and this season (March-May to June-October) was characterized by climatic factors like low (or) no rainfall and high temperatures ranging from 35 to 45°C coupled with high velocity winds and these climatic factors had enormous effect on grain yield production in rice. These climatic extremes reduce the activity of many physiological processes through physiological traits like SCMR, flag leaf length, flag leaf width, flag leaf area and harvest index. Hence, the morphological traits of flag leaf such as size and shape, and physiological traits of flag leaf such as chlorophyll content and photosynthesis capacity have been considered to be the important determinants of grain yield in cereals (Chen *et al.*, 1995; Hirota *et al.*, 1990). However, harvest index reflects the division of photosynthates between the grains and the vegetative parts and improvement in harvest index emphasize the importance of carbon allocation in grain production. So, effect on above mentioned characters leads to show a significant impact on yield and yield contributing characters.

The varieties grown during this season were mostly of short duration and they could be harvested in about 110 to 130 days. However, there is a dearth of short duration varieties which will fit well into the reduced growing period brought about by the

changing climatic and rainfall pattern. Therefore greater emphasis should be placed on the development and release of varieties suitable for early *kharif* season, because about 2 to 3 million hectares of rice crop in India is grown in this season.

Yield is a complex character, which is influenced by several quantitative traits and is governed by polygenes. Application of biometrical techniques in plant breeding has led to the greater understanding of genetics of quantitative characters and proved to be extremely useful to the plant breeder for systematic genetic analysis.

The large spectrum of genetic variability in segregating population depends on the amount of the genetic variability among genotypes and offer better scope for selection. The magnitude of heritable variation in the traits studied has immense value in understanding the potential of the genotype for further breeding programme. Genetic diversity in a crop species is essential to sustain high level of productivity. The importance of information about the extent and magnitude of genetic divergence in rice and its utilization for the selection of desirable parents/ donors either for exploitation of hybrid vigor or to get desirable recombinants has been stressed by many researchers (Murthy and Arunachalam, 1966). Arunachalam (1981) reported that the greater chance of getting heterotic hybrids and enhanced variation in the segregating population of varietal improvement programmes mainly depends on genetic divergence. Germplasm is the core of any breeding work. The variability and novel characters existing in the germplasm can be exploited during crossing programme to develop need based varieties and hybrids. Before using the germplasm it has to be characterized and also the genetic diversity has to be studied to use effectively in the crossing programme.

Correlation is the measure of the mutual relationship between two variables. The study of correlations may help the plant breeder to know how the improvement of one character will bring simultaneous improvement in other characters. Path coefficient analysis is a standardized regression coefficient and measures the direct influence of one variable upon the other. Direct selection for yield is not a reliable approach since it is influenced by the environment. Therefore, it is essential to identify the component characters through which yield can be improved. Selection would be more effective for the trait, which has got high genetic advance and high correlation with grain yield.

The choice of suitable parents is of paramount importance for a planned hybridization programme. As the present study was taken up in early *kharif* season it is imperative to identify the best parents with genetic divergence for characters of

economic importance. So that they can be utilized in breeding programme to produce desirable recombinants suitable for early *kharif* season.

Keeping this in view, the present investigation was proposed with the following objectives.

1. To estimate variability, heritability and genetic advance for various yield, physiological and yield attributing characters in 60 rice genotypes suitable for early *kharif* season.
2. To study the genetic divergence among 60 rice genotypes.
3. To study the association among yield and yield attributing characters in early *kharif* situation.
4. To study the direct and indirect affect of different yield attributing characters on yield in early *kharif* situation.

Chapter II

REVIEW OF LITERATURE

The review of literature on rice (*Oryza sativa* L.) regarding the present study is presented under the following headings.

2.1 Genetic variability, heritability and genetic advance for yield parameters

2.2 Genetic divergence

2.3 Character association

2.4 Path coefficient analysis.

2.1 GENETIC VARIABILITY

Presence of variation in a given population is a primary requirement for improvement of any crop species and for developing an effective breeding programme. Selection is effective only when there is enough magnitude of genetic variability in the breeding population, hence an insight into the magnitude of genetic variability present in the population is utmost importance to a plant breeder for starting a plant breeding programme for crop improvement. According to Allard (1960), yield is polygenically controlled quantitative character and is highly influenced by environment. Partitioning of observed variability into heritable and non-heritable components is very much essential to get a true indication of the genetic coefficient of variability as a useful measure of the magnitude of genetic variance present in the population.

Table 2.1. Review of literature on genetic variability of yield, yield components and physiological traits in rice (*Oryza sativa* L.)

S.No.	Character	Variability	Reference
1.	Days to 50% flowering	High PCV, GCV	Jayasudha and Sharma (2010) Nandan <i>et al.</i> (2010) Seyoum <i>et al.</i> (2012) Nayak <i>et al.</i> (2016)
		Moderate PCV, GCV	Bekele <i>et al.</i> (2013) Sravan <i>et al.</i> (2014) Shrivastava <i>et al.</i> (2015) Shankar <i>et al.</i> (2016)
		Low PCV, GCV	Vanisree <i>et al.</i> (2013) Gangashetty <i>et al.</i> (2013) Reddy <i>et al.</i> (2013) Prasad <i>et al.</i> (2013) Singh <i>et al.</i> (2014) Rahman <i>et al.</i> (2014) Dhurai <i>et al.</i> (2014) Suresh <i>et al.</i> (2014) Mohan <i>et al.</i> (2015) Sameera <i>et al.</i> (2015) Shekawat <i>et al.</i> (2015) Padmaja <i>et al.</i> (2008)
2.	Days to maturity	High PCV, GCV	Prasad <i>et al.</i> (2011) Neha <i>et al.</i> (2014) Nayak <i>et al.</i> (2016)
		Moderate PCV, GCV	Aishwarya <i>et al.</i> (2014) Vineeth <i>et al.</i> (2014)
		Low PCV, GCV	Khare <i>et al.</i> (2014) Ria <i>et al.</i> (2015) Khatun <i>et al.</i> (2015) Allam <i>et al.</i> (2015) Sameera <i>et al.</i> (2015)

Table 2.1 (contd.)

3.	Plant height (cm)	High PCV, GCV	Gangashetty <i>et al.</i> (2013) Rahman <i>et al.</i> (2014) Biswash <i>et al.</i> (2015) Islam <i>et al.</i> (2015) Nayak <i>et al.</i> (2016)
		Low PCV, GCV	Reddy <i>et al.</i> (2013) Mohan <i>et al.</i> (2015) Sameera <i>et al.</i> (2015)
		Moderate PCV, GCV	Jayasudha and Sharma (2010) Vanisree <i>et al.</i> (2013) Dhurai <i>et al.</i> (2014) Sravan <i>et al.</i> (2014) Shrivastava <i>et al.</i> (2015) Shankar <i>et al.</i> (2016) Padmaja <i>et al.</i> (2008)
4.	Number of ear bearing tillers per plant	High PCV, GCV	Jayasudha and Sharma (2010) Singh <i>et al.</i> (2012) Reddy <i>et al.</i> (2013) Prasad <i>et al.</i> (2013) Vanisree <i>et al.</i> (2013) Gangashetty <i>et al.</i> (2013) Singh <i>et al.</i> (2014) Dhurai <i>et al.</i> (2014) Allam <i>et al.</i> (2015) Biswash <i>et al.</i> (2015) Karande <i>et al.</i> (2015) Sameera <i>et al.</i> (2015) Shekawat <i>et al.</i> (2015) Nayak <i>et al.</i> (2016)
		Moderate PCV, GCV	Krishna <i>et al.</i> (2008) Chandra <i>et al.</i> (2009) Sravan <i>et al.</i> (2012) Dhanwani <i>et al.</i> (2013) Shankar <i>et al.</i> (2016)

Table 2.1 (contd.)

		Low PCV, GCV	Garg <i>et al.</i> (2010) Yadav <i>et al.</i> (2010) Mohan <i>et al.</i> (2015)
5.	Panicle length (cm)	High PCV, GCV	Rahman <i>et al.</i> (2014) Sachan <i>et al.</i> (2015)
		Moderate PCV, GCV	Jayasudha and Sharma (2010) Dhanwani <i>et al.</i> (2013) Gangashetty <i>et al.</i> (2013) Singh <i>et al.</i> (2014) Dhurai <i>et al.</i> (2014) Shekawat <i>et al.</i> (2015) Nayak <i>et al.</i> (2016)
		Moderate PCV, Low GCV	Padmaja <i>et al.</i> (2008)
		Low GCV, PCV	Mohanty <i>et al.</i> (2012) Sravan <i>et al.</i> (2012) Pandey <i>et al.</i> (2010) Reddy <i>et al.</i> (2013) Vanisree <i>et al.</i> (2013) Sravan <i>et al.</i> (2014) Suresh <i>et al.</i> (2014) Singh <i>et al.</i> (2014) Gampala <i>et al.</i> (2015) Mohan <i>et al.</i> (2015) Sameera <i>et al.</i> (2015) Shankar <i>et al.</i> (2016)
6.	Number of filled grains per panicle	High PCV, GCV	Allam <i>et al.</i> (2015) Sameera <i>et al.</i> (2015) Rahman <i>et al.</i> (2014) Padmaja <i>et al.</i> (2008) Nayak <i>et al.</i> (2016)
		Moderate PCV, GCV	Tetwar <i>et al.</i> (2014) Sathya and Jebaraj (2015) Hossain <i>et al.</i> (2015) Shankar <i>et al.</i> (2016)

Table 2.1 (contd.)

		Low PCV, GCV	Vineeth <i>et al.</i> (2014)
7.	Number of ill-filled grains per panicle	High PCV, GCV	Mamun <i>et al.</i> (2012) Vineeth <i>et al.</i> (2014) Shrivastava <i>et al.</i> (2014) Khatun <i>et al.</i> (2015)
		Moderate PCV, GCV	Hossain <i>et al.</i> (2015)
8.	1000-grains weight (g)	High PCV, GCV	Seyoum <i>et al.</i> (2012) Reddy <i>et al.</i> (2013) Prasad <i>et al.</i> (2013) Patel <i>et al.</i> (2014) Allam <i>et al.</i> (2015) Bhati <i>et al.</i> (2015) Biswash <i>et al.</i> (2015) Islam <i>et al.</i> (2015) Karande <i>et al.</i> (2015) Shekawat <i>et al.</i> (2015) Singh <i>et al.</i> (2014) Nayak <i>et al.</i> (2016)
		Moderate PCV, GCV	Allam <i>et al.</i> (2015) Dhurai <i>et al.</i> (2014) Patel <i>et al.</i> (2014) Suresh <i>et al.</i> (2014) Shekawat <i>et al.</i> (2015) Shankar <i>et al.</i> (2016)
		Low PCV, GCV	Reddy <i>et al.</i> (2013) Sravan <i>et al.</i> (2014) Rahman <i>et al.</i> (2014) Kumar <i>et al.</i> (2015) Hossain <i>et al.</i> (2015)
9.	Flag leaf length (cm)	High PCV, GCV	Sadeghi (2011) Kumar <i>et al.</i> (2011) Sravan <i>et al.</i> (2012)

Table 2.1 (contd.)

		Moderate GCV, PCV	Singh <i>et al.</i> (2011) Thomas and Lal (2012) Lal and Chauhan (2011) Kumar <i>et al.</i> (2015) Chanbeni <i>et al.</i> (2012)
		Moderate PCV, Low GCV	Aditya and Bhartiya (2013)
		Low PCV, GCV	Paikhomba <i>etal.</i> (2014)
10.	Flag leaf width (cm)	Moderate GCV, High PCV	Sadeghi (2011)
		Moderate PCV, GCV	Kumar <i>et al.</i> (2011) Lal and Chauhan (2011) Singh <i>et al.</i> (2011) Chanbeni <i>et al.</i> (2012) Sravan <i>et al.</i> (2012)
		Moderate PCV, Low GCV	Thomas and Lal (2012)
		Low PCV, GCV	Paikhomba <i>e tal.</i> (2014)
		Low GCV, PCV	Aditya and Bhartiya (2013) Singh <i>et al.</i> (2014)
11.	Flag leaf area (cm ²)	Low PCV, GCV	Nilanjaya and Kumar (2015)
12.	SCMR	High PCV, GCV	Sathya and Jebaraj (2015)
		Low PCV, GCV	Ullah <i>et al.</i> (2011) Khatun <i>et al.</i> (2015)
13.	Harvest index (%)	High PCV, GCV	Ukaoma <i>et al.</i> (2013) Khatun <i>et al.</i> (2015)
		Moderate PCV, GCV	Paikhomba <i>et al.</i> (2014) Vineeth <i>et al.</i> (2014) Sathya and Jebaraj (2015)
		Moderate PCV, Low GCV	Ullah <i>et al.</i> (2011) Ramanjaneyulu <i>et al.</i> (2014)
		Low PCV, GCV	Adilakshmi and Raghavareddy (2012) Tetwar <i>et al.</i> (2014)

Table 2.1 (contd.)

14.	Grain length (mm)	High GCV, PCV	Gangashetty <i>et al.</i> (2013)
		Moderate PCV,GCV	Subbaiah <i>et al.</i> (2011) Bekele <i>et al.</i> (2013) Nitesh <i>et al.</i> (2015)
		Low GCV.PCV	Ubarhande <i>et al.</i> (2009) Kumar and Senapathi (2013) Corazon <i>et al.</i> (2015) Vanaja and Babu (2006) Ketan and Sarkar (2014) Kiani <i>et al.</i> (2013) Gokulakrishnan <i>et al.</i> (2014)
15.	Grain width (mm)	Moderate GCV,PCV	Ubarhande <i>et al</i> (2009) Gangashetty <i>et al.</i> (2013) Kiani (2013) Gokulakrishnan <i>et al.</i> (2014)
		Moderate PCV,GCV	Subbaiah <i>et al.</i> (2011) Bekele <i>et al.</i> (2013) Nitesh <i>et al.</i> (2015)
		Low GCV.PCV	Corazon <i>et al.</i> (2015) Kumar and Senapathi (2013) Vanaja and Babu (2006) Ketan and Sarkar (2014)
16.	Grain L/B ratio	High PCV, GCV	Saxena <i>et al.</i> (2005) Lal and Chauhan (2011)
		Moderate GCV,PCV	Sarkar <i>et al.</i> (2007) Rajeswari <i>et al</i> (2010) Umadevi <i>et al.</i> (2009) Subbaiah <i>et al.</i> (2011) Shejul <i>et al.</i> (2013) Patel <i>et al.</i> (2014) Gokulakrishnan <i>et al.</i> (2014)
		Low GCV.PCV	Krishnaveni and Sobharani (2006) Aditya and Bhartiya (2013) Ketan and Sarkar (2014)

Table 2.1 (contd.)

17.	Grain yield per plant (g)	High PCV, GCV	Seyoum <i>et al.</i> (2012) Reddy <i>et al.</i> (2013) Prasad <i>et al.</i> (2013) Patel <i>et al.</i> (2014) Allam <i>et al.</i> (2015) Bhati <i>et al.</i> (2015) Biswash <i>et al.</i> (2015) Gampala <i>et al.</i> (2015) Islam <i>et al.</i> (2015) Karande <i>et al.</i> (2015) Shekawat <i>et al.</i> (2015) Padmaja <i>et al.</i> (2008) Nayak <i>et al.</i> (2016)
		Moderate GCV, PCV	Ullah <i>et al.</i> (2011) Sameera <i>et al.</i> (2015) Shankar <i>et al.</i> (2016)
		Low PCV, GCV	Reddy <i>et al.</i> (2013)

Table 2.2. Review of literature on heritability $h^2_{(b)}$ and genetic advance as per cent of mean for yield, yield components and physiological traits in rice (*Oryza sativa* L.)

S.No.	Character	Heritability	Genetic advance as % of mean	Reference
1.	Days to 50% flowering	High	High	Gampala <i>et al.</i> (2015) Sameera <i>et al.</i> (2015) Shankar <i>et al.</i> (2016) Nayak <i>et al.</i> (2016)
		High	Moderate	Reddy <i>et al.</i> (2013) Dhurai <i>et al.</i> (2014) Patel <i>et al.</i> (2014) Padmaja <i>et al.</i> (2008)
		High	Low	Dhanwani <i>et al.</i> (2013) Singh <i>et al.</i> (2014) Islam <i>et al.</i> (2015) Karande <i>et al.</i> (2015) Shekawat <i>et al.</i> (2015)
2.	Days to maturity	High	High	Prasad <i>et al.</i> (2011) Neha <i>et al.</i> (2014) Vineeth <i>et al.</i> (2014) Nayak <i>et al.</i> (2016)
		High	Moderate	Aishwarya <i>et al.</i> (2014) Singh <i>et al.</i> (2014) Khare <i>et al.</i> (2014) Khatun <i>et al.</i> (2015)
		High	Low	Aishwarya <i>et al.</i> (2014) Kumar <i>et al.</i> (2015) Sameera <i>et al.</i> (2015)
3.	Plant height (cm)	High	High	Seyoum <i>et al.</i> (2012) Babu <i>et al.</i> (2012) Prasad <i>et al.</i> (2013)

				Dhurai <i>et al.</i> (2014) Lingaiah (2015) Sravan <i>et al.</i> (2014) Bhati <i>et al.</i> (2015) Gampala <i>et al.</i> (2015) Sameera <i>et al.</i> (2015) Shankar <i>et al.</i> (2016) Padmaja <i>et al.</i> (2008) Nayak <i>et al.</i> (2016)
		High	Moderate	Patel <i>et al.</i> (2014) Shekawat <i>et al.</i> (2015)
		Moderate	Low	Mohan <i>et al.</i> (2015)
		Low	Low	Reddy <i>et al.</i> (2013) Islam <i>et al.</i> (2015)
4.	Number of ear bearing tillers per plant	High	High	Prasad <i>et al.</i> (2013) Gangashetty <i>et al.</i> (2013) Dhurai <i>et al.</i> (2014) Singh <i>et al.</i> (2014) Karande <i>et al.</i> (2015) Sameera <i>et al.</i> (2015) Shankar <i>et al.</i> (2016) Nayak <i>et al.</i> (2016)
		High	Moderate	Ullah <i>et al.</i> (2011) Bornare <i>et al.</i> (2014)
		High	Low	Vineeth <i>et al.</i> (2014)
		Moderate	High	Paikhomba <i>et al.</i> (2014)
		Moderate	Moderate	Singh <i>et al.</i> (2011)
		Low	Low	Reddy <i>et al.</i> (2013) Mohan <i>et al.</i> (2015)
5.	Panicle length (cm)	High	High	Jayasudha and Sharma (2010) Selvaraj <i>et al.</i> (2011) Prasad <i>et al.</i> (2011) Dhurai <i>et al.</i> (2014) Sameera <i>et al.</i> (2015) Nayak <i>et al.</i> (2016)

Table2.2(contd.)

		High	Moderate	Ullah <i>et al.</i> (2011) Singh <i>et al.</i> (2011) Shekawat <i>et al.</i> (2015) Shankar <i>et al.</i> (2016) Padmaja <i>et al.</i> (2008)
		High	Low	Reddy <i>et al.</i> (2013) Singh <i>et al.</i> (2014)
		Moderate	High	Khatun <i>et al.</i> (2015)
		Moderate	Low	Paikhomba <i>et al.</i> (2014) Sathya and Jebaraj (2015)
		Low	Low	Kole <i>et al.</i> (2008)
6.	Number of filled grains per panicle	High	High	Sharma <i>et al.</i> (2013) Dhurai <i>et al.</i> (2014) Vineeth <i>et al.</i> (2014) Khatun <i>et al.</i> (2015) Sathya and Jebaraj (2015) Shankar <i>et al.</i> (2016) Padmaja <i>et al.</i> (2008) Nayak <i>et al.</i> (2016)
		Moderate	High	Bharadwaj <i>et al.</i> (2007)
		Low	Moderate	Tetwar <i>et al.</i> (2014)
		Low	Low	Mamun <i>et al.</i> (2012)
7.	Number of ill-filled grains per panicle	High	High	Vineeth <i>et al.</i> (2014) Shrivastava <i>et al.</i> (2014) Khatun <i>et al.</i> (2015) Hossain <i>et al.</i> (2015)
		Moderate	High	Mamun <i>et al.</i> (2012)
		Low	High	Tetwar <i>et al.</i> (2014)
8.	1000 grain weight (g)	High	High	Dhurai <i>et al.</i> (2014) Suresh <i>et al.</i> (2014) Gampala <i>et al.</i> (2015) Islam <i>et al.</i> (2015) Sameera <i>et al.</i> (2015) Shekawat <i>et al.</i> (2015)

Table2.2(contd.)

				Shankar <i>et al.</i> (2016) Nayak <i>et al.</i> (2016)
		High	Low	Reddy <i>et al.</i> (2013) Mohan <i>et al.</i> (2015)
		High	Moderate	Seyoum <i>et al.</i> (2012) Kumar <i>et al.</i> (2015) Hossain <i>et al.</i> (2015)
		Low	High	Paikhomba <i>et al.</i> (2014)
		Moderate	Low	Tetwar <i>et al.</i> (2014) Sathya and Jebaraj (2015)
9.	Flag leaf length (cm)	High	High	Kumar <i>et al.</i> (2011) Aditya and Bhartiya (2013)
		High	Moderate	Sadeghi (2011) Kumar <i>et al.</i> (2015) Chanbeni <i>et al.</i> (2012) Singh <i>et al.</i> (2014)
		High	Low	Singh <i>et al.</i> (2011) Thomas and Lal (2012)
		Moderate	Low	Paikhomba <i>etal.</i> (2014)
10.	Flag leaf width (cm)	High	High	kumar <i>et al.</i> (2011) Sravan <i>et al.</i> (2012)
		High	Moderate	Aditya and Bhartiya (2013) Kumar <i>et al.</i> (2015)
		High	Low	Sadeghi (2011) Singh <i>et al.</i> (2011) Chanbeni <i>et al.</i> (2012)
		Low	Low	Thomas and lal (2012) Paikhomba <i>etal.</i> (2014) Singh <i>et al.</i> (2014)
11.	Flag leaf area (cm ²)	High	Moderate	Nilanjaya and Kumar C (2015) Sravan <i>et al.</i> (2012)
		High	High	Dhanwani <i>et al.</i> (2013)
12.	SCMR	High	High	Adilakshmi and Raghavareddy (2012)

Table2.2(contd.)

				Sathya and Jebaraj (2015)
13.	Harvest index (%)	High	High	Ukaoma <i>et al.</i> (2013) Paikhomba <i>et al.</i> (2014) Khatun <i>et al.</i> (2015) Sathya and Jebaraj (2015)
		High	Moderate	Singh <i>et al.</i> (2011) Adilakshmi and Raghavareddy (2012) Vineeth <i>et al.</i> (2014)
		Moderate	Moderate	Ullah <i>et al.</i> (2011)
		Moderate	High	Karim (2007)
		Low	Low	Ramanjaneyulu <i>et al.</i> (2014) Tetwar <i>et al.</i> (2014)
14.	Grain length (mm)	High	Low	Gangashetty <i>et al.</i> (2013) Vanaja <i>et al.</i> (2006) Ubarhande <i>et al.</i> (2009)
		Low	Low	Kumar and Senapathi (2013) Corazon <i>et al.</i> (2015) Ketan and Sarkar (2014) Umadevi <i>et al.</i> (2009)
		High	High	Kiani <i>et al.</i> (2013)
		High	Moderate	Gokulakrishnan <i>et al.</i> (2014)
15.	Grain width (mm)	High	Low	Gangashetty <i>et al.</i> (2013) Corazon <i>et al.</i> (2015) Vanaja <i>et al.</i> (2006) Ubarhande <i>et al.</i> (2009)
		Low	Low	Kumar and Senapathi (2013) Ketan and Sarkar (2014) Kiani <i>et al.</i> (2013)
		Moderate	Moderate	Umadevi <i>et al.</i> (2009)
		High	High	Gokulakrishnan <i>et al.</i> (2014)
16.	Grain L/B ratio	High	Low	Gangashetty <i>et al.</i> (2013) Vanaja <i>et al.</i> (2006)
		Moderate	Moderate	Umadevi <i>et al.</i> (2009)

Table 2.2 (contd.)

		Low	Low	Kumar and Senapathi (2013) Ketan and Sarkar (2014)
		High	High	Rajeswari <i>et al.</i> (2010) Shejul <i>et al.</i> (2013) Karuppaiyan <i>et al.</i> (2013) Gokulakrishnan <i>et al.</i> (2014)
17.	Grain yield per plant (g)	High	High	Mohanty <i>et al.</i> (2012) Gangashetty <i>et al.</i> (2013) Reddy <i>et al.</i> (2013) Prasad <i>et al.</i> (2013) Dhurai <i>et al.</i> (2014) Singh <i>et al.</i> (2014) Suresh <i>et al.</i> (2014) Karande <i>et al.</i> (2015) Sachan (2015) Sameera <i>et al.</i> (2015) Padmaja <i>et al.</i> (2008) Nayak <i>et al.</i> (2016)
		High	Moderate	Chandra <i>et al.</i> (2009) Singh <i>et al.</i> (2011) Singh <i>et al.</i> (2012) Shankar <i>et al.</i> (2016)
		Moderate	Low	Mohan <i>et al.</i> (2015)
		Moderate	High	Mamatasingh <i>et al.</i> (2007) Satishchandra <i>et al.</i> (2009)

2.2 GENETIC DIVERGENCE

Knowledge on the nature and magnitude of genetic variability present in the plant material plays an important role in planning a sound breeding programme. It has been well established that genetically diverse parents are likely to yield desirable gene recombinants and or to produce high heterotic effect. Mahalanobis's D^2 statistic has proved to be powerful tool for quantifying genetic divergence in a given population.

Earlier studies indicated that the geographical distribution of the genotypes was not related to genetic diversity. Some of the available literature on the above aspects in rice is reviewed hereunder.

Sarawgi *et al.* (1998) studied the genetic divergence in 132 rice genotypes by using the D^2 technique and grouped them into 10 clusters. The maximum intra-cluster distance was observed in cluster VIII. Clusters VI and VIII were identified as genetically divergent. Considering the cluster means and cluster distances, Bakal-B and Jondhera Dhan of cluster VI, Gonda Jhul of cluster VIII, Poorva and IR-36 of cluster VII, Kranchi, X-12, Moti Bakiya and Assam Chudi of cluster V and Kranti of cluster X were the most promising varieties.

Shanthi and Singh (2001) studied the genetic divergence by using Mahalanobis D^2 statistic and Tocher's method and grouped them into 4 clusters. The first cluster contained nine genotypes, the second containing six while third (MM-72) and fourth (MM-71) clusters were monogenic. The genotypes belonging to clusters II and III having greater cluster distance were recommended for inclusion in a hybridization programme as they were expected to produce good segregants.

Yadav *et al.* (2002) assessed the genetic divergence of 100 aromatic rice genotypes and grouped them into 9 clusters. The pattern of distribution of genotypes within various clusters was random and independent of geographical isolation. Based on mean performance, genetic distance and clustering pattern, inter-crossing of genotypes Gam Poon, Khao Jao Hawam, Basmati Sufaid 187, KCN 80152, Abor Bora and Hara may be useful in creating wider variability for important agronomic and quality traits with high yielding segregants.

Chauhan and Singh (2003) studied genetic divergence in 45 genotypes and grouped into 11 clusters. Cluster II was the largest and consisted of 10 genotypes

followed by cluster I with 9 genotypes. Clusters III and V had 7 genotypes each, similarly clusters VI and VII contained 3 genotypes each. Clusters VIII to XI were monogenetic. Hybridization among genotypes included in the diverse clusters (I, IV, VIII, X and XI) and the clusters having high means for quality traits such as high elongation (cluster IV), intermediate alkali value (cluster VIII and IX) and high milling recovery (cluster IX and X) would give high heterotic combinations and produce large variability, better segregants in the segregating generations.

Mani (2003) assessed the degree and nature of genetic divergence among a set of 61 elite basmati rice genotypes and grouped into 4 clusters. Maximum number of genotypes (43) was included in cluster I, followed by cluster II (13), cluster III (4) and cluster IV (1). Cluster III and II showed the maximum and minimum intra cluster distance, respectively. Cluster III showed the maximum genetic distance from cluster IV, while cluster II and III had the minimum genetic distance. Plant height contributed the maximum towards genetic divergence followed by days to 50% flowering and grain yield per plant.

Souroush *et al.* (2004) studied the genetic diversity of quantitative and qualitative traits of 36 lines and cultivars of rice. Cluster analysis with Ward's method classified all of the genotypes into 5 clusters. Genotypes of the third cluster including 4 pure lines (Nos. 4, 21, 22 and 24) had high yield, high number of panicle and filled grains per panicle, intermediate amylose and lower plant height, therefore, these suitable traits can be transferred through hybridization programmes. Genotypes of the first and fifth clusters can also be used to improve yield and grain cooking quality, respectively.

Awasthi *et al.* (2005) studied the genetic divergence of 21 Indian aromatic rice genotypes and grouped into 6 clusters for different characters. The inter-cluster distance ranged from 0.00 for clusters IV, V and VI to 40.21 for cluster III. The inter-cluster distance was observed to be highest between clusters II and III, indicating that the genotypes of these 2 clusters were genetically more diverse. The number of grains per panicle grain yield per plant, days to 50% flowering, leaf length and leaf width showed high percent contribution towards total genetic divergence.

Bhutia *et al.* (2005) carried out genetic divergence studies in 41 high yielding and local rice genotypes and grouped them into six clusters. Cluster I had the highest number of genotypes (27) followed by cluster II with eight, and cluster III with three

genotypes, respectively. Clusters IV, V and VI were mono genotypic. Cluster IV showed the maximum genetic distance from cluster VI followed by its distance from cluster V. The genotypes included in clusters III and IV may be used as parents in hybridization programme to improve yield and cooking quality.

Bose and Pradhan (2005) assessed the nature and magnitude of genetic divergence among 35 deep water rice genotypes and grouped them into 10 clusters showing fair degree of relationship between geographic distribution and genetic divergence. Traits such as plant yield days to 50% flowering, and plant height were the major contributors to genetic divergence.

Chaturvedi and Maurya (2005) studied genetic divergence analysis in 26 rice genotypes which were grouped into 8 clusters. The maximum inter-cluster D^2 value was obtained between cluster III and VI and III and VIII. It is suggested that for developing better cultivar, the genotypes of cluster III could be utilized in hybridization programme with the genotypes of cluster VI and VIII.

Kandamoorthy and Govindarasu (2005) studied genetic diversity in 30 extra-early rice genotypes. Cluster I had the highest number of genotypes. The highest inter-cluster distance was observed between cluster I and III followed by cluster II in direct sown condition. Under transplanted condition, cluster II showed the highest inter-cluster distance with cluster V followed by cluster II and IV. Plant height and days to flowering contributed to genetic diversity in transplanted conditions.

Madhavalatha *et al.* (2005) studied the genetic diversity in 44 elite rice germplasm lines and classified them into 9 clusters based on Mahalanobis D^2 statistic. Results on inter-cluster distances revealed maximum diversity between genotypes of clusters IV and VIII. Intra-cluster distance was maximum for cluster V, indicating the existence of variability within the cluster. Plant height and days to 50% flowering accounted for 82.04% of the total genetic divergence, indicating their importance in the choice of parents for hybridization programmes.

Sankar *et al.* (2005) assessed the nature and magnitude of genetic divergence among 34 genotypes for 8 characters using Mahalanobis D^2 statistics. The genotypes were grouped into 8 clusters. Days to 50% flowering, single plant yield and grains per panicle were the major characters contributing towards divergence.

Senapati and Sarkar (2005) studied the genetic divergence in 40 tall indica rice genotypes and clustered them into 5 groups. Majority of the genotypes (30) were included in cluster I. Cluster II was second with 6 genotypes, while cluster III had only 2 genotypes. Cluster IV and V were the mono genotypic clusters. Cluster IV showed maximum genetic distance from cluster V suggested wide diversity between these groups. Panicle number per hill, panicle length, sterility percentage, yield per plot and 1000-grain weight was the chief contributors towards genetic divergence.

Sood *et al.* (2005) studied genetic divergence in 43 rice genotypes and grouped them into nine clusters. Cluster IV showed highest intra-cluster distance. Based on the mean performance, genetic distance and clustering pattern, hybridization involving genotypes HPR 824 and KC 1 (Achhoo) are likely to give desirable segregants for yield and its component traits.

Suman *et al.* (2005) grouped 114 rice genotypes into 10 clusters by using Mahalanobis D^2 statistic. The maximum inter-cluster distance was observed between clusters V and X. Harvest index gave the highest contribution towards divergence followed by seed density and total number of tillers per plant. Geographical diversity did not relate to genetic diversity.

Vaithiyalingan (2005) studied 29 strains of rice collected from different geographical regions of world to analyze the extent of genetic divergence and grouped them into four clusters. The clustering pattern was independent of the geographical distribution, cluster II included 23 genotypes and those can be useful in hybridization to create a wide spectrum of variability. Maximum distance was observed between clusters III and IV. Plant height, single plant yield and 1000-seed weight were found to be important contributors to genetic divergence.

Naik *et al.* (2006) studied genetic divergence to estimate the nature and magnitude of diversity in 50 aromatic rice accessions and grouped them into 7 clusters. The cluster VI had the highest mean for grain yield per plant and for biological yield per plant. Inter-cluster distance was recorded highest between cluster 3 and cluster 4. The conclusion drawn by the cluster analysis is that in the studied population high variability observed between the genotypes in different clusters for different characters.

Devi *et al.* (2006) evaluated genetic diversity in 54 rice cultivars for yield and yield components. The genotypes were grouped into 9 clusters. Cluster VI recorded high mean values for plant height (140.33 cm), flag leaf length (48.11 cm) and flag leaf

width (2.10 cm). Plant height contributed the most to genetic divergence (40.16%), followed by flag leaf width (20.12%) and yield per plant (15.79%).

Mundhe *et al.* (2006) studied genetic diversity in 39 rice genotypes and grouped them into 7 clusters. Intra-cluster distance was maximum in cluster III followed by cluster II and cluster I. Inter-cluster distance was maximum between cluster V and VII followed by cluster III and V, and cluster II and V.

Ravinder *et al.* (2006) studied genetic divergence in 50 unscented rice genotypes for yield and grouped them in 3 and 4 clusters in normal and late-sown conditions, respectively. There was no relationship between clustering pattern and geographical distribution. Based on the high cluster mean and wide genetic distance, hybridization between superior genotypes of clusters Individuals (IR 36, Palman 579, BR 827, HKR 117, HKR 126, HKR 86-105, IR 64 and RP 2151-21-22) and cluster III (Govind and NDR 84) had been advocated to achieve high heterosis and high yielding segregants.

Reddy *et al.* (2006) assessed the genetic divergence in 64 early rice genotypes and the genotypes were grouped into 13 clusters. There was no relationship observed between geographical distribution and genetic diversity. Percent contribution of characters, i.e. 1000-grain weight, plant height, grain yield per plant and number of spikelets per panicle was highest towards genetic divergence indicating that due consideration should be given to these characters while selecting parents from distant clusters for hybridization.

Singh *et al.* (2006) studied the genetic divergence in 52 traditional lowland rice genotypes by using Mahalanobis D^2 statistics and grouped into six clusters. Clusters II, III, and IV exhibited high values for most of the characters. Plant height, followed by leaf angle and leaf area, highly contributed to the formation of clusters. Clusters II, IV, and V showed maximum inter-cluster distances and high values of plant height, days to 50% flowering, panicle length, grain yield per plant and milling percent, may be used for initiating a hybridization programme.

Chandra *et al.* (2007) assessed the nature and magnitude of genetic divergence in 57 upland rice genotypes for and grouped them into five clusters. The most divergent clusters were III and IV ($D^2=3387.9$) followed by III and V ($D^2=2808.2$) and clusters II and III ($D^2=1908.7$). The clustering patterns of the genotypes were quite at random indicating that the geographical origin and genetic diversity were not related. The

characters contributing more towards the genetic divergence were 1000-grain weight, grain yield and biological yield.

Kumar and Ramesh (2008) estimated genetic divergence in 30 genetically diverse genotypes of rice by using Mahalanobis D^2 statistic and grouped them into eight clusters. The inter-cluster distance was highest between clusters V and VI. This indicates that the genotypes could be used in hybridization programme and are likely to exhibit high heterosis and possibility of throwing transgressive segregants in subsequent generations.

Ramya and Kumar (2008) studied the genetic divergence in 50 genotypes of rice and formed them 11 clusters. Cluster I was the largest with 35 genotypes. The inter cluster distances were greater than intra cluster distances. The inter cluster distance between clusters IV and VIII recorded maximum distance (37.58), which indicates that the divergence among these clusters was the highest. Number of grains per panicle, number of productive tillers per plant and grain yield per plant showed high per cent contribution towards genetic divergence.

Sabesan *et al.* (2009) studied the genetic diversity in rice genotypes by using Mahalanobis D^2 statistic and grouped them into 13 clusters. Cluster I with seven genotypes was the largest cluster followed by Cluster V with four genotypes. Clusters IV, VII, VIII, X, XI, XII and XIII were mono genotypic clusters. The maximum inter cluster distance ($D^2 = 8235.56$) was recorded between clusters II and III. Cluster XII recorded highest mean value for grain yield per plant and lowest mean value for days to first flower. Number of grains per panicle (42.71%) followed by days to first flower (25.62%) contributed maximum to total divergence.

Shahidullah *et al.* (2009) assessed the genetic divergence in 40 aromatic rices for grain quality and nutrition aspects. In multivariate analysis, genotypes were grouped into six clusters. The inter-cluster D^2 value was maximum (26.53) between I and VI followed by 21.28 (between I and V). Majority of the local aromatic rice varieties with smaller kernels were included in the cluster I. The cluster III contains Elai, sarwati and sugandha-1 with long-slender kernel and 'very good' appearance. Thus, these varieties can be used in breeding programme for improvement of germplasm.

Raut *et al.* (2009) grouped 40 rice genotypes into 3 clusters by using Mahalanobis D^2 statistic. Cluster I emerged as the largest with 36 genotypes. Cluster II

had 3 genotypes while cluster III was mono genotypic. Investigation revealed the independence of the genetic diversity from the eco geographic distribution of the genotypes. Length to breadth ratio of grain followed by number of grains per panicle, length of grain and seed yield per plant exhibited the greater contribution to the genetic divergence among genotypes.

Ubarhande *et al.* 2009 studied Forty four indica rice cultivars On the basis of D^2 analysis 44 rice genotypes were grouped into nine clusters and three ungrouped clusters. Cluster I was the largest and contained 22 genotypes. Rest of the clusters contained 2-3 genotypes. The highest intracluster distance was observed in cluster IX, containing two genotypes differing mainly for maturity and grain yield/plant. The most distant clusters were Cluster IV and ungrouped cluster XII. The genotypes of cluster IV showed promise for rain-fed condition with regard to days to maturity, effective tillers/plant, grain yield/plant and chlorophyll content. Contribution (%) towards the total divergence was maximum through grain length and grain breadth followed by chlorophyll content, grain length and total tillers/plant.

Pandey and Anurag (2010) assessed the nature and magnitude of genetic divergence in 40 rice genotypes by using Mahalanobis D^2 -statistics and grouped them into seven clusters. Cluster VI was the largest one containing 11 genotypes followed by cluster III with 9 genotypes. Plant height, biological yield and test weight contributed considerably, accounting for 86.16% of total divergence. The highest inter-cluster distance was observed between cluster II and VII.

Padmaja *et al.* (2010) analysed the genetic divergence in 150 genotypes of rice by using Mahalanobis D^2 statistics revealed the existence of considerable diversity among the genotypes. On the basis of D^2 values, the genotypes were categorized into 13 clusters. Cluster XI was the largest consisting of 28 genotypes, while cluster I contained only two genotypes. Cluster I showed maximum inter-cluster distance with cluster IX indicating that the genotypes from these clusters may be used as potential donors in hybridization programme to obtain desirable recombinants.

Reddy *et al.* (2010) estimated the genetic divergence in 50 rice genotypes and grouped into 11 clusters. Cluster IV was emerged as largest cluster with 12 genotypes. The highest inter-cluster distance was observed between clusters VIII and XI. The genotypes UPR-1840, PAU-3042-3-3-4, UPR-2554-9-1 and NDR-2062 were identified

as genetically diverse parents. These genotypes may be used further as parents in hybridization programme.

Chaturvedi *et al.* (2011) assessed the nature and magnitude of genetic divergence in 35 rice genotypes by using Mahalanobis D^2 and grouped them into eight clusters. The panicle weight followed by effective tillers per plant and yield per plant contributed maximum towards divergence. The genotypes belonging to cluster VII could be utilized as diverse parent in hybridization program with the genotypes of clusters II and VIII respectively, to achieve greater variability in the segregating generations

Dutta *et al.* (2011) studied the genetic divergence in 62 aromatic rice genotypes by using Mahalanobis D^2 statistic and grouped into eight clusters where, cluster I was the largest containing 38 genotypes followed by cluster II with 9 genotypes. Based on the inter cluster distance, the entries viz., Pankey, 60-Chali, Dudheswar, Sitabhog, Kalonunia, MTU-7029, Netaisail, Bhutmuri (Kelias) were selected which could be intercrossed to obtain high heterotic effect and also to recover desirable transgressive segregants.

Baradhan and Thangavel (2011) studied 45 rice genotypes and grouped into 6 clusters. Cluster I had the maximum divergence which was closely followed by cluster II and cluster V. The inter cluster distance ranged from 7.52 to 13.20 as exhibited between clusters III and V and clusters II and VI respectively. In these study parental lines selected from cluster VI for grain yield, number of productive tillers per plant, panicle length, and plant height and cluster I for number of grains per panicle exhibited high mean values.

Sridevi *et al.* (2012) studied a total of 24 rice genotypes and all were grouped into 3 clusters. All cultivated types grouped in one cluster (cluster 1) except Rasi and CTH1, which were included in cluster II and cluster III, respectively. Cluster I contained 9 cultivated genotypes, whereas cluster II contained 11 land races and cluster 3 had 4 upland lines. Out of 4 upland lines, one line (AC-35341) intermixed, with C, and three lines (PS-229, JBT-37/4 and AC-35310) with C3. The study of SSR markers on chromosome 1 facilitated the classification of these lines according to their adaptability.

Singh *et al.* (2012) studied thirty aromatic rice genotypes and grouped them into six clusters by both Tocher's and Euclidian methods of divergence. The most diverse

parent combination for the component characters of grain yield improvement have been identified on the basis of 3D diagram of PCA scores and Euclidian distance matrix, which were JGL 15336 x Taroari Basmati for effective tillers per plant, Badsabhog x Rajendra Kasturi for filled grain per panicle, JGL 15336 x Birsamati for grain weight per panicle and Gandhasala x Pusa Sugandha-3 for leaf area index.

Chakravorty and Ghosh (2012) studied 51 land races of rice and grouped them into 11 clusters. The grouping showed 6 multigenotypic, 3 digenotypic, and two monogenotypic clusters. The maximum intra cluster D^2 value was shown by the cluster X followed by cluster IX, III and I, while the intra cluster distance was maximum between genotypes present in cluster IX. Maximum contribution towards genetic divergence came from the characters, culm length and grain length. Cluster VII recorded highest mean value for plant height, ligule length, culm length, culm diameter, culm number, panicle length and maturity. Hybridization among these genotypes from the cluster I, III and IX which had maximum inter cluster distances and desirable values for flag leaf angle, grain breadth, grain weight, kernel weight, no of primary branches for panicle, likely to produce heterotic combinations and wide variability in segregating generations.

Karupaiyan *et al.* (2013) grouped 27 genotypes were grouped into 4 clusters. The characters Yield ha^{-1} (20.80%) contributed maximum towards divergence followed by plant height (16.81%), grain breadth (16.52%) and grain length (15.10%).

Kar *et al.* (2013) studied 65 indigenous aromatic rice genotypes and the genotypes were grouped into thirteen clusters. Based on clustering pattern, the maximum genetic distance among genotypes existed between cluster IV, V and XI. The clusters, V and X, were ascertained outstanding on the basis of higher cluster means for most of the component characters.

Kumar *et al.* (2015) were evaluated for thirteen yield and yield attributing characters and based on D2 analysis, 57 genotypes were grouped into 13 clusters. The pattern of distribution of genotypes within different clusters was random and independent of geographical origin or region of adaptation. The characters like days to maturity (34.21%), days to flowering (27.44), grain length (19.55%) and grain width (12.16%) contributing maximum towards diversity. Hence these characters can be given consideration for selection of genotypes for future breeding programmes.

Beevi and Venkatesan (2015) studied 60 rice genotypes and grouped into six clusters. The characters grain yield plant⁻¹, number of grains panicle⁻¹ and plant height contributed maximum towards genetic divergence among the genotypes. Cluster III recorded highest mean value for grain yield plant⁻¹ and lowest mean value for days to first flower. The highest inter-cluster distance ($D_2 = 7925.46$) was recorded between clusters III and VI. Selection of genotypes in these clusters which may serve as potential donors for future hybridization programmes to develop potential recombinants with high yield coupled with desirable traits.

Bharathi *et al.* (2016) studied 32 rice (*Oryza sativa* L.) genotypes using D_2 technique for ten characters. The 32 genotypes were grouped into 9 clusters containing 1 to 12 genotypes. Cluster I was the largest with 12 genotypes and cluster III, V, VI, VII and VIII were lowest with one genotype each. In D_2 analysis, filled grains per panicle followed by ear bearing tillers per panicle and days to 50% flowering contributed maximum for the divergence.

Chapter III

MATERIAL AND METHODS

The present experiment was carried out during early *kharif*, 2016 at Agricultural Research station, Nellore, Andhra Pradesh, which is located at an altitude of 20 m above MSL, latitude of 14⁰, 54' N and longitude of 79⁰, 59' E. The material used and methods followed are described below.

3.1 MATERIAL

The experimental material consisted of 60 rice genotypes obtained from different sources. The information on source/origin of the genotypes was presented in table 3.1.

Table 3.1 Sixty rice genotypes with pedigree and source.

	Genotypes	Pedigree	source
1	NLR 30491	IR 36/Sasyasree	ARS, Nellore.
2	NLR 34449	IR 72/BPT 5204	ARS, Nellore.
3	NLR 34242	IR 64/Sasyasree	ARS, Nellore.
4	NLR 40024	WGL 14280-1/NLR 30491	ARS, Nellore.
5	NLR 40065	NLR 34150/NLR 33057	ARS, Nellore.
6	NLR33671	NLR 33055/NLR 145	ARS, Nellore.
7	NLR 40058	NLR 34150/NLR 33057	ARS, Nellore.
8	NLR 3042	BPT 5204/NLR 145	ARS, Nellore.
9	IR 64	IR 5657-33-2-1 x IR 2061-465-1-5-5	IRRI, Philippines.
10	MTU 1010	MTU 2077/IR 64	RARS, Maruteru.
11	NLR 3217	NLR 34449/NLR 33358	ARS, Nellore.
12	NLR 3241	NLR 145/NLR 34449	ARS, Nellore.
13	NLR 3242	BPT 5204/MTU 1010	ARS, Nellore.
14	NLR 3251	GEB 24/NLR 33671	ARS, Nellore.
15	NLR 3296	NLR 30491/NLR 34449	ARS, Nellore.
16	NLR 3302	NLR 34449/NLR 33671	ARS, Nellore.
17	NLR 3346	NLR 34449/NLR 33358//BPT 5204	ARS, Nellore.
18	NLR 3350	NLR 145/Pusa basmathi//BPT 5204	ARS, Nellore.

19	NLR 3353	BPT 5204/MTU 7029//BPT 5204	ARS, Nellore.
20	NLR 3354	NLR 34242/NLR 34303	ARS, Nellore.
21	NLR 3415	NLR 34242/NLR 34449	ARS, Nellore.
22	NLR 3369	GEB 24/NLR 33671	ARS, Nellore.
23	NLR 3412	NLR 40007/NLR 34449	ARS, Nellore.
24	NLR 3407	MTU 1010/NLR 34449	ARS, Nellore.
25	NLR 3411	NLR 40007/NLR 34449	ARS, Nellore.
26	NLR 3414	NLR 40007/NLR 34449	ARS, Nellore.
27	NLR 3413	NLR 40007/NLR 34449	ARS, Nellore.
28	NLR 3367	(NLR34449/NLR33671)/(ADT37/NLR 33671)	ARS, Nellore.
29	NLR 3366	NLR 145/NLR 34452	ARS, Nellore.
30	NLR 3417	NLR 145/NLR 34449	ARS, Nellore.
31	NLR 3410	NLR 40007/NLR 34449	ARS, Nellore.
32	NLR 3408	NLR 145/MTU 1010	ARS, Nellore.
33	JGL 11118	IET8585/JGL 1798	RARS, Jagtial.
34	JGL1798	Samba mahsuri / kavya	RARS, Jagtial.
35	NLR 4002	BPT 5204/MTU 2077	ARS, Nellore.
36	NLR 33358	Selection from IR 50	ARS, Nellore.
37	NLR 33359	Selection from IR 50	ARS, Nellore.
38	NLR 34303	WGL 3962/IET 9994	ARS, Nellore.
39	ADT 43	IR50/White ponni	TRRI, Aduthurai.
40	WHITE PONNI	Taichung 65/2/mayang ebos-80	TRRI, Aduthurai.
41	ADT 37	BG 280-12/PTB 33	TRRI, Aduthurai.
42	ADT 45	IR 50/ADT 37	TRRI, Aduthurai.
43	TN 1	Dwarf Chow-wu-gen/ Tsai-Yuan-Chunj	Taichung District Agricultural Improvement Station, Taiwan .
44	MDT 6	IR 64/Lalnakandha 41	RARS, Maruteru.
45	MDT 10	MTU 1010/Annada	RARS, Maruteru.
46	NLR 33057	IR 36/MTU 4569	ARS, Nellore.
47	IR11C 186	International rice heat tolerant nurseries	IRRI, Philippines.

		from IRRI, Philippines.	
48	IR11C 202	International rice heat tolerant nurseries from IRRI, Philippines.	IRRI, Philippines.
49	IR11C 208	International rice heat tolerant nurseries from IRRI, Philippines.	IRRI, Philippines.
50	IR11C 214	International rice heat tolerant nurseries from IRRI, Philippines.	IRRI, Philippines.
51	IR11C 219	International rice heat tolerant nurseries from IRRI, Philippines.	IRRI, Philippines.
52	IR11C 221	International rice heat tolerant nurseries from IRRI, Philippines.	IRRI, Philippines.
53	IR11C 228	International rice heat tolerant nurseries from IRRI, Philippines.	IRRI, Philippines.
54	IR10C 172	International rice heat tolerant nurseries from IRRI, Philippines.	IRRI, Philippines.
55	HHZ5-DT20-DT2-DT1	International rice heat tolerant nurseries from IRRI, Philippines.	IRRI, Philippines.
56	IR64197-3B- 15-2	International rice nurseries from IRRI, Philippines.	IRRI, Philippines.
57	IR10F 221	International rice BPH nurseries from IRRI, Philippines.	IRRI, Philippines.
58	IR109A 235	International rice BPH nurseries from IRRI, Philippines.	IRRI, Philippines.
59	IR 62	PTB30/IR30(BPHS)//IR36	IRRI, Philippines.
60	BG 367-2	International rice BPH nurseries from IRRI, Philippines.	Srilanka

3.2 METHODS

3.2.1 EXPERIMENTAL TECHNIQUE

The detailed experimental technique for the present investigation has been furnished below and layout was represented in Fig 3.1

Location	:	Agricultural Research Station, Nellore.
Season	:	Early <i>kharif</i> -2016
Design	:	Randomized Complete Block Design
Entries	:	60 genotypes
Replications	:	2
Spacing	:	15 ×10 cm
Row number	:	5
Row length	:	5 m
Plot size	:	3.75 m ²
Fertilizers	:	120 kg N: 60 kg P ₂ O ₅ : 40 kg K ₂ O/ha.
Plant protection	:	Need based
Date of sowing	:	21-05-2016
Date of transplanting	:	18-06-2016

3.2.2 RECORDING OF OBSERVATIONS

Observations were recorded on ten randomly selected plants per treatment per replication and were used for statistical analysis. However, days to 50% flowering and days to maturity were recorded per plot basis and physiological parameters like SCMR are recorded after 50% flowering.

3.2.2.1. Days to 50 per cent flowering

The number of days taken from the day of sowing to opening of panicles and blooming in 50 per cent of the plants in a plot was taken as days to 50 per cent flowering. Observations for this trait were recorded per plot basis.

3.2.2.2. Days to maturity

The number of days taken to complete maturity from the date of sowing to 80-85 % of the grains attain straw (yellow) colour was recorded.

3.2.2.3. Plant height (cm)

The plant height was measured in centimeters from ground level to the tip of the panicle of the mother tiller excluding awns at the time of harvest.

3.2.2.4 Number of ear bearing tillers per plant

Total number of ear bearing tillers in each randomly selected plant was counted at maturity.

3.2.2.5 Panicle length (cm)

Length of panicle was measured from base neck of the panicle to the top most spikelet and was measured in centimeters.

3.2.2.6 Number of filled grains per panicle

The number of filled grains per panicle were counted and recorded.

3.2.2.7 Number of ill-filled grains per panicle

The number of ill- filled grains per panicle were counted and recorded.

3.2.2.8 1000 grain weight (test weight) (g)

One thousand well filled grains from each treatment were counted and weighed to nearest milligram at 12 % moisture level. The weight was recorded in grams.

3.2.2.9 Flag leaf length (cm)

The length of the flag leaf was measured for ten randomly selected plants from each treatment and the average was calculated.

3.2.2.10 Flag leaf width (cm)

The width of the flag leaf was measured for ten randomly selected plants from each treatment and the average was calculated.

3.2.2.11 Flag leaf area

The leaf area is given as: Leaf area (cm²) = K (0.75) × length (cm) × width (cm). The K is correction factor and its value is 0.75 suggested by Yoshida et al 1981.

3.2.2.12 SCMR (SPAD Chlorophyll meter reading)

The total chlorophyll content was measured with SPAD (soil plant analytical development) chlorophyll meter reading (SCMR) following the method of Turner and Jund (1991) at 60 days after transplanting in each treatment. SCMR data was recorded on boot leaf from top of each representative plant, between 10.00 a.m to 12.00 noon of the day. A mean of 25 readings from five representative plants per plot was taken.

3.2.2.13 Harvest index

It is calculated by dividing the grain yield with biological yield per plant and expressed in percentage.

$$\text{Harvest index (\%)} = \frac{\text{Economic yield per plant (g)}}{\text{Biological yield per plant (g)}} \times 100$$

3.2.2.14 Grain length (mm)

Longitudinal dimension was measured from 10 well developed grains as the distance from the base of the lower most of sterile lemma to the tip of the apiculus with Dial micrometer and expressed in mm.

3.2.2.15 Grain width (mm)

Lateral diameter measured from 10 matured spikelets as the distance between the two lateral sides in the middle part of the caryopsis with Dial micrometer and expressed in mm.

3.2.2.16 Grain L/B ratio

The L/B ratio was calculated by using the following formula of Murthy and Govindaswamy (1967).

$$\text{L/B ratio} = \frac{\text{Mean length of the grain in (mm)}}{\text{Mean breadth of the grain in (mm)}}$$

3.2.2.17 Grain yield per plant (g)

The matured panicles were harvested, threshed, cleaned and seed dried to 12% moisture level. The grain yield per plant was recorded in grams.

3.2.2.18 Meteorological observations

Meteorological observations were recorded for characters *i.e.*, minimum and maximum temperatures, relative humidity, rain fall, sunshine hours, and minimum and maximum wind velocity during crop period from metrological centre Nellore (IMD, Nellore weather research station).

3.2.2.3 Impact of Temperature on Rice

The optimum temperatures for anthesis are 30-33 °C and for ripening is 20-25 °C (Yoshida, 1981). At Agricultural Research Station, Nellore the maximum temperatures during anthesis and ripening of the present experiment was beyond 30 °C in almost all days (table no. 3.2) (fig. 3.2) indicating that the crop was subjected to the high temperatures during grain ripening. More over the wind velocity was also high *i.e.*, beyond 8 kmph in more than 30 days. These two factors had influence on the crop. The data was collected on different characters from the genotypes grown under these climatic conditions and it was subjected to various analysis.

3.3 STATISTICAL PROCEDURE

The data with respect to the above characters was subjected to the following analysis with the help of standard statistical procedures:

3.3.1 Analysis of Variance

Analysis of variance of the characters was done as per standard statistical procedure for randomized complete block design as given by Panse and Sukhatme (1967).

$$Y_{ij} = \mu + t_i + r_j + e_{ij}$$

Where,

Y_{ij} = Performance of i^{th} genotype in j^{th} block

μ = General mean

t_i = i^{th} genotype effect

r_j = j^{th} block effect

e_{ij} = Random error

The structure of analysis of variance was as follows.

ANOVA Table for Randomized Block Design

Source of variation	Degrees of freedom	Mean sum of squares	Expected mean sum of squares	“F” calculated value
Replications	r-1	M_r	$\sigma_e^2 + t \sigma_r^2$	M_r / M_e
Treatments	t-1	M_t	$\sigma_e^2 + r \sigma_g^2$	M_t / M_e
Error	(r-1)(t-1)	M_e	σ_e^2	
Total	(rt-1)			

Where,

r = Number of replications

g = Number of genotypes

M_r = Mean sum of square of replication

M_t = Mean sum of square of treatment

M_e = Mean sum of square of error

σ_e^2 = Environmental variance

σ_r^2 = Variance due to replications

σ_g^2 = Variance due to genotypes

3.3.2 Estimation of Genetic Parameters

In order to assess and quantify the genetic variability among the parents and F_1 s for the characters under study, the following parameters were estimated as given below.

3.3.2.1 Estimation of variance components

Phenotypic and genotypic variances were estimated using the following formula,

$$\text{Genotypic variance } (\sigma_g^2) = \frac{Mt - Me}{r}$$

$$\text{Phenotypic variance } (\sigma_p^2) = \sigma_g^2 + M_e = \frac{Mt - Me}{r} + M_e$$

The test of significance was carried out using ‘F’ table value of Fisher and Yates (1963).

3.3.2.2 Coefficient of variation

The genotypic and phenotypic coefficients of variation were calculated using the formula by Burton (1952).

$$PCV = \frac{\text{Phenotypic standard deviation } (\sigma_p)}{\text{General mean } (\bar{X})} \times 100$$

$$GCV = \frac{\text{Genotypic standard deviation } (\sigma_g)}{\text{General mean } (\bar{X})} \times 100$$

The GCV and PCV values were classified as described by Sivasubramanian and Menon (1973).

Classification	GCV/ PCV
Low	Less than 10%
Moderate	10 – 20%
High	More than 20%

3.3.2.3 Heritability

Heritability in broad sense was computed as the ratio of genetic variance to the total phenotypic variance and narrow sense heritability was the ratio of additive genetic variance to the total phenotypic variance as suggested by Hanson *et al.* (1956) and expressed as percentage.

$$h^2 (b) = \frac{\text{Genotypic variance } (\sigma_g^2)}{\text{Phenotypic variance } (\sigma_p^2)} \times 100$$

Heritability in broad sense was categorized as per the classification given by Johnson *et al.* (1955).

Classification	Heritability
Low	Less than 30%
Moderate	30 – 60%
High	More than 60%

3.3.2.4 Expected genetic advance

Genetic advance was calculated based on formula given by Johnson *et al.* (1955).

$$\text{Expected genetic advance (GA)} = K \times \sigma_p \times h^2$$

Where,

K = Selection differential at 5% selection intensity (2.06)

σ_p = Phenotypic standard deviation

h^2 = Heritability in broad sense

3.3.2.5 Genetic advance as per cent of mean (GAM)

$$\text{GAM} = \frac{\text{GA}}{\text{Grand mean } (\bar{X})} \times 100$$

Where,

GA = Genetic advance

$\bar{X}$ = Grand mean of the character

The range of genetic advance as per cent of mean was classified as suggested by Johnson *et al.* (1955).

Classification	GAM
Low	Less than 10%
Moderate	10 – 20%
High	More than 20%

3.3.3. GENETIC DIVERGENCE

3.3.3.1 Mahalanobis' D² analysis

The data collected on different characters was analyzed using Mahalanobis' D² analysis to determine the genetic divergence among the genotypes (Mahalanobis, 1928).

D² value between ith and jth genotypes for 'P' characters was calculated as

$$D_{ij}^2 = \sum_{t=1}^P (Y_i^t - Y_j^t)^2$$

Where,

Y_i^t is uncorrelated mean value of ith genotype for 't' characters

Y_j^t is uncorrelated mean value of jth genotype for 't' characters

D_{ij}^2 is D² between ith and jth genotypes.

The various steps involved in estimation of D² values are given below.

3.3.3.1.1 Test of significance

Variances were calculated for all the characters investigated and test of significance was done. Analysis of covariance for the character pairs was estimated on the basis of mean values (Panse and Sukhatme, 1967). After testing the difference between genotypes for each of the characters, a simultaneous test of significance for differences in the mean values of a number of correlated variables with regard to the pooled effect of characters was carried out using 'V' statistic, which in turn utilizes

Wilk's criterion. The sum of squares and sum of products of error and error + variety, variance and covariance matrix were used for this purpose. The estimation of Wilk's criterion was done using the following relationship.

$$\hat{\Lambda} = \frac{(E)}{(E+V)} = \frac{\text{Determinant of error matrix}}{\text{Determinant of error + variety matrix}}$$

Where,

$\hat{\Lambda}$ = Wilk's criterion

(E) = Determinant of error matrix and

(E+V) = Determinant of error + variety sum of squares and sum of product matrix.

$$V_{(Stat)} = -m \log_e \hat{\Lambda} = -[n-(p+q+1)/2] \log_e \hat{\Lambda}$$

Where,

$$m = n-(P+Q+1)/2$$

n = Degrees of freedom for error + varieties

$$\log_e \hat{\Lambda} = 2.3026 \log_{10} \hat{\Lambda}$$

P = Number of variables or characters (17)

Q = Number of variables – 1 (or d.f for varieties) (60-1=59)

V (Stat) is distributed as χ^2 with PQ (16 x 59 = 944) degrees of freedom.

Transformation of correlated variables

In the present model, computation of D^2 values were reduced to simple summation of the differences in the mean values of various characters of the two genotypes *i.e.*, $\sum d_i^2$. Therefore, transformation of the correlated variables into uncorrelated ones was done before working out the D^2 values. Transformation was done using pivotal condensation method.

3.3.3.1.2 Computation of D^2 values

For the given combination of i and j genotype, the mean deviation *i.e.*, $Y_i^t - Y_j^t$ for $t=1,2,\dots,p$ variables are computed and the D^2 values were calculated as

$$D_{ij}^2 = \sum_{t=1}^p (Y_i^t - Y_j^t)^2$$

Where,

Y_i^t is uncorrelated mean value of i^{th} genotype for character 't'

Y_j^t is uncorrelated mean value of j^{th} genotype for character 't'

D_{ij}^2 is D^2 between i^{th} and j^{th} genotype.

3.3.3.1.3 Testing the significance of D^2 values

The D^2 value obtained for a pair of population is taken as calculated value of χ^2 and is tested against the tabulated value of χ^2 for P degrees of freedom where P is the number of characters considered. In the present study P is 17.

3.3.3.1.4 Contribution of individual characters towards divergence

In all combinations, each character was ranked on the basis of its contribution towards divergence between two entries ($d_i = Y_i^t - Y_j^t$). Rank 1 is given to the highest mean difference and the rank P to the lowest difference, where, P is the total number of characters. Percentage contribution towards genetic divergence was calculated using the following formula.

$$\text{Percentage contribution of the character} = \frac{N}{M} \times 100$$

Where, N= Number of genotype combinations where the character was ranked first.

M = All possible combinations of number of genotypes considered.

3.3.3.1.5 Grouping of genotypes into various clusters

The grouping of genotypes into different clusters was done using the Tocher's method as described by Rao (1952). The criterion was that the two varieties belonging to the same cluster at least on an average show a smaller D^2 value than those belonging to different clusters. For this purpose D^2 values of all combinations of each genotype were arranged in ascending order of magnitude in a tabular form as described by Singh and Chaudhary (1977). To start with, two populations having the closest distance from each other were considered, to which the third population having the smallest D^2 value from the first two populations was added. Similarly, the next nearest fourth population was considered and this procedure was continued. At certain stage when it was felt that after adding a particular population there was an abrupt increase in the average D^2 , that population was not considered for including in that cluster. The genotypes of the first cluster were then eliminated and the rest were treated in a similar way. This procedure was continued till all the genotypes were included into one or other cluster.

3.3.3.1.6 Average intra- cluster distance

For the measurement of intra-cluster distances, the formula used was $\Sigma D_i^2/n$ where, ΣD_i^2 was the sum of distances between all possible combinations (n) of the populations included in a cluster.

3.3.3.1.7 Average inter cluster distance

Clusters were taken one by one and the distances from other clusters were calculated. The distance between two clusters was the sum of D^2 values between the members of one cluster to each of the members of the other clusters divided by the product of number of genotypes in both the clusters under consideration.

$$\text{Average inter-cluster distance} = \frac{D^2}{(n_1 \times n_2)}$$

Where, n_1 and n_2 are number of genotypes of two clusters.

D^2 = Difference in mean value between two populations when all the characters are considered simultaneously.

3.3.4 Correlation Studies

The phenotypic and genotypic correlation coefficients were worked out to determine the degree of association of a character with yield and also among the yield components by using covariance technique as per Falconer (1964).

$$\text{Phenotypic coefficients of correlation } (r_p) = r(x_i x_j)_p = \frac{\text{Cov}(x_i x_j)_p}{\left[V(x_i)_p \cdot V(x_j)_p \right]^{1/2}}$$

Where,

$r(x_i x_j)_p$ = Phenotypic correlation between i^{th} and j^{th} characters

$\text{Cov}(x_i x_j)_p$ = Phenotypic covariance between i^{th} and j^{th} characters

$V(x_i)_p$ and $V(x_j)_p$ = Phenotypic variance of i^{th} and j^{th} characters respectively

$$\text{Genotypic coefficients of correlation } (r_g) = r(x_i x_j)_g = \frac{\text{Cov}(x_i x_j)_g}{\left[V(x_i)_g \cdot V(x_j)_g \right]^{1/2}}$$

Where,

$r(x_i x_j)_g$ = Genotypic correlation between i^{th} and j^{th} characters

$\text{Cov}(x_i x_j)_g$ = Genotypic covariance between i^{th} and j^{th} characters

$V(x_i)_g$ and $V(x_j)_g$ = Genotypic variance of i^{th} and j^{th} characters respectively

3.3.4.1 Test of significance

Significance of correlation coefficients was tested by comparing phenotypic correlation coefficients with the table values (Fisher and Yates, 1963) at (n-2) degrees of freedom at 5% and 1% level where 'n' denotes the number of paired observations used in the calculation.

3.3.5 Path Coefficient Analysis

Path coefficient analysis was carried out by using the correlation coefficients to know the direct and indirect effects of the component characters on yield as suggested by Wright (1921) and illustrated by Dewey and Lu (1959).

Path coefficients were obtained by solving the simultaneous equations which express the basic relationship between correlations and path coefficients.

The equations are as follows:

$$\begin{aligned}
 r_{1,y} &= P_{1,y} + r_{1,2} P_{2,y} + r_{1,3} P_{3,y} + \dots + r_{1,k} P_{k,y} \\
 r_{2,y} &= r_{2,1} P_{1,y} + P_{2,y} + r_{2,3} P_{3,y} + \dots + r_{2,k} P_{k,y} \\
 &\cdot \quad \quad \cdot \quad \quad \cdot \quad \quad \cdot \quad \quad \cdot \\
 &\cdot \quad \quad \cdot \quad \quad \cdot \quad \quad \cdot \quad \quad \cdot \\
 &\cdot \quad \quad \cdot \quad \quad \cdot \quad \quad \cdot \quad \quad \cdot \\
 r_{k,y} &= r_{k,1} P_{1,y} + r_{k,2} P_{2,y} + r_{k,3} P_{3,y} + \dots + r_{k,k} P_{k,y}
 \end{aligned}$$

Where,

$r_{1,y}$ to $r_{k,y}$ = Correlation coefficients between independent characters

$r_{1,2}$ to $r_{k-1,k}$ = Correlation coefficients between all possible combinations of independent characters

$P_{1,y}$ to $P_{k,y}$ = Direct effects of characters 1 to k on character y

The residual effect was computed by using the formula

$$R = \left[1 - (P_{1,y} r_{1,y} + P_{2,y} r_{2,y} + P_{3,y} r_{3,y} + \dots) \right]^{1/2}$$

Where,

R = Residual effect

$P_{1,y}$ = Direct effect of independent character '1' on dependent character 'y'

$r_{1,y}$ = Correlation coefficient of independent character '1' on dependent character 'y'

Chapter IV

RESULTS AND DISCUSSION

The present investigation was carried out with 60 genotypes, at Agricultural Research Station, Nellore, Andhra Pradesh, during early *kharif* 2016 to know the variability, heritability, genetic advance, character association and direct and indirect effects for yield, yield contributing and physiological traits in rice.

The details of results obtained from the above investigation are discussed character-wise and presented here under in following headings.

4.1 Analysis of variance

4.2 Mean, variability, heritability and genetic advance as per cent of mean

4.3 Genetic divergence

4.4 Correlation

4.5 Path coefficient analysis

4.1 ANALYSIS OF VARIANCE

The analysis of variance revealed significant differences for all the 17 characters studied in 60 rice genotypes is furnished in Table 4.1 and mean performance in the table 4.2.

4.2 MEAN, GENETIC VARIABILITY, HERITABILITY AND GENETIC ADVANCE

The success of any breeding programme depends on presence of sufficient variability in the population and that the variability observed should be heritable with no or least influence by the environment. In addition to the genetic variability, knowledge on heritability and genetic advance helps the breeder to employ the suitable breeding strategy.

Genetic variability together with the heritability estimates would give a better idea on the amount of genetic gain expected out of selection (Burton, 1952 and Swarup and Chaugle, 1962). Further, the magnitude of heritable variability is the most important aspect (Panse and Sukhatme, 1967), which has close relationship with response to selection. Heritability estimates along with genetic advance are more helpful in

predicting the gain under selection than heritability estimates alone. However, it is not necessary that a character showing high heritability will always exhibit high genetic advance (Johnson *et al.*, 1955).

The details of mean values, analysis of variance, genetic variability, heritability and genetic advance as per cent of mean are presented in Table 4.1, 4.2 and 4.3 respectively. The estimates of variability revealed that PCV values slightly higher than GCV values indicating little role of environment in the expression of traits.

4.2.1 Days to 50% Flowering

In the present study, days to 50% flowering varied from 79.50 days (JGL 11118) to 109.50 days (NLR 3241) with a mean of 94.59. The estimates of GCV (5.84) and PCV (6.08) were low indicating less variation among the genotypes studied and high heritability (92%) coupled with moderate genetic advance as per cent of mean (11.57) was observed for this trait. The trait days to 50 % flowering indicates appropriate duration of the variety, which is an important criterion in rice breeding programmes to develop rice varieties with early to long duration. The PCV and GCV were low for this trait though the heritability was very high with moderate genetic advance indicating the operation of both additive and non additive gene actions, thus offering less scope for selection. Similar trend was observed by Khare *et al.* (2014).

4.2.2 Days to Maturity

Days to maturity varied from 107.50 days (JGL 11118) to 138.50 days (TN 1) with a mean of 123.05 days. The lower estimates of GCV (5.04), PCV (5.16) and high heritability (95%) coupled with moderate genetic advance as per cent of mean (10.14) was observed for this trait. Genotypes with low number of days to maturity indicate the earliness of a variety, which is a desirable criterion for developing of rice varieties suitable for early *kharif* season. The trait exhibited high heritability and moderate genetic advance indicating the operation of both additive and non additive gene actions in the inheritance and hence simple selection may not be rewarding. The above findings are in agreement with Aishwarya *et al.* (2014).

4.2.3 Plant Height (cm)

For early *kharif* season tall statured genotypes grow high and tend to lodge, hence short statured genotypes were desirable. The range of variability from 80.10 cm

(IR10F 221) to 133.25 cm (IR11C 208) was observed for plant height with a mean of 100.76 cm. The coefficient of variations for this trait were low with 9.10 for GCV and 9.71 for PCV. High heritability (88%) coupled with moderate genetic advance as per cent of mean (17.59) was observed for this trait indicates the operation of both additive and non additive gene actions in the inheritance of this trait, which were in accordance with Ullah *et al.* (2011), Singh *et al.* (2011) and Verma *et al.* (2011).

4.2.4 Number of ear bearing Tillers per Plant

The grain yield of any variety mainly depends upon the contribution of yield determining characters and among them ear bearing tillers per plant is important. The range of variation for number of ear bearing tillers per plant varied from 4.78 (ADT 45) to 8.07 (NLR 3042) with a mean of 6.34. The other genotypes which recorded more number of ear bearing tillers per plant were IR 11C 186 (7.57), NLR 3415 (7.35), NLR 3366 (7.35) and NLR 3412 (7.21). Moderate estimates of GCV (10.20), PCV (14.10), heritability (52%) and moderate genetic advance as per cent of mean (15.19) was observed for this trait indicates the predominance of additive and non additive gene actions in the inheritance of this trait. These findings are in accordance with Singh *et al.* (2011).

4.2.5 Panicle Length (cm)

Length of the panicle is an important yield contributing trait for which the range was from 18.00 cm (NLR 3367) to 26.45 cm (IR11C 228) with mean of 22.88 cm. The entries viz., MDT 10 (25.55), TN 1 (25.25), IR11C 228 (24.60), IR11C 208 (24.25) also recorded more panicle length. The estimates of GCV (6.06) and PCV (6.61) were low. The heritability was high (84%) and genetic advance as per cent of mean (11.45) was moderate for this trait. suggesting the role of both additive and non additive gene action in the inheritance of this trait. The above findings are in agreement with Padmaja *et al.* (2008), Shekawat *et al.* (2015), and Shankar *et al.* (2016).

4.2.6 Number of Filled Grains per Panicle

The range for number of filled grains per panicle is not only an index of the photosynthetic efficiency but also an indicator for source sink relationship of the plant was found to vary from 67.68 (IR10C 172) to 168.11 (NLR 3350), with a mean of 108.56. The other genotypes which recorded high number of filled grains per panicle were NLR 3042 (159.77), MDT 10 (148.35) and ADT 43 (147.74).

Moderate estimate of GCV (18.34) and higher estimate of PCV (21.20), heritability (75%) and genetic advance as per cent of mean (32.68) was observed for this trait revealing the preponderance of additive gene action, which may be exploited through simple selection procedures. These observations were in conformity with the results of Padmaja *et al.* (2008), Shankar *et al.* (2016), and Nayak *et al.* (2016).

4.2.7 Number of Ill-filled Grains per Panicle

The number of ill-filled grains per panicle is an undesirable character, the genotypes with less number of ill filled grains yields well in early *kharif* season. For this trait the range was from 9.51 (MTU 1010) to 51.40 (NLR 33057) with a mean of 22.79. High estimates of GCV (38.89), PCV (44.65), heritability (76%) and genetic advance as per cent of mean (69.78) were observed for this trait indicated the presence of wide variability among genotypes and suggesting the importance of additive gene action in the inheritance of this trait. These findings were in accordance with the results of Shrivastava *et al.* (2014), Hossain *et al.* (2015), Khatun *et al.* (2015).

4.2.8 1000 Grain Weight (g)

The 1000 grain weight ranged from 15.60 gm (JGL 1798) to 25.61 gm (IR109A 235) with a mean of 19.12 gm. Moderate GCV (13.69), PCV (14.04) and high heritability (95%) coupled with high genetic advance as per cent of mean (27.49) was observed for this trait, suggesting the role of additive gene action in the inheritance of this trait. Similar results were observed by Shekawat *et al.* (2015), Shankar *et al.* (2016) and Nayak *et al.* (2016).

4.2.9 Flag leaf length (cm)

The top three leaves especially flag leaf contributes most to grain yield (Ray *et al.*, 1983, Misra, 1986). Flag leaf photosynthesis activity has an important effect on rice grain yield. Flag leaf help in maintaining photosynthesis during the grain-filling period, this could increase yield capacity because photosynthesis during ripening contributes to grain carbohydrate by 60–100% (Yoshida, 1981). Abou-Khalifa *et al.* (2008) reported that flag leaf contributed to 45% of rice grain yield and, when removed, was the major component for yield loss. The flag leaf length ranged from 19.99 cm (IR11C 186) to 39.42cm (JGL 11118) with a mean of 28.26 cm. The GCV (12.88) and PCV (13.58) were moderate, whereas high heritability (90%) coupled with high genetic advance as per cent of mean (25.17) was observed for this trait indicates the role of additive gene

action in the inheritance of this trait. Kumar *et al.* (2011) and Aditya and Bhartiya *et al.* (2013) also reported similar results for this trait.

4.2.10 Flag leaf width (cm)

The flag leaf width ranged from 1.16 cm (NLR 3407) to 1.83 cm (NLR 3296) with a mean of 1.47 cm. The GCV (9.70) and PCV (10.64) were low and moderate, whereas high heritability (83%) coupled with moderate genetic advance as per cent of mean (18.23) was observed for this trait indicates role of both additive and non additive gene action in the inheritance of this trait. Similar trend was observed by Aditya and Bhartiya *et al.* (2013) and Kumar *et al.* (2015).

4.2.11 flag leaf area (cm²)

The flag leaf area ranged from 19.59 cm² (NLR 3407) to highest 42.73 cm² (JGL 11118) with a mean of 31.44 cm. The GCV (16.95) and PCV (18.38) were moderate, high heritability (85%) coupled with high genetic advance as per cent of mean (32.22) was observed for this trait indicates the role of additive gene action in the inheritance of this trait. These findings were in accordance with the results of Dhanwani *et al.* (2013).

4.2.12 SCMR

The rice plant at any point of time is composed of leaves of physiologically different ages, so it follows that the leaves differ in their contributions to the growth of the whole plant and its grain yield. SPAD chlorophyll meter reading is an indication of light transmittance characteristics of the leaf which is dependent on the leaf chlorophyll content (Richardson *et al.*, 2002). As the leaf chlorophyll content (Soil Plant Analytical Division value) is the best indicator of photosynthetic activity in rice, the chlorophyll content of rice after booting was determined.

SCMR was ranged from 29.90 (IR11C 219) to 45.27 (ADT 37) with a mean of 36.27. The other genotypes with high SCMR were NLR 3042 (42.25), JGL11118 (45.15), and NLR 3411 (40.39). The GCV (6.74) and PCV (8.14) were low, whereas high heritability (68%) and moderate genetic advance as per cent of mean (11.48) were observed for this trait. High heritability coupled with moderate genetic advance as per cent of mean for this trait indicated the role of both additive and non additive gene action in the expression of this character. High SCMR values maintains strong source

sink relationship leading to increased grain yield for which, high values of heritability was also observed earlier by Ullah *et al.* (2011).

4.2.13 Harvest Index (%)

Grain yield in rice related to biological yield and harvest index. Harvest index is directly proportional to grain yield. Harvest index ranged from 33.68 (NLR 3367) to 64.49 (NLR 40024) with a mean of 49.35. The other genotypes with more harvest index were NLR 3354 (64.24), HH25-DT20-DT2-DT1 (63.75), ADT 37 (62.45), IR 62 (61.89) and NLR 33358 (61.01). For harvest index GCV (13.21), PCV (17.38) and heritability (58%) were moderate coupled with high genetic advance as per cent of mean (20.67) indicating the preponderance of both additive and non additive gene actions and further improvement of this character would be possible through heterosis breeding rather than simple selection. These findings were in line with the results of Karim *et al.* (2007).

4.2.14 Grain length (mm)

The grain length ranged from 7.14 mm (NLR 3367) to 9.96 mm (BG367-2) with a mean of 8.32 mm. Low GCV (8.44), PCV (8.80) and high heritability (92%) coupled with moderate genetic advance as per cent of mean (16.68) was observed for this trait indicates role of both additive and non additive gene action in the inheritance of this trait. Which were in accordance with the results of Gokulakrishnan *et al.* (2014).

4.2.15 Grain width (mm)

The grain width ranged from 1.97 mm (White ponni) to 2.83 mm (IR10F 221) with a mean of 2.34 mm. The GCV (6.77) and PCV (7.48) were low, high heritability (82%) coupled with moderate genetic advance as per cent of mean (12.62) was observed for this trait indicates role of both additive and non additive gene action in the inheritance of this trait. These findings were in accordance with the results of Gangashetty *et al.* (2013) and Vanaja and Babu (2006).

4.2.16 Grain L/B Ratio

The grain L/B ratio ranged from 2.57 mm (IR10F 221) to 4.38 mm (IR109A235) with a mean of 3.59 mm. The GCV (11.43) and PCV (12.19) were moderate, and high heritability (88%) coupled with high genetic advance as per cent of mean (22.07) was

observed for this trait indicates the role of additive gene action in the inheritance of this trait. Similar results were reported by Gokulakrishnan *et al.* (2014).

4.2.17 Grain Yield per Plant (g)

The range of variation for grain yield per plant varied from 9.64 gm (ADT 45) to 22.72 gm (NLR 3042) with a mean of 12.84 gm. Moderate estimates of GCV (13.92) PCV (18.48), and Moderate heritability (57%) coupled with high genetic advance as per cent of mean (21.59) indicates role of additive and non additive gene action in the inheritance of this trait. These findings were in accordance with the results of Mamtasingh *et al.* (2007) and Satishchandra *et al.* (2009).

The estimates of PCV and GCV were high for Number of ill-filled grains per panicle. Moderate PCV and GCV were observed for flag leaf length, effective tillers per plant, grain yield per plant, test weight, grain L/B ratio, flag leaf area, and harvest index. High PCV and Moderate GCV were observed for number of filled grains per panicle. Moderate PCV and low GCV were observed for flag leaf width while, low PCV and GCV were observed for days to 50 % flowering, days to maturity, plant height, panicle length, SCMR, grain length, and grain width.

PCV values were close to GCV for the traits, days to 50% flowering, days to maturity, plant height, panicle length, flag leaf length, flag leaf width, 1000 grain weight, grain length, grain width, grain L/B ratio exhibiting little or no influence of environment on these traits, while for the traits, flag leaf area, effective tillers per plant, filled grains per panicle, ill filled grains per panicle, SCMR, grain yield per plant, harvest index, PCV was higher than GCV indicating the effect of environment in expression of these traits.

The estimates of heritability and genetic advance as per cent of mean were high for the characters viz., number of filled grains per panicle, number of ill filled grains per panicle, 1000 grain weight, flag leaf length, flag leaf area, and grain L/B ratio indicating the influence of additive gene action in the inheritance of these traits hence simple selection would be rewarding.

High heritability coupled with moderate genetic advance as per cent of mean was observed for days to 50% flowering, days to maturity, plant height, panicle length, flag leaf width, SCMR, grain length, and grain width. Moderate heritability coupled with high genetic advance as per cent of mean observed for harvest index and grain

yield per plant. Moderate heritability coupled with moderate genetic advance as per cent of mean observed for effective tillers per plant. Involvement of both additive and non additive gene action in the inheritance of all these traits thus simple selection may not be effective instead population improvement for these traits would be desirable.

4.3 GENETIC DIVERGENCE

For a successful breeding programme, the diversity of parents is of utmost importance, since the crosses made between the parents with maximum genetic divergence would more likely to yield desirable recombinants in the progenies. However, it is desirable to select suitable genetically divergent parents, based on information about the genetic variability and genetic diversity present in the available germplasm (Singh and Chaudhary 1997).

Generally, geographical diversity was considered as a measure of genetic diversity when no scientific tools were available. However, this is an inferential criterion and may not be useful for discrimination among the population occupying ecologically marginal habitats. The variability among different genotypes of a species often reflects the genetic diversity of different characters considered in totality. One of potent techniques of measuring genetic diversity is the D^2 statistic proposed by Mahalanobis in 1936. This technique measures the forces of differentiation at two levels, namely intra cluster and inter cluster level, thus help in selection of genetically divergent parents for their exploitation in hybridization. D^2 statistic measures the degree of diversification and determines the relative importance of each character to total divergence. The present investigation was taken up to ascertain the nature and magnitude of divergence for rice yield and its attributing characters to such genetic diversity. The material for present study consisted of 60 genotypes of rice collected from different geographical regions. The data collected on the 17 characters including yield attributing and physiological traits from 60 rice genotypes were subjected to multivariate analysis using D^2 statistic, to assess the diversity of 60 rice genotypes and identify promising genotypes suitable for early *kharif* season characterized by high temperatures and high velocity winds.

4.3.1 Test with wilk's criterion

Wilk's 'V' (statistic) criterion was used to test the significant differences between the groups based on the pooled effects of all the characters. The significance of

‘V’ (statistic) value was tested by per cent (%) at 944 degrees of freedom. The ‘V’ statistic value was highly significant indicating that the genotypes differed significantly when all the characters were considered simultaneously. The significance of 60 genotypes in the analysis of variance of dispersion clearly indicated the significant pooled effect of all the characters studied between different genotypes. Hence, further analysis was made to estimate D^2 analysis.

4.3.2 Mahalanobis’s generalized distance D^2 values

In order to assess the genetic diversity among 60 genotypes, D^2 statistic was used following the procedure given by Rao (1952). Since the entire 17 characters were correlated, they were transformed into uncorrelated linear combination via pivotal condensation method.

4.3.3 Grouping of genotypes into various clusters

The 60 genotypes were grouped into eight clusters using the Tocher's method with the criterion that the intra-cluster average D^2 values should be less than inter-cluster D^2 values. The distribution of 60 genotypes into eight clusters was random and presented in Table 4.4.

Out of eight clusters, cluster I was largest with maximum number of twenty seven genotypes among which MTU 1010 and MDT 6 from RARS Maruteru, NLR 33359, NLR 3414, NLR 3413, NLR 4002, NLR 3242, NLR 3411, NLR 33671, NLR 3407, NLR 34303, NLR 40058, NLR 3366, NLR 3412, NLR 3217, NLR 3415 and NLR 3302 were from ARS, Nellore, IR11C 202, IR11C 214, IR10C 172, IR11C 221, IR11C 219, IR11C 228, IR11C 186, HHZ5-DT20-DT2-DT1, IR 62 and IR 64 were from IRRI, Philippines, based on magnitude of D^2 values.

Cluster II, which possess twenty five genotypes. Among them, White ponni and ADT 43 were from TRRI, Aduthurai, TN1 from Taichung District Agricultural Improvement Station, Taiwan, MDT 10 from RARS, Maruteru, IR10F 221 from IRRI, Philippines and NLR 3251, NLR 3369, NLR 3246, NLR 3354, NLR 3353, NLR 3410, NLR 3417, NLR 3296, NLR 40024, NLR 40065, NLR 34242, NLR 3042, NLR 3408, NLR 30491, NLR 3350, NLR 3367, NLR 33358, NLR 3241 and NLR 34449 were from ARS, Nellore and JGL 1798 from RARS, Jagityal.

Cluster III was solitary cluster consists of single genotype IR 109A235 from IRRI, Philippines. Cluster IV with single genotype ADT 45 from TRRI, Aduthurai.

Cluster V has single genotype IR 11C 208 from IRRI, Philippines. Cluster VI comprising of three genotypes BG 367-2 from Srilanka and IR 64197-3B-15-2 were from IRRI, Philippines and NLR 33057 from ARS, Nellore. Cluster VII has single genotype ADT 37 from TRRI, Aduthurai and Cluster VIII has single genotype JGL 11118 which is from RARS, Jagityala.

The cluster analysis revealed that most of the genotypes were fall in two clusters only *i.e.*, 27 into cluster I and 25 into cluster II. Clusters III, IV, V, VII and, VIII were solitary clusters containing only one genotype and three genotypes from different origins were grouped into Cluster VI. Similar results of 3 clusters with single genotype each were earlier reported by Bhutia *et al.* (2005).

The pattern of distribution of genotypes into various clusters was at random indicating that geographical and genetic diversity was not related, as genotypes from diverse source were grouped into the same clusters *viz.*, I, II and VI, and genotypes from similar origin were grouped into different clusters evidenced by the distribution of genotypes developed at Agriculture research station, Nellore into different clusters *viz.*, cluster I, II and VI. Bhatt (1970) and Raut *et al.* (1985) suggested that genetic drift and artificial selection could cause greater diversity than geographic distances. The genotypes grouped into different clusters are more divergent than that one's which are placed in same clusters. These results were in accordance with Kar *et al.* (2013), Karupaiyan *et al.* (2013) and Beevi and Venkatesan (2015).

4.3.4 Average intra and inter cluster D^2 values

The average intra and inter cluster D^2 values estimated as per the procedure given by Singh and Chaudhary (1977) and were presented in Table 4.10. Intra-and inter-cluster distance of 60 rice genotypes showed in Fig. 4.3. Dendrogram represented relationship among 60 rice genotypes in eight clusters based on Mahalanobis's D^2 values are presented in Fig. 4.5.

The intra cluster D^2 values ranged from 0.00 for (clusters III, IV, V VII and VIII), to 205.19 for (cluster VI), followed by 105.51 for (cluster II) and 102.06 for (cluster I). While the high intra cluster distance in cluster VI indicated the presence of wide genetic diversity among the genotypes *viz.*, NLR 33057, BG 367-2 and IR64197, it could be due to heterogeneity, genetic architecture of the population, past history of the selection in development traits and degree of combining ability (Dikshit and Swain,

2000). Cluster mean values showed wide range indicating the presence of variation among the genotypes studied.

From the inter cluster D^2 values of eight clusters, it can be seen that the highest divergence occurred between cluster III and cluster VIII (839.69) followed by cluster V and cluster VIII (838.74), cluster IV and cluster V (718.24), cluster III and cluster IV (697.48), cluster IV and cluster VI (636.84), cluster VI and cluster VIII (624.24) and cluster VI and cluster VII (614.75), which indicated that the parents selected from these clusters in crossing programme would give high heterotic response and thus desirable combinations. The lowest divergence was noticed between cluster IV and VII (146.02) followed by cluster I and II (168.17), cluster I and III (194.51) and cluster IV and cluster VIII (202.75). Parents selected from these clusters in crossing programme may not result in desirable consideration in desired direction as they were very closely related without much divergence. These results were in accordance with Chaturvedi and Maurya (2005).

4.3.5 Cluster mean values of characters

For a successful breeding programme selection of genetically diverse parents is an important prerequisite so as to obtain better and desirable recombinants. The cluster mean values for 17 characters are presented in Table 4.6. The data indicated a wide range of mean values between the characters under study. Days to 50% flowering had a range of 79.50 (cluster VIII) to 100.50 days (cluster III), days to maturity had a range of 107.50 days (cluster VIII) to 128.50 days (cluster III), plant height (cm) varied from 84.20 (cluster IV) to 133.25 (cluster V), number of ear bearing tillers per plant had a range of 4.79 (cluster IV) to 6.64 (cluster III), Panicle length (cm) varied from 21.00 (cluster IV) to 24.25 (cluster V), number of filled grains per panicle had a range from 92.56 (cluster V) to 122.28 (cluster II), ill filled grains per panicle recorded as 11.42 (cluster VII) to 34.08 (cluster III), 1000 grain weight (g) ranged from 16.55gm (cluster VIII) to 25.62 gm (cluster III), flag leaf length (cm) varied from 24.25 (cluster III) to 39.42 (cluster VIII), flag leaf width (cm) ranged from 1.28 (cluster V) to 1.55 (cluster II), flag leaf area(cm^2) ranged from 24.45 (cluster III) to 42.73 (cluster VIII), SCMR had a range of 32.78 (cluster IV) to 45.28 (cluster VII), harvest index (%) varied from 39.98 (cluster V) to 62.45 (cluster VIII), grain length (mm) had a range of 7.32 (cluster VII) to 9.84 (cluster III), grain width had a range of 2.02 mm (cluster VIII) to 2.76 mm (cluster IV), grain L/B ratio varied from 2.77 (cluster IV) to 4.38 for (cluster III) and

grain yield per plant varied from 9.64 g (cluster IV) to 16.39 g (cluster III). The cluster mean values showed wide range among the genotypes studied, which indicates that genetic differences among the clusters were also reflected in the cluster means.

It is observed that cluster III consists of only one genotype namely IR109A235 had recorded highest mean values for most of the characters like days to 50% flowering, days to maturity, grain length and grain L/B ratio, hence selection of this genotype for direct use may be beneficial. Whereas cluster II had highest mean values for flag leaf width, filled grains per panicle, cluster IV for grain width, cluster V for plant height, panicle length, cluster VII for SCMR, harvest index, and cluster VIII for flag leaf length and flag leaf area. Therefore, hybridization between the selected genotypes from divergent clusters is essential to judiciously combine all the targeted traits.

Whereas lowest cluster means were observed in cluster III for flag leaf length and flag leaf area, cluster IV contain lowest means for traits plant height, panicle length, ear bearing tiller per plant, SCMR, grain yield per plant and grain L/B ratio, cluster V for flag leaf width, number of filled grains per panicle and harvest index, cluster VII for number of ill filled grains per panicle and grain length and finally cluster VIII for days to 50 % flowering, days to maturity, 1000 grain weight and grain width.

4.3.6 Relative contribution of individual characters towards divergence

The per cent contribution towards genetic divergence by all the 17 characters is presented in Table 4.7. The trait 10000 grain weight (23.45) showed maximum contribution towards genetic divergence followed by flag leaf width (22.43) days to maturity (11.41), flag leaf length (9.55), grain width (7.63), grain yield per plant (6.84), grain length (3.22), harvest index (3.16), plant height (2.77), ill filled grains per panicle (2.49), panicle length (1.92), ear bearing tillers per plant (1.36), filled grains per plant (1.36), days to 50% flowering (1.24), SCMR (0.73), flag leaf area (0.28) and grain L/B ratio (0.17).

Out of 17 characters studied the maximum contribution (74.47%) towards total divergence is by 4 characters only. They are test weight, flag leaf width, flag leaf length and days to maturity. These characters should be taken into consideration while selecting parents for hybridization. On the other hand low contributing characters towards total genetic diversity were SCMR, flag leaf area and grain L/B ratio. Senapathi

and Sarkar (2005) reported that the trait 1000 grain weight was the highest contributor to total genetic divergence. Devi *et al.* (2006) reported flag leaf length and flag leaf width were the highest contributors to total genetic divergence. While Garg *et al.* (2011) reported days to maturity was the highest contributor to total genetic divergence, Ubarhande *et al.* (2009) reported that grain characters like grain length and grain width were the highest contributors to total genetic divergence and Sankar *et al.* (2005) reported grain yield per plant and grains per panicle were the major characters contributing towards divergence.

From the cluster analysis it was observed that there was high variability was observed between the genotypes in different clusters for different traits. The main aim of this study was to develop varieties suitable for early *kharif* season, so the selected genotypes should contained characters like early maturity, more number of ear bearing tillers per plant, high panicle length, more number of filled grains per panicle, high 1000 grain weight, and more grain yield per plant and physiological characters like high SCMR, high harvest index, high flag leaf area and low flag leaf length would be desirable for this season.

Cluster III (IR 109A235) and VIII (JGL 11118) had majority of the above mentioned desirable characters. Apart from this, these clusters also had highest inter cluster distance between them and followed by cluster V (IR 11C 208) and VIII (JGL 11118). Based on these studies crosses involving genotypes from these clusters would give wider and desirable recombinations. Recombination breeding among genotypes belonging to cluster VI having maximum intra cluster distance can improve the yield potential.

4.4 CORRELATION

Crop yield is the end product of the interaction of a number of other, often interrelated attributes. A thorough understanding of interaction of characters among themselves had been of great use in plant breeding. The cumulative effects of such characters determine the dependent variable yield. These characters play an important role in modification of yield as a whole in magnitude as well as in desired direction. Further, direct selection for seed yield is not effective as it is a complex quantitative character and much influenced by environment. The change in one character brings about a series of changes in other characters, since they are interrelated. Therefore, the

study of correlation between yield and yield components are of considerable importance in selection programmes.

Correlation studies would provide reliable information on nature, extent and the direction of selection, especially when the breeder needs to combine high yield potential with desirable agronomic traits. In the present study genotypic correlation coefficients in most cases were higher than their phenotypic correlation coefficients indicating elimination of environmental effects led to strengthen genetic association and these characters are positive governed by additive gene action and are useful in improvement. In some cases phenotypic correlation coefficient were higher than genotypic correlation indicating suppressing effect of the environment which modified the expression of the characters at phenotypic level. The genotypic and phenotypic correlation coefficients among yield and its component characters are presented in the table 4.8 and 4.9.

4.4.1. Days to 50% flowering

In the present investigation days to 50% flowering had significant positive correlation with days to maturity (0.8490**/0.8964**), plant height (0.3147**/0.3380**), flag leaf width (0.2388**/0.2246*), grain length (0.1876*/0.2099*) and grain L/B ratio (0.2099*/0.2355**) at both phenotypic and genotypic levels. Similar association of days to 50% flowering with plant height and grain L/B ratio were also reported by Bekele *et al.* (2013), with grain length by Sadeghi (2011), with days to maturity by Sadeghi (2011) and Bekele *et al.* (2013) and with flag leaf width by Reddy *et al.* (2013).

Days to 50% flowering showed significant negative correlation with grain width (-0.1934*/-0.2211*) at both phenotypic and genotypic levels, and at genotypic level with harvest index (-0.2339*). Sadeghi (2011) and Bekele *et al.* (2013) reported negative significant correlation of days to 50% flowering with grain width. Sravan *et al.* (2012) reported negative but non significant correlation with harvest index.

This trait showed positive but non significant association with panicle length (0.1099/0.1032), flag leaf area (0.1282/0.1130), number of filled grains per panicle (0.0578/0.0403) and test weight (0.1309/0.1257). Similar association of days to 50% flowering with panicle length observed by Kishore *et al.* (2015) and Shankar *et al.* (2016), with number of filled grains per panicle and test weight by Sridhar *et al.* (2016) at phenotypic level and Shankar *et al.* (2016) at both phenotypic and genotypic levels

and with flag leaf area by Mohekar *et al.* (2015), Bekele *et al.* (2013) and Sadeghi (2011) at both phenotypic and genotypic levels.

As majority of the genotypes studied were of early maturing types, hence positive correlation exists between days to maturity there by more plant height, more flag leaf width, more grain length and more grain L/B ratio and ultimately lead to increase in grain yield per plant. However the correlation between days to 50% flowering and grain yield per plant was positive non-significant (0.1565/0.1205) as supported by Chandra *et al.* (2009), Rangare *et al.* (2012) and Nagaraju *et al.* (2013).

4.4.2 Days to maturity

Days to maturity was having significant positive correlation with plant height (0.2328*/0.2509*), flag leaf area (0.1971*/0.1944*) and flag leaf width (0.2609*/0.2672*) at phenotypic and genotypic levels. Similar results were reported by Ahamed *et al.* (2015) for flag leaf area, Aditya and Bhartiya (2013) for flag leaf width at phenotypic level and Sanghera *et al.* (2013) reported positive non significant correlation with plant height.

The association of day to maturity with rest of the characters viz., panicle length (0.1694/0.1678), flag leaf length (0.0741/0.0561), number of filled grains per panicle (0.1198/0.1490), 1000-grain weight (0.0993/0.0970), grain length (0.0957/0.1049), grain L/B ratio (0.1100/0.1349) and with grain yield per plant (0.1430/0.1761) was positive non significant at both phenotypic and genotypic levels. However Sanghera *et al.* (2013) reported positive significant association with panicle length and positive non significant association with number of filled grains per panicle and grain L/B ratio. The positive non significant association of days to maturity with other characters viz., 1000 grain weight, grain length and grain yield were also reported by Mohekar *et al.* (2015), Bekele *et al.* (2013) and Sadeghi (2011) at both phenotypic and genotypic levels respectively. Aditya and bharitya (2013) reported significantly positive association of day to maturity with flag leaf length.

The correlation of day to maturity with number of ear bearing tillers (-0.0576/-0.1054), SCMR (-0.0687/-0.0683), grain width (-0.1101/-0.1480) and harvest index (-0.1385/-0.1891) was negative non significant. Similar results were earlier observed by Mohekar *et al.* (2015) with harvest index and negative significant

association of days to maturity with grain width by Sanghera *et al.* (2013) and Bekele *et al.* (2013).

The positive significant association of days to maturity with plant height, flag leaf width and flag leaf area indicates the importance of days to maturity in getting more biomass finally more grain yield. However the association between days to maturity and grain yield per plant in present study was positive non significant. Whereas Rashid *et al.* (2014) and Bornare *et al.* (2014) reported significant positive association.

4.4.3 Plant height (cm)

The correlation of plant height with panicle length (0.6111**/0.6956**), 1000 grain weight (0.2332*/0.2703*) and grain length (0.2887**/0.3179**) was significant positive at phenotypic and genotypic levels. Significant positive correlation of plant height with panicle length was in corroboration with Sadeghi (2011), Sravan *et al.* (2012), Sanghera *et al.* (2013), Hossian *et al.* (2015) and Shankar *et al.* (2016). Borbora *et al.* (2005), Minnie *et al.* (2013) and Sravan *et al.* (2012) and Bekele *et al.* (2013) reported similar association with 1000 grain weight. There was significant negative association with number of ear bearing tillers per plant (-0.3485**) at genotypic level. High accumulation of photosynthetic assimilates in vegetative parts *i.e.*, unproductive tillers rather than reproductive tillers might be the reason for negative association with ear bearing tillers. Similar results were earlier reported by Binse *et al.* (2006) and Bekele *et al.* (2013). The association of plant height with harvest index was (-0.0527/-0.0614) negative non significant at both phenotypic and genotypic levels.

The other correlations of plant height with flag leaf length (0.1022/0.0712), flag leaf width (0.0942/0.0104), flag leaf area (0.1193/0.0480), number of filled grains per panicle (0.0657/0.0423), number of ill filled grains per panicle (0.1142/0.1603) and grain width (0.0158/0.0113) was positive non significant. These results were in accordance with Shankar *et al.* (2016), Sadeghi (2011) and Kishore *et al.* (2015) for number of filled grains per panicle, Shankar *et al.* (2016), Sadeghi (2011) for grain width, Mohekar *et al.* (2015) for flag leaf length, Mohekar *et al.* (2015) and Naseem *et al.* (2014) for flag leaf area, Srijan *et al.* (2016) for flag leaf width at genotypic level. However Hossain *et al.* (2015) reported negative non significant association of plant height with number of ill filled grains per panicle.

This trait showed positive significant correlation (0.1800*) with grain L/B ratio at genotypic level and positive non significant correlation (0.1505) at phenotypic level with grain L/B ratio, where as Srijan *et al.* (2016) observed positive significant association at phenotypic level and positive non significant association at genotypic level for this trait. The association of plant height with SCMR showed positive non significant correlation (0.0019) at genotypic level and negative non significant correlation (-0.0487) at phenotypic level and finally the correlation with grain yield per plant was positive non significant at phenotypic level (0.0824) and negative non significant association (-0.0038) at genotypic level. These results were in conformity with Ullah *et al.* (2011) and Malath and Gomathinayagam (2013) for SCMR at genotypic level. Further Rani and Reddy (2010) and Rangare *et al.* (2012) recorded positive non significant association of plant height with grain yield at phenotypic and genotypic levels. The association of plant height with grain yield per plant at genotypic level was supported by Laxuman *et al.* (2011) and at both levels by Seyoum *et al.* (2012). Different types of association of plant height with other characters at phenotypic and genotypic levels may be due to intensity of modifying effect of environment at various levels.

These results showed that increase in plant height would leads to increase in panicle length, 1000 grain weight, and grain length because of significant positive association of plant height and other traits at phenotypic and genotypic level. However, there is non significant negative association of plant height with grain yield per plant in present study may be due to the significant negative association observed between plant height with ear bearing tillers per plant.

4.4.4 Number of Ear bearing Tillers per Plant

The trait number of ear bearing tillers per plant showed positive significant association with 1000 grain weight (0.1921*) and harvest index (0.2118**) at genotypic level. However Shankar *et al.* (2016) and Sravan *et al.* (2012) reported similar association at both phenotypic and genotypic levels. Whereas, it showed negative significant association with filled grains per panicle (-0.3967**/-0.3904**) and flag leaf area (-0.2728**/-0.4127**) at both phenotypic and genotypic levels, might be due to the fact that the tillers had not produced the grains in proportionate ratio due to negative association of flag leaf area. These results were in accordance with Kishore *et al.* (2015), Hossian *et al.* (2015) and Shankar *et al.* (2016).

The association of ear bearing tillers per plant with 1000 grain weight was positive significant (0.1921*) at genotypic level which was masked by the environmental effects such as high temperatures ($> 30^{\circ}\text{C}$) resulted in non significant positive correlation (0.1439) at phenotypic level. The association of ear bearing tillers per plant with grain length (0.1058/0.0950) was positive non significant, with grain width was negative non significant (-0.0564/-0.0668) and with grain L/B ratio was positive non significant (0.1502/0.1332) at both levels. Bekele *et al.* (2013) also showed similar results with grain length, grain width and grain L/B ratio. The positive association of ear bearing tillers per plant with 1000 grain weight was reported by Panwar (2006), Panwar and Ali (2007), Rani and Reddy (2010), Garg *et al.* (2010) and Kishore *et al.* (2015).

The association of ear bearing tillers per plant was negative non significant with number of ill filled grains per panicle (-0.1481/-0.1750) and flag leaf width (-0.0437/-0.1047) at both phenotypic and genotypic levels, whereas with SCMR (-0.0427) at phenotypic level only. These results were in corroboration with Sadeghi (2011) and Srijan *et al.* (2016) for flag leaf width. Ullah *et al.* (2011) and Malath and Gomathinayagam (2013) also observed similar association of ear bearing tillers per plant with SCMR at genotypic level.

Ear bearing tillers per plant had positive significant association with grain yield (0.4087**/0.3914**) at both phenotypic and genotypic levels. The results were in accordance with Eradasappa *et al.* (2007), Kumar *et al.* (2013), Rashid *et al.* (2014), Bornare *et al.* (2014), Kishore *et al.* (2015), Hossian *et al.* (2015) and Shankar *et al.* (2016).

Though there was significant negative correlation between ear bearing tillers per plant and filled grains per panicle, its association with other characters like 1000 grain weight and harvest index and grain yield per plant was significant positive, indicating that selection for high grain yield per plant based on number of effective tillers per plant is beneficial.

4.4.5 Panicle Length (cm)

Panicle length was an important yield contributing character had positive significant association with 1000 grain weight (0.2434*/0.2671**), grain length (0.2295**/0.2753**) and grain yield (0.2491**/0.2936**) at phenotypic and genotypic

levels. Hasib (2005), Borbora *et al.* (2005), Panwar and Ali (2007), Babu *et al.* (2012), Minnie *et al.* (2013) and Shankar *et al.* (2016) reported similar association of panicle length with 1000 grain weight. Its association with grain length was in accordance with Sadeghi (2011). Similar result of positive significant association of panicle length with grain yield per plant was reported by Sravan *et al.* (2012), Sanghera *et al.* (2013) and Shankar *et al.* (2016).

Panicle length showed negative significant association with ill filled grains per panicle (-0.1952*) at genotypic level, as observed by Prasad *et al.* (2015). The association of panicle length with other characters like flag leaf length (0.0163/0.0158), flag leaf width (0.0146/0.0144), flag leaf area (0.0048/0.0160), number of filled grains per panicle (0.01236/0.1076), grain width (0.0186/0.0377), grain L/B ratio (0.1308/0.1456) and harvest index (0.0787/0.1266) was positive non significant at phenotypic and genotypic levels. These results are supported by Kishore *et al.* (2015) for number of filled grains per panicle, Mohekar *et al.* (2015) for flag leaf length and flag leaf area. Whereas, Sravan *et al.* (2012) reported positive significant association of panicle length with harvest index.

Panicle length can be considered as one of the important attribute for improvement of grain yield due to its significant positive association with traits such as grain length, 1000 grain weight, flag leaf area and grain yield.

4.4.6 Number of Filled Grains per Panicle

Number of Filled grains per panicle is one of the most important yield contributing trait, and its association was positive significant with flag leaf length (0.2340*/0.2562**) and grain yield (0.4270**/0.3738**) at both phenotypic and genotypic levels. It showed genotypic positive significant association with SCMR (0.2573**) and flag leaf width (0.3816**), whereas phenotypic positive significant association with harvest index (0.2050*). Similar association of number of filled grains per panicle with flag leaf length was reported by Sadeghi (2011) and Sadeghi (2011) and Srijan *et al.* (2016) for flag leaf width at both levels. Chakraborty *et al.* (2010), Sudharani *et al.* (2012) and Saikumar *et al.* (2014) reported similar association of number of filled grains per panicle with harvest index. Genotypic positive significant association of number of filled grains with SCMR was in accordance with Sudharani *et al.* (2012) and Gopikannan and Ganesh (2013).

Its association with four important grain characters namely 1000 grain weight (-0.5523**/-0.6734**), Grain length (-0.4625**/-0.5012**), grain width (-0.1803*/-0.2388*) and grain L/B ratio (-0.2504**/-0.2565**) was negative significant at both phenotypic and genotypic levels. These results are supported by Srijan *et al.* (2016) for grain length, Sadeghi (2011) for grain width and Garg *et al.* (2010) and Kishore *et al.* (2015) for 1000 grain weight.

In the present study, the significant positive association of number of filled grains per panicle with flag leaf characters like flag leaf length, flag leaf width and flag leaf area clearly explains that the dependence of this trait on physiological characters to attain effective grains finally, it leads to increased grain yield per plant. Hence, these associations were considered to be desirable. The results were in accordance with Panwar (2006), Panwar and Ali (2007), Eradasappa *et al.* (2007), Sadeghi (2011), Sanghera *et al.* (2013), Kishore *et al.* (2015) and Shankar *et al.* (2016).

4.4.7. Number of Ill filled Grains per Panicle

Number of ill filled grains per panicle showed positive significant association with flag leaf length (0.1942*) at genotypic level and positive non significant with grain length (0.0214/0.0232) and grain L/B ratio (0.0488/0.0718). The trait number of ill-filled grains per panicle showed negative non significant association with the characters namely, flag leaf width (-0.1188/-0.1234), SCMR (-0.0481/-0.1376-), 1000 grain weight (-0.0822/0.0975), grain width (-0.0451/-0.0776), harvest index (-0.0177/-0.1123) and grain yield (-0.0185/-0.0265) at phenotypic and genotypic levels. Its association with grain yield was in corroboration with Ratna *et al.* (2015).

4.4.8. 1000 Grain Weight (g)

The trait 1000 grain weight had phenotypic and genotypic positive significant association with grain characters like grain length (0.7204*/0.7702), grain width (0.2176*/0.2484**), grain L/B ratio (0.3909**/0.4313**), harvest index (0.2418*/0.2230*) and finally with grain yield (0.2084*/0.2056*), indicating that all these characters were important for yield improvement. Hence, these characters could be considered as selection criteria for higher yield as these were mutually and directly associated with grain yield. Similar association of 1000 grain weight with grain length, grain width and grain L/B ratio were reported by Bekele *et al.* (2013) and Nikam *et al.* (2014). Sravan *et al.* (2012) reported similar association with harvest index. Positive

significant association of 1000 grain weight with grain yield were earlier presented by Sravan *et al.* (2012), Seyoum *et al.* (2012), Gangashetty *et al.* (2013), Sudharani *et al.* (2012), Rashid *et al.* (2014) and Shankar *et al.* (2016).

1000 grain weight also recorded phenotypic and genotypic negative significant association with flag leaf length ($-0.2144^*/-0.2330^*$), flag leaf width ($-0.2100^*/-0.2464^{**}$) and flag leaf area ($-0.2861^*/-0.3242^{**}$). The negative association of 1000 grain weight with all the flag leaf characters, may be due to the effect of high temperatures during grain ripening phase only (more than 30 °C), (Table no.3.3) as the optimum temperature required for grain ripening is 20-25°C (Yoshida, 1981). Srijan *et al.* (2016) reported similar association with flag leaf width, whereas Naseem *et al.* (2014) reported negative non significant association with flag leaf area.

4.4.9 Flag leaf length (cm)

The flag leaf length showed positive significant association with flag leaf area ($0.8245^{**}/0.8402^{**}$) at both phenotypic and genotypic levels. Whereas its association with flag leaf width (0.2009^*) was positive significant at phenotypic level and positive non significant (0.1393) at genotypic level, Mohekar *et al.* (2015) reported positive non significant association with flag leaf area and Sravan *et al.* (2012) and Sadeghi (2011) for flag leaf width. Flag leaf length showed negative significant association with harvest index ($-0.2815^{**}/-0.3511^{**}$) at both phenotypic and genotypic levels. Whereas, Mohekar *et al.* (2015) and Sravan *et al.* (2012) reported positive non significant association.

Flag leaf length showed negative non significant association with grain yield (-0.1333) at phenotypic level and negative significant association (-0.2113^*) at genotypic level. As majority of the genotypes (30) studied were having lengthy flag leaf ranging from 28.0 to 39.2cm, which tend to droop causing mutual shading and not intercept more sunlight resulted in negative association and finally low grain yield. However, its role in contributing towards grain yield could not be overlooked, as this character exhibited positive association with important yield attributes like number of filled grains per panicle, flag leaf area, flag leaf width and panicle length and this *inter se* correlation play an important role in grain yield improvement. Smriti *et al.* (2015) and Srijan *et al.* (2016) reported negative non significant association with grain yield per plant at genotypic level. These results were in contrary with results of Sravan *et al.*

(2012) and Sadeghi (2011) as they reported significant positive association between boot leaf length and grain yield per plant.

4.4.10 Flag leaf width (cm)

The flag leaf width had positive significant association with flag leaf area ($0.7036^{**}/0.6665^{**}$) at both phenotypic and genotypic levels and with SCMR (0.1831^{*}) at genotypic level only. This trait showed negative significant association with grain length ($-0.2265^{**}/-0.2552^{**}$) at both phenotypic and genotypic levels and with grain width (-0.1968^{*}) at genotypic level. Similar association of flag leaf width with grain length was earlier reported by Sadeghi (2011) and negative non significant association with grain width reported by Srijan *et al.* (2016). The association of flag leaf width with other characters like grain L/B ratio ($-0.0852/-0.0984$) and harvest index ($-0.0761/-0.0972$) was negative non significant.

The increase in flag leaf width leads to increase in flag leaf area, chlorophyll content in leaves and number of filled grains per panicle which ultimately leads to increase in grain yield per plant, Which reflected in present investigation as there was positive significant association of flag leaf width with grain yield ($0.2075^{*}/0.2038^{*}$) at phenotypic and genotypic levels. Whereas Smriti *et al.* (2015) reported positive non significant association of flag leaf width with grain yield per plant at phenotypic level only.

4.4.11 Flag leaf area (cm²)

Flag leaf area had negative significant association with grain length ($-0.2822^{**}/-0.3106^{**}$) and harvest index ($-0.2398^{**}/-0.3495^{**}$). Flag leaf area showed positive non significant association at phenotypic level (0.0058), negative non significant association (-0.0697) at genotypic level with grain yield. In general contribution of flag leaf area was more towards grain yield, but in present experiment the different correlations at phenotypic and genotypic levels may be attributed to the environmental effects as the growing season was early *kharif*. Where high temperatures ranged from 27-41 °C prevailed during grain ripening period, due to which most of the genotypes showed leaf tip drying which lead to negative association of flag leaf area with all the grain characters and finally negative non significant association with grain yield per plant at genotypic level and non significant positive association at phenotypic level. However Mohekar *et al.* (2015) reported positive non significant association of

flag leaf area with grain yield at both phenotypic and genotypic levels. Wattoo *et al.* (2010) reported positive significant association of flag leaf area with grain yield in their studies.

4.4.12. SCMR

Many crop scientists have believed that enhancing photosynthesis at the level of the single leaf would increase yields (Amane, 2011), Murata (1981) reviewed the relationship between potential leaf photosynthesis and maximal crop growth rate of many crops and found a highly positive correlation between them. This also indicates that photosynthesis at the single leaf level can be an important factor for potential biomass production. The trait SCMR recorded positive significant association with harvest index (0.2696**/0.4453**) and grain yield per plant (0.2595**/0.5169**) at phenotypic and genotypic levels. Ullah *et al.* (2011) reported positive significant association of SCMR with harvest index at genotypic level. SCMR showed positive non significant association with grain L/B ratio (0.0608/0.0900) and negative non significant association with grain length (-0.0150/-0.0341) and grain width (-0.1219/-0.1671) at phenotypic and genotypic levels. The negative (or) positive non significant association of SCMR with flag leaf characters like flag leaf length, flag leaf width and flag leaf and grain characters like grain length, grain width and L/B ratio showed that they were independently inherited.

The significant positive association of SCMR with harvest index and grain yield indicates importance of this character in realizing higher grain yield. Hence genotypes maintaining higher leaf chlorophyll content during active growth period may be considered as potential donors for the ability of producing higher biomass and photosynthetic capacity which results in higher yields. Consideration of this character during selection has prominent role in selecting good yielders. Similar results of positive significant association of SCMR with grain yield were earlier presented by Adilakshmi and Raghavareddy (2012).

4.4.13. Harvest index

It was major economic character in rice, yield improvement is possible by increasing harvest index, which indicates the partitioning of assimilation products to grain, and or total biomass production. Harvest index showed positive association with grain yield per plant (0.5291**/0.4685**) at both phenotypic and genotypic level

respectively, which were supported by Sravan *et al.* (2012). Harvest index have positive significant *inter se* association with other important component characters like SCMR, 1000 grain weight and filled grains per panicle. Simultaneous expression of these characters is due to pleiotropy (or) genetic linkage. If the relationship is due to manifold effect of genes, it is difficult to separate those effects by selecting single character. Improvement of grain yield might be observed by increase in above characters through increase in harvest index. Hence, these associations were considered to be desirable.

4.4.14. Grain length (mm)

Grain length recorded positive significant association at both phenotypic and genotypic level with grain L/B ratio (0.7978**/8197**) as reported by Umadevi *et al.* (2009), Bekele *et al.* (2013) and Srijan *et al.* (2016). Grain length also recorded positive non significant association with grain yield (0.0325/0.0740) at phenotypic and genotypic levels. Similar result was earlier reported by Umadevi *et al.* (2009). Its association with grain width (-0.1358/-0.1627) is negative non significant, this was in conformity with results of Umadevi *et al.* (2009), Bekele *et al.* (2013) and Srijan *et al.* (2016).

4.4.15 Grain width (mm)

This trait showed negative significant association at both phenotypic and genotypic levels with Grain L/B ratio (-0.6637**/-0.7052**) as earlier reported by Kumar and senapathi (2013). Grain width recorded negative non significant association with grain yield (-0.0603/-0.0816) at both phenotypic genotypic levels. Similar results of positive non significant association with grain yield were earlier reported by Umadevi *et al.* (2009) and Sadeghi (2011).

4.4.16 Grain L/B ratio

Grain L/B ratio showed positive non significant association with grain yield per plant (0.0441/0.1015). Umadevi *et al.* (2009) and Kumar and Senapathi (2013) also reported similar association with grain yield per plant.

From the present investigation, phenotypic and genotypic character association studies indicated significant positive association of panicle length, flag leaf width, number of ear bearing tillers per plant, number of filled grains per panicle, SCMR, test

weight and harvest index with grain yield. Hence, selection of these traits would be more effective to bring simultaneous improvement in grain yield. From this study which was taken up in early *kharif* season where high temperatures ($>35^{\circ}\text{C}$ during booting to grain ripening period) exists had profound influence on the experiment at all the characters finally resulted in low number of ear bearing tillers per plant, low number of filled grains per panicle and low grain yield per plant per plant.

4.5 PATH ANALYSIS

The observed correlation between yield and its component characters is the net result of the direct and indirect effects of the component character through other yield attributes. The total correlation coefficient between yield and its component characters may sometimes be misleading, as it may be an over or under estimate of its association with other characters. In these cases, direct selection on the basis of correlated response may not be fruitful. For critical evaluation, the correlation coefficient need to be split into direct and indirect effects using path coefficient analysis since, many characters affect a given trait. Thus, the correlation and path coefficients in combination can give a better insight into cause and effect relationship between different pairs of character.

If the correlation coefficient between a causal factor and the effect is almost equal to its direct effect, then correlation explains the true relationship and a direct selection through this trait will be effective.

If the correlation coefficient is positive, but the direct effect is negative or negligible, the indirect effects seem to be the cause of positive correlation. In such situations, the indirect causal factors are to be considered simultaneously for selection.

Correlation coefficient may be negative but the direct effect is positive and high. Under these circumstances, a restricted simultaneous selection model is to be followed *i.e.*, restrictions are to be imposed to nullify the undesirable indirect effects in order to make use of the direct effect.

If correlation coefficient is negative and direct effect is also negative, then the character cannot be considered as a selection criterion.

The residual effect determines how best the causal factors account for the variability of the dependent factor. If the residual effect is high, some other factors

which have not been considered here need to be included in this analysis to account fully for the variation in yield.

In the present study, path analysis was used to work out the direct and indirect effects of yield contributing characters on yield in 60 genotypes and the prominent indirect effects were only considered in discussion, the results are presented (Table 4.9 and 4.10) character wise hereunder. The path diagram is given in Figure 4.9 and 4.10.

4.5.1 Days to 50% Flowering

At phenotypic level the trait days to 50% flowering exhibited very low positive direct effect (0.0314) but due to the positive indirect effect of 1000 grain weight (0.1039), resulted in non significant positive correlation (0.1565) on grain yield per plant. At genotypic level the direct effect (-0.1879) of days to 50 % flowering on grain yield per plant was negative but its association was non significant positive (0.1205). The negative direct effect was nullified by the prominent positive indirect effect of 1000 grain weight (0.1601), days to maturity (0.0852) and number of filled grains per panicle (0.0600) and finally resulted in positive non significant association with grain yield.

However as the indirect effect of 1000 grain weight had prominent role at both levels through days to 50% flowering towards grain yield per plant, this character has to be considered as a selection criterion instead of days to 50% flowering. Jaiswal *et al.* (2007), Panwar (2006), Krishna *et al.* (2008), Pal *et al.* (2011) and Basavaraja *et al.* (2012) reported positive direct effect towards grain yield at phenotypic level. Whereas, Borbora *et al.* (2005) and Binse *et al.* (2006) reported negative direct effect at genotypic level.

4.5.2 Days to Maturity

Days to maturity exhibited low negative direct effect (-0.0413) and positive non significant correlation (0.1430) on grain yield per plant at phenotypic level. Though it exhibited low negative direct effect, it was nullified by high positive indirect effects of number of filled grains per panicle (0.1346), 1000 grain weight (0.0788) finally resulted in positive non significant correlation with grain yield per plant .

This trait exhibited genotypic positive direct effect (0.0951) and positive non significant correlation (0.1761) on grain yield per plant. Though it exhibited low positive direct effect, it was enhanced by the positive indirect effects *via* number of

filled grains per panicle (0.2221) and 1000 grain weight (0.1236) resulted in non significant positive correlation with grain yield per plant. Hence, the traits number of filled grains per panicle and 1000 grain weight can be considered for simultaneous selection for improving the yield.

Sadeghi (2011) reported negative direct effect at both levels and Bekele *et al.* (2013) and Mohekar *et al.* (2015) reported positive direct effect at phenotypic and genotypic levels.

4.5.3 Plant Height (cm)

Plant height exhibited phenotypic low positive direct effect (0.0062) and positive non-significant association (0.0824) on grain yield per plant. The low positive direct effect was enhanced by the high positive indirect effect of 1000 grain weight (0.1851) and reduced by the negative effect of number of ear bearing tillers per plant (-0.1292) finally resulted in low positive non significant association with grain yield per plant.

At genotypic level the trait exhibited positive direct effect (0.1342) and negative non significant association (-0.0038) on grain yield per plant. The positive direct effect and positive indirect effect of 1000 grain weight (0.3444) was nullified by the high negative indirect effect of number of ear bearing tillers per plant (-0.2711) and panicle length (-0.1583) resulted in negative non significant association with grain yield. However the indirect effect of 1000 grain weight had exhibited prominent role at both levels through plant height towards grain yield per plant, hence this character to be considered as a selection criterion instead of plant height.

Similar results were reported by Shashidhar *et al.* (2005), Swain and Reddy (2006), Rangare *et al.* (2012), Sravan *et al.* (2012), Sanghera *et al.* (2013) and Shankar *et al.* (2016).

4.5.4 Number of ear bearing Tillers per Plant

Number of ear bearing tillers per plant exhibited positive direct effects (0.7452/0.7779) and positive significant association (0.4087**/0.3914**) on grain yield per plant at both phenotypic and genotypic levels respectively. As the direct effect and its correlations of this trait on grain yield were high and association was positive significant, it indicated that this trait had true relationship with grain yield per plant.

Hence, direct selection on this trait would be effective. Similar results were also reported by Nagajyothi *et al.* (2001), Manna *et al.* (2006), Sravan *et al.* (2012), Sanghera *et al.* (2013), Kumar *et al.* (2013) and Shankar *et al.* (2016).

4.5.5 Panicle Length (cm)

Panicle length exhibited negative direct effect (-0.0359/-0.2275) and positive significant association (0.2491**/0.2936**) at both phenotypic and genotypic levels on grain yield per plant. Though direct effects were negative they were nullified by the high positive indirect effects like 1000 grain weight (0.1932/0.3403) and number of filled grains per panicle (0.1389/0.1603) at both phenotypic and genotypic levels, which resulted in positive significant association of panicle length with grain yield per plant. In such situations, the indirect casual factors are to be considered simultaneously for selection. Similar results were also reported Janardhanam *et al.* (2001) and Sravan *et al.* (2012) at both levels. Whereas Rani and Reddy (2010), Garg *et al.* (2010), Gopikannan and Ganesh (2012), Sudharani *et al.* (2012) and Seesang *et al.* (2013) at genotypic level only.

4.5.6 Number of Filled Grains per Panicle

Number of filled grains per panicle had positive direct effect (1.1233/1.4905) and positive significant association (0.4270**/0.3738**) on grain yield at both phenotypic and genotypic levels. The direct effect of number of filled grains per panicle on grain yield per plant accounted for the major portion in the total correlation between them, and it reveals true relationship between number of filled grains per panicle and grain yield per plant. Hence direct selection will be rewarded for this trait. Similar results were reported by Janardhanam *et al.* (2001), Nagajyothi *et al.* (2001), Sadeghi (2011) and Sravan *et al.* (2012).

4.5.7 Number of Ill-filled Grains per Panicle

This trait exhibited negative direct effect (-0.0209/-0.1174) and negative non significant association (-0.0185/-0.0265) with grain yield per plant at both phenotypic and genotypic levels respectively. Hence this character cannot be considered as a selection criterion. These results were in corroboration with results of Hossain *et al.* (2015).

4.5.8 1000 Grain Weight (g)

The direct effect of test weight was positive (0.7936/1.2743) coupled with positive significant correlation (0.2084*/0.2056*) at both phenotypic and genotypic levels on grain yield per plant. As the direct effect of this trait on grain yield was high and association was positive, indicating that this trait had true relationship with grain yield per plant. Hence, direct selection on this trait would be effective. These results were in conformity with Nagajyothi *et al.* (2001) Rangare *et al.* (2012), Gangashetty *et al.* (2013), Kumar *et al.* (2013), Mohekar *et al.* (2015), Seyoum *et al.* (2012) and Shankar *et al.* (2016).

4.5.9 Flag leaf length

Flag leaf length exhibited negative direct effects (-0.0057/-0.0779) and negative non significant correlations (-0.1333) at phenotypic level and significant negative correlation (-0.2133*) at genotypic levels. If correlation coefficient is negative and direct effect is also negative, then the character cannot be considered as a selection criterion. Similar result of negative significant correlation with negative direct effect was in corroboration with Sravan *et al.* (2012).

4.5.10 Flag leaf width

Flag leaf width exhibited positive direct effect (0.0121) and positive significant correlation (0.2075*) on grain yield per plant at phenotypic level. At genotypic level, it exhibited negative direct effect (-0.0689) and positive significant correlation (0.2038*) on grain yield per plant. Though the low direct effects of flag leaf width *i.e.*, positive at phenotypic level and negative at genotypic level, it was nullified by the high positive indirect effect of number of filled grains per panicle (0.3666/0.5688) resulted in its positive significant association towards grain yield at both levels. This relation expressed that the trait flag leaf width had little effect on grain yield per plant on its own hence selection on flag leaf width along with high positive indirect causal factor number of filled grains per panicle would be rewarding. The positive direct effect of this trait with grain yield per plant was in conformity with Sadeghi (2011) Sravan *et al.* (2012) and Srijan *et al.* (2016).

4.5.11 Flag leaf area

Flag leaf area exhibited phenotypic positive direct effect (0.0198) and positive non significant correlation (0.0058) on grain yield per plant and it also exhibited genotypic positive direct effect (0.0899) and negative non significant correlation (-0.0697) on grain yield per plant. Here the low positive direct effect were nullified through prominent negative indirect effects like number of ear bearing tillers (-0.2033/-0.3210) and 1000 grain weight (-0.2271/-0.4131) resulted in non significant positive and negative association of this trait at both phenotypic and genotypic levels respectively. Hence this character cannot be considered as selection criteria. Mohekar *et al.* (2015) and Nilanjaya and kumar (2015) reported positive direct effect of flag leaf area towards grain yield.

4.5.12 SCMR

SCMR exhibited positive direct effect (0.0023) and positive significant correlation (0.2595**) at phenotypic level, whereas at genotypic level it showed negative direct effect (-0.0936) and positive significant correlation (0.5169**) on grain yield per plant. Since the direct effects were very low at phenotypic level and negative at genotypic level, these effects were nullified by the high positive indirect effects of number of filled grains per panicle (0.1963/0.3835) and 1000 grain weight (0.0876/0.1552) resulted in expressing positive significant association. In such situations, the indirect causal factors are to be considered simultaneously for selection. Adilakshmi and Raghavareddy (2012) and Mohekar *et al.* (2015) reported positive direct effect, whereas Sudharani *et al.* (2012) reported negative direct effect of this trait with grain yield per plant.

4.5.13 Harvest index

Harvest index exhibited very low positive direct effect (0.0084) and positive significant correlation (0.5291**) at phenotypic level, and at genotypic level it showed negative direct effect (-0.0558) and positive significant association (0.4685**) on grain yield per plant. The significant positive correlation was due to high positive indirect effects like number of filled grains per panicle (0.2302/0.1407), 1000 grain weight (0.1919/0.2842) and ear bearing tillers per plant (0.1119/0.1648) at both phenotypic and genotypic levels. Hence emphasis should be made on these characters for improving the grain yield. The positive association of harvest index with positive direct effects on

grain yield was observed by Mohekar *et al.* (2015) at both phenotypic and genotypic level. Whereas, Sridhar *et al.* (2016) at phenotypic level only.

4.5.14 Grain length

Grain length exhibited high negative direct effects (-0.1877/-0.1367) and positive non significant correlation (0.0325/0.0740) at both phenotypic and genotypic levels on grain yield per plant. Non significant positive association with grain yield even in the presence of high negative direct effects indicated the involvement of positive indirect effects in producing positive correlation, thus positive indirect effect of 1000 grain weight (0.5717/0.9814) should be given greater emphasis for improving the yield. Similar results were observed by Sanghera *et al.* (2013), Sadeghi (2011) at both genotypic and phenotypic levels and Srijan *et al.* (2016) at genotypic level only.

4.5.15 Grain width

At phenotypic level grain width exhibited positive direct effect (0.0851) and negative non significant correlation (-0.0603) with grain yield per plant. While at genotypic level it exhibited negative direct effect (-0.1196) and negative non significant correlation (-0.0816) towards grain yield per plant. Though it exhibited positive direct effect at phenotypic level and negative direct effect at genotypic level, they were nullified by high negative indirect effect of number of filled grains per panicle (-0.2025/-0.3559) and high positive indirect effect of 1000 grain weight (0.1727/0.3165) finally resulted in negative non significant association of grain width with grain yield per plant at both levels. Hence this character cannot be considered as a selection criterion. In their findings of Sanghera *et al.* (2013), Sadeghi (2011) and Bekele *et al.* (2013) reported positive direct effects at both phenotypic and genotypic levels. Patel *et al.* (2014) and Srijan *et al.* (2016) reported negative direct effect at both levels.

4.5.16 Grain L/B ratio

Grain L/B ratio exhibited positive direct effect (0.1403) and positive non significant phenotypic correlation (0.0441) on grain yield per plant. It also exhibited negative direct effect (-0.0791) and positive non significant correlation (0.1015) at genotypic level with grain yield per plant. The positive direct effect at phenotypic level and negative direct effect at genotypic level was nullified by the indirect effects via., number of ear bearing tillers per plant (0.0858/0.1040), number of filled grains per panicle (-0.2812/-0.3823), 1000 grain weight (0.3103/0.5469) and grain length (-

0.1497/-0.1121) finally resulted in non significant association with grain yield at both levels. Though there was no relation between direct effects and their association with grain yield at both levels, the indirect effects of number of ear bearing tillers per plant and 1000 grain weight may not be ignored while selecting for higher grain yield. Srijan *et al.* (2016) reported similar association at genotypic level. The result of positive direct effect was in accordance with the results of Sanghera *et al.* (2013) and Patel *et al.* (2014) at both phenotypic and genotypic levels. Srijan *et al.* (2016) reported negative direct effect at genotypic level.

Path coefficient analysis revealed that number of ear bearing tillers per plant, number of filled grains per panicle and 1000 grain weight showed a positive direct effect and significant positive correlation with grain yield per plant at both phenotypic and genotypic level. These characters also showed prominent role as indirect effects on grain yield per plant through most of component characters. Hence, these yield contributing traits may be given prime importance for the direct improvement of grain yield.

In plant breeding, it is very difficult to have complete knowledge of all component traits of yield. The residual effect permits precise explanation about the pattern of interaction of other possible components of yield *i.e.*, residual effect measures the role of the possible independent variables which were not included in the study. The residual effect at genotypic level was (0.182) and at phenotypic level (0.237) indicating that the characters included in the study are contributing more than 82 per cent at genotypic level and 77 per cent at phenotypic level of variability pertaining to the dependent variable *i.e.*, yield. Less than 18 per cent at genotypic level and 23 per cent at phenotypic level of contribution is from the few other characters which were not included in the present study.

FUTURE LINE OF WORK

1. The present study revealed that considerable variability existed in the genotypes for all the characters studied. Involvement of both additive and non additive gene action in the inheritance was observed for all the studied characters. Thus simple selection may not be effective instead population improvement for these traits would be desirable.

2. It is observed that cluster III consists of only one genotype namely IR109A235 had recorded highest means values for most of the grain yield characters like number of ear bearing tillers per plant, grain yield per plant, 1000 grain weight, grain length and grain L/B ratio. Hence selection of this genotype for immediate use in early *kharif* season may be beneficial. As the maximum inter cluster distance was noticed cluster III (IR 109A235) and cluster VIII (JGL 11118) these two can be used in crossing programme to get desirable recombinants suitable for early *kharif*. As the inter cluster distance between cluster V (IR11C 208) and cluster VIII (JGL 11118) was also more , these two clusters also be used as parents in crossing programme to obtain better seggretnets for early *kharif* season.
3. The characters ear bearing tillers per plant, filled grains per plant and 1000 grain weight had shown positive significant association along with positive direct effect, hence these characters may be considered for improvement of grain yield while selecting suitable genotypes for early *kharif* season

Chapter V

SUMMARY AND CONCLUSIONS

The present investigation was carried out during *early kharif* season 2016 at Agricultural Research Station farm, Nellore with 60 rice genotypes (*Oryza sativa* L.). The mean, variability, heritability, genetic advance as per cent of mean, genetic divergence, correlation and path analysis of different yield, yield contributing and physiological traits viz., days to 50 % flowering, days to maturity, plant height, number of ear bearing tillers per plant, panicle length, number of filled grains per panicle, number of ill-filled grains per panicle, 1000 grain weight, flag leaf length, flag leaf width, flag leaf area, SPAD chlorophyll meter reading, harvest index, grain length, grain width, grain L/B ratio, and grain yield per plant were recorded for all the genotypes.

The analysis of variance indicated significant differences among the 60 genotypes for majority of the characters studied. The phenotypic coefficient of variation was higher than the genotypic coefficient of variation indicating the influence of environment in the expression of the traits. The estimates of PCV and GCV were high for the character number of ill-filled grains per panicle, phenotypic co-efficient of variation for this character was noticed to be closely and essentially associated with high genotypic co-efficient of variation indicating the minimum influence of environment and presence of high genetic variability for this traits in the experimental material. Hence, selection on the basis of phenotype for these trait can be effective. High PCV and moderate GCV were observed for number of filled grains per panicle. Moderate PCV and GCV were observed for flag leaf length, ear bearing tillers per plant, grain yield per plant, test weight, grain L/B ratio, flag leaf area and harvest index. Moderate PCV Low GCV was observed for flag leaf width. Low PCV and GCV were observed for days to 50 % flowering, days to maturity, plant height, panicle length, SCMR, grain length and grain width indicating low variability for these characters in the present experimental material and therefore little scope for improvement of these traits.

The estimates of heritability and genetic advance as per cent of means were high for the characters viz., number of filled grains per panicle, number of ill-filled grains per panicle, 1000 grain weight, flag leaf length, flag leaf area and grain L/B ratio indicating the involvement of additive gene action in the inheritance of these traits. Hence simple selection would be rewarding. High heritability coupled with moderate genetic advance as per cent of mean was observed for days to 50% flowering, days to maturity, plant height, panicle length,

flag leaf width, SCMR, grain length and grain width. Moderate heritability coupled with high genetic advance as per cent of mean was observed for harvest index and grain yield per plant, moderate heritability coupled with moderate genetic advance as per cent of mean was observed for effective tillers per plant indicating involvement of both additive and non additive gene action in the inheritance of these traits thus simple selection may not be effective instead population improvement for these traits would be desirable.

D² analysis revealed that out of 17 characters studied the maximum contribution (74.47%) towards total divergence is by four characters only. They are 1000 grain weight, flag leaf width, flag leaf length and days to maturity. These characters should be taken into consideration while selecting parents for hybridization. Based on genetic distance the 60 rice genotypes were grouped into 8 clusters. Cluster I was the largest comprising of 27 genotypes followed by cluster II with 25 genotypes, cluster VI with 3 genotypes and the remaining were solitary clusters. The pattern of distribution of genotypes into various clusters was at random indicating that geographical and genetic diversity were not related. The pattern of group constellations indicated significant variability among the genotypes.

It is observed that cluster III consists of only genotype namely IR109A235 had recorded highest mean values for most of the characters like days to 50% flowering, days to maturity, number of ear bearing tillers per plant, ill filled grains per panicle, grain yield per plant, 1000 grain weight, grain length and grain L/B ratio, hence selection of this genotype for direct use may be beneficial, cluster II is having highest mean value for flag leaf width, number of filled grains per panicle, cluster IV for grain width, cluster V for plant height, panicle length, cluster VII for SCMR, harvest index and cluster VIII for flag leaf length and flag leaf area.

Based upon the divergence studies crosses may be made between genotypes of cluster III (IR 109A235) and VIII (JGL 11118) followed by cluster V (IR 11C208) and cluster VIII (JGL 11118) to obtain desirable transgressive recombinants for early *khari*f situation.

Phenotypic and genotypic Correlation studies revealed that the traits panicle length, SCMR, flag leaf width number of ear bearing tillers per plant, number of filled grains per panicle, 1000 grain weight, and harvest index were found to possess significant association in desirable direction with grain yield per plant. The association studies indicating grain yield of rice can be improved by selecting genotypes having higher values for these traits.

Path analysis revealed that number of ear bearing tillers per plant, number of filled grains per panicle and 1000 grain weight are having true relationship by establishing positive association and positive direct effect on grain yield per plant. These characters also showed prominent role as indirect effects on grain yield per plant through most of the component characters. Hence, these traits should be considered as important selection criteria for grain yield improvement in early *kharif* season.

Considering the nature and magnitude of character association and their direct and indirect effects, it can be inferred that simultaneous improvement of grain yield per plant is possible through increase in the number of ear bearing tillers per plant, number of filled grains per panicle and 1000 grain weight.

CONCLUSIONS

1. Considerable variability existed in the genotypes for all the characters studied. These were the genotypes with high mean values in desirable direction *i.e.*, JGL 11118 had characters like early maturity (107.50), high flag leaf length (39.42) and high flag leaf area (42.27), NLR 3042 showed more number of ear bearing tillers per plant (8.07), IR11C 228 showed longer panicle (26.54), more number of filled grains per panicle (168.11) was recorded for NLR 3350, 1000 grain weight (25.61) for IR109A235, high SCMR (45.27) value exhibited by ADT 37, whereas high harvest index (64.49) and more grain yield per plant (22.72) was recorded by NLR40024 and NLR 3042 respectively.
2. The estimates of PCV and GCV were high for characters *viz.*, Number of ill-filled grains per panicle. Moderate PCV and moderate GCV were observed for flag leaf length, ear bearing tillers per plant, grain yield per plant, 1000 grain weight, grain L/B ratio, flag leaf area and harvest index. While, low PCV and GCV were observed for days to 50 % flowering, days to maturity, plant height, panicle length, SCMR, grain length, and grain width. The estimates of heritability coupled with genetic advance as per cent of mean were high for the characters *viz.*, number of filled grains per panicle, number of ill-filled grains per panicle, 1000 grain weight, flag leaf length, flag leaf area and grain L/B ratio indicating the involvement of additive gene action in the inheritance of these traits.

3. It is observed that cluster III consists of only one genotype namely IR109A235 had recorded highest means values for most of the characters like days to 50% flowering, days to maturity, number of ear bearing tillers per plant, ill filled grains per panicle, grain yield per plant, 1000 grain weight, grain length and grain L/B ratio, hence selection of this genotype for immediate use may be beneficial. The maximum inter cluster distance was noticed between cluster III (IR 109A235) and cluster VIII (JGL 11118) followed by cluster V (IR 11C208) and cluster VIII (JGL 11118). Crosses involving genotypes from these clusters would give wider and desirable recombinants, which will fit well in the early *kharif* situation.
4. The characters ear bearing tillers per plant, filled grains per plant and 1000 grain weight had shown positive significant association along with positive direct effect, hence these characters may be considered for improvement of grain yield in early *kharif* season.

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2.3 CORRELATION

Correlation coefficient is a measure of the degree of closeness and the linear relationship between two variables. Studies on correlation between yield and its components in population helps the breeder in understanding the shifts associated with different components to yield. The study of association between different characters may help the plant breeder to know how the improvement of one character will bring simultaneous changes in other characters. Character association studies indicate the magnitude of association between pairs of characters and are useful for selecting genotypes with desirable combination of characters thereby aiding the plant breeder in the improvement of the concerned trait. If the correlation is strong between a set of desirable traits then if we make selection for one character, the other character will be taken care automatically. If unfavourable association exists between desirable and undesirable traits, selection may results in genetic slippage and limit genetic advance.

Literature reviewed on the scientific studies made by several workers on correlation in rice and is summarized in the Tables 2.3 and 2.4.

Table 2.3. Review of literature on association of different components with yield in rice (*Oryza sativa* L.)

S.No.	Character	Correlation	S/NS	P/G	Reference
1.	Days to 50% flowering	Positive	S	P, G	Swain and Reddy (2006)
				P	Krishna <i>et al.</i> (2009)
				P, G	Panwar (2006)
				P, G	Sharma and Sharma (2007)
				P	Hefena <i>et al.</i> (2016)
				P, G	Hossian <i>et al.</i> (2015)
				P	Shankar <i>et al.</i> (2016)
				P, G	Sadeghi (2011)
		Negative	NS	P, G	Chandra <i>et al.</i> (2009)
				P, G	Rangare <i>et al.</i> (2012)
				P, G	Nagaraju <i>et al.</i> (2013)
				P, G	Mohekar <i>et al.</i> (2015)
				P	Sridhar <i>et al.</i> (2016)
				G	Shankar <i>et al.</i> (2016)
		Positive	S	P, G	Eradasappa <i>et al.</i> (2007)
				P, G	Gangashetty <i>et al.</i> (2013)
				P, G	Bornare <i>et al.</i> (2014)
				P, G	Sravan <i>et al.</i> (2012)
		Negative	NS	P, G	Borbora <i>et al.</i> (2005)
				P, G	Kumar and Bapu (2005)
				G	Binse <i>et al.</i> (2006)
				P, G	Panwar and Ali (2007)
				P	Seyoum <i>et al.</i> (2012)
				P, G	Kishore <i>et al.</i> (2015)
				P, G	Sanghera <i>et al.</i> (2013)
				P, G	Bekele <i>et al.</i> (2013)
2.	Days to maturity	Positive	S	P, G	Rashid <i>et al.</i> (2014)
				P, G	Bornare <i>et al.</i> (2014)
			NS	P	Sridhar <i>et al.</i> (2016)
				P, G	Sadeghi (2011)
		Negative	NS	P, G	Mohekar <i>et al.</i> (2015)
				P, G	Bekele <i>et al.</i> (2013)

Table 2.3 (cont.).

			S	P, G	Sanghera <i>et al.</i> (2013)
3.	Plant height (cm)	Positive	S	P, G	Shashidhar <i>et al.</i> (2005)
				P, G	Eradasappa <i>et al.</i> (2007)
				P	Rani and Reddy (2010)
				P, G	Sravan <i>et al.</i> (2012)
				P, G	Sheet <i>et al.</i> (2012)
				G	Kumar and Senapathi (2013)
				P, G	Bekele <i>et al.</i> (2013)
				P	Hefena <i>et al.</i> (2016)
				P	Sridhar <i>et al.</i> (2016)
				P, G	Hossian <i>et al.</i> (2015)
				P, G	Sravan <i>et al.</i> (2012)
				P, G	Sadeghi (2011)
				P, G	Sanghera <i>et al.</i> (2013)
				P, G	Bekele <i>et al.</i> (2013)
				NS	P, G
		P, G	Janardhanam <i>et al.</i> (2001)		
		P, G	Kumar and Bapu (2005)		
		G	Binse <i>et al.</i> (2006)		
		P, G	Swain and Reddy (2006)		
		P, G	Sharma and Sharma (2007)		
		P, G	Krishna <i>et al.</i> (2009)		
		G	Rani and Reddy (2010)		
		P, G	Rangare <i>et al.</i> (2012)		
		G	Kumar and Senapathi (2013)		
		P, G	Kishore <i>et al.</i> (2015)		
		P, G	Mohekar <i>et al.</i> (2015)		
		G	Shankar <i>et al.</i> (2016)		
Negative	S	P, G	Borbora <i>et al.</i> (2005)		
		P, G	Panwar and Ali (2007)		
		P, G	Gangashetty <i>et al.</i> (2013)		
		P, G	Rashid <i>et al.</i> (2014)		

Table 2.3 (cont.).

			NS	P, G P, G P, G P, G P, G P, G P, G P, G	Chaudhary and Motiramani (2003) Manna <i>et al.</i> (2006) Panwar (2006) Chandra <i>et al.</i> (2009) Dey <i>et al.</i> (2010) Akhtar <i>et al.</i> (2011) Laxuman <i>et al.</i> (2011) Seyoum <i>et al.</i> (2012)
4.	Number of ear bearing tillers per plant	Positive	S	P P P, G P, G G P P, G P, G P P P, G P, G G P, G P, G P P, G P, G P, G	Nagajyothi <i>et al.</i> (2001) Chaudhary and Motiramani (2003) Shashidhar <i>et al.</i> (2005) Swain and Reddy (2006) Panwar (2006) Manna <i>et al.</i> (2006) Panwar and Ali (2007) Eradasappa <i>et al.</i> (2007) Krishna <i>et al.</i> (2009) Rani and Reddy (2010) Kumar <i>et al.</i> (2013) Rashid <i>et al.</i> (2014) Neha <i>et al.</i> (2014) Bornare <i>et al.</i> (2014) Kishore <i>et al.</i> (2015) Hefena <i>et al.</i> (2016) Hossian <i>et al.</i> (2015) Sravan <i>et al.</i> (2012) Sadeghi (2011)
			NS	P, G P, G G P P, G P, G	Janardhanam <i>et al.</i> (2001) Sharma and Sharma (2007) Rani and Reddy (2010) Sridhar <i>et al.</i> (2016) Mohekar <i>et al.</i> (2015) Shankar <i>et al.</i> (2016)

Table 2.3 (cont.).

		Negative	NS	P P G P, G	Bhavana (2003) Borbora <i>et al.</i> (2005) Binse <i>et al.</i> (2006) Bekele <i>et al.</i> (2013)
5.	Panicle length (cm)	Positive	S	P, G P, G P P, G P P P P, G P, G P, G P, G P P, G P, G P, G P P P, G P, G P, G P, G	Hasib (2005) Kumar and Bapu (2005) Sharma and Sharma (2007) Eradasappa <i>et al.</i> (2007) Krishna <i>et al.</i> (2009) Rani and Reddy (2010) Parmhansh <i>et al.</i> (2010) Laxuman <i>et al.</i> (2011) Rangare <i>et al.</i> (2012) Sravan <i>et al.</i> (2012) Sheet <i>et al.</i> (2012) Gangashetty (2013) Nagaraju <i>et al.</i> (2013) Sudharani <i>et al.</i> (2012) Bornare <i>et al.</i> (2014) Hefena <i>et al.</i> (2016) Sridhar <i>et al.</i> (2016) Sravan <i>et al.</i> (2012) Shankar <i>et al.</i> (2016) Sadeghi (2011) Sanghera <i>et al.</i> (2013)
			NS	P, G	Kishore <i>et al.</i> (2015)
		Negative	S	P, G	Rashid <i>et al.</i> (2014)
			NS	P, G	Mohekar <i>et al.</i> (2015)
6	Number of filled grains per panicle	Positive	S	P, G P, G P, G P P, G P, G P, G	Kumar and Bapu (2005) Panwar (2006) Panwar and Ali (2007) Sharma and Sharma (2007) Eradasappa <i>et al.</i> (2007) Kishore <i>et al.</i> (2015) Shankar <i>et al.</i> (2016)

Table 2.3 (cont.).

				P, G	Sadeghi (2011)
				P, G	Sanghera <i>et al.</i> (2013)
			NS	P, G	Gulzar and Parray (2010)
				P, G	Borbora <i>et al.</i> (2005)
				P, G	Rani and Reddy (2010)
				P	Parmhansh <i>et al.</i> (2010)
				P, G	Rashid <i>et al.</i> (2014)
				P	Sridhar <i>et al.</i> (2016)
				P, G	Hossian <i>et al.</i> (2015)
		Negative	NS	P, G	Manna <i>et al.</i> (2006)
7	Number of ill filled grains per panicle	Positive	S	P, G	Hossian <i>et al.</i> (2015)
		Negative	S	G	Sarwar <i>et al.</i> (2015)
				G	Prasad <i>et al.</i> (2015)
			NS	G	Ratna <i>et al.</i> (2015)
8	1000-grain weight (g)	Positive	S	G	Sharma and Sharma (2007)
				P	Krishna <i>et al.</i> (2009)
				G	Rani and Reddy (2010)
				P	Parmhansh <i>et al.</i> (2010)
				P, G	Seyoum <i>et al.</i> (2012)
				P, G	Sravan <i>et al.</i> (2012)
				P, G	Gangashetty <i>et al.</i> (2013)
				P, G	Sudharani <i>et al.</i> (2012)
				P, G	Rashid <i>et al.</i> (2014)
				P, G	Sravan <i>et al.</i> (2012)
				P	Sridhar <i>et al.</i> (2016)
				P, G	Hossian <i>et al.</i> (2015)
				P, G	Shankar <i>et al.</i> (2016)
			NS	P, G	Bornare <i>et al.</i> (2014)
				P, G	Eradasappa <i>et al.</i> (2007)
				P	Rani and Reddy (2010)
				P, G	Garg <i>et al.</i> (2010)
				P, G	Nagaraju <i>et al.</i> (2013)
				P, G	Kishore <i>et al.</i> (2015)
				P, G	Hossian <i>et al.</i> (2015)
				P, G	Mohekar <i>et al.</i> (2015)

Table 2.3 (cont.).

				P, G P, G	Sadeghi (2011) Sanghera <i>et al.</i> (2013)
9	Flag leaf length (cm)	Positive	S	P, G P, G	Sravan <i>et al.</i> (2012) Sadeghi (2011)
			NS	P, G P P	Mohekar <i>et al.</i> (2015) Smriti <i>et al.</i> (2015) Srijan <i>et al.</i> (2016)
		Negative	NS	G G	Smriti <i>et al.</i> (2015) Srijan <i>et al.</i> (2016)
10.	Flag leaf width (cm)	Negative	NS	P, G P, G G P, G	Sravan <i>et al.</i> (2012) Sadeghi (2011) Smriti <i>et al.</i> (2015) Srijan <i>et al.</i> (2016)
		Positive	NS	P	Smriti <i>et al.</i> (2015)
11.	Flag leaf area (cm ²)	Negative	NS	P, G P	Mohekar <i>et al.</i> (2015) Naseem <i>et al.</i> (2014)
		Positive	S	G P, G	Naseem <i>et al.</i> (2014) Wattoo <i>et al.</i> (2010)
12.	SCMR	Positive	S	P, G	Adilakshmi and Raghavareddy (2012)
			NS	P, G	Mohekar <i>et al.</i> (2015)
		Negative	NS	G	Sudharani <i>et al.</i> (2012)
13.	Harvest index (%)	Positive	NS	G P, G P P, G	Sudharani <i>et al.</i> (2012) Adilakshmi and Raghavareddy (2012) Sridhar <i>et al.</i> (2016) Mohekar <i>et al.</i> (2015)
				S	Sravan <i>et al.</i> (2012)
			S	P, G	Umadevi <i>et al.</i> (2009) Patel <i>et al.</i> (2014)
14.	Grain length (mm)	Positive	NS	P, G G	Umadevi <i>et al.</i> (2009) Patel <i>et al.</i> (2014)
			S	P	Patel <i>et al.</i> (2014)
		Negative	S	P, G	Sadeghi (2011)
			NS	P, G P, G	Sanghera <i>et al.</i> (2013) Srijan <i>et al.</i> (2016)

Table 2.3 (cont.).

15.	Grain width (mm)	Positive	S	P, G P, G	Sanghera <i>et al.</i> (2013) Patel <i>et al.</i> (2014)
		Negative	NS	P, G P, G P, G	Umadevi <i>et al.</i> (2009) Sadeghi <i>et al.</i> (2011) Srijan <i>et al.</i> (2016)
16	L/B ratio	Positive	NS	P, G P, G P P, G P, G	Umadevi <i>et al.</i> (2009) Kumar and Senapathi (2013) Ketan and Sarkar (2014) Patel <i>et al.</i> (2014) Srijan <i>et al.</i> (2016)
		Negative	S	P, G	Sanghera <i>et al.</i> (2013)

Table 2.4 Review of literature on association among different characters in rice (*Oryza sativa* L.)

S.No.	Character	Correlation	S/NS	P/G	Reference
I. Association of Days to 50% flowering with					
a	Days to maturity	Positive	NS	P, G P, G	Mohekar <i>et al.</i> (2015) Sanghera <i>et al.</i> (2013)
		Negative	S	P, G P, G	Sadeghi (2011) Bekele <i>et al.</i> (2013)
			NS	P	Sridhar <i>et al.</i> (2016)
b	Plant height (cm)	Positive	S	P, G P P, G	Babu <i>et al.</i> (2012) Sridhar <i>et al.</i> (2016) Shankar <i>et al.</i> (2016)
			NS	P P, G P, G	Hefena <i>et al.</i> (2016) Mohekar <i>et al.</i> (2015) Sanghera <i>et al.</i> (2013)
		Negative	NS	P, G P, G P, G P, G	Kishore <i>et al.</i> (2015) Sravan <i>et al.</i> (2012) Sadeghi (2011) Bekele <i>et al.</i> (2013)
c	Number of ear bearing tillers per plant	Positive	S	P P, G	Hefena <i>et al.</i> (2016) Shankar <i>et al.</i> (2016)
		Negative	NS	P ,G P, G P, G	Sridhar <i>et al.</i> (2016) Sadeghi (2011) Bekele <i>et al.</i> (2013)
				NS	P, G P, G
		Negative	NS	P P, G P, G	Hefena <i>et al.</i> (2016) Mohekar <i>et al.</i> (2015) Sravan <i>et al.</i> (2012)
d	Number of filled grains per panicle	Positive	NS	P P P, G	Hefena <i>et al.</i> (2016) Sridhar <i>et al.</i> (2016) Shankar <i>et al.</i> (2016)
			S	P, G P, G P, G	Hossian <i>et al.</i> (2015) Sadeghi (2011) Sanghera <i>et al.</i> (2013)

Table 2.4 (cont.).

		Negative	NS	P, G	Kishore <i>et al.</i> (2015)
e	Number of ill filled grains per panicle	Positive	S	P, G G G	Hossian <i>et al.</i> (2015) Ratna <i>et al.</i> (2015) Kishore <i>et al.</i> (2015)
f	1000 grain weight (g)	Positive	S	P, G P P P, G	Panwar (2006) Sharma and Sharma (2007) Hefena <i>et al.</i> (2016) Sravan <i>et al.</i> (2012)
			NS	P, G P, G P P,G	Borbora <i>et al.</i> (2005) Panwar and Ali (2007) Sridhar <i>et al.</i> (2016) Shankar <i>et al.</i> (2016)
		Negative	S	G P,G P, G P, G P, G	Swain and Reddy (2006) Hossian <i>et al.</i> (2015) Sadeghi (2011) Sanghera <i>et al.</i> (2013) Bekele <i>et al.</i> (2013)
			NS	P, G G P, G P, G P, G P, G	Kumar and Bapu (2005) Binse <i>et al.</i> (2006) Eradasappa <i>et al.</i> (2007) Garg <i>et al.</i> (2010) Kishore <i>et al.</i> (2015) Mohekar <i>et al.</i> (2015)
g	Flag leaf length (cm)	Positive	NS	P, G P, G	Mohekar <i>et al.</i> (2015) Sadeghi <i>et al.</i> (2011)
			S	P, G	Reddy <i>et al.</i> (2013)
		Negative	NS	P, G P, G	Sravan <i>et al.</i> (2012) Srijan <i>et al.</i> (2016)
h	Flag leaf width (cm)	Positive	NS	P, G P, G P, G	Sravan <i>et al.</i> (2012) Sadeghi <i>et al.</i> (2011) Srijan <i>et al.</i> (2016)
			S	P, G	Reddy <i>et al.</i> (2013)
i	Flag leaf	Positive	NS	P, G	Mohekar <i>et al.</i> (2015)

Table 2.4 (cont.).

	area (cm ²)	Negative	S	P	Naseem <i>et al.</i> (2014)
			NS	G P, G	Naseem <i>et al.</i> (2014) Wattoo <i>et al.</i> (2010)
j	SCMR	Positive	S	G	Sudharani <i>et al.</i> (2012)
		Negative	S	G	Nilanjaya and Kumar (2015)
			NS	G G	Malath and Gomathinayagam (2013) Gopikannan and Ganesh (2013)
k	Harvest index (%)	Positive	NS	P, G	Mohekar <i>et al.</i> (2015)
		Negative	NS	P P, G	Sridhar <i>et al.</i> (2016) Sravan <i>et al.</i> (2012)
l	Grain length (mm)	Positive	S	P, G	Sadeghi (2011)
			NS	P, G	Bekele <i>et al.</i> (2013)
		Negative	NS	P, G P, G	Umadevi <i>et al.</i> (2009) Sanghera <i>et al.</i> (2013)
m	Grain width (mm)	Positive	NS	P, G P, G	Umadevi <i>et al.</i> (2009) Srijan <i>et al.</i> (2016)
		Negative	S	P, G P, G P	Sadeghi (2011) Bekele <i>et al.</i> (2013) Srijan <i>et al.</i> (2016)
			NS	P, G G	Sanghera <i>et al.</i> (2013) Srijan <i>et al.</i> (2016)
n	L/B ratio	Positive	NS	P, G P, G G	Umadevi <i>et al.</i> (2009) Sanghera <i>et al.</i> (2013) Srijan <i>et al.</i> (2016)
			S	P, G P, G P	Bekele <i>et al.</i> (2013) Kumar and Senapathi (2013) Srijan <i>et al.</i> (2016)
II. Association of days to maturity with					
a	Plant height (cm)	Positive	NS	P, G	Sanghera <i>et al.</i> (2013)

Table 2.4.(cont.)

		Negative	NS	P P, G P, G	Sridhar <i>et al.</i> (2016) Mohekar <i>et al.</i> (2015) Bekele <i>et al.</i> (2013)
b	Ear bearing tillers per plant	Positive	NS	P P, G P, G	Sridhar <i>et al.</i> (2016) Mohekar <i>et al.</i> (2015) Bekele <i>et al.</i> (2013)
c	Panicle length (cm)	Positive	S	P, G	Sanghera <i>et al.</i> (2013)
d	Number of filled grains per panicle	Positive	NS	P, G	Sanghera <i>et al.</i> (2013)
		Negative	NS	P	Sridhar <i>et al.</i> (2016)
e	1000 grain weight (g)	Positive	NS	P, G	Mohekar <i>et al.</i> (2015)
		Negative	S	P P, G P, G	Sridhar <i>et al.</i> (2016) Sanghera <i>et al.</i> (2013) Bekele <i>et al.</i> (2013)
f	Flag leaf length (cm)	Positive	S	P	Aditya and Bhartiya (2013)
		Negative	NS	P, G	Mohekar <i>et al.</i> (2015)
g	Flag leaf width (cm)	Positive	S	P	Aditya and Bhartiya (2013)
h	Flag leaf area (cm ²)	Positive	S	P, G	Ahamed <i>et al.</i> (2015)
			NS	P, G	Wattoo <i>et al.</i> (2010)
		Negative	NS	P, G P, G	Mohekar <i>et al.</i> (2015) Naseem <i>et al.</i> (2014)
I	Grain length (cm)	Positive	NS	P, G	Bekele <i>et al.</i> (2013)
		Negative	S	P, G	Sanghera <i>et al.</i> (2013)
j	Grain width (cm)	Negative	S	P, G P, G	Sanghera <i>et al.</i> (2013) Bekele <i>et al.</i> (2013)

Table 2.4.(cont.).

k	L/B ratio	Positive	NS	P, G P, G	Sanghera <i>et al.</i> (2013) Bekele <i>et al.</i> (2013)
III. Association of Plant height with					
a	Number of ear bearing tillers per plant	Positive	S	P, G P G	Janardhanam <i>et al.</i> (2001) Hefena <i>et al.</i> (2016) Sravan <i>et al.</i> (2012)
			NS	P, G P, G P, G P, G P, G P, G P P, G P, G P, G P, G	Chaudhary and Motiramani (2003) Shashidhar <i>et al.</i> (2005) Swain and Reddy (2006) Panwar (2006) Panwar and Ali (2007) Sharma and Sharma (2007) Eradasappa <i>et al.</i> (2007) Sridhar <i>et al.</i> (2016) Hossian <i>et al.</i> (2015) Mohekar <i>et al.</i> (2015) Shankar <i>et al.</i> (2016) Sadeghi (2011)
		Negative	S	G P, G	Binse <i>et al.</i> (2006) Bekele <i>et al.</i> (2013)
			NS	P, G P, G P, G P P, G	Borbora <i>et al.</i> (2005) Manna <i>et al.</i> (2006) Krishna <i>et al.</i> (2009) Sridhar <i>et al.</i> (2016) Kishore <i>et al.</i> (2015)
		Positive	S	P, G P P, G P P, G P P, G	Janardhanam <i>et al.</i> (2001) Chaudhary and Motiramani (2003) Kumar and Bapu (2005) Krishna <i>et al.</i> (2009) Garg <i>et al.</i> (2010) Rani and Reddy (2010) Babu <i>et al.</i> (2012)
b	Panicle length (cm)	Positive	S	P, G P P, G P P, G P P, G	Janardhanam <i>et al.</i> (2001) Chaudhary and Motiramani (2003) Kumar and Bapu (2005) Krishna <i>et al.</i> (2009) Garg <i>et al.</i> (2010) Rani and Reddy (2010) Babu <i>et al.</i> (2012)

Table 2.4.(cont.).

				P, G P, G P P, G P P, G P, G P, G P, G P, G	Datt <i>et al.</i> (2012) Minnie <i>et al.</i> (2013) Hefena <i>et al.</i> (2016) Kishore <i>et al.</i> (2015) Sridhar <i>et al.</i> (2016) Hossian <i>et al.</i> (2015) Sravan <i>et al.</i> (2012) Shankar <i>et al.</i> (2016) Sadeghi (2011) Sanghera <i>et al.</i> (2013)
			NS	P, G P, G G P, G P, G P, G P, G G	Borbora <i>et al.</i> (2005) Manna <i>et al.</i> (2006) Binse <i>et al.</i> (2006) Panwar (2006) Panwar and Ali (2007) Sharma and Sharma (2007) Eradasappa <i>et al.</i> (2007) Rani and Reddy(2010)
		Negative	NS	-	Krishnaveni and Sobharani (2006)
c	Number of filled grains per panicle	Positive	NS	P P, G P, G G	Hefena <i>et al.</i> (2016) Kishore <i>et al.</i> (2015) Shankar <i>et al.</i> (2016) Sadeghi (2011)
		Negative	S	P, G	Sanghera <i>et al.</i> (2013)
			NS	P G	Sridhar <i>et al.</i> (2016) Hossian <i>et al.</i> (2015)
d	Number of ill filled grains per panicle	Negative	NS	P, G	Hossian <i>et al.</i> (2015)
e	1000-grain weight (g)	Positive	S	G P, G P P, G	Binse <i>et al.</i> (2006) Panwar and Ali (2007) Rani and Reddy (2010) Minnie <i>et al.</i> (2013)

Table 2.4.(cont.).

				P, G P,G G P,G	Borbora <i>et al.</i> (2005) Sravan <i>et al.</i> (2012) Bekele <i>et al.</i> (2013) Shankar <i>et al.</i> (2016)
			NS	P, G P, G P, G - G P P, G G	Sharma and Sharma (2007) Eradasappa <i>et al.</i> (2007) Krishna <i>et al.</i> (2009) Chandra <i>et al.</i> (2009) Rani and Reddy (2010) Sridhar <i>et al.</i> (2016) Kishore <i>et al.</i> (2015) Mohekar <i>et al.</i> (2015)
		Negative	S	-	Krishnaveni and Sobharani (2006)
			NS	P, G P, G P, G P P P, G	Chaudhary and Motiramani (2003) Kumar and Bapu (2005) Swain and Reddy (2006) Garg <i>et al.</i> (2010) Hefena <i>et al.</i> (2016) Sanghera <i>et al.</i> (2013)
f	Flag leaf length (cm)	Positive	NS	P, G G	Mohekar <i>et al.</i> (2015) Srijan <i>et al.</i> (2016)
			S	P, G P, G P	Sravan <i>et al.</i> (2012) Sadeghi (2011) Srijan <i>et al.</i> (2016)
g	Flag leaf width (cm)	Positive	S	P, G P	Sadeghi <i>et al.</i> (2011) Srijan <i>et al.</i> (2016)
			NS	G	Srijan <i>et al.</i> (2016)
		Negative	NS	P, G	Sravan <i>et al.</i> (2012)
h	Flag leaf area (cm ²)	Positive	NS	P, G P, G	Mohekar <i>et al.</i> (2015) Naseem <i>et al.</i> (2014)
			S	P, G	Wattoo <i>et al.</i> (2010)
i	SCMR	Positive	S	-	Adilakshmi and Raghavareddy (2012)

Table 2.4.(cont.).

				G	Sudharani <i>et al.</i> (2012)
			NS	G	Ullah <i>et al.</i> (2011)
				G	Malath and Gomathinayagam (2013)
		P, G	Mohekar <i>et al.</i> (2015)		
		Negative	S	G	Nilanjaya and Kumar (2015)
			NS	G	Gopikannan and Ganesh (2013)
j	Harvest index (%)	Positive	S	P	Sridhar <i>et al.</i> (2016)
				P, G	Sravan <i>et al.</i> (2012)
			NS	P, G	Mohekar <i>et al.</i> (2015)
k	Grain length (mm)	Positive	NS	P, G	Umadevi <i>et al.</i> (2009)
		Negative	NS	P, G P, G P, G G	Sadeghi <i>et al.</i> (2011) Sanghera <i>et al.</i> (2013) Bekele <i>et al.</i> (2013) Srijan <i>et al.</i> (2016)
l	Grain width (mm)	Negative	NS	P, G G	Umadevi <i>et al.</i> (2009) Srijan <i>et al.</i> (2016)
			S	P	Srijan <i>et al.</i> (2016)
		Positive	NS	P, G P, G	Sadeghi (2011) Sanghera <i>et al.</i> (2013)
			S	P, G	Bekele <i>et al.</i> (2013)
m	Grain L/B ratio	Positive	NS	P,G G	Umadevi <i>et al.</i> (2009) Srijan <i>et al.</i> (2016)
			S	P, G P	Bekele <i>et al.</i> (2013) Srijan <i>et al.</i> (2016)
IV. Association of ear bearing tillers per plant with					
a	Panicle length (cm)	Positive	S	P, G P, G P	Janardhanam <i>et al.</i> (2001) Eradasappa <i>et al.</i> (2007) Rani and Reddy (2010)
			NS	P, G P, G G	Panwar and Ali (2007) Krishna <i>et al.</i> (2009) Rani and Reddy (2010)

Table 2.4 (cont.).

				P P P, G	Garg <i>et al.</i> (2010) Hefena <i>et al.</i> (2016) Sravan <i>et al.</i> (2012)
		Negative	S	P P, G	Manna <i>et al.</i> (2006) Hossian <i>et al.</i> (2015)
			NS	P, G G P, G P, G P, G	Borbora <i>et al.</i> (2005) Binse <i>et al.</i> (2006) Panwar (2006) Sharma and Sharma (2007) Kishore <i>et al.</i> (2015)
b	Number of filled grains per panicle	Positive	S	P, G P, G P P, G	Janardhanam <i>et al.</i> (2001) Eradasappa <i>et al.</i> (2007) Hefena <i>et al.</i> (2016) Sadeghi (2011)
			NS	P, G P, G P P	Panwar (2006) Borbora <i>et al.</i> (2005) Garg <i>et al.</i> (2010) Sridhar <i>et al.</i> (2016)
		Negative	S	P, G P, G P, G	Kishore <i>et al.</i> (2015) Hossian <i>et al.</i> (2015) Shankar <i>et al.</i> (2016)
			NS	P, G G P, G P, G G p	Manna <i>et al.</i> (2006) Binse <i>et al.</i> (2006) Sharma and Sharma (2007) Rani and Reddy (2010) Garg <i>et al.</i> (2010) Sridhar <i>et al.</i> (2016)
c	Number of ill filled grains per panicle	Positive	NS	P, G	Hossian <i>et al.</i> (2015)
d	1000 grain weight (g)	Positive	NS	P, G P, G P, G P, G P, G	Panwar (2006) Panwar and Ali (2007) Rani and Reddy (2010) Garg <i>et al.</i> (2010) Kishore <i>et al.</i> (2015)

Table 2.4.(cont.).

		Negative		P, G	Hossian <i>et al.</i> (2015)
			S	P, G	Shankar <i>et al.</i> (2016)
			S	P	Chaudhary and Motiramani (2003)
				P, G	Borbora <i>et al.</i> (2005)
				P, G	Swain and Reddy (2006)
				P, G	Eradasappa <i>et al.</i> (2007)
				P, G	Sadeghi (2011)
			NS	G	Binse <i>et al.</i> (2006)
				P, G	Bhattacharyya <i>et al.</i> (2007)
				P, G	Sharma and Sharma (2007)
e	Flag leaf length (cm)	Negative	NS	P, G	Mohekar <i>et al.</i> (2015)
				P, G	Sravan <i>et al.</i> (2012)
				P, G	Sadeghi (2011)
f	Flag leaf width (cm)	Negative	S	P,G	Sravan <i>et al.</i> (2012)
			NS	P, G	Sadeghi (2011)
				P, G	Srijan <i>et al.</i> (2016)
g	Flag leaf area (cm ²)	Negative	NS	P, G	Mohekar <i>et al.</i> (2015)
		Positive	S	G	Naseem <i>et al.</i> (2014)
				P	Wattoo <i>et al.</i> (2010)
			NS	P	Naseem <i>et al.</i> (2014)
h	SCMR	Positive		G	Wattoo <i>et al.</i> (2010)
			S	G	Gopikannan and Ganesh (2013)
				G	Nilanjaya and Kumar (2015)
		Negative	NS	P	Sathya and Jebaraj (2015)
			NS	G	Ullah <i>et al.</i> (2011)
				-	Adilakshmi and Raghavareddy (2012)
				G	Malath and

Table 2.4.(cont.).

					Gomathinayagam (2013)
i	Harvest index (%)	Positive	S	P, G	Sravan <i>et al.</i> (2012)
			NS	P P, G	Sridhar <i>et al.</i> (2016) Mohekar <i>et al.</i> (2015)
j	Grain length (mm)	Positive	NS	P P, G P, G	Umadevi <i>et al.</i> (2009) Bekele <i>et al.</i> (2013) Srijan <i>et al.</i> (2016)
		Negative	NS	G P, G P, G	Umadevi <i>et al.</i> (2009) Sadeghi (2011) Srijan <i>et al.</i> (2016)
k	Grain width (mm)	Positive	NS	P, G P, G	Umadevi <i>et al.</i> (2009) Srijan <i>et al.</i> (2016)
			Negative	S	P, G
			NS	P, G	Bekele <i>et al.</i> (2013)
L	Grain L/B ratio	Negative	NS	P, G P, G	Umadevi <i>et al.</i> (2009) Srijan <i>et al.</i> (2016)
		Positive	NS	P, G	Bekele <i>et al.</i> (2013)
V. Association of Panicle length with					
a	Number of filled grains per panicle	Positive	NS	P, G	Kishore <i>et al.</i> (2015)
			S	P, G P, G P, G	Shankar <i>et al.</i> (2016) Sadeghi (2011) Sanghera <i>et al.</i> (2013)
		Negative	NS	P, G	Hossian <i>et al.</i> (2015)
b	Number of ill filled grains per panicle	Positive	S	P, G	Hossian <i>et al.</i> (2015)
		Negative	S	G	Prasad <i>et al.</i> (2015)
c	1000 grain weight (g)	Positive	S	P, G P P P P, G P, G P, G	Hasib (2005) Sharma and Sharma (2007) Krishna <i>et al.</i> (2009) Rani and Reddy (2010) Babu <i>et al.</i> (2012) Minnie <i>et al.</i> (2013) Shankar <i>et al.</i> (2016)

Table 2.4.(cont.).

				P, G	Sadeghi (2011)
			NS	P, G	Borbora <i>et al.</i> (2005)
				G	Binse <i>et al.</i> (2006)
				P, G	Panwar and Ali (2007)
				G	Rani and Reddy (2010)
		P		Kishore <i>et al.</i> (2015)	
Negative	NS	P, G	Kumar and Bapu (2005)		
		P, G	Panwar (2006)		
		P, G	Garg <i>et al.</i> (2010)		
		P	Hefena <i>et al.</i> (2016)		
		P	Sridhar <i>et al.</i> (2016)		
		P, G	Sravan <i>et al.</i> (2012)		
		P, G	Hossian <i>et al.</i> (2015)		
d	Flag leaf length (cm)	Positive	NS	P, G	Mohekar <i>et al.</i> (2015)
			S	P, G	Sravan <i>et al.</i> (2012)
			P, G	Sadeghi (2011)	
	Negative	NS	P, G	Srijan <i>et al.</i> (2016)	
e	Flag leaf width (cm)	Negative	NS	P, G	Sravan <i>et al.</i> (2012)
			NS	P, G	Sadeghi (2011)
			P, G	Srijan <i>et al.</i> (2016)	
f	Flag leaf area (cm ²)	Positive	NS	P, G	Mohekar <i>et al.</i> (2015)
				G	Naseem <i>et al.</i> (2014)
			S	P	Naseem <i>et al.</i> (2014)
g	SCMR	Positive	S	G	Sudharani <i>et al.</i> (2012)
				G	Malath and Gomathinayagam (2013)
			G	Gopikannan and Ganesh (2013)	
		NS	-	Adilakshmi and Raghavareddy (2012)	
Negative	S	G	Ullah <i>et al.</i> (2011)		
		G	Nilanjaya and Kumar (2015)		
	NS	P	Ullah <i>et al.</i> (2011)		

Table 2.4 (cont.).

h	Harvest index (%)	Positive	S	P P, G	Sridhar <i>et al.</i> (2016) Sravan <i>et al.</i> (2012)
			S	G	Saikumar <i>et al.</i> (2014)
i	Grain length (mm)	Positive	NS	P, G P, G P, G	Umadevi <i>et al.</i> (2009) Sanghera <i>et al.</i> (2013) Srijan <i>et al.</i> (2016)
			S	P, G	Sadeghi (2011)
j	Grain width (mm)	Negative	NS	P, G P, G P, G P, G	Umadevi <i>et al.</i> (2009) Sadeghi (2011) Sanghera <i>et al.</i> (2013) Srijan <i>et al.</i> (2016)
k	Grain L/B ratio	Positive	S	P, G P	Umadevi <i>et al.</i> (2009) Srijan <i>et al.</i> (2016)
			NS	P, G G	Sanghera <i>et al.</i> (2013) Srijan <i>et al.</i> (2016)
VI. Association of number of filled grains per panicle with					
a	1000 grain weight (g)	Positive	S	P P, G G P P, G	Chaudhary and Motiramani (2003) Panwar (2006) Binse <i>et al.</i> (2006) Sridhar <i>et al.</i> (2016) Hossian <i>et al.</i> (2015)
			NS		Gulzar and Parray (2010)
		Negative	S	P, G P - P, G P, G P, G	Borbora <i>et al.</i> (2005) Sharma and Sharma (2007) Krishna <i>et al.</i> (2008) Garg <i>et al.</i> (2010) Kishore <i>et al.</i> (2015) Sanghera <i>et al.</i> (2013)
			NS	P, G P P, G	Rani and Reddy (2010) Parmhansh <i>et al.</i> (2010) Shankar <i>et al.</i> (2016)

Table 2.4.(cont.).

b	Number of ill filled grains per panicle	Negative	NS	P, G	Hossian <i>et al.</i> (2015)
c	SCMR	Positive	S	G G	Sudharani <i>et al.</i> (2012) Gopikannan and Ganesh (2013)
			NS	P	Sudharani <i>et al.</i> (2012)
		Negative	S	P	Sathya and Jebaraj (2015)
			NS	- G	Adilakshmi and Raghavareddy (2012) Malath and Gomathinayagam (2013)
d	Harvest index (%)	Negative	NS	p	Sridhar <i>et al.</i> (2016)
		Positive	S	G G G	Chakraborty <i>et al.</i> (2010) Sudharani <i>et al.</i> (2012) Saikumar <i>et al.</i> (2014)
e	Flag leaf length (cm)	Positive	S	P, G	Sadeghi (2011)
		Negative	NS	P, G	Srijan <i>et al.</i> (2016)
f	Flag leaf width (cm)	Positive	NS	P, G P, G	Sadeghi (2011) Srijan <i>et al.</i> (2016)
g	Flag leaf area (cm ²)	positive	S	P, G P, G	Naseem <i>et al.</i> (2014) Wattoo <i>et al.</i> (2010)
h	Grain length (mm)	Positive	S	P, G	Sadeghi (2011)
		Negative	NS	P, G	Sanghera <i>et al.</i> (2013)
			S	P, G	Srijan <i>et al.</i> (2016)
I	Grain width (mm)	Positive	S	P, G P	Sanghera <i>et al.</i> (2013) Srijan <i>et al.</i> (2016)
			S	P, G	Sadeghi (2011)
		Negative	NS	P, G	Srijan <i>et al.</i> (2016)
J	Grain L/B Ratio	Positive	S	P, G P, G	Sanghera <i>et al.</i> (2013) Srijan <i>et al.</i> (2016)

Table 2.4.(cont.).

a	Flag leaf length (cm)	Positive	NS	P, G P, G P, G P, G	Mohekar <i>et al.</i> (2015) Sravan <i>et al.</i> (2012) Sadeghi (2011) Srijan <i>et al.</i> (2016)
b	Flag leaf width (cm)	Positive	S	P, G P, G	Sravan <i>et al.</i> (2012) Sadeghi (2011)
		Negative	S	P, G	Srijan <i>et al.</i> (2016)
c	Flag leaf area (cm ²)	Negative	NS	P, G	Naseem <i>et al.</i> (2014)
		Positive	S	P	Wattoo <i>et al.</i> (2010)
			NS	G	Wattoo <i>et al.</i> (2010)
d	SCMR	Positive	S	G	Ullah <i>et al.</i> (2011)
			NS	-	Adilakshmi and Raghavareddy (2012)
				G	Malath and Gomathinayagam (2013)
				G	Gopikannan and Ganesh (2013)
				P, G	Mohekar <i>et al.</i> (2015)
		Negative	S	G	Sudharani <i>et al.</i> (2012)
			NS	P	Sathya and Jebaraj (2015)
e	Harvest index (%)	Positive	S	P P,G	Sridhar <i>et al.</i> (2016) Sravan <i>et al.</i> (2012)
			NS	P, G	Mohekar <i>et al.</i> (2015)
f	Grain length (mm)	Positive	S	P, G P, G P, G P	Sanghera <i>et al.</i> (2013) Bekele <i>et al.</i> (2013) Nikam <i>et al.</i> (2014) Srijan <i>et al.</i> (2016)
				NS	G Srijan <i>et al.</i> (2016)
		Negative	S	P, G	Sadeghi (2011)
g	Grain width (mm)	Positive	S	P, G P, G P, G P	Sadeghi (2011) Bekele <i>et al.</i> (2013) Nikam <i>et al.</i> (2014) Srijan <i>et al.</i> (2016)
				NS	P, G Sanghera <i>et al.</i> (2013)
				G	Srijan <i>et al.</i> (2016)

Table 2.4.(cont.)

h	L/B Ratio	Positive	NS	P, G	Sanghera <i>et al.</i> (2013)
			S	P, G	Bekele <i>et al.</i> (2013)
			P, G	Nikam <i>et al.</i> (2014)	
		Negative	S	P, G	Srijan <i>et al.</i> (2016)
IX. Association of flag leaf length with					
a	Flag leaf width (cm)	Positive	S	P, G	Sravan <i>et al.</i> (2012)
				P, G	Sadeghi (2011)
		Negative	NS	P, G	Srijan <i>et al.</i> (2016)
b	Flag leaf area (cm ²)	Positive	NS	P, G	Mohekar <i>et al.</i> (2015)
c	Harvest index (%)	Positive	NS	P, G	Mohekar <i>et al.</i> (2015)
				P, G	Sravan <i>et al.</i> (2012)
d	Grain length (mm)	Positive	S	P, G	Sadeghi (2011)
			NS	P, G	Srijan <i>et al.</i> (2016)
e	Grain width (mm)	Negative	NS	P, G	Sadeghi (2011)
		Positive	NS	P, G	Srijan <i>et al.</i> (2016)
f	Grain L/B ratio	Negative	NS	P, G	Srijan <i>et al.</i> (2016)
X. Association of flag leaf width with					
a	Harvest index (%)	Negative	NS	P, G	Sravan <i>et al.</i> (2012)
b	Grain length (mm)	Negative	S	P, G	Sadeghi (2011)
		positive	NS	P, G	Srijan <i>et al.</i> (2016)
c	Grain width (mm)	Positive	S	P, G	Sadeghi (2011)
		Negative	NS	P, G	Srijan <i>et al.</i> (2016)
d	Grain L/B ratio	Positive	NS	P, G	Srijan <i>et al.</i> (2016)
XI. Association of flag leaf area with					
a	Harvest index (%)	Positive	NS	P, G	Mohekar <i>et al.</i> (2015)
XII. Association of harvest Index with					
a	SCMR	Positive	S	G	Ullah <i>et al.</i> (2011)

Table 2.4.(cont.).

XII. Association of grain length with					
a	Grain width (mm)	Positive	NS	P, G	Sanghera <i>et al.</i> (2013)
		Negative	NS	P, G P, G P,G	Umadevi <i>et al.</i> (2009) Bekele <i>et al.</i> (2013) Srijan <i>et al.</i> (2016)
b	Grain L/B ratio	Positive	S	P, G P, G P,G	Umadevi <i>et al.</i> (2009) Bekele <i>et al.</i> (2013) Srijan <i>et al.</i> (2016)
XIII. Association of grain width with					
a	Grain L/B ratio	Positive	S	P,G P	Umadevi <i>et al.</i> (2009) Srijan <i>et al.</i> (2016)
		Negative	NS	P, G G	Sanghera <i>et al.</i> (2013) Srijan <i>et al.</i> (2016)
			S	P,G	Kumar and Senapathi (2013)

S = Significant
NS = Non-significant

P = Phenotypic
G = Genotypic

Table 2.5: Review of literature on direct effects of different traits on yield in rice (*Oryza sativa* L.)

S. No.	Character	Direction of effect	P/G	Reference
1.	Days to 50 % flowering	Positive	P	Jaiswal <i>et al.</i> (2007)
			P	Panwar (2006)
			P	Krishna <i>et al.</i> (2008)
			P, G	Sadeghi (2011)
			P	Pal <i>et al.</i> (2011)
			G	Seyoum <i>et al.</i> (2012)
			P, G	Rangare <i>et al.</i> (2012)
			P	Basavaraja <i>et al.</i> (2012)
			G	Seesang <i>et al.</i> (2013)
			P, G	Sanghera <i>et al.</i> (2013)
			P, G	Mohekar <i>et al.</i> (2015)
			P, G	Sravan <i>et al.</i> (2015)
			P, G	Shankar <i>et al.</i> (2016)
		Negative	G	Borbora <i>et al.</i> (2005)
			P	Kumar and Bapu (2005)
			G	Binse <i>et al.</i> (2006)
			P, G	Swain and Reddy (2006)
			P	Eradasappa <i>et al.</i> (2007)
			P, G	Garg <i>et al.</i> (2010)
			P	Babu <i>et al.</i> (2012)
			P	Bekele <i>et al.</i> (2013)
			p	Sridhar <i>et al.</i> (2016)
2.	Days to maturity	Positive	P, G	Bekele <i>et al.</i> (2013)
			P, G	Mohekar <i>et al.</i> (2015)
			P	Sridhar <i>et al.</i> (2016)
		Negative	P, G	Sadeghi (2011)
3.	Plant height (cm)	Positive	P, G	Janardhanam <i>et al.</i> (2001)
			P	Nagajyothi <i>et al.</i> (2001)
			P	Kumar and Bapu (2005)
			G	Borbora <i>et al.</i> (2005)
			P, G	Shashidhar <i>et al.</i> (2005)

Table 2.5 (cont.).

			P, G G P P P P P P, G G P, G P P, G P P P, G P P, G	Swain and Reddy (2006) Binse <i>et al.</i> (2006) Manna <i>et al.</i> (2006) Bhattacharyya <i>et al.</i> (2007) Jaiswal <i>et al.</i> (2007) Krishna <i>et al.</i> (2008) Garg <i>et al.</i> (2010) Sadeghi (2011) Seyoum <i>et al.</i> (2012) Rangare <i>et al.</i> (2012) Basavaraja <i>et al.</i> (2012) Sravan <i>et al.</i> (2012) Bekele <i>et al.</i> (2013) Nagaraju <i>et al.</i> (2013) Sanghera <i>et al.</i> (2013) Sridhar <i>et al.</i> (2016) Shankar <i>et al.</i> (2016)
		Negative	G P G G P P P, G	Nagajyothi <i>et al.</i> (2001) Panwar (2006) Manna <i>et al.</i> (2006) Rani and Reddy (2010) Kumar and Saravanan (2012) Babu <i>et al.</i> (2012) Mohekar <i>et al.</i> (2015)
4.	Number of ear bearing tillers	Positive	P, G P, G G P P, G P P P P G P	Nagajyothi <i>et al.</i> (2001) Swain and Reddy (2006) Binse <i>et al.</i> (2006) Panwar (2006) Manna <i>et al.</i> (2006) Eradasappa <i>et al.</i> (2007) Jaiswal <i>et al.</i> (2007) Panwar and Ali (2007) Krishna <i>et al.</i> (2008) Rani and Reddy (2010) Garg <i>et al.</i> (2010)

Table 2.5 (cont.).

			P, G P, G P, G P, G P P, G	Sadeghi (2011) Sravan <i>et al.</i> (2012) Kumar <i>et al.</i> (2013) Mohekar <i>et al.</i> (2015) Sridhar <i>et al.</i> (2016) Shankar <i>et al.</i> (2016)
		Negative	P, G G	Janardhanam <i>et al.</i> (2001) Rani and Reddy (2010)
5.	Panicle length (cm)	Positive	P, G G P P P G P G P P, G G P, G P P P, G P, G P, G	Nagajyothi <i>et al.</i> (2001) Borbora <i>et al.</i> (2005) Kumar and Bapu (2005) Panwar <i>et al.</i> (2006) Manna <i>et al.</i> (2006) Binse <i>et al.</i> (2006) Jaiswal <i>et al.</i> (2007) Rani and Reddy (2010) Garg <i>et al.</i> (2010) Sadeghi (2011) Seyoum <i>et al.</i> (2012) Rangare <i>et al.</i> (2012) Babu <i>et al.</i> (2012) Basavaraja <i>et al.</i> (2012) Sanghera <i>et al.</i> (2013) Mohekar <i>et al.</i> (2015) Shankar <i>et al.</i> (2016)
		Negative	P, G G G P P P G G G P, G	Janardhanam <i>et al.</i> (2001) Borbora <i>et al.</i> (2005) Manna <i>et al.</i> (2006) Eradasappa <i>et al.</i> (2007) Bhattacharyya <i>et al.</i> (2007) Krishna <i>et al.</i> (2008) Rani and Reddy (2010) Garg <i>et al.</i> (2010) Gopikannan and Ganesh (2012) Sravan <i>et al.</i> (2012)

Table 2.5 (cont.).

			G G P	Seesang <i>et al.</i> (2013) Sudharani <i>et al.</i> (2013) Sridhar <i>et al.</i> (2016)
6.	Number of filled grains per panicle	Positive	P, G P, G G P P P P P P P G P P, G P, G	Janardhanam <i>et al.</i> (2001) Nagajyothi <i>et al.</i> (2001) Borbora <i>et al.</i> (2005) Kumar and Bapu (2005) Panwar (2006) Swain and Reddy (2006) Jaiswal <i>et al.</i> (2007) Eradasappa <i>et al.</i> (2007) Bhattacharya <i>et al.</i> (2007) Krishna <i>et al.</i> (2008) Rani and Reddy (2010) Garg <i>et al.</i> (2010) Sadeghi (2011) Sravan <i>et al.</i> (2012)
		Negative	P, G G G G P, G P P, G	Manna <i>et al.</i> (2006) Binse <i>et al.</i> (2006) Swain and Reddy (2006) Rani and Reddy (2010) Sanghera <i>et al.</i> (2013) Sridhar <i>et al.</i> (2016) Shankar <i>et al.</i> (2016)
7.	Number of ill filled grains per panicle	Negative	P, G	Hossain <i>et al.</i> (2015)
8.	1000 grain weight (g)	Positive	P, G P P P G P P P	Nagajyothi <i>et al.</i> (2001) Kumar and Bapu (2005) Swain and Reddy (2006) Panwar (2006) Binse <i>et al.</i> (2006) Eradasappa <i>et al.</i> (2007) Bhattacharyya <i>et al.</i> (2007) Krishna <i>et al.</i> (2008)

Table 2.5 (cont.).

			G P P P, G G P, G P, G P, G P, G P, G P P, G	Rani and Reddy (2010) Garg <i>et al.</i> (2010) Pal <i>et al.</i> (2011) Sadeghi (2011) Seyoum <i>et al.</i> (2012) Sravan <i>et al.</i> (2012) Rangare <i>et al.</i> (2012) Gangashetty <i>et al.</i> (2013) Kumar <i>et al.</i> (2013) Sanghera <i>et al.</i> (2013) Mohekar <i>et al.</i> (2015) Sridhar <i>et al.</i> (2016) Shankar <i>et al.</i> (2016)
		Negative	G G G	Swain and Reddy (2006) Rani and Reddy (2010) Garg <i>et al.</i> (2010)
9.	Flag leaf length (cm)	Positive	P, G P, G	Sadeghi (2011) Srijan <i>et al.</i> (2016)
		Negative	P, G	Sravan <i>et al.</i> (2012)
10..	Flag leaf width (cm)	Positive	P, G P, G P, G	Sadeghi (2011) Sravan <i>et al.</i> (2012) Srijan <i>et al.</i> (2016)
11.	Flag leaf area (cm ²)	Positive	G P, G P, G	Wattoo <i>et al.</i> (2010) Mohekar <i>et al.</i> (2015) Nilanjaya and kumar (2015)
		Negative	P, G	Naseem <i>et al.</i> (2014)
12.	SCMR	Positive	P, G P, G G	Adilakshmi and Raghavareddy (2012) Mohekar <i>et al.</i> (2015) Nilanjaya and Kumar (2015)
		Negative	G	Sudharani <i>et al.</i> (2012)
13.	Harvest index (%)	Positive	P, G P	Mohekar <i>et al.</i> (2015) Sridhar <i>et al.</i> (2016)
14.	Grain length (mm)	Positive	P, G P, G	Bekele <i>et al.</i> (2013) Patel <i>et al.</i> (2014)

Table 2.5 (cont.).

			P	Srijan <i>et al.</i> (2016)
		Negative	P, G P, G G	Sanghera <i>et al.</i> (2013) Sadeghi (2011) Srijan <i>et al.</i> (2016)
15.	Grain width (mm)	Positive	P, G P, G P, G G	Sanghera <i>et al.</i> (2013) Sadeghi (2011) Bekele <i>et al.</i> (2013) Srijan <i>et al.</i> (2016)
		Negative	P, G P	Patel <i>et al.</i> (2014) Srijan <i>et al.</i> (2016)
16.	Grain L/B ratio	Positive	P, G P, G P	Sanghera <i>et al.</i> (2013) Patel <i>et al.</i> (2014) Srijan <i>et al.</i> (2016)
		Negative	G	Srijan <i>et al.</i> (2016)

S = Significant
NS = Non-significant

P = Phenotypic
G = Genotypic

Table 2.6. Review of literature on indirect effects of different yield components on yield in rice (*Oryza sativa* L.).

S. No	Character showing indirect effect on yield	Direction of effect	Characters through which indirect effect is expressed	P/ G	Reference
1.	Days to 50% flowering	Positive	Plant height, ear bearing tillers per plant, filled grains per panicle.	P	Kumar and Bapu (2005)
			No. of ear bearing tillers per plant.	G	Borbora <i>et al.</i> (2005)
			Grains per panicle, ear bearing tillers per plant, Panicle length, 1000 grain weight.	G	Binse <i>et al.</i> (2006)
			Plant height, panicle length, filled grains per panicle.	P	Panwar and Ali (2007)
			Number of ear bearing tillers per plant.	P	Jaiswal <i>et al.</i> (2007)
			Plant height, ear bearing tillers per plant, panicle length.	G	Garg <i>et al.</i> (2010)
			Days to maturity, plant height, grain length, Panicle length, flag leaf length, ear bearing tillers pr plant, filled grains per panicle.	P, G	Sanghera <i>et al.</i> (2013)
			Plant height, panicle length, grain length, grain L/B ratio.	P, G	Sadeghi (2011)
			Panicle length, Ear bearing tillers per plant, 1000	P, G	Mohekar <i>et al.</i> (2015)

Table 2.6 (cont.).

			grain weight.		
			Plant height, Panicle length.	P, G	Sravan <i>et al.</i> (2012)
			Days to maturity.	P	Sridhar <i>et al.</i> (2016)
			Plant height, panicle length, filled grains per panicle, 1000 grain weight.	P, G	Shankar <i>et al.</i> (2016)
		Negative	Plant height, panicle length, filled grains per panicle, 1000 grain weight.	G	Borbora <i>et al.</i> (2005)
			Panicle length, ear bearing tillers per plant, 1000 grain weight.	G	Binse <i>et al.</i> (2006)
			Ear bearing tillers per plant, grains per panicle, 1000 grain weight.	P	Jaiswal <i>et al.</i> (2007)
			Ear bearing tillers per plant, panicle length, filled grains per panicle.	P	Garg <i>et al.</i> (2010)
			Filled grains, 1000 grain weight, grain width.	P, G	Sanghera <i>et al.</i> (2013)
			Grain width, flag leaf width, 1000 grain weight.	P, G	Sadeghi (2011)
			Flag leaf length, plant height, days to maturity, harvest index.	P, G	Mohekar <i>et al.</i> (2015)
			Ear bearing tillers per plant, filled grains/panicle, 1000 grain weight.	P, G	Sravan <i>et al.</i> (2012)

Table 2.6 (cont.).

			Plant height, panicle length, ear bearing tillers per plant, filled grains/panicle, 1000 grain weight, harvest index.	P	Sridhar <i>et al.</i> (2016)
2.	Days to maturity	Positive	Days to 50 %flowering, plant height, panicle length, grain length, grain L/B ratio.	P, G	Sanghera <i>et al.</i> (2013)
			Plant height, grain width, panicle length, flag leaf width, 1000 grain weight.	P, G	Sadeghi (2011)
			Flag leaf length, panicle length, plant height. Ear bearing tillers/plant	P, G	Mohekar <i>et al.</i> (2015)
		Negative	Filled grains, 1000 grain weight, grain width.	P, G	Sanghera <i>et al.</i> (2013)
			Days to 50 %flowering, grain length, flag leaf length, ear bearing tillers, filled grain / panicle.	P, G	Sadeghi (2011)
			Days to 50 % flowering, ear bearing tillers, test weight, harvest index.	P, G	Mohekar <i>et al.</i> (2015)
			Days to 50 % flowering, plant height, panicle length, filed grains /panicle, 1000grain weight, harvest index.	P	Sridhar <i>et al.</i> (2016)
3.	Plant height (cm)	Positive	Number of grains per panicle, no. of ear bearing tillers per plant.	P, G	Shashidhar <i>et al.</i> (2005)

Table 2.6 (cont.).

			Days to 50% flowering, ear bearing tillers per plant, panicle length, filled grains per panicle, 1000 grain weight.	P	Panwar and Ali (2007)
			Panicle length, grains per panicle, ear bearing tillers per plant.	P	Jaiswal <i>et al.</i> (2007)
			Ear bearing tillers per plant, panicle length, number of grains per panicle, 1000 grain weight.	P	Neelima <i>et al.</i> (2007)
			Ear bearing tillers, panicle length, number of filled grains per panicle, 1000 grain weight.	G	Rani and Reddy (2010)
			Ear bearing tillers per plant, panicle length, filled grains per panicle, 1000 grain weight.	P	Garg <i>et al.</i> (2010)
			Days to 50 flowering, panicle length, 1000 grain weight, grain length, grain L/B ratio.	G	Sanghera <i>et al.</i> (2013)
			Days to 50% flowering, plant height, 1000 grain weight, harvest index.	P	Sridhar <i>et al.</i> (2016)
			Days to 50 flowering, panicle length, 1000 grain weight, filled grains per panicle, ear bearing tillers per plant.	P, G	Shankar <i>et al.</i> (2016)
		Negative	Days to 50% flowering, panicle length, 1000 grain weight.	P	Kumar and Bapu (2005)

Table 2.6 (cont.).

			1000 grain weight.	P	Jaiswal <i>et al.</i> (2007)
			No. of ear bearing tillers per plant, panicle length.	P, G	Krishna <i>et al.</i> (2009)
			Days to 50% flowering, 1000 grain weight.	P, G	Yadav <i>et al.</i> (2010)
			Days to maturity, filled grains, grain width.	P, G	Sanghera <i>et al.</i> (2013)
			Ear bearing tillers, filled grains, 1000 grain weight, days to maturity, harvest index.	P	Sridhar <i>et al.</i> (2016)
4.	Number of ear bearing tillers per plant	Positive	Plant height, filled grains per panicle.	P, G	Shashidhar <i>et al.</i> (2005)
			Days to 50% flowering, filled grains per panicle, 1000 grain weight.	P	Panwar and Ali (2007)
			Days to 50% flowering, total number of grains per panicle.	G	Binse <i>et al.</i> (2006)
			Plant height, ear bearing tillers per plant, 1000 grain weight.	P	Neelima <i>et al.</i> (2007)
			Days to 50% flowering, days to maturity, plant height, panicle length, flag leaf width, filled grain per panicle.	P, G	Sadeghi (2011)

Table 2.6 (cont.).

			Days to 50 % flowering, Flag leaf length, panicle length, 1000 grain weight.	P,G	Mohekar <i>et al.</i> (2015)
			Days to 50 % flowering, filled grains /panicle, 1000-grain weight.	P	Sravan <i>et al.</i> (2012)
			Days to 50 % flowering, panicle length, days to maturity, harvest index.	P, G	Sridhar <i>et al.</i> (2016)
			Plant height, 1000-grain weight.	P, G	Shankar <i>et al.</i> (2016)
		Negative	Plant height, panicle length.	P	Panwar and Ali (2007)
			Filled grains per panicle, 1000 grain weight.	P	Jaiswal <i>et al.</i> (2007)
			Plant height, panicle length, 1000 grain weight.	G	Binse <i>et al.</i> (2006)
			Plant height, panicle length.	P, G	Krishna <i>et al.</i> (2009)
			Grain length, grain width, flag leaf length, 1000 grain weight.	P, G	Sadeghi <i>et al.</i> (2011)
			Plant height, days to maturity, harvest index.	P, G	Mohekar <i>et al.</i> (2015)
			Plant height, panicle length.	P, G	Sravan <i>et al.</i> (2012)
			Days to 50% flowering, panicle length, filled grains per panicle.	P, G	Shankar <i>et al.</i> (2016)

Table 2.6 (cont.).

5.	Panicle length (cm)	Positive	Days to 50% flowering, plant height, filled grains per panicle, ear bearing tillers per plant.	P	Jaiswal <i>et al.</i> (2007)
			Plant height, ear bearing tillers per plant, grains per panicle.	P	Kumar and Bapu (2005)
			Filled grains per panicle.	P, G	Manna <i>et al.</i> (2006)
			Plant height, number of filled grains per panicle.	P	Neelima <i>et al.</i> (2007)
			Plant height, number of filled grains per panicle.	G	Rani and Reddy (2010)
			Plant height, ear bearing tillers per plant, grain length.	P	Garg <i>et al.</i> (2010)
			Plant height, ear bearing tillers per plant, 1000 grain weight.	G	Garg <i>et al.</i> (2010)
			Days to 50% flowering, plant height, grain L/B ratio.	P, G	Sanghera <i>et al.</i> (2013)
			Flag leaf length, panicle length, plant height, 1000 grain weight.	P, G	Mohekar <i>et al.</i> (2015)
			Filled grains/panicle, test weight, days to maturity, harvest index.	P	Sridhar <i>et al.</i> (2016)
			Plant height, 1000 grain weight, filled grains/panicle, days to 50% flowering.	P, G	Shankar <i>et al.</i> (2016)

Table 2.6 (cont.).

		Negative	Plant height, ear bearing tillers per plant, filled grains per panicle, 1000 grain weight.	P	Panwar and Ali (2007)
			Days to 50% flowering, 1000 grain weight.	P	Kumar and Bapu (2005)
			Ear bearing tillers number, ear bearing tillers, 1000 grain weight.	P	Neelima <i>et al.</i> (2007)
			Ear bearing tillers per plant, number of filled grains per panicle.	G	Rani and Reddy (2010)
			Ear bearing per plant, filled grains per panicle, 1000 grain weight.	P	Garg <i>et al.</i> (2010)
			Filled grains/panicle, test weight, grain length, grain width.	P, G	Sanghera <i>et al.</i> (2013)
			Days to 50 % flowering, ear bearing tillers, days to maturity.	P, G	Mohekar <i>et al.</i> (2015)
			Ear bearing tillers per plant.	P, G	Shankar <i>et al.</i> (2016)
6.	Number of filled grains per panicle	Positive	Plant height, ear bearing tillers per plant, panicle length, 1000 grain weight.	P	Neelima <i>et al.</i> (2007)
			Plant height, ear bearing per plant, 1000 grain weight.	P	Kumar and Bapu (2005)

Table 2.6 (cont.).

			Days to 50% flowering, plant height, 1000 grain weight.	G	Binse <i>et al.</i> (2006)
			Days to 50% flowering, plant height, grain length	P, G	Sanghera <i>et al.</i> (2013)
			Plant height, panicle length, ear bearing tillers per plant, days to maturity, harvest index.	P	Sridhar <i>et al.</i> (2016)
			Ear bearing tillers/plant, 1000 grain weight.	P, G	Shankar <i>et al.</i> (2016)
		Negative	Days to 50% flowering, ear bearing tillers per plant, 1000 grain weight.	P	Panwar and Ali (2007)
			Ear bearing tillers, 1000 grain weight.	P	Jaiswal <i>et al.</i> (2007)
			Plant height, 1000 grain weight.	G	Borbora <i>et al.</i> (2005)
			Days to maturity, grain width.	P, G	Sanghera <i>et al.</i> (2013)
			Days to 50% flowering, plant height, panicle length.	P, G	Shankar <i>et al.</i> (2016)
7.	Number of ill filled grains per panicle	Negative	Panicle length, filled grains per panicle, 1000 grain weight.	P, G	Hossain <i>et al.</i> (2015)
8.	1000 grain weight (g)	Positive	Plant height, tiller number, ear bearing tillers per panicle, filled grains per panicle.	P	Neelima <i>et al.</i> (2007)
			Days to 50% flowering, plant height, panicle length.	G	Binse <i>et al.</i> (2006)

Table 2.6 (cont.).

			Days to 50% flowering, ear bearing tillers per plant, plant height.	P, G	Krishna <i>et al.</i> (2009)
			Plant height, number of grains per panicle.	G	Rani and Reddy (2010)
			Ear bearing tillers per plant, grain length, panicle length.	P, G	Garg <i>et al.</i> (2010)
			Days to 50% flowering, plant height, ear bearing tillers, grain width, grain L/B ratio.	P, G	Sanghera <i>et al.</i> (2013)
			Days to 50 % flowering, plant height, effective tillers, and filled grains.	P, G	Mohekar <i>et al.</i> (2015)
			Days to 50 % flowering, plant height, filled grains per panicle, test weight, harvest index.	P	Sridhar <i>et al.</i> (2016)
			Days to 50 % flowering, plant height, Ear bearing tillers per plant, panicle length.	P, G	Shankar <i>et al.</i> (2016)
		Negative	Productive tillers per plant, number of grains per panicle.	G	Binse <i>et al.</i> (2006)
			Panicle length.	P, G	Krishna <i>et al.</i> (2009)
			Ear bearing tillers per plant, panicle length.	G	Rani and Reddy (2010)
			Plant height, ear bearing tillers per plant, panicle length, total grains per panicle.	P	Garg <i>et al.</i> (2010)

Table 2.6 (cont.).

			Plant height, ear bearing tillers per plant, filled rains per panicle.	G	Garg <i>et al.</i> (2010)
			Days to 50%flowering, filled grains/panicle, panicle length, grain length.	P, G	Sanghera <i>et al.</i> (2013)
			Flag leaf length, panicle length, plant height, ear bearing tillers, days to maturity, harvest index.	P, G	Mohekar <i>et al.</i> (2015)
			Panicle length, ear bearing tillers/plant, days to maturity.	P	Sridhar <i>et al.</i> (2016)
			Filled grains per panicle.	P, G	Shankar <i>et al.</i> (2016)
9.	Flag leaf length (cm)	Positive	Days to 50 % flowering, grain length, panicle length, flag leaf width, filled grains/panicle, 1000 grain weight.	P, G	Sadeghi <i>et al.</i> (2011)
			Panicle length, plant height, 1000 grain weight, harvest index.	P, G	Mohekar <i>et al.</i> (2015)
			Panicle length, flag leaf length, 1000 grain weight	P, G	Srijan <i>et al.</i> (2016)
		Negative	Days to maturity, plant height, grain width, ear bearing tillers	P, G	Sadeghi <i>et al.</i> (2011)
			Ear bearing tillers, days to maturity.	P, G	Mohekar <i>et al.</i> (2015)
10.	Flag leaf width	Positive	Days to maturity, plant height, grain width, flag	P.G	Sadeghi <i>et al.</i> (2011)

Table 2.6 (cont.).

	(cm)		leaf length, ear bearing tillers, filled grains per panicle, 1000 grain weight.		
			Days to 50 % flowering panicle length, flag leaf length.	P,G	Srijan <i>et al.</i> (2016)
		Negative	Days to 50 % flowering, grain length, panicle length.	P, G	Sadeghi (2011)
11.	Flag leaf area (cm ²)	Positive	Days to 50 % flowering, days to maturity, plant height, panicle length, and 1000 grain weight.	P, G	Nilanjaya and Kumar (2015)
			Ear bearing tillers, filled grains/panicle, days to 50% flowering, 1000 grain weight.	P, G	Naseem <i>et al.</i> (2014)
		Negative	Ear bearing tillers per plant, SCMR.	P, G	Nilanjaya and Kumar (2015)
			Plant height, panicle length, days to maturity.	P, G	Naseem <i>et al.</i> (2014)
			Days to 50 % flowering, days to maturity, ear bearing tillers, filled grains/panicle, 1000 grain weight.	G	Wattoo <i>et al.</i> (2010)
12.	SCMR	positive	Days to 50 %flowering, ear bearing tillers per plant, panicle length, filled grains per panicle,	G	Sudharani <i>et al.</i> (2012)
		negative	Days to 50 % flowering, days to maturity, ear bearing tillers per plant, panicle length 1000 grain	P, G	Nilanjaya and Kumar (2015)

Table 2.6 (cont.).

			weight		
13.	Harvest index (%)	Positive	Days to 50 % flowering, flag leaf length, plant height, 1000 grain weight.	P, G	Mohekar <i>et al.</i> (2015)
			Days to 50 % flowering, panicle length, ear bearing tillers/plant, filled grains/plant, 1000 grain weight.	P	Sridhar <i>et al.</i> (2016)
		Negative	Panicle length, ear bearing tillers, days to maturity.	P, G	Mohekar <i>et al.</i> (2015)
			Days to maturity.	P	Sridhar <i>et al.</i> (2016)
14.	Grain length (cm)	Positive	Filled grains/panicle, panicle length, 1000 grain weight, grain width, grain L/B ratio.	P, G	Sanghera <i>et al.</i> (2013)
			Plant height, flag leaf width, 1000 grain weight.	P, G	Sadeghi (2011)
			Days to maturity, ear bearing tillers, 1000 grain weight.	P, G	Bekele <i>et al.</i> (2013)
			Days to 50% flowering, flag leaf length, flag leaf width.	P, G	Srijan <i>et al.</i> (2016)
		Negative	Days to 50 % flowering. Plant height.	P, G	Sanghera <i>et al.</i> (2013)
			Days to 50 % flowering, Days to maturity, Grain width, Panicle length, flag leaf length, ear bearing	P, G	Sadeghi (2011)

Table 2.6 (cont.).

			tillers, filled grains/panicle, flag leaf length.		
			Days to 50 % flowering, plant height, grain width.	P, G	Bekele <i>et al.</i> (2013)
15.	Grain width (cm)	positive	Filled grains /panicle, 1000 grain weight.	P, G	Sanghera <i>et al.</i> (2013)
			Plant height, grain length, flag leaf width, ear bearing tillers, 1000 grain weight.	P, G	Sadeghi (2011)
			Days to 50% flowering, plant height, 1000 grain weight.	P, G	Bekele <i>et al.</i> (2013)
			Panicle length, flag leaf length.	P, G	Srijan <i>et al.</i> (2016)
		Negative	Days to 50%flowering, panicle length, grain length, grain L/B ratio	P, G	Sanghera <i>et al.</i> (2013)
			Days to 50% flowering, days to maturity, panicle length, flag leaf length, filled grains/panicle.	P, G	Sadeghi (2011)
			Days to maturity, ear bearing tillers, grain length.	P, G	Bekele <i>et al.</i> (2013)
			Days to 50% flowering, flag leaf width	P, G	Srijan <i>et al.</i> (2016)
16.	Grain L/B ratio	Positive	Days to 50% flowering, plant height, panicle length, test weight.	P, G	Sanghera <i>et al.</i> (2013)
			Days to 50% flowering, flag leaf width.	P, G	Srijan <i>et al.</i> (2016)

Table 2.6 (cont.).

		Negative	Filled grains/panicle, grain length, grain width	P, G	Sanghera <i>et al.</i> (2013)
			Panicle length, flag leaf length	P, G	Srijan <i>et al.</i> (2016)

P = Phenotypic

G = Genotypic