

STUDIES ON GENETIC VARIABILITY FOR LOW PHOSPHORUS TOLERANCE AND ITS USE EFFICIENCY IN RICE(*Oryza sativa* L.)

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B.Sc. (Ag.)

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(GENETICS AND PLANT BREEDING)**



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**STUDIES ON GENETIC VARIABILITY FOR LOW PHOSPHORUS TOLERANCE AND
ITS USE EFFICIENCY IN RICE
(*Oryza sativa* L.)**

By
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**THESIS SUBMITTED TO THE
PROFESSOR JAYASHANKAR TELANGANA STATE AGRICULTURAL UNIVERSITY
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COLLEGE OF AGRICULTURE, RAJENDRANAGAR, HYDERABAD
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2018**

DECLARATION

I, **A. DHAKESHWER GOUD** hereby declare that the thesis entitled “**STUDIES ON GENETIC VARIABILITY FOR LOW PHOSPHORUS TOLERANCE AND ITS USE EFFICIENCY IN RICE (*Oryza sativa* L.)**” submitted to the Professor Jayashankar Telangana State Agricultural University for the degree of **MASTER IN AGRICULTURE** is a result of original research work done by me. I also declare that any material contained in the thesis has not been published earlier in any manner.

Date: 11.06.2018

(A. DHAKESHWER GOUD)

Place: Rajendranagar, Hyderabad

CERTIFICATE

Mr. A. DHAKESHWER GOUD has satisfactorily prosecuted the course of research and that the thesis entitled “**STUDIES ON GENETIC VARIABILITY FOR LOW PHOSPHORUS TOLERANCE AND ITS USE EFFICIENCY IN RICE (*Oryza sativa* L.)**” 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 the thesis or part thereof has not been previously submitted by him for a degree of any university.

Date:

(Dr. C. CHERALU)

Chairman of the Advisory Committee

Place: Rajendranagar,
Hyderabad.

CERTIFICATE

This is to certify that the thesis entitled “**STUDIES ON GENETIC VARIABILITY FOR LOW PHOSPHORUS TOLERANCE AND ITS USE EFFICIENCY IN RICE (*Oryza sativa* L.)**” submitted in partial fulfilment of the requirements for the degree of **MASTER IN AGRICULTURE** of the **Professor Jayashankar Telangana State Agricultural University, Hyderabad**, is a record of the bonafide research work carried out by **A. DHAKESHWER GOUD** under my guidance and supervision. The subject of the thesis has been approved by the Student's Advisory Committee.

No part of the thesis has been submitted for any other degree or diploma. The published part has been fully acknowledged. All assistance and help 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 ABBREVIATION

%	:	per cent
σ^2g	:	Genotypic variance
σ^2p	:	Phenotypic variance
ANOVA	:	Analysis of variance
C.D.	:	Critical difference
C.V.	:	Coefficient of variation
cm	:	Centimeter
cm ²	:	Square centimeter
d.f.	:	Degrees of freedom
<i>et al.</i>	:	And others
Fig	:	Figure
g	:	Gram
GCV	:	Genotypic coefficient of variation
ha	:	Hectare
<i>i.e.</i>	:	That is
IIRR	:	Indian Institute of Rice Research
kg ha ⁻¹	:	Kilogram per hectare
kg	:	Kilogram
mha	:	Million hectare
MSS	:	Mean Sum of Squares
No.	:	Number
PCV	:	Phenotypic coefficient of variation

PJTSAU	:	Professor Jayashankar Telanagana State Agricultural
University		
PUE	:	Phosphorus Use Efficiency
FRBD	:	Factorial Randomized Block Design
rg	:	Genotypic correlation
rp	:	Phenotypic correlation
t	:	Tonne
viz.	:	Namely

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ABSTRACT

The investigation entitled “Studies on genetic variability for low Phosphorus tolerance and its use efficiency in rice (*Oryza sativa* L.)” was carried out at ICAR-IIRR, Rajendranagar, Hyderabad, during *Kharif* 2015 with the objectives to evaluate the rice genotypes for low P tolerance, P use efficiency, genetic variability and to study association between yield and other component traits under different levels of Phosphorus (P). The experimental material comprised of 90 rice genotypes, which include Green Super Rice (GSR) lines, cultivated varieties and Hybrids. The genotypes were evaluated in graded level (0, 20, 40 and 60 Kg/ha) of Phosphorus (P) in factorial RBD. The results indicated significant difference among the varieties for all the characters studied, except for flag leaf length, flag leaf width, panicle length and straw yield. The differences among the P levels and interactions were also significant for all the characters studied except for straw yield.

Under P₀ condition the genotype GSR134 showed high Phosphorus Use Efficiency

(PUE) and lowest response was observed for the genotype GSR 116. Among the cultivated varieties, hybrid INH 10002 showed highest PUE while IR-64 indicated low PUE. The analysis indicated that the PCV values were higher than GCV values for all the characters studied at all the levels of P, the estimates of PCV and GCV were high for grain yield under low P condition (P_0) than that of high P condition (P_{60}). Days to 50 percent flowering changed based on the P levels,. Number of tillers showed high to medium PCV and GCV, while panicle length and flag leaf length showed medium to low PCV and GCV values. Heritability for all the traits was high at P_0 and P_{20} except for flag leaf width, which indicated medium heritability. At P_{40} heritability estimates were high for all the traits except number of productive tillers and grain yield, which had medium heritability. At P_{60} heritability was low for Number of productive tillers and straw yield, it was medium for grain yield. Genetic advance as percent mean at P_0 was high for grain yield, number of productive tillers, shoot length, root weight, straw yield, P content in grain and P content in straw, while it was low for panicle length and flag leaf width.

Genetic advance as percent mean at P_{20} was high for number of productive tillers, root weight, straw yield, P content in grain and P content in straw, medium for grain yield, days to fifty percent flowering, plant height, flag leaf length, shoot length and root length while it was low for flag leaf width and panicle length . At P_{40} and P_{60} genetic advance as percent mean was low for grain yield. Grain yield was positively associated with all the traits except root weight and P content in grain, they were negative associated with grain yield in P_0 , the plant height had negative association with days to 50 percent flowering and root weight in P_0 . while under P_{40} grain yield was positively correlated with all the traits except P content in grain and P content in straw, Under P_{60} grain yield had negative association with number of tillers, P content in grain, plant height, root weight while with all other traits it showed positive association.

CHAPTER I

INTRODUCTION

Chapter I

INTRODUCTION

Rice (*Oryza sativa* L.) is the staple food of over half the world's population. It provides 20% of the world's dietary energy supply. The global production of paddy rice in 2014 was about 740.96 million tones and the cultivated area is estimated as 163.24 million hectares. From the total production, Asia accounts the largest production totaling to about 144.25 million tones whereas Africa produces approximately 11.58 million tons [12]. In 2014, average yield of rice for high producing countries 6.69, 6.75, 9.52, 5.75, 5.13 and 8.48 ton ha⁻¹ for Japan, China, Egypt, Vietnam, Indonesia and USA, respectively (Abebe *et.al.*,2017). In India, rice is cultivated in an area of nearly 43.46 million hectares with an annual production of 104.32 million tones and productivity of 2404 kg ha⁻¹, while in Telangana rice is grown in an area of 10.01 million hectares with an annual production and productivity of 29.33 million tonnes and 2930 kg ha⁻¹, respectively (Indiastat, 2016).

which helped in bringing down the quantum of imports and ushering in self-sufficiency in food production. All this could be realized because of wide scale adoption of high yielding varieties and use of chemical fertilizers. Of late, it has also been realized that yield of rice particularly in most productive irrigated ecology is stagnating and further increase in rice production for the ever growing population in sustainable manner is a challenge to all the stakeholders. In fact, a number of challenges such as changing scenario of diseases and insect pests in view of climate change, shrinking arable land, depleting water resources and increasing cost and demand of fertilizers are really complex.

There has been a dramatic increase worldwide in fertilizer applications in the last 50 years, and this has particularly been the case in India. Imbalanced and indiscriminate use of chemical fertilizers has not only greatly reduced the economic return of the fertilizers applied and placed a heavy economic burden on the farmers, but it has also resulted in widespread water eutrophication. phosphorus (P) is essential for plant growth, it is one of the least available nutrients in many agroecosystems, principally because P is bound to soil chemical and biological components that make it unavailable to growing plants (Richardson et al. 2009). In modern farming systems, P fertilization is used to remedy P deficiency. However, rock phosphate reserves are limited, fertilizers are costly for subsistence farmers, and phosphate use is inefficient because of immobilization by the soil

(Cordell et al. 2009). Improving P efficiency of crops would be an important contribution to sustainability of agro ecosystems (Richardson *et al.* 2011), both in developing countries where fertilizer use is negligible and in developed countries where excess P fertilization is responsible for environmental degradation (Cordell *et al.* 2009). P deficiency is considered a major limiting factor for rice production, especially in upland and rain fed lowland production systems and almost 50 % of rice soils are considered P deficient. Key aspect of improving crop performance in low-P soils is improving P acquisition efficiency via improved root traits (Lynch and Brown 2008; Richardson et al. 2011; Rose *et al.* 2012). Since P is diffusion-limited and depletion zones develop around existing roots, continuous exploration of soil is important for P acquisition. Root systems that can explore relevant soil domains at low metabolic cost are particularly important, since roots depend on and compete with shoots for fixed carbon (Lynch and Ho 2005; Lynch 2014). A number of root traits have been shown to be important for P acquisition in crops, including root hairs; (Vandamme *et al.* 2013), traits affecting topsoil exploration such as axial root angle (and elongation of lateral roots with high specific root length (Zhu and Lynch 2004). Similar strategies are likely to be useful in developing rice genotypes with better P acquisition efficiency. Increasing input cost is rendering the agriculture non-remunerative and farmers want to leave the agriculture if given some viable alternative. This situation would have been rather worst had government not bearing major chunk of spending on fertilizers in the form of subsidies. Demand for fertilizers is increasing while response of crop varieties is decreasing. So far, breeders have been breeding varieties which respond to heavy doses of fertilizers and nutrient use efficiency or tolerance to low nutrient status in soil has never attracted the attention of the breeders, as a result the high yielding varieties could not become popular among the poor farmers who cannot afford to apply the required quantity of chemical fertilizers.

Mineral nutrition in rice requires 17 essential elements, of which nitrogen (N), phosphorus (P) and potassium (K) are applied to rice fields as chemical fertilizers in large quantities. Nitrogen and P are fundamental to crop development because they form the basic component of many organic molecules, nucleic acids and proteins. Among these, phosphorus is from non-renewable natural resource and there is growing concern that the natural reserves of rock phosphate, the source of P fertilizer, are limited. A recent study conducted by the International Fertilizer Development Centre concluded that currently known and easily accessible world rock phosphate reserves will last for approximately

another 300–400 years. P is an important component of nutrient supply chain that ensures potential yield realization of rice as it plays a crucial role in energy storage and transfer within cells, speeds up root development, facilitates greater N uptake and results in higher grain protein yields.

The overwhelming majority of soils in the rice-producing areas are P-deficient with a high P-fixing capacity. In acidic soils free iron and aluminium oxides bind native and applied P into forms unavailable to plants, whereas in calcareous soils the abundant calcium and magnesium compounds bind inorganic phosphates into forms highly unavailable to plants. The high P-fixing capacity in both types of soils results in very low P-availability and thus low rates of uptake by the plants. Thus, improving the uptake efficiency of the rice plant in P-fixing soils need to be a major research target. Very often, breeders practice selection under well managed and heavily fertilized situation and during this course the genotypes possessing gene or gene combinations conferring tolerance to low inputs get lost and as a result most of the modern day varieties fare badly if not applied with heavy doses of fertilizers. The development of rice cultivars capable of using available P present in soils may be an attractive and cost effective approach to increasing rice yields where P deficiency is the major constraint. In view of above the present investigation was carried out with the following objectives:

1. To evaluate the rice genotypes in graded level of phosphorus (P) for low P tolerance and its use efficiency
2. To estimate the genetic variability in the genotypes evaluated under graded level of phosphorus(P).
3. To study the trait association between yield and other component traits under different levels of Phosphorus (P)

CHAPTER II

REVIEW OF LITERATURE

Chapter II

REVIEW OF LITERATURE

A brief review of available literature in consonance with the objectives of the present investigation in respect of rice crop are reviewed and presented under the following heads.

2.1 Genetic parameters

2.2 Character association

2.3 Phosphorus use efficiency

2.1 Genetic parameters

2.1.1 Variability

The nature and extent of variability forms the basis for all crop improvement programmes. According to Allard (1960), yield is polygenically controlled character and is highly influenced by environment. Partitioning of observed variability into heritable and non-heritable components is 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.

2.1.1.1 Days to 50 per cent flowering

Maurya *et al.* (1986), Rajamani (1993), Chookar *et al.* (1994), Kaw *et al.* (1999) and Awasthi and Pandey (2000), Ukaoma *et al.* (2013), reported high genotypic and phenotypic coefficients of variation. However, moderate amount of variability was observed for days to 50 per cent flowering by Manonmani *et al.* (1996), Vange and Ojo (1997) and Chikkalingaiah *et al.* (1999), whereas, Verma *et al.* (2000) reported high to moderate genotypic coefficient of variation, while Balan *et al.* (1999) reported low genotypic coefficient of variation.

Nayak *et al.* (2002), Patil *et al.* (2003), Suman (2003), Sinha *et al.* (2004) and Kole *et al.* (2008), Rai *et al.* (2014), Dhurai *et al.* (2014), Tirumala Rao *et al.* (2014), Shinde *et al.* (2015), observed low genotypic and phenotypic coefficients of variation

for days to 50 per cent flowering.

Devi *et al.* (2006) and Kishore *et al.* (2015) in their studies the magnitude of reported that phenotypic coefficients of variation.

2.1.1.2 Plant height (cm)

Gonzales and Ramirez (1998), Tripathi *et al.* (1999), Awasthi and Pandey (2000) and Sinha *et al.* (2004) observed high genotypic and phenotypic coefficients of variation for plant height, while Sadhukan *et al.* (2000), Shivani and Sree Ram Reddy (2000) and Kishore *et al.* (2008) reported high to moderate amount of phenotypic and genotypic coefficients of variation. Ganesan and Subramanian (1990), Singh and Choudhary (1996), Vange and Ojo (1997), Manonmani *et al.* (1996), Nagajyothi (2001), Tara Satyavathi *et al.* (2001), Nayak *et al.* (2002), Patil *et al.* (2003), Dhurai *et al.* (2014), Shinde *et al.* (2015), Aluwihare *et al.* (2016), Veronica *et al.* (2017) and Zhang *et al.* (2018) observed moderate variability for plant height.

Das *et al.* (2005), Singh *et al.* (2005) and Karad and Pol (2008) reported high genotypic coefficient of variation for this trait, while, studies of Verma *et al.* (2000) reported high to moderate estimates of genotypic coefficient of variation for this character. Whereas Chikkalingaiah *et al.* (1999), Patil *et al.* (2003) and Kole *et al.* (2008) observed low genotypic coefficient of variation. Studies of Remabai *et al.* (1992), Chookar *et al.* (1994) and Devi *et al.* (2006) indicated high phenotypic coefficient of variation for plant height in rice. Tirumala Rao *et al.* (2014), Rai *et al.* (2014), Kishore *et al.* (2015), Mahender *et al.* (2017), Veronica *et al.* (2017) and Zhang *et al.* (2018) indicated a low phenotypic coefficient of variation and genotypic coefficient of variation for plant height in rice.

2.1.1.3 Number of productive tillers per plant

Chookar *et al.* (1994), Manonmani *et al.* (1996), Chikkalingaiah *et al.* (1999), Sinha *et al.* (2004) Raut *et al.* (2009), Shinde *et al.* (2015) and Umesh *et al.* (2015) reported high genotypic coefficient of variation and phenotypic coefficient of variation.

Sardana and Sasi Kumar (1987), Basavaraja *et al.* (1997), Chaudhary and Motiramani (2003), Tirumala Rao *et al.* (2014), Rai *et al.* (2014) studied high phenotypic

coefficient of variation for number of productive tillers per plant, while studies of Das *et al.* (2005), Singh *et al.* (2005) and Jaiswal *et al.* (2007) indicated that high genotypic coefficient of variation for this trait. On the other hand Vange and Ojo (1997), Nagajyothi (2001), Dhurai *et al.* (2014) and Veronica *et al.*, (2017) reported moderate amount of variability.

Niranjana Murthy *et al.* (1999), Tara Satyavathi *et al.* (2001) and Surender Raju (2002), Kishore *et al.* (2015), Aluwihare *et al.*, (2016), Mahender *et al.*, (2017) and Zhang *et al.*, (2018) observed low genotypic and phenotypic coefficients of variation for number of productive tillers per plant.

2.1.1.4 Flag leaf length (cm)

Madakemohekar *et al.* (2015) reported high genetic coefficient of variation and phenotypic coefficient of variation. Rai *et al.* (2014) and Umesh *et al.* (2015) observed moderate genetic coefficient of variation and phenotypic coefficient of variation, while Ogunbayo *et al.* (2014), Paikhomba *et al.* (2014), Aluwihare *et al.*, (2016), Mahender *et al.*, (2017), Veronica *et al.*, (2017) and Zhang *et al.*, (2018) reported low genetic coefficient of variation and phenotypic coefficient of variation.

2.1.1.5 Flag leaf width (cm)

Madakemohekar *et al.* (2015) reported high genetic coefficient of variation and phenotypic coefficient of variation. Sathish kumar rai *et al.* (2014) and Umesh *et al.* (2015) observed as moderated genetic coefficient of variation and phenotypic coefficient of variation. Ogunbayo *et al.* (2014) and Paikhomba *et al.* (2014), studied low genetic coefficient of variation and phenotypic coefficient of variation.

2.1.1.6 Panicle length (cm)

Rajamani (1993), Chookar *et al.* (1994) and Kaw *et al.* (1999) reported wide range of variation for panicle length in rice whereas, Rao and Shrivastav (1994), Manonmani *et al.* (1996), Vange and Ojo (1997), Chikkalingaiah *et al.* (1999), Nagajyothi (2001), Tara Satyavathi *et al.* (2001), Patil *et al.* (2003), Kole *et al.* (2008), Paikhomba *et al.* (2014) and Umesh *et al.* (2015) reported low genotypic and phenotypic coefficients of variation for panicle length in rice.

Tripathi *et al.* (1999) reported high genotypic and phenotypic coefficients of

variation for panicle length in rice. While studies of Sardana and Sasi Kumar (1987), Devi *et al.* (2006) and Shinde *et al.* (2015), indicated that phenotypic coefficient of variation were higher than genotypic coefficient of variation.

Nayak *et al.* (2002), Singh *et al.* (2002), Dhurai *et al.* (2014), Sathish kumar rai *et al.* (2014) and Madakemohekar *et al.* (2015) reported moderate amount of variability for this trait.

Ukaoma *et al.* (2013) reported high genetic coefficient of variation and phenotypic coefficient of variation and also observed PCV greater than GCV.

2.1.1.7 Shoot weight (g)

Ukaoma *et al.* (2013) reported high genetic coefficient of variation and phenotypic coefficient of variation for shoot weight and also observed PCV greater than GCV.

2.1.1.8 Straw yield per plant (g)

Girish Chandra Tiwari *et al.* (2014) studied moderated genetic coefficient of variation and phenotypic coefficient of variation for straw yield per plant (g). Ramanjaneyulu *et al.* (2014) observed PCV greater than GCV. J. R. Patel *et al.* (2014), Shinde *et al.* (2015) and Mst. Tuhina-Khatun *et al.* (2015) reported high genetic coefficient of variation and phenotypic coefficient of variation and also observed PCV greater than GCV.

2.1.1.9 Grain yield per plant (g)

Girish chandra tiwari *et al.* (2014), Paikhomba *et al.* (2014) and Tirumala rao *et al.* (2014) studied moderat genetic coefficient of variation and phenotypic coefficient of variation for grain yield per plant (g). A.V. Ramanjaneyulu *et al.* (2014) observed PCV greater than GCV.

Patel *et al.* (2014), Sathish kumar rai *et al.* (2014), Dhurai *et al.* (2014), Umesh *et al.* (2015), Shinde *et al.* (2015), Madakemohekar *et al.* (2015) and Kishore *et al.* (2015), observed high genetic coefficient of variation and phenotypic coefficient of variation.

2.1.1.10 1000-Grain weight (g)

Paikhomba *et al.* (2014) reported as low genetic coefficient of variation and phenotypic coefficient of variation for grain weight (g). Tirumala rao *et al.* (2014) , Shinde *et al.* (2015) reported PCV greater than GCV. J. R. Patel *et al.* (2014), Sathish kumar rai *et al.* (2014) , Dhurai *et al.* (2014) and Kishore *et al.* (2015) reported moderate genetic coefficient of variation and phenotypic coefficient of variation . Madakemohekar *et al.* (2015), observed high genetic coefficient of variation and phenotypic coefficient of variation .

2.1.2 Heritability and Genetic Advance

Heritability in broad sense refers to the genetic variation present in the population in relation to the total observed variance. Genetic advance refers to the improvement in the mean genotypic value of the selected plants over the base population.

High heritability coupled with high genetic advance suggests that character improvement could be made by selection based on phenotypic performance. This estimation of broad sense heritability and genetic advance for different characters by different workers are reviewed below.

2.1.2.1 Days to 50 per cent flowering

Chikkalingaiah *et al.* (1999), Balan *et al.* (2000), Bhandarkar *et al.* (2002), Singh *et al.* (2005), Ashvani Panwar *et al.* (2007) and Kishore *et al.* (2008), Patel *et al.* (2014), Sathish kumar rai *et al.* (2014) ., Dhurai *et al.* (2014) and Shinde *et al.* (2015), reported high heritability estimates for days to 50 per cent flowering, while Sanjeev Kumar *et al.* (2008) reported high heritability in narrow sense for this trait.

Madhavalatha (2002), Nayak *et al.* (2002), Mahto *et al.* (2003), Sankar *et al.* (2006), Sharma and Sharma (2007) , Kishore *et al.* (2008) and Raut *et al.* (2009), Ukaoma *et al.* (2013), Girish chandra Tiwari *et al.* (2014) observed high heritability coupled with high genetic advance to 50 percent flowering in rice. While Marimuthu *et al.* (1990) Rao and Shrivastav (1994) studied high heritability coupled with moderate genetic advance for days to 50 per cent flowering. Whereas, Sardana and Sasikumar (1987), Balan *et al.* (1999), Niranjana Murthy *et al.* (1999), Patil *et al.* (2003), Suman (2003) and Sinha *et al.* (2004) reported high heritability coupled with low genetic advance for days to 50 per cent flowering.

Chauhan *et al.*(1993), Sahdev Singh *et al.*.(1996) and Singh and Choudhary (1996) observed medium heritability coupled with high genetic advance for this trait.

Ananthi *et al.*. (2006) reported moderate genetic advance as percent of mean, while, Sharma and Sharma (2007) reported high genetic advance as percent of mean.

Verma *et al.* (2000) reported high narrow sense heritability along with high genetic advance for days to 50 per cent flowering in rice. Whereas Bharadwaj *et al.*. (2007) reported high heritability and high genetic advance as percent of mean for this character. Paikhomba *et al.* (2014) reported high heritability and low genetic advance as percent of mean for this character.

2.1.2.2 Plant height (cm)

Yadav (1992), Mokate *et al.*.(1998), Chikkalingaiah *et al.*(1999) and Kaw *et al.*.(1999), Souroush *et al.*. (2004) Saxena *et al.*. (2005), Dhurai *et al.* (2014), Sathish kumar rai *et al.* (2014) .reported high heritability estimates, while moderate heritability for this trait was reported by Sharma and Sharma (2007) and Sanjeev Kumar *et al.*. (2008).

High heritability coupled with high genetic advance for plant height in rice were reported by Vange and Ojo (1997), Singh *et al.*. (2000), Das *et al.*. (2001), Nagajyothi (2001), Venkata Suresh (2001), Mishra and Varma (2002), Mahto *et al.*. (2003), Nayak *et al.*.(2003), Das *et al.*. (2005), Mall *et al.*. (2005), Singh *et al.*. (2005), Sankar *et al.*. (2006), Chandra Kishore *et al.*.(2008), Karod and Pol (2008),Kishore *et al.*. (2008) ,Kumar and Ramesh (2008), Raut *et al.*. (2009). , Shinde *et al.* (2015) , While Singh *et al.*. (2006), Mamta Singh (2007) and J. R. Patel *et al.* (2014), observed high heritability along with moderate genetic advance for this trait. Where as Marimuthu *et al.*.(1990), Patil *et al.*. (2003), Suman (2003) and Sinha *et al.*.(2004) observed high heritability along with moderate or low genetic advance for this trait.

High heritability along with moderate genetic advance as percent of mean was observed by Sadhukan (2000), Bhandarkar *et al.*. (2002) and Bharadwaj *et al.*. (2007). Whereas, high genetic gain as percent of mean was reported by Das *et al.*. (2005), Singh *et al.*. (2005) and Chandra Kishore *et al.*. (2008) for this trait.

Sahdev Singh *et al.*. (1996) reported low to high heritability and low genetic

advance in F₃ populations of the cross Jhona-349 x IR-8. Paikhomba *et al.* (2014) reported high heritability and low genetic advance as percent of mean for this character.

2.1.2.3 Number of productive tillers per plant

Mishra and Verma (2002), Sankar *et al.* (2006), Jaiswal *et al.* (2007), Mall *et al.* (2008) Anbanandan (2009) and Ukaoma *et al.* (2013) reported high heritability coupled with high genetic advance for number of productive tillers per plant. Whereas, Ananda Kumar (1992), Borbora and Hazarika (1998), Chikkalingaiah *et al.* (1999), Nagajyothi (2001), Nayak *et al.* (2002), Patil *et al.* (2003), Suman (2003), Das *et al.* (2005), Patil and Sarawgi (2003), Singh *et al.* (2005), Sethu Raghava Nayudu (2007) and Dhurai *et al.* (2014), reported high heritability coupled with high genetic advance as per cent of mean for number of productive tillers per plant.

Baradwaj *et al.* (2007) reported low to moderate heritability and low to moderate genetic advance as percent of mean for this trait. Venkata Suresh (2001) studied moderate heritability coupled with moderate genetic advance for this trait.

Mamta Singh *et al.* (2007) and Sharma and Sharma (2007) observed moderate heritability and low genetic advance for ear bearing tillers per plant in rice. Whereas, Sardana and Sasikumar (1987) observed moderate heritability and high genetic advance for this trait.

Ravindranath *et al.* (1982), Umesh *et al.* (2015) and Shinde *et al.* (2015) observed high heritability and low genetic advance for ear bearing tillers in rice. While Shivani and Sree Ram Reddy (2000) reported high heritability and low genetic advance as percent of mean for number of productive tillers per plant.

Medium to high heritability and low genetic advance were reported by Sahdev Singh *et al.* (1996) for productive tillers per plant in rice. Whereas, Ramesh Kumar (1989) and Niranjana Murthy *et al.* (1999) studied low heritability with very low genetic advance for this trait.

2.1.2.4 Flag leaf length (cm)

Madakemohekar *et al.* (2015) reported high heritability coupled with high genetic

advance. Ogunbayo *et al.* (2014), reported high heritability coupled with moderate genetic advance. Sathish kumar rai *et al.* (2014) reported high heritability coupled with high genetic advance.as percent of mean and moderate genetic advance. Umesh *et al.* (2015) observed reported as high heritability coupled with moderate genetic advance. Paikhomba *et al.* (2014) and Mahender *et al.*, (2017) observed moderate heritability coupled with low genetic advance.

2.1.2.5 Flag leaf width (cm)

Madakemohekar *et al.* (2015) reported high heritability coupled with high genetic advance. Ogunbayo *et al.* (2014) reported high heritability coupled with low genetic advance. Sathish kumar rai *et al.* (2014) observed high heritability coupled with high genetic advance.as percent of mean and moderate genetic advance. Umesh *et al.* (2015) studied moderate heritability coupled with low genetic advance. Paikhomba *et al.* (2014) reported low heritability coupled with low genetic advance.

2.1.2.6 Panicle length (cm)

Paramasivam *et al.* (1995), Chikkalingaiah *et al.* (1999), Nayak *et al.* (2002) , Singh *et al.* (2005), Sankar *et al.* (2006) and Madakemohekar *et al.* (2015) reported high heritability coupled with high genetic advance for panicle length in rice. Whereas, Bharadwaj *et al.* (2007) and Sethu Raghava Nayudu (2007) reported high heritability coupled with high genetic advance as percent of mean for this trait.

Kaw *et al.* (1999), Bhandarkar *et al.* (2002), Saxena *et al.* (2005) and Sharma and Sharma (2007) reported high heritability for this trait, while Sanjeev Kumar *et al.* (2005) reported medium heritability in narrow sense for this trait.

Remabai *et al.* (1992), Borbora and Hazarika (1998), Mokate *et al.* (1998), Shivani and Sree Ram Reddy (2000), Nagajyothi (2001), Suman (2003), Mamta Singh *et al.* (2007), Kishore *et al.* (2015) and Shinde *et al.* (2015) reported high heritability and low genetic advance for panicle length in rice. While Das *et al.* (2001) reported high heritability and moderate to low genetic advance for panicle length in rice.

Satya Priya Lalitha and Sreedhar (1996) and Venkata Suresh (2001) observed moderate heritability and moderate genetic advance for panicle length in rice. Whereas,

Ananthi *et al.*. (2006) reported moderate genetic advance as percent of mean for this trait.

Sardana and Sasikumar (1987) and Singh and Chaudhary (1996) reported low heritability with low genetic advance for this trait. Umesh *et al.* (2015) reported high heritability with low genetic advance for this trait. .

2.1.2.7 Root weight (g)

Ukaoma *et al.* (2013) reported high heritability coupled with high genetic advance.

2.1.2.8 Shoot weight (g)

Ukaoma *et al.* (2013) reported high heritability coupled with high genetic advance.

2.1.2.9 Straw yield per plant (g)

Girish Chandra Tiwari *et al.* (2014) reported low heritability coupled with low genetic advance. J. R. Patel *et al.* (2014) observed high value of heritability coupled with high expected genetic advance per cent of mean. Shinde *et al.* (2015), reported high heritability coupled with moderate genetic advance. Mst. Tuhina-Khatun *et al.* (2015) reported high heritability coupled with high genetic advance .

2.1.2.10 Grain yield per plant (g)

Girish Chandra Tiwari *et al.* (2014) reported low heritability coupled with low genetic advance, Paikhomba *et al.* (2014), reported high heritability coupled with moderate genetic advance. Tirumala rao *et al.* (2014) observed high heritability coupled with high genetic advance as per cent of mean, Patel *et al.* (2014) observed high heritability coupled with high expected genetic advance as per cent of mean. Sathish kumar rai *et al.* (2014) , Dhurai *et al.* (2014) and Umesh *et al.* (2015), reported high value of heritability coupled with high genetic advance as per cent of mean. Madakemohekar *et al.* (2015) reported high heritability coupled with high genetic advance.

2.1.2.11 1000-Grain weight (g)

Paikhomba *et al.* (2014) reported high heritability coupled with low genetic advance as percent of mean. Tirumala rao *et al.* (2014), Sathish kumar rai *et al.* (2014) and Dhurai *et*

al. (2014), reported high heritability coupled with high genetic advance as percent of mean. Kishore *et al.* (2015) results revealed high heritability coupled with low genetic advance as percent of mean. Shinde *et al.* (2015) reported high heritability coupled with low genetic advance.

2.2 CHARACTER ASSOCIATION

Study of character association helps the breeder in fixing selection criteria for grain yield in parental lines, such that selections will be effective in isolating the plants with desired combination of characters. Phenotypic correlation is the correlation of phenotypic values and is subjected to changes in the environment. It measures the environment deviation together with non-additive gene action. Genotypic correlation is the correlation of breeding value (additive + additive, additive epistatic) gene action. Hence, knowledge of association between different characters is highly essential for planning a sound breeding programme.

Several workers have studied the correlation coefficients in rice and contradictory association have been reported for almost all the character pairs which may be due to the different experimental material handled by them.

A brief review of studies on the association of characters in rice is presented hereunder (Table 2.1)

2.3 PHOSPHORUS USE EFFICIENCY

Fageria *et al.* (1988) screened 25 rice cultivars (*Oryza sativa* L.) at low, medium, and high levels of soil P and observed significant cultivar differences in P use efficiency. They also observed positive correlations among growth parameters such as plant height, tillers, root and shoot weight, and P content of roots and shoots. These results indicate that selection of rice cultivars for satisfactory performance under low P availability can be carried out using shoot and root dry weight as criteria

Fageria and Baligar (1997) evaluated the growth and P-use efficiency of 20 upland rice (*Oryza sativa* L.) Genotypes at low (0 mg P kg⁻¹), medium (75 mg P kg⁻¹), and high (150 mg P kg⁻¹) levels of applied P on an Oxisol. Plant height, tillers, shoot and root dry weight, shoot-root ratio, P concentration in root and shoot, P uptake in root and shoot and P-use efficiency were significantly (P (P<0.01) affected by level of soil P as well as the

genotype. Shoot weight and P uptake in shoot were found to be the plant parameters most sensitive to P deficiency suggesting that these two parameters may be most suitable for screening rice genotypes for P-use efficiency under green house conditions.

Wissuwa *et al.* (1998) identified three QTLs for dryweight and four QTLs for P uptake, together explaining 45.4% and 54.5% of the variation for the respective traits. In the study they also reported that P-deficiency tolerance was mainly caused by differences in P uptake and not in P-use efficiency. Using this trait indirectly related to P-deficiency tolerance such as tiller number. They also detected a major QTL but none of the minor QTLs detected for P uptake or dry weight.

Table 2.1 Association of yield component traits with grain yield per plant in rice

Character	Nature of association	Reference
Days to 50% flowering	Positive significant	Satpute (1996) Chaudhary and Das (1997) Selvarani and Rangaswamy (1998) Balan <i>et al.</i> (1999) Sakthivel (2001) Bandarkar <i>et al.</i> (2002) Madhavi Latha (2002) Suman (2003) Mahto <i>et al.</i> (2003) Kuldeep <i>et al.</i> (2004) Souroush <i>et al.</i> (2004) Madhavilatha <i>et al.</i> (2005) Patil and Sarawgi (2005) Sankar <i>et al.</i> (2006) Singh <i>et al.</i> (2006) Jaiswal <i>et al.</i> (2007) Raut <i>et al.</i> (2009) Bhadru <i>et al.</i> (2011) Dhurai <i>et al.</i> (2014) Shinde <i>et al.</i> (2015) Mahender <i>et al.</i> , (2017)
	Positive non-significant	Kumar <i>et al.</i> (1998) Rao and Shrivastav (1999) Vange <i>et al.</i> (1999) Dhurai <i>et al.</i> (2014) Shinde <i>et al.</i> (2015) Mahender <i>et al.</i> , (2017)

		Veronica <i>et al.</i> , (2017) Zhang <i>et al.</i> , (2018)
	Negative non-significant	Sarma and Roy (1993) Yolanda and Vijendra Das (1995) Meenakshi <i>et al.</i> . (1999) Bhadru <i>et al.</i> (2011) Eswara Reddy <i>et al.</i> (2013) Patel <i>et al.</i> (2014) Veronica <i>et al.</i> , (2017)
	Negative Significant	Adil Jamal <i>et al.</i> . (2007) Sanjeev Kumar <i>et al.</i> . (2008)
Plant height	Positive Significant	Basavaraja <i>et al.</i> . (1997) Chaudhary and Das (1997) Debchoudhury and Das (1998) Sarawgi <i>et al.</i> . (2000) Nayak <i>et al.</i> . (2001) Bala (2001) Sakthivel (2001) Madhavi Latha (2002) Bhandarkar <i>et al.</i> . (2002) Madhavi Latha (2002) Bhandarkar <i>et al.</i> . (2002) Abhinav Sao <i>et al.</i> . (2004) Borkakati <i>et al.</i> . (2005) Madhavi Latha <i>et al.</i> . (2005) Patil and Sarawgi (2005) Shashidhar <i>et al.</i> . (2005) Vaithiyalingam and Nadarajan (2005) Jaiswal <i>et al.</i> . (2007) Chandra kishore <i>et al.</i> . (2008) Kole <i>et al.</i> . (2008) Raut <i>et al.</i> . (2009) Bhadru <i>et al.</i> .(2011) Eswara reddy <i>et al.</i> .(2013) Dhurai <i>et al.</i> (2014) Patel <i>et al.</i> (2014) Shinde <i>et al.</i> (2015)
	Positive non-significant	Suman (2003) Veronica <i>et al.</i> , (2017)
	Negative significant	Yolanda and Vijendra Das (1995) Reddy <i>et al.</i> . (1997) Tara Satyavathi <i>et al.</i> . (2001) Mahto <i>et al.</i> . (2003)

	Negative non-significant	Chauhan <i>et al.</i> (1993) Gupta <i>et al.</i> (1998) Meenakshi <i>et al.</i> (1999)
No. of productive tillers	Positive significant	Basavaraj <i>et al.</i> (1997) Nayak <i>et al.</i> (2001) Tara Satyavathi <i>et al.</i> (2001) Sakthivel (2001) Janardhanam <i>et al.</i> (2001) Madhavi Latha (2002) Suman (2003) Chaudhary and Motiramani (2003) Shrirame <i>et al.</i> (2003) Souroush <i>et al.</i> (2004) Kuldeep <i>et al.</i> (2004) Borkakati <i>et al.</i> (2005) Shashidhar <i>et al.</i> (2005) Siva Kumar (2005) Vaithialingam and Nadarajan (2005) Gazafrodi <i>et al.</i> (2006) Manna <i>et al.</i> (2006) Panwar (2006) Sankar <i>et al.</i> (2006) Usha Kumari <i>et al.</i> (2006) Ishwar Dutt <i>et al.</i> (2007) Jaiswal <i>et al.</i> (2007) Chandra Kishore <i>et al.</i> (2008) Rokonuzzaman <i>et al.</i> (2008) Raut <i>et al.</i> (2009)
	Positive and non-significant	Chaubey and Singh (1994) Yolanda and Vijendra Das (1995) Reddy <i>et al.</i> (1997)
	Negative Non-significant	Awasthi and Borthakur (1986) Haque <i>et al.</i> (1991)
Panicle length	Positive significant	Chaudhary and Das (1997) Shivani and Sree Ram Reddy (2000) Nayak <i>et al.</i> (2001) Bala (2001) Sakthivel (2001) Madhavi Latha (2002) Suman (2003) Kuldeep <i>et al.</i> (2004) Abhinav Sao <i>et al.</i> (2004)

		Akter <i>et al.</i> (2004) Mankesh Kumar (2004) Madhavalatha <i>et al.</i> (2005) Siva Kumar (2005) Vaithiyalingam and Nadarajan (2005) Sankar <i>et al.</i> (2006) Singh <i>et al.</i> (2006) Sharma and Sharma (2007) Chandra Kishore <i>et al.</i> (2008) Raut <i>et al.</i> (2009)
	Positive Non-significant	Vange <i>et al.</i> (1999) Tara Satyavathi <i>et al.</i> (2001)
	Negative Non-significant	Chauhan <i>et al.</i> (1993) Ramesh Babu (1999)
1000-grain weight	Positive significant	Bagali <i>et al.</i> (1999) Sakthivel (2001) Tara Satyavathi <i>et al.</i> (2001) Madhavi Latha (2002) Kuldeep <i>et al.</i> (2004) Sinha <i>et al.</i> (2004) Akter <i>et al.</i> (2004) Mankesh Kumar (2004) Madhavalatha <i>et al.</i> (2005) Vaithiyalingam and Nadarajan (2005) Krishnaveni <i>et al.</i> (2006) Habib <i>et al.</i> (2007) Sharma and Sharma (2007) Chandra kishore <i>et al.</i> (2008) Raut <i>et al.</i> (2009)
	Positive Non-significant	Supriyo Chakraborty and Hazarika (1994) Gupta <i>et al.</i> (1998) Vange <i>et al.</i> (1999)
	Negative Significant	Suman (2003) Mahto <i>et al.</i> (2003) Hasib (2005) Karod and Pol (2008)
	Negative Non-significant	Wilfred Manuel and Rangaswamy (1993) Geeta <i>et al.</i> (1994)
Flag leaf length	Positive significant	Yugandhar Reddy <i>et al.</i> (2008) Eswara Reddy <i>et al.</i> (2013)
	Positive non-significant	Bhadru <i>et al.</i> (2011)

Flag leaf width	Positive significant	Yugandhar Reddy et al.. (2008) Sathish kumari rai et al. (2014) Ogunbayo et al.(2014) Eswara Reddy et al.. (2013)
	Negative significant	Bhadru <i>et al..</i> (2011)
Straw yield	Positive significant	Patel et al.. (2014) Girichandra tiwari et al.. (2014) Shinde et al.. (2015)

**Table 2.2 Association among the yield component traits in rice,
(i)Association of days to 50 per cent flowering**

Character	Nature of association	reference
Plant height	Positive significant	Meenakshi <i>et al.</i> (1999) Kavitha and Sree Rama Reddi (2001) Sakthivel (2001) Madhavi Latha (2002) Patel <i>et al.</i> (2014)
	Positive Non-significant	Chauhan <i>et al.</i> (1993) Ramesh Babu (1999)
	Negative Non-significant	Debchoudhury and Das (1998)
Number of productive tillers/plant	Positive significant	Sawant <i>et al.</i> (1995) Sakthivel (2001)
	Positive Non-significant	Kavitha and Sree Rama Reddi (2001) Surender Raju (2002)
	Negative Non-significant	Yolanda and Vijendra Das (1995) Meenakshi <i>et al.</i> (1999)
Panicle length	Positive significant	Vange <i>et al.</i> (1999) Nayak <i>et al.</i> (2001) Sakthivel (2001) Madhavi Latha (2002) Suman (2003) Eswara reddy <i>et al.</i> (2013)
	Positive Non-significant	Sarma and Roy (1993) Sawant <i>et al.</i> (1995) Kavitha and Sree Rama Reddi (2001)
	Negative Non-significant	Chauhan <i>et al.</i> (1993) Ramesh Babu (1999)
1000-grain weight	Positive significant	Ravindranath <i>et al.</i> (1982) Sharma and Sharma (2007) Patel <i>et al.</i> (2014)
	Positive and non-significant	Roy <i>et al.</i> (1995)
	Negative significant	Ramesh Babu (1999) Nayak <i>et al.</i> (2001) Kavitha and Sree Rama Reddi (2001)
	Negative non-significant	Sawant <i>et al.</i> (1995) Vange <i>et al.</i> (1999)

Flage leaf length	Positive significant	Eswara Reddy et al.. (2013)
Flage leaf width	Positive significant	Bhadru et al.(2011)
Straw yield	Positive significant	Girish Chandra tiwari et al. (2014)
	Positive and non-significant	Shinde et al. (2015)

(ii) Association of plant height

Table 2.3 Association among the yield component traits in rice;

character	Nature of association	Reference
Number of productive tillers	Positive significant	Kavitha and Sree Rama Reddi (2001) Sakthivel (2001) Janardhanam <i>et al.</i> (2001) Surender Raju (2002)
	Positive Non-significant	Roy <i>et al.</i> (1995) Yolanda and Vijendra Das (1995) Pradyumna Rao <i>et al.</i> (1996)
	Negative significant	Meenakshi <i>et al.</i> (1999) Nayak <i>et al.</i> (2001)
Panicle length	Positive significant	Tara Satyavathi <i>et al.</i> (2001) Sakthivel (2001) Janardhanam <i>et al.</i> (2001) Madhavi Latha (2002) Suman (2003) Sinha <i>et al.</i> .(2004)
	Positive non-significant	Chaubey and Singh (1994) Yolanda and Vijendra Das (1995) Reddy <i>et al.</i> (1997) Debchoudhury and Das (1998)
	Negative significant	Ananda Kumar (1992)
1000-grain weight	Positive and significant	Reddy <i>et al.</i> (1997) Suman (2003) Yogameenakshi <i>et al.</i> .(2004)
	Positive and non-significant	Awasthi and Borthakur (1986) Ramesh Babu (1999)
	Negative significant	Sukanya Subramanian and Rathinam (1984)
	Negative non-significant	Roy <i>et al.</i> (1995) Meenakshi <i>et al.</i> (1999)

		Nayak <i>et al.</i> (2001)
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(iii) Association of panicle length

Table 2.4 Association among the yield component traits in rice;

Character	Nature of association	Reference
Number of productive tillers	Positive significant	Bala (2001)
Days to 50% flowering	Positive significant	Bala (2001) Sakthivel (2001)
Plant height	Positive significant	Bala (2001) Sakthivel (2001)
1000-grain weight	Positive significant	Gopinath <i>et al.</i> (1984) Yogameenakshi <i>et al.</i> (2004)
	Positive and non-significant	Reddy <i>et al.</i> (1997) Kavitha and Sree Rama Reddi (2001)
	Negative significant	Sukanya Subramanian and Rathinam (1984)
	Negative and non-significant	Roy <i>et al.</i> (1995) Vange <i>et al.</i> (1999) Nayak <i>et al.</i> (2001)

iv) Association of number of productive tillers

Table 2.5 Association among the yield component traits in rice

Character	Nature of association	Reference
Panicle length	Positive significant	Roy <i>et al.</i> (1995) Sakthivel (2001) Janardhanam <i>et al.</i> (2001)
	Positive non-significant	Yolanda and Vijendra Das (1996) Kavitha and Sree Rama Reddi (2001)
	Negative significant	Chaubey and Richharia (1993) Tara Satyavathi <i>et al.</i> (2001) Suman (2003)
	Negative non-significant	Reddy <i>et al.</i> (1997) Satya Priya Lalitha and Sreedhar (1996)
Plant height	Positive significant	Sakthivel (2001)
1000-grain weight	Positive and significant	Suryanarayana (2000) Sakthivel (2001)
	Positive and non-significant	Yolanda and Vijendra Das (1995)

		Meenakshi <i>et al.</i> (1999) Kavitha and Sree Rama Reddi (2001) Tara Satyavathi <i>et al.</i> (2001)
	Negative significant	Gopinath <i>et al.</i> (1984) Nayak <i>et al.</i> (2001)
	Negative non-significant	Roy <i>et al.</i> (1995) Nanja Reddy <i>et al.</i> (1995) Reddy <i>et al.</i> (1997)

v) Association of flag leaf length

Table 2.6 Association among the yield component traits in rice

Character	nature of association	Reference
Days to 50% flowering	Positive significant	Eswara Reddy <i>et al.</i> (2013)
Plant height	Positive significant	Bhadru <i>et al.</i> (2011) Eswara reddy <i>et al.</i> (2013)
Panicle length	Positive significant	Bhadru <i>et al.</i> (2011) Eswara reddy <i>et al.</i> (2013)
1000 grain weight	Positive significant	Eswara Reddy <i>et al.</i> (2013)
No. of productive tillers	Positive significant	Bhadru <i>et al.</i> (2011)

Vi) Association of flag leaf width

Table 2.7 Association among the yield component traits in rice

Character	Nature of association	reference
Days to 50% flowering	Positive significant	Bhadru <i>et al.</i> (2011)
Plant height	Positive significant	Bhadru <i>et al.</i> (2011) Eswara reddy <i>et al.</i> (2013)
Panicle length	Positive significant	Eswara Reddy <i>et al.</i> (2013)
No. of productive tillers	Positive significant	Bhadru <i>et al.</i> (2011) Eswara reddy <i>et al.</i> (2013)
Flag leaf length	Positive significant	Bhadru <i>et al.</i> (2011)
1000 grain weight	Positive significant	Bhadru <i>et al.</i> (2011) Eswara reddy <i>et al.</i> (2013)

vii) Association of 1000 grain weight

Table 2.8 Association among the yield component traits in rice

Character	Nature of association	Reference
Days 50% flowering	Positive significant	Patel et al. (2014)
Plant height	Positive significant	Panwar and Mashiat Ali (2007) Eswara Reddy <i>et al.</i> (2013)
Panicle length	Positive significant	Patel et al. (2014) Eswara Reddy <i>et al.</i> (2013)
No .of productive tillers	Positive significant	Bhadru et al.(2011) Moosavi et al. (2015)
Flage leaf length	Positive significant	Eswara Reddy <i>et al.</i> (2013)
Flge leaf width	Negative significant	Bhadru et al.(2011)

CHAPTER III

MATERIAL AND METHODS

Chapter III

MATERIAL AND METHODS

The details of materials used and methodologies adopted during the course of present investigation are elucidated under appropriate heads in this chapter. The present investigation entitled “Studies on genetic variability for low Phosphorus tolerance and its use efficiency in rice (*Oryza sativa* L.)’ was carried out under field conditions during *kharif 2015* at the Research Farm of the ICAR - Indian Institute of Rice Research (IIRR) (formerly DRR), Rajendranagar, Hyderabad, Telangana state. The farm is geographically located at 17°19’ North and 78°23’ East, at an altitude of 1719 ft.

The details of the research work carried out, materials used and methodologies adopted in this investigation are described here under.

3.1 MATERIAL

The experimental material consisted of 90 genotypes obtained from Department of Genetics and Plant Breeding, ICAR - Indian Institute of Rice Research (IIRR) (formerly DRR), Rajendranagar, Hyderabad. The genotypes were evaluated in graded level of phosphorus (P) for low P tolerance and its use efficiency to estimate the genetic variability in the genotypes under graded level of phosphorus(P) and to study the trait association between yield and other component traits under different levels of Phosphorus (P). The information on source of the genotypes is given in following table.

Table 3.1: Details of the experimental material (90 rice genotypes)

S.no	GSR lines	Varieties	Hybrids	Other breeding stocks
1	GSR101	ADITHYA	DRRH3	N22
2	GSR102	AKSHAYADANA	INH10001	SM59
3	GSR103	BPT5204	INH10002	SM101
4	GSR104	IR64	INH12013	SM363
5	GSR105	KASALATH	KRH2	SM686
6	GSR106	MAHSURI	PR133	SM787(PY2)

7	GSR107	MTU1010	PA6444	VANDHANA
8	GSR108	RASI		IET24036
9	GSR109	RAVI		IET24003
10	GSR110	RPBIO226		
11	GSR111	RNR15048		
12	GSR112	SAMPADHA		
13	GSR113	SUGANDHAMATHI		
14	GSR114	SWARNA		
15	GSR115	TULASI		
16	GSR116	TRIGUNA		
17	GSR117	TELLAHAMSA		
18	GSR118	VARDHAN		
19	GSR119	VASUMATHI		
20	GSR120	VIKAS		
21	GSR121	WGL14		
22	GSR122			
23	GSR123			
24	GSR124			
25	GSR125			
26	GSR126			
27	GSR127			
28	GSR128			
29	GSR129			
30	GSR130			
31	GSR131			
32	GSR132			
33	GSR133			
34	GSR134			
35	GSR135			
36	GSR136			
37	GSR137			
38	GSR138			
39	GSR139			
40	GSR140			
41	GSR141			
42	GSR142			
43	GSR143			
44	GSR144			
45	GSR145			
46	GSR146			
47	GSR147			

48	GSR148			
49	GSR317			
50	GSR311			
51	GSR322			
52	GSR333			
53	GSR111(OLD)			

3.2 METHODS

Ninty genotypes were sown separately in the nursery on raised beds. Twenty seven days old seedlings of each genotype were transplanted in the main field with a spacing of 20 cm between rows and 15 cm between plants in a Factorial Randomized Block Design (FRBD) with 2 replications, 4 levels of phosphorus gradients. All necessary precautions were taken to maintain uniform plant population in each treatment per replication. All the recommended agronomic practices and plant protection methods for raising a healthy crop were taken up during experimentation.

3.3 RECORDING OF OBSERVATIONS

Three plants of each genotype in each replication selected randomly from the middle of the rows, used to record data and their mean values were considered for statistical analysis.

The observations were recorded at appropriate growth stages.

3.3.1 Days to 50 per cent flowering

The number of days from sowing to the primary panicles in 50 per cent plants were in heading was recorded.

3.3.2 Plant height (cm)

Plant height is measured in centimeter from ground level to the tip of the tallest panicle in each plant at the time of maturity.

3.3.3 Number of productive tillers per plant

Number of ear bearing tillers per plant was counted at the time of maturity.

3.3.4 Flag leaf length (cm)

Flag leaf length was measured in centimeters from the base of flag leaf to its tip during flowering

3.3.5 Flag leaf width (cm)

Flag leaf width was measured in centimeter at broader place of leaf blade during flowering

3.3.6 Panicle length (cm)

It was measured in centimeter at the time of plant maturity from the base of panicle to tip of last spikelet prior to harvesting.

3.3.7 Root length (cm)

The plant was uprooted first and then cleaned in water and measured the length of the root with the help of a meter scale before flowering stage.

3.3.8 Shoot length (cm)

The plant was uprooted first and then cleaned in water and measured the length of the shoot with the help of a meter scale before flowering stage.

3.3.9 Root weight (g)

Root portion is separated from the uprooted plant and cleaned in water and then sun dried, oven dried, taken the weight of the root portion before flowering stage.

3.3.10 Shoot weight (g)

Shoot portion is separated from the uprooted plant and cleaned in water and then sun dried, oven dried and taken the weight of the shoot portion before flowering stage.

3.3.11 Straw yield per plant (g)

The weight of straw harvested from each plant was recorded in grams after removing the grains and drying to remove moisture (8-10 %).

3.3.12 Grain yield per plant (g)

The weight of filled grains harvested from each plant was recorded in grams after

bringing the grains to required moisture content (12%).

3.3.13 1000-grain weight (g)

One thousand well filled grains were counted at random from each plant and weighed at 15 per cent moisture content and recorded in grams.

3.3.14 Phosphorus content in straw & grain (ppm)

One gram each of oven-dried and processed grain and straw samples were digested with a 9:4 mixture of nitric acid and perchloric acid on a hot plate. The clear digested residue was cooled, diluted to 100 ml distilled water and filtered to remove insoluble silica.

In digested extract, phosphorus content was determined by Vanado–molybdo phosphoric yellow color method as described by Piper (1966) using Spectrophotometer (Elico SL – 177) at 420 nm and P content was expressed as percent.

3.4 STATISTICAL PROCEDURE

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

1. Analysis of variance
2. Genotypic and phenotypic coefficients of variation
3. Heritability and genetic advance
4. Estimation of correlation coefficients
5. Estimation of phosphorus content by colorimetric method (Jackson, M.L. 1967)

3.4.1 Analysis of variance

Analysis of variance was computed based on factorial randomized block design for each character separately as per standard statistical procedure. (Rangaswamy R, 1995)

$$Y_{ijkl} = \mu + r_i + a_j + b_k + c_l + ab_{jk} + ac_{jl} + bc_{kl} + abc_{jkl} + e_{ijkl}$$

Where,

Y_{ijkl} =phenotypic observation of I replication (j,k&l)th treatments

U =mean effect

R_i =ith replication effect

A,b,c are factors

E_{ijkl} =residual effect

Table .3.2. The structure of analysis of variance:

Source	Degrees of freedom	Mean sum of squares	F cal value
Replication	(r-1)	rms	rms/ems
Treatment	(t-1)	tms	tms/ems
A	1	ams	ams/ems
B	1	bms	bms/ems
C	1	cms	cms/ems
Ab	1	abms	abms/ems
Bc	1	bcms	bcms/ems
Ca	1	cams	cams/ems
Abc	1	abcms	abcms/ems
Error	(r-1) (23-1)	ems	
Total	r.23-1		

Where,

r and t = number of replications and treatments, respectively

$M's$, $M't$ and $M'e$ = mean sum of squares due to replications, treatments and error respectively.

Or

Two way nested anova (Engineering statistics Hand book)

$$y_{ijk} = m + a_i + b_j(i) + e_{ijk}$$

where,

y_{ijk} = phenotypic observation of the ith factor(A) and jth factor(B).

m = mean effect

a_i = ith effect of factor (A)

$b_{j(i)}$ = jth effect of factor (B) nested within the factor A

e_{ijk} = residual effect.

Table.3.3 .

Source	df	Mean Square	F ratio
A	I - 1	$MSA = SSA/(I - 1)$	MSA/MSB
B within A	$I(J - 1)$	$MSB = SSB/(I(J - 1))$	MSB/MSE
Residuals	$IJ(K - 1)$	$MSE = SSE/(IJ(K - 1))$	
Corr. Total	$IJK - 1$		

3.4.2 Variance

The genotypic and phenotypic variances were calculated as per the formulae (Burton and Devane, 1953).

$$\text{Genotypic variance } (\sigma^2g) = \frac{(\text{Mean sum of squares due to treatments} - \text{Mean sum of squares due to error})}{\text{Number of replications}}$$

$$\text{Phenotypic variance } (\sigma^2p) = \sigma^2g + \sigma^2e$$

$$(\sigma^2e) = \text{Error variance}$$

3.4.3 Genotypic and phenotypic coefficients of variation

The genotypic and phenotypic coefficients of variation were calculated according to the formula given by Falconer (1981).

$$\text{Genotypic coefficient of variation (GCV)} = \frac{\text{Genotypic standard deviation}}{\text{Mean}} \times 100$$

$$\text{Phenotypic coefficient of variation (PCV)} = \frac{\text{Phenotypic standard deviation}}{\text{Mean}} \times 100$$

Categorization of the range of variation was effected as proposed by Sivasubramanian and Madhavamenon (1973).

< 10% : Low

10-20% : Moderate

> 20% : High

3.4.4 Heritability and genetic advance

3.4.4.1 Heritability

Heritability in the broad sense refers to the proportion of genotypic variance to the total observed variance in the total population. Heritability (h^2) in the broad sense was calculated according to the formula given by Allard (1960).

$$h^2 = \frac{\sigma^2_g}{\sigma^2_p}$$

h^2 = heritability in broad sense

σ^2_g = genotypic variance

σ^2_p = phenotypic variance ($\sigma^2_g + \sigma^2_e$)

σ^2_e = environmental variance

As suggested by Johnson *et al.* (1955) h^2 estimates were categorized as:

Low : 0-30%

Medium : 30-60%

High : above 60

3.4.4.2 Genetic advance

Genetic advance refers to the expected gain or improvement in the next generation by selecting the superior individuals under certain amount of selection pressure. From the heritability estimates the genetic advance was estimated by the following formula given by Burton (1952).

$$GA = K \cdot h^2 (b) \cdot \sigma_p$$

Where,

GA = expected genetic advance

K = Selection differential, the value of which is
2.06 at 5 per cent selection intensity

σ_p = phenotypic standard deviation
 $h^2(b)$ = heritability in broad sense

In order to visualize the relative utility of genetic advance among the characters, genetic advance as per cent of mean was computed

$$\text{Genetic advance as per cent of mean} = \frac{\text{GA}}{\text{Grand mean}} \times 100$$

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

Low = Less than 10%
 Moderate = 10-20 %
 High = More than 20%

3.4.5 Estimation of correlation coefficients

Correlation coefficients were calculated at genotypic and phenotypic level using the formulae suggested by Falconer (1964).

$$\text{Genotypic coefficient of correlation } (r_g) = r(x_i . x_j)_g = \frac{\text{Cov.}(x_i . x_j)_g}{\sqrt{v(x_i)_g \cdot v(x_j)_g}}$$

Where,

$r(x_i . x_j)_g$ is genotypic correlation between i^{th} and j^{th} characters

$\text{Cov. } (x_i . x_j)_g$ is genotypic covariance between i^{th} and j^{th} characters

$v(x_i)_g$ is genotypic variance of i^{th} character

$v(x_j)_g$ is genotypic variance of j^{th} character

$$\text{Phenotypic coefficient of correlation } (r_p) = r(x_i . x_j)_p = \frac{\text{Cov.}(x_i . x_j)_p}{\sqrt{v(x_i)_p \cdot v(x_j)_p}}$$

Where,

$r(x_i . x_j)_p$ is phenotypic correlation between i^{th} and j^{th} characters

$\text{Cov. } (x_i . x_j)_p$ is phenotypic covariance between i^{th} and j^{th} characters

$v(x_i)_p$ is phenotypic variance of i^{th} character

$v(x_j)_p$ is phenotypic variance of j^{th} character

3.5 Estimation of phosphorus content by colorimetric method (Jackson, M.L. 1967)

Digestion of the plant samples: For nutrients other than N, the plant material can be digested in a diacid mixture or a triacid mixture or dry ashed and dissolved in acid.

Diacid digestion: It is carried out using 5:1 of HNO_3 : HClO_4 if the sample is high in fats / oils, pre-digestion using 25 ml HNO_3 /g sample is recommended to avoid explosion.

Triacid digestion: It is carried out using a mixture of HNO_3 : H_2SO_4 : HClO_4 in the ratio of 9 : 4 : 1.

The sample digestion is carried out as described under

- Weigh 1 g ground plant material in 100 ml conical flask.
- To this add 10 ml of acid mixture and swirl the content of the flask gently.
- Keep for overnight for predigestion.
- Place the flask on low heat hot plate in a digestion chamber then heat the contents at higher temperature until the production of red N_2O fumes ceases.
- Evaporate the contents until 3 to 5 ml digest is obtained but not to dryness. The completion of digestion is confirmed when the liquid become colourless.
- After cooling the flask, add 20 ml of deionized or glass distilled water to the plant digest. Transfer the digest quantitatively into a 100 ml volumetric flask .
- Make up the volume with deionized water.
- Filtered through Whatman No. 1 filter paper.
- Aliquots of this diluted digest are used for the determination of P, K, Ca, Mg, S, Fe, Mn, Zn and Cu.

Principle : When vanadomolybdate and phosphate radical reacts in nitric acid medium a heteropoly compound is formed which is yellow in colour. The intensity of yellow colour is measured in a spectrophotometer at 420 nm. The amount of P in the plant sample is determined from the absorbance values.

Reagents

1. Ammonium molybdate – ammonium vanadate in HNO_3 (Barton's reagent)

- Dissolve 22.5 g of ammonium molybdate in 400 ml of warm distilled water.
- Also dissolve 1.25 g of ammonium metavanadate in 150 ml of boiling water.
- Add the two solutions and cool to room temperature.

- Add 250 ml of concentrated nitric acid (HNO₃) and dilute to 1 litre.

2. Standard P solution: Dissolve 0.2195 g of analytical grade KH₂PO₄ and dilute to 1 litre. This solution contains 50 µg P / ml.

Procedure

Preparation of standard curve:

- ✓ Transfer 0, 1, 2, 3, 4 and 5 ml of standard solution into 50 ml volumetric flasks and add 10 mL of vanado molybdate reagent to each flask. Make up the volume with distilled water to obtain 0, 1, 2, 3, 4 and 5 ppm P standards respectively. Read the absorbance after 30 minutes.
- ✓ Plot the absorbance (Y axis) against concentration of working standards (X axis). Linear calibration curve is established.

Sample preparation

- Pipette out 5 ml of plant digest into a 50 ml of volumetric flask.
- Add 10 ml of Barton's reagent, shake well and make up the volume.
- Allow to stand for 30 minutes for yellow colour development.
- Read the intensity of the colour at 420 nm in a spectrophotometer.
- Plot the absorbance value in the standard graph to obtain the concentration of P in the colored solution (X ppm).

Calculations

Concentration of P in colored solution = X ppm

i.e., 1 mL of colored solution contains X µg P

50 mL of colored solution contains 50 x X µg P

→ Which is present in 5 mL of the plant digest

100 mL of plant digest consists of $50 \times X \times 100/5 = X \times 1000$ µg P

→ Which is obtained from 1 g plant sample

100 g of plant sample consists of $X \times 1000 \times 100/1$

= $X \times 10^5 \times 10^{-6}$ g P

= X x 0.1 %

CHAPTER IV

RESULTS AND DISCUSSION

Chapter IV

RESULTS AND DISCUSSION

Experimental findings of the present investigation are presented here under with the following headings

4.1 Evaluation of rice genotypes under graded level of P.

4.2 Analysis of variance for the different traits under graded level of phosphorus.

4.3 Association behavior of different traits under graded level of phosphorus.

4.1 Evaluation of rice genotypes under graded levels of P

Ninety rice genotypes were evaluated under four levels of P (0, 20, 40 and 60) in factorial RBD (Table 4.1). The results showed that there is a significant difference among the rice genotypes for all the character studied. P levels were also significant for days to 50 percent flowering, plant height, number of productive tillers, root length, root weight, P content in straw and P content in grain. The significant interaction was also observed for days to 50 percent flowering, plant height, number of productive tillers, root length, root weight, P content in straw and p content in grain. These results are in accordance with Fageria and Baligar (1997).

4.1.1 Phosphorus use efficiency of rice genotypes under P_0 condition

Phosphorus use efficiency (PUE) of rice genotypes under P_0 were worked out and are presented in the Table (4.2) The PUE was highest for GSR134 (77.1%) and lowest for GSR 116 (25.34) among the cultivated varieties and hybrid INH10002 showed to highest PUE(74.8), followed by WGL 14, Tella hamsa, BPT 5204, Akshyadan, Swarna, KRH2, Kasalath, Mahsuri, Vandana, Varadan, RPbio 226 and MTU 1010. The lowest PUE among the cultivated variety was for IR64 (34.39 %).

Table 4.1 ANOVA of rice genotypes under graded levels of Phosphorus (P)

S.no	CHARACTER	MEAN SUM OF SQUARES			Mean	CV(%)
		Genotypes (G)	P Levels (PL)	G*PL		
1	Days to 50% flowering	460.73**	818.17**	248.57**	106.48	8.38
2	Plant height(cm)	657.19**	138.91*	139.64**	72.18	9.64
3	No. of Productive tillers per plant	45.37**	3.09	2.40	7.766	20.75
4	Flag leaf length(cm)	65.97**	23.07	19.20**	24.538	14.01
5	Flag leaf width (cm)	0.09**	0.01	0.02**	1.121	11.14
6	Panicle length (cm)	26.38**	0.25	5.84**	20.313	8.29
7	Root length (cm)	66.21**	42.95*	21.62**	23.628	15.41
8	Shoot length(cm)	921.46**	244.14**	141.33**	77.806	7.26
9	Root weight (g)	55.47**	19.65**	13.22**	4.652	38.88
10	Shoot weight (g)	538.56**	41.03**	48.78**	16.399	10.61
11	Straw yield(g)	68.05**	17.15	11.84	9.603	34.88
12	Test weight (g)	78.49**	51.10**	25.01**	28.182	4.08
13	Grain yield (g)	142.06**	10.24	14.89	11.13	32.43
14	Phosphorus content in straw (ppm)	0.75**	0.93**	0.15**	1.239	0.30
15	Phosphorus content in grain (ppm)	3.30**	0.05**	0.55**	2.181	0.27

Table 4.2 Phosphorus use efficiency in P₀ level

S.No	Genotypes	Straw yield (Kg/ha)	% Content P in straw	Straw P uptake (Kg/ha)	Grain yield (Kg/ha)	% Content P in grain	Grain P uptake (Kg/ha)	Total P uptake (Kg/ha)	PUE (%)
1	GSR101	2435.00	0.09	2.27	1700.00	0.17	2.87	5.14	55.85
2	GSR102	2720.00	0.08	2.06	2125.00	0.10	2.18	4.24	51.50
3	GSR103	1690.00	0.12	1.95	1245.00	0.16	2.04	4.00	51.11
4	GSR104	2035.00	0.13	2.66	1830.00	0.10	1.85	4.51	41.06
5	GSR105	1865.00	0.11	2.09	1515.00	0.17	2.58	4.67	55.21
6	GSR106	1680.00	0.11	1.91	1745.00	0.13	2.23	4.14	53.88
7	GSR107	2375.00	0.11	2.51	1545.00	0.19	2.88	5.39	53.47
8	GSR108	1070.00	0.09	0.93	940.00	0.19	1.80	2.73	65.84
9	GSR109	2950.00	0.07	2.12	3920.00	0.14	5.40	7.52	71.80
10	GSR110	1125.00	0.11	1.25	540.00	0.19	1.02	2.27	44.93
11	GSR111	1045.00	0.08	0.86	975.00	0.19	1.81	2.67	67.68
12	GSR112	1095.00	0.10	1.10	1210.00	0.11	1.34	2.44	55.01
13	GSR113	2215.00	0.05	1.12	800.00	0.21	1.68	2.80	60.16
14	GSR114	1405.00	0.10	1.42	1075.00	0.18	1.96	3.39	58.01
15	GSR115	1250.00	0.11	1.42	820.00	0.18	1.44	2.86	50.40
16	GSR116	1310.00	0.13	1.71	437.00	0.13	0.58	2.29	25.34
17	GSR117	985.00	0.09	0.88	450.00	0.19	0.86	1.74	49.62
18	GSR118	1375.00	0.10	1.37	1160.00	0.17	2.02	3.39	59.72
19	GSR119	1335.00	0.11	1.43	1050.00	0.18	1.88	3.30	56.83
20	GSR120	1820.00	0.12	2.14	1010.00	0.19	1.93	4.07	47.50
21	GSR121	2260.00	0.09	2.08	1665.00	0.16	2.65	4.73	55.95
22	GSR122	1520.00	0.09	1.42	650.00	0.20	1.32	2.74	48.12
23	GSR123	1445.00	0.07	1.01	825.00	0.16	1.29	2.29	56.10

24	GSR124	1480.00	0.12	1.72	1320.00	0.13	1.78	3.51	50.82
25	GSR125	1150.00	0.10	1.15	1210.00	0.25	2.98	4.13	72.06
26	GSR126	1310.00	0.09	1.12	1175.00	0.18	2.07	3.18	64.95
27	GSR127	1385.00	0.08	1.13	1560.00	0.17	2.63	3.77	69.87
28	GSR128	1130.00	0.08	0.86	620.00	0.17	1.05	1.91	54.84
29	GSR129	1105.00	0.11	1.24	850.00	0.16	1.34	2.57	51.92
30	GSR130	930.00	0.09	0.81	625.00	0.30	1.87	2.68	69.71
31	GSR131	3375.00	0.06	2.01	1930.00	0.20	3.85	5.87	65.71
32	GSR132	1690.00	0.09	1.44	840.00	0.18	1.48	2.92	50.60
33	GSR133	1360.00	0.07	0.89	1135.00	0.24	2.67	3.56	75.00
34	GSR134	1310.00	0.08	1.06	2440.00	0.15	3.56	4.62	77.10
35	GSR135	985.00	0.10	1.03	625.00	0.17	1.04	2.08	50.22
36	GSR136	970.00	0.12	1.18	835.00	0.17	1.46	2.64	55.35
37	GSR137	1200.00	0.09	1.04	680.00	0.16	1.06	2.10	50.51
38	GSR138	2400.00	0.09	2.05	2535.00	0.19	4.72	6.77	69.73
39	GSR139	790.00	0.10	0.82	645.00	0.17	1.09	1.91	56.91
40	GSR140	1400.00	0.12	1.69	1000.00	0.21	2.12	3.81	55.62
41	GSR141	445.00	0.09	0.40	380.00	0.16	0.61	1.01	60.14
42	GSR142	1615.00	0.12	1.96	775.00	0.19	1.50	3.46	43.40
43	GSR143	1310.00	0.09	1.15	960.00	0.16	1.53	2.68	57.04
44	GSR144	440.00	0.11	0.50	265.00	0.17	0.44	0.93	46.87
45	GSR145	1140.00	0.12	1.33	1680.00	0.16	2.77	4.09	67.56
46	GSR146	1985.00	0.10	1.95	2305.00	0.15	3.53	5.48	64.44
47	GSR147	2735.00	0.10	2.65	2815.00	0.20	5.66	8.30	68.12
48	GSR148	1670.00	0.10	1.71	1665.00	0.21	3.49	5.20	67.16
49	AKSHAYADAN	2535.00	0.14	3.64	2775.00	0.26	7.09	10.74	66.07
50	VASUMATHI	2575.00	0.08	2.13	1495.00	0.17	2.54	4.68	54.37

51	SUGANDHA	1270.00	0.13	1.69	950.00	0.27	2.58	4.27	60.31
52	T.HAMSA	1770.00	0.09	1.56	1700.00	0.20	3.46	5.02	69.00
53	VARDHAN	1540.00	0.13	1.98	795.00	0.27	2.12	4.11	51.70
54	VIKAS	3305.00	0.08	2.72	2245.00	0.16	3.63	6.35	57.22
55	TULASI	1520.00	0.14	2.13	1065.00	0.23	2.45	4.58	53.56
56	MAHSURI	3275.00	0.07	2.27	2580.00	0.16	4.13	6.40	64.54
57	MTU1010	1600.00	0.12	1.93	980.00	0.19	1.84	3.77	48.81
58	RPBIO226	1235.00	0.09	1.09	810.00	0.18	1.45	2.54	57.02
59	IR64	1530.00	0.13	1.99	1030.00	0.10	1.05	3.04	34.39
60	VANDHANA	1440.00	0.08	1.12	855.00	0.21	1.79	2.91	61.53
61	RASI	1355.00	0.13	1.82	830.00	0.17	1.44	3.26	44.28
62	KASALATHA	1450.00	0.09	1.24	1000.00	0.23	2.32	3.55	65.18
63	SWARNA	2575.00	0.12	3.14	2395.00	0.26	6.12	9.27	66.07
64	BPT5204	1850.00	0.09	1.64	1700.00	0.23	3.92	5.56	70.55
65	SM59	2865.00	0.11	3.14	2895.00	0.24	7.00	10.15	69.01
66	SM101	2135.00	0.06	1.35	1885.00	0.14	2.70	4.05	66.70
67	SM686	1850.00	0.13	2.49	1775.00	0.21	3.75	6.24	60.07
68	SM363	1250.00	0.09	1.11	665.00	0.19	1.24	2.36	52.75
69	SM787(PY2)	1575.00	0.08	1.24	1460.00	0.25	3.61	4.84	74.44
70	N22	930.00	0.12	1.13	855.00	0.20	1.73	2.87	60.52
71	GSR317	2245.00	0.09	1.97	1890.00	0.17	3.12	5.09	61.38
72	GSR311	2240.00	0.10	2.26	1990.00	0.23	4.56	6.82	66.86
73	GSR322	2380.00	0.07	1.68	1870.00	0.18	3.28	4.96	66.12
74	GSR333	1495.00	0.12	1.80	1730.00	0.24	4.12	5.92	69.61
75	GSR111(OL)	1305.00	0.07	0.95	1260.00	0.23	2.87	3.82	75.01
76	WGL14	1925.00	0.10	1.89	1915.00	0.23	4.38	6.28	69.82
77	KRH2	2865.00	0.07	1.97	2370.00	0.16	3.73	5.69	65.46
78	IET24036	2400.00	0.12	2.87	1535.00	0.19	2.93	5.80	50.57

79	RAVI	1680.00	0.10	1.69	970.00	0.14	1.40	3.09	45.24
80	IET24003	2755.00	0.14	3.76	2165.00	0.21	4.59	8.35	54.98
81	TRIGUNA	3285.00	0.10	3.16	3410.00	0.14	4.78	7.93	60.22
82	SAMPADHA	2335.00	0.12	2.71	1985.00	0.18	3.52	6.23	56.55
83	DRRH3	3930.00	0.07	2.58	2920.00	0.16	4.69	7.27	64.52
84	ADITHA	2125.00	0.13	2.68	1550.00	0.22	3.41	6.09	56.00
85	PA6444	2995.00	0.06	1.87	2695.00	0.17	4.59	6.46	71.07
86	PR133	2465.00	0.12	3.00	2330.00	0.21	4.82	7.82	61.68
87	RNR15048	3225.00	0.08	2.67	3115.00	0.18	5.67	8.35	67.96
88	INH10001	3075.00	0.10	3.20	2690.00	0.19	5.03	8.22	61.14
89	INH10002	2950.00	0.06	1.88	2980.00	0.19	5.58	7.46	74.80
90	INH12013	2805.00	0.11	3.08	3050.00	0.14	4.29	7.37	58.19

Table 4.3. Analysis of Variance for different traits in rice (P₀ level)

Source of variation	Treatments	Error	General mean	Standard Error mean	CD at 5%	CV %
Degree of freedom	89	89				
Days to 50% flowering			104.75**	5.28	14.84	7.13
Plant height (cm)			80.35**	4.49	12.62	7.91
No. of productive tillers per plant			9.34	1.33	3.74	20.15
Flag leaf length (cm)			27.11**	2.76	7.76	14.40
Flag leaf width (cm)			1.19**	0.09	0.25	10.64
Panicle length (cm)			21.76**	1.17	3.28	7.60
Root length (cm)			25.53**	2.11	5.93	11.69
Shoot length (cm)			86.59**	4.65	13.07	7.60
Root weight (g)			8.23**	1.71	4.80	29.35
Shoot weight (g)			23.08**	1.38	3.88	8.46
Straw yield (g)			13.08	2.67	7.52	28.91
Grain yield (g)			15.96*	2.65	7.46	23.53
Test weight (g)			30.70**	0.67	1.88	3.08
Phosphorus content in straw (ppm)			0.84	0.90	0.25	1.53
Phosphorus content in grain (ppm)			0.14**	0.16	0.46	1.65

*Significant at 5% level of significance, ** Significant at 1% level of significance

Table 4.4. Analysis of variance for different traits in rice (P₂₀ level)

Source of variation	Treatments	Error	General mean	Standard Error mean	CD at 5%	CV %
Degree of freedom	89	89				
Days to 50% flowering			108.89**	5.94	16.70	7.72
Plant height (cm)			72.36**	4.61	12.96	9.01
No. of productive tillers per plant			7.83**	1.16	3.27	21.02
Flag leaf length (cm)			24.54**	2.23	6.26	12.84
Flag leaf width (cm)			1.12	0.94	0.26	11.82
Panicle length (cm)			20.80**	1.05	2.95	7.14
Root length (cm)			21.82**	1.38	3.88	8.94
Shoot length (cm)			74.37**	3.65	10.27	6.95
Root weight (g)			3.01**	0.89	2.50	41.88
Shoot weight (g)			14.21**	1.44	4.03	14.29
Straw yield (g)			9.82**	2.04	5.74	29.42
Grain yield (g)			11.89*	2.48	6.96	29.46
Test weight (g)			28.22**	0.64	1.80	3.20
Phosphorus content in straw (ppm)			1.08**	0.21	0.58	0.27
Phosphorus content in grain (ppm)			1.94**	0.35	0.99	0.26

*Significant at 5% level of significance, ** Significant at 1% level of significance

Table 4.5. Analysis of variance for different traits in rice (P₄₀ level)

Source of variation	Treatments	Error	General mean	Standard Error mean	CD at 5%	CV %
Degree of freedom	89	89				
Days to 50% flowering			105.24**	5.82	16.37	7.83
Plant height (cm)			76.29**	4.03	11.31	7.46
No. of productive tillers per plant			9.56*	1.18	3.31	17.45
Flag leaf length (cm)			25.03**	2.71	7.62	15.33
Flag leaf width (cm)			1.19**	0.72	0.20	8.58
Panicle length (cm)			20.97**	1.14	3.19	7.66
Root length (cm)			24.78**	2.15	6.04	12.28
Shoot length (cm)			84.88**	3.43	9.63	5.71
Root weight (g)			5.19**	1.57	4.41	42.77
Shoot weight (g)			22.70**	1.17	3.30	7.32
Straw yield (g)			9.36**	2.06	5.78	31.10
Grain yield (g)			11.59	2.95	8.30	36.04
Test weight (g)			29.69	0.92	2.59	4.39
Phosphorus content in straw (ppm)			1.21	0.25	0.70	0.29
Phosphorus content in grain (ppm)			2.13**	0.46	0.13	0.30

*Significant at 5% level of significance, ** Significant at 1% level of significance

Table 4.6. Analysis of variance for different traits in rice (P₆₀ level)

Source of variation	Treatments	Error	General mean	Standard Error mean	CD at 5%	CV %
Degree of freedom	89	89				
Days to 50% flowering			104.60**	5.28	14.83	7.13
Plant height (cm)			80.35**	4.49	12.62	7.91
No. of productive tillers per plant			9.34	1.33	3.74	20.15
Flag leaf length (cm)			27.11**	2.76	7.76	14.40
Flag leaf width (cm)			1.19**	0.90	0.25	10.64
Panicle length (cm)			21.76**	1.17	3.28	7.60
Root length (cm)			25.53**	2.11	5.93	11.69
Shoot length (cm)			86.59**	4.65	13.07	7.60
Root weight (g)			8.23**	1.71	4.80	29.35
Shoot weight (g)			23.08**	1.38	3.88	8.46
Straw yield (g)			13.08	2.67	7.52	28.91
Grain yield (g)			15.96	2.65	7.46	23.53
Test weight (g)			30.70**	0.67	1.88	3.08
Phosphorus content in straw (ppm)			1.68**	0.30	0.85	0.26
Phosphorus content in grain (ppm)			2.81**	0.40	0.11	0.20

*Significant at 5% level of significance, ** Significant at 1% level of significance

4.2 (a) Analysis of variance for the different traits under graded level of phosphorus

The 90 rice genotypes were evaluated under the graded levels of phosphorus (P) in the field of ICAR-IRRI farm. Variance estimation for various traits was calculated at different levels of P and findings were presented as follows.

4.2(a) 1 Days to 50 percent flowering

Days to 50 percent flowering showed significant variation among the genotypes at all levels of P (Table4.3–Table4.6) viz 0, 20, 40, 60. Its mean ranged from 82days (Tella Hamsa,Vandana, Rasi) to 128 days (GSR 107, GSR 108) days in P₀, with the mean 107 ± 5.28 days and coefficient of variation (CV) 7.1. In P₂₀ it varied from 82 days (GSR103) to 131 days (GSR118) with the mean of 108.89 ± 5.94 days and CV found to 7.72. The P₄₀ values for days to fifty percent flowering ranged from 82 days (GSR130, GSR131, GSR132) to 128(GSR106) days with a mean of 105.24 ± 5.82 days with 7.83CV and in P₆₀ it varied from 82 days (GSR129, GSR130) to 127 days (GSR106) with a mean of 104.60 ± 5.28 days and CV 7.13.

Days to fifty percent flowering is very important trait which decides the growth period of the crop. Results obtained showed that varieties behave differently to flower in respect of availability of phosphorus. Some varieties will postpone flowering in low availability of phosphorus while others prepone it.(Vejchasarn *et al.* 2016).

4.2(a) 2 Plant height

Plant height showed significant variation among the genotypes at all levels of P (Table4.3–Table4.6) viz 0, 20, 40, 60. Its mean ranged from 45.67cm (Ravi) to 88.83cm (SM 363) in P₀, with the mean 59.72 ± 4.49 cm and coefficient of variation (CV) 7.9. In P₂₀ it varied from 58.67cm (PR133) to 110cm (SM101) with the mean of 72.36 ± 4.61 cm and coefficient of variation (CV) 9.01. The P₄₀ values for plant height ranged from 61.83 cm (GSR 126) to 106.17 cm(SM 106) with a mean of 76.29 ± 4.03 cm with 7.46 CV and in P₆₀ it varied from 62.83cm (BPT5204) to 106.17cm (SM 01) with a mean of 80.35 ± 4.49 cm with CV 7.91.

Under the low phosphorus condition plant growth reduces drastically. Availability of P significantly affects plant height (Cancellier et al., 2012).Under P₀ height of the rice plants was drastically reduce, while little availability help the plant to maintain its growth at P₂₀. Under P₄₀ most of varieties attained their normal height. Much difference was observed between P₄₀ and P₆₀. These results are similar to previous study with upland rice

genotypes (Fageria *et al.*,1988, Fageria and Baligar 1997)

4.2(a) 3 Number of productive tillers:

Number of productive tillers showed significant variation among the genotypes at all levels of P (Table4.3 –Table4.6) viz 0, 20, 40, 60. In P₀ its mean ranged from 2.83 (GSR123) to 7.83 (INH12013) with a mean 4.34 ± 1.33 and CV 20.15. In P₂₀ mean ranged from 4.17 (GSR108) to 11.83 (PA6444) with a mean 7.83 ± 1.16 and CV 21.02. In P₄₀ mean ranged from 6.17 (GSR105) to 15 (TULASI) with a mean 9.56 ± 1.18 and CV 17.45. In P₆₀ mean ranged from 5.67 (GSR104) to 13.17 (N22) with a mean of 9.34 ± 1.33 and CV 20.15 %.

The occurrence of reduced number of productive tillers per plant was also observed under limited P conditions. Number of tillers per plant was very low under P₀ condition and P₂₀ condition was better than P₀. P₄₀ and P₆₀ there was no noticeable difference for Number of productive tillers. Under low P condition some lines produce profuse tillering but most of them were not productive, they were not produced any panicle (Dobermann and Fairhurst, 2000). The P efficient genotype produce average tiller at low P condition but it produce panicle with some filled seeds (Wissuwa *et al.*, 1998)

4.2(a) 4 Flag leaf length and 4.2(a)5 Flag leaf width This trait showed significant variation among the genotypes at all levels of P (Table4.3 –Table4.6) viz 0, 20, 40, 60. Flag leaf length mean ranged from 16.17cm (Tulasi) to 28.33cm (DRRH3) with a mean of 21.47 ± 2.76 cm and CV 14.40. In P₂₀ it mean ranged from 16.83 cm (Swarna) to 34.33cm (GSR121) with a mean of 24.54 ± 2.23 cm and CV 12.84. In P₄₀ it mean ranged from 17.83cm (GSR333) to 35.17cm (GSR118) with a mean of 25.03 ± 2.71 cm and CV 15.33. In P₆₀ its mean ranged from 19.33 cm (SM686) to 35 cm (GSR118) with a mean of 27.11 ± 2.76 cm and CV 14.40. While flag leaf width in P₀ ranged from 0.80 cm (GSR130) to 1.20 cm (GSR148) with a mean of 0.98 ± 0.09 cm and CV 10.64. In P₂₀ its mean ranged from 0.82 cm (GSR128) to 1.53 cm (GSR118) with a mean of 1.12 ± 0.94 cm and CV 11.82. In P₄₀ its mean ranged from 0.87cm (Kasalath, Adithya) to 1.82cm (GSR118) with a mean of 1.19 ± 0.72 cm and CV 8.58. In P₆₀ its mean ranged from 0.78 cm (Kasalath) to 1.55cm (GSR118) with a mean of 1.19 ± 0.90 cm and CV 10.64. (Wissuwa *et al.* 1998)

The uppermost leaf below the panicle is the flag leaf that provides the most important source of photosynthetic energy during reproduction and grain filling, thereby it has great importance in panicle development and grain yield in rice. Both flag leaf width and length were reduced under P₀ and P₂₀. In P₄₀ and P₆₀ not much difference was found.

4.2(a) 6 Panicle length:

Panicle length showed significant variation among the genotypes at all levels of P (Table 4.3 – Table 4.6) viz 0, 20, 40, 60. In P_0 its mean ranged from 13.67 cm (GSR144) to 23.50 cm (IET24003) with a mean of 17.72 ± 1.17 and CV 7.60. In P_{20} its mean ranged from 17.33 cm (N22) to 25.50 cm (Sugandhamathi) with a mean of 20.80 ± 1.05 cm and CV 7.14. In P_{40} its mean ranged from 17.00 cm (N22) to 25.67 cm (GSR118) with a mean of 20.97 ± 1.14 cm and CV 7.66. In P_{60} with a mean ranged from 17.33 cm (SM686) to 26.33 cm (IET24036) with a mean of 21.76 ± 1.17 cm with CV 7.60 %.

Length of the panicle determines the grain yield, panicle length greatly reduced under P_0 . Under P_{20} few grains were produced and in P_{40} and P_{60} panicle length was normal. Fageria and Baligar 1999, 2001 reported the same in low land rice varieties.

4.2(a) 7 Root length:

Root length showed significant variation among the genotypes at all levels of P (Table 4.3 – Table 4.6) viz 0, 20, 40, 60. In P_0 its mean ranged from 14 cm (GSR139) to 54 cm (GSR135) with a mean of 22.38 ± 2.11 cm and CV 11.69. In P_{20} its mean ranged from 15.50 cm (GSR143) to 31.50 cm (DRRH3) with a mean of 21.82 ± 1.38 cm and CV 8.94. In P_{40} with a mean ranged from 18 cm (GSR147) to 34 cm (GSR126) with a mean of 24.78 ± 2.15 cm and CV 12.28. In P_{60} its mean ranged from 19 cm (GSR146) to 36.50 cm (GSR139) with a mean of 25.53 ± 2.11 cm and CV 11.69.

Root length showed a very broad range under P_0 and its range get narrowed as level of available P increases, (Fageria and Baligar 1999, 2001). In many varieties especially which derived from *aus* type, upland type, low available P in the soil triggers the root growth in search P repository. Gamuyao et al. 2012 reported a gene called *PSTOL1* expected to be present in most of the upland rice varieties, induces root growth under low P condition. Significant differences among genotypes indicate a difference in P utilization at a given level of P supply (Fageria and Baligar 1997).

4.2(a) 8 Shoot length:

Shoot length showed significant variation among the genotypes at all levels of P (Table 4.3 – Table 4.6) viz 0, 20, 40, 60. In P_0 its mean ranged from 46.50 cm (GSR133) to 92.50 cm (GSR311) with a mean of 65.39 ± 4.65 cm and CV 7.60. In P_{20} its mean ranged from 57 cm (GSR126) to 100.50 cm (SM363) with a mean of 74.37 ± 3.65 cm and CV 6.95. In P_{40} its mean ranged from 64.50 cm (IR64) to 104.50 cm (GSR122) with a mean of 84.88 ± 3.43 cm and CV 5.71. In P_{60} its mean ranged from 54 cm (GSR106) to 118.50 cm

(SM101) with a mean of 86.59 ± 4.65 cm and CV 7.60

Shoot length showed increase with increase in the available P levels, because P involved in cell division and their by growth of the plant, this kind of relation was clear up P_{40} . Between P_{40} and P_{60} no such response was observed. Similar kind of responses were observed by Fageria and Baligar 1997.

4.2(a) 9 Root weight:

Root weight showed significant variation among the genotypes at all levels of P (Table4.3 –Table4.6) viz 0, 20, 40, 60. In P_0 its mean ranged from 1g (GSR123) to 5.70 g (Vikas) with a mean of 2.18 ± 1.71 g and CV29.35. In P_{20} its mean ranged from 1.40g (GSR116) to 9.50 g (SM101) with a mean of 3.01 ± 0.89 g and CV 41.88. In P_{40} its mean ranged from 1.90 g (GSR135) to 13.30g (Mahsuri) with a mean of 5.19 ± 1.57 g and CV 42.77. In P_{60} its mean ranged from 2.70g (GSR136) to 25.20g (GSR111) with a mean of 8.23 ± 1.71 and CV 29.35.

P is very much essential for root proliferation, more P availability helps in more root proliferation and their by root weight. Significant differences among genotypes indicate a difference in P utilization at a given level of P supply (Fageria and Baligar 1997, 2001).

4.2(a) 10 Shoot weight:

Shoot weight showed significant variation among the genotypes at all levels of P (Table4.3 –Table4.6) viz 0, 20, 40, 60. In P_0 its mean ranged from 1.15g (GSR110) to 16.05g (Mahsuri) with a mean of 5.61 ± 1.38 g and CV 8.46. In P_{20} its mean ranged from 6.30g (Vandana) to 30.30g (PA6444) with a mean of 14.21 ± 1.44 g and CV14.29. In P_{40} its mean ranged from 11 g (Varadhan) to 45.40g (GSR122) with a mean of 22.70 ± 1.17 g and CV 7.32. In P_{60} its mean ranged from 9.80g (Rasi) to 42.30g (GSR120) with a mean of 23.08 ± 1.38 g and CV8.46. (Vejchasarn *et al.* 2016).

4.2(a)11 Straw yield

Straw yield showed significant variation among the genotypes at all levels of P (Table4.3 –Table4.6) viz 0, 20, 40, 60. In P_0 its mean ranged from 1.47 g (GSR144) to 13.10g (DRRH3) with a mean of 6.16 ± 2.67 g and CV28.91. In P_{20} its mean ranged from 4.93g (GSR141) to 17.72g (INH12013) with a mean of 9.82 ± 2.04 g and CV 29.42. In P_{40} its mean ranged from 5.70 g (GSR113) to 17.47 g (Mahsuri) with a mean of 9.36 ± 2.06 g and CV 31.10. In P_{60} its mean ranged from 7.68g (SM59) to 22.20 g (Vandhana) with a mean of 13.08 ± 2.67 g and CV 28.91.

Straw yield and shoot weight showed increase with increase in the available P levels, because P involved in cell division and their by growth of the plant. This kind of relation was clear up to P₄₀. Between P₄₀ and P₆₀ no such responses are observed. Significant differences among genotypes indicate difference in P utilization at a given level of P supply. Similar kind of response was observed by Fageria and Baligar 1997.

4.2(a) 12 Grain yield (g):

Grain yield showed significant variation among the genotypes at all levels of P (Table 4.3 –Table 4.6) viz 0, 20, 40, 60. In P₀ its mean ranged from 0.88g (GSR144) to 13.7 g (GSR109) with a mean of 5.08 ± 2.65 g and CV 23.53. In P₂₀ its mean ranged from 6.08g (GSR131) to 21.15g (GSR101) with a mean of 11.89 ± 2.48 g and CV 29.46. In P₄₀ its mean ranged from 5.85g (N22) to 17.17g (MTU1010) with a mean of 11.59 ± 2.95 g and CV 36.04. In P₆₀ its mean ranged from 10.13 g (Sugandhamathi) to 23.10 g (GSR127) with a mean of 15.96 ± 2.65 g and CV 23.53. .(Vejchasarn *et al.* 2016).

Grain yield is low in P₀, improved in P₂₀ but good in P₄₀ and P₆₀ levels. It mainly due to more productive tillers at P₄₀ and P₆₀ levels. Panicles per unit area is the single most important component of yield associated with rice yield (Gravois and Mc New, 1993). Significant differences among genotypes indicate a difference in P utilization at a given level of P supply.

4.2(a) 13 Test weight (g):

Test weight showed significant variation among the genotypes at all levels of P (Table 4.3 –Table 4.6) viz 0, 20, 40, 60. In P₀ its mean ranged 19.85g (gsr108) to 31.70g (krh2) with a mean of 24.11 ± 0.67 g and CV 3.08. In P₂₀ its mean ranged from 20.05 g (rnr15048) to 36.05 g (gsr137) with a mean of 28.22 ± 0.64 g and cv 3.20. In P₄₀ its mean ranged from 20.05g (RNR15048) to 38.35g (GSR133) with a mean of 29.69 ± 0.92 g and CV 4.39. In P₆₀ its mean ranged from 20.85 g (RNR 15048) to 37.20 g (GSR125) with a mean of 30.70 ± 0.67 g and CV 3.08. Mean test weight among the P₀ and P₂₀ were almost similar, and mean test weight between P₄₀ and P₆₀ were also not differ much, but it differ between this two groups, indicating that P availability definitely influence on test weight. Kaleem *et al.* 2009, Tabar, 2013 reported the same. .(Vejchasarn *et al.* 2016).

Table 4.7: General mean, range, PCV, GCV, heritability and genetic advance for different traits in rice (P₀ level)

S. No	character	Mean	Range		GV	PV	GCV %	PCV%	Heritability (%)	Genetic advance (%)	Genetic advance as 5 percent of mean
			Minimum	Maximum							
1	Grain yield (g)	5.08	0.88	13.07	3.86	10.25	38.62	62.98	37.61	248.06	48.79
2	Days to 50% flowering	107.20	82.00	128.00	87.68	208.93	8.73	13.48	41.97	1249.71	11.66
3	Plant height (cm)	59.72	45.67	88.83	30.92	91.56	9.31	16.02	33.77	665.64	11.15
4	No .of productive tillers per plant	4.34	2.83	7.83	0.48	1.11	15.91	24.30	42.84	93.02	21.45
5	Flag leaf length (cm)	21.47	16.17	28.33	4.70	10.56	10.09	15.14	44.45	297.61	13.86
6	Flag leaf width (cm)	0.98	0.80	1.20	0.00	0.01	4.65	10.41	19.69	4.16	4.22
7	Panicle length (cm)	17.72	13.67	23.50	1.73	5.48	7.42	13.22	31.55	152.20	8.59
8	Root length (cm)	22.38	14.00	54.00	10.73	42.14	14.64	29.01	25.47	340.59	15.22
9	Shoot length (cm)	65.39	46.50	92.50	100.52	135.11	15.33	17.78	74.40	1781.47	27.24
10	Root weight (g)	2.18	1.00	5.70	0.38	0.81	28.20	41.26	46.70	86.37	39.70
11	Shoot weight (g)	5.61	1.15	16.05	8.66	9.76	52.45	55.66	88.78	571.34	101.80
12	Straw yield (g)	6.16	1.47	13.10	3.48	8.92	30.30	48.52	39.00	239.97	38.98
13	Test weight(g)	24.11	19.85	31.70	7.94	9.69	11.69	12.91	81.91	525.37	21.79
14	Phosphorus content in straw (ppm)	0.99	0.50	1.44	0.05	0.05	21.83	21.83	100.00	44.47	44.98
15	Phosphorus content in grain (ppm)	1.85	1.01	2.98	0.15	0.15	20.75	20.75	100.00	79.01	42.75

Table 4.8: General mean, range, PCV, GCV, heritability and genetic advance for different traits in rice (P₂₀ level)

S.No	character	mean	Range		GV	PV	GCV%	PCV%	Heritability (%)	Genetic advance (%)	Genetic advance in 5 percent of mean
			mini mum	maxi mum							
1	Grain yield (g)	11.89	6.08	21.15	3.22	15.49	15.10	33.10	20.80	168.64	14.18
2	Days to 50% flowering	108.89	82.00	131.50	130.01	200.64	10.47	13.01	64.80	1890.80	17.36
3	Plant height (cm)	72.36	58.67	110.00	56.99	99.52	10.43	13.79	57.26	1176.71	16.26
4	No .of productive tillers per plant	7.83	4.17	11.83	2.59	5.30	20.56	29.40	48.91	232.05	29.62
5	Flag leaf length (cm)	24.54	16.83	34.33	6.11	16.04	10.07	16.32	38.08	314.18	12.80
6	Flag leaf width (cm)	1.12	0.82	1.53	0.00	0.02	4.89	12.84	14.70	4.36	3.89
7	Panicle length (cm)	20.80	17.33	25.50	1.27	3.47	5.41	8.96	36.50	140.16	6.74
8	Root length (cm)	21.82	15.50	31.50	4.53	8.34	9.75	13.23	54.35	323.29	14.81
9	Shoot length (cm)	74.37	57.00	100.50	64.32	91.03	10.78	12.83	70.66	1388.80	18.68
10	Root weight (g)	3.01	1.40	9.50	1.22	2.80	36.69	55.68	43.43	149.75	49.81
11	Shoot weight (g)	14.21	6.30	30.30	28.91	33.03	37.85	40.46	87.52	1036.19	72.94
12	Straw yield (g)	9.82	4.93	17.72	3.93	12.27	20.20	35.68	32.06	231.34	23.57
13	Test weight(g)	28.22	20.05	36.05	15.74	16.55	14.05	14.42	95.06	796.72	28.23
14	Phosphorus content in straw (ppm)	1.08	0.67	1.58	0.05	0.05	20.18	20.18	100.00	44.99	41.57
15	Phosphorus content in grain (ppm)	1.94	0.83	3.36	0.39	0.39	32.34	32.35	100.00	129.37	66.64

Table 4.9: General mean, range, PCV, GCV, heritability and genetic advance for different traits in rice (P₄₀ level)

S. No	Character	Mean	Range		GV	PV	GCV (%)	PCV (%)	Heritability (%)	Genetic advance (%)	Genetic advance in 5 percent of mean
			Minimum	Maximum							
1	Grain Yield (g)	11.59	5.85	17.17	1.87	15.56	11.80	34.05	12.05	97.92	8.45
2	Days to 50% flowering	105.24	82.00	128.50	140.35	208.21	11.26	13.71	67.41	2003.75	19.04
3	Plant Height (cm)	76.29	61.83	106.17	55.31	87.74	9.75	12.28	63.04	1216.41	15.95
4	No .of productive Tillers per plant	9.56	6.17	15.00	0.66	3.44	8.52	19.42	19.27	73.67	7.71
5	Flag leaf Length (cm)	25.03	17.83	35.17	6.08	20.80	9.85	18.22	29.23	274.60	10.97
6	Flag leaf width (cm)	1.19	0.87	1.82	0.01	0.02	8.83	12.32	51.42	15.50	13.05
7	Panicle length (cm)	20.97	17.00	25.67	1.68	4.27	6.19	9.85	39.49	168.01	8.01
8	Root Length (cm)	24.78	18.00	34.00	6.42	15.68	10.23	15.98	40.97	334.18	13.49
9	Shoot Length (cm)	84.88	64.50	104.50	68.58	92.07	9.76	11.31	74.48	1472.23	17.35
10	Root weight (g)	5.19	1.90	13.30	2.83	7.77	32.40	53.66	36.46	209.34	40.30
11	Shoot weight (g)	22.70	11.00	45.40	47.77	50.53	30.45	31.31	94.54	1384.45	60.98
12	Straw yield (g)	9.36	5.70	17.47	0.74	9.21	9.22	32.44	8.08	50.52	5.40
13	Test weight(g)	29.69	20.05	38.35	13.49	15.18	12.37	13.12	88.85	713.18	24.02
14	Phosphorus content straw (ppm)	1.21	0.60	1.84	0.07	0.07	22.17	22.17	100.00	55.16	45.67
15	Phosphorus content grain (ppm)	2.13	0.56	4.87	0.76	0.76	41.03	41.03	100.00	179.83	84.52

Table 4.10: General mean, range, PCV, GCV, heritability and genetic advance for different traits in rice (P₆₀ level)

S.No	Character	Mean	Range		GV	PV	GCV(%)	PCV(%)	Heritability(%)	Genetic advance (%)	Genetic advance in 5 percent of mean
			Minimum	Maximum							
1	Grain yield (g)	15.96	10.13	23.10	1.90	16.00	8.65	25.07	11.91	98.13	6.15
2	Days to 50% flowering	104.60	82.00	127.50	89.74	145.42	9.06	11.53	61.71	1532.98	14.66
3	Plant height (cm)	80.35	62.83	114.00	67.57	107.96	10.23	12.93	62.59	1339.68	16.67
4	No .of productive tillers per plant	9.34	5.67	13.17	0.14	3.68	3.94	20.54	3.68	14.54	1.56
5	Flag leaf length (cm)	27.11	19.33	35.00	5.96	21.22	9.00	16.99	28.07	266.37	9.83
6	Flag leaf width (cm)	1.19	0.78	1.55	0.01	0.02	7.60	13.06	33.83	10.84	9.10
7	Panicle length (cm)	21.76	17.33	26.33	2.03	4.75	6.55	10.02	42.70	191.79	8.81
8	Root length (cm)	25.53	19.00	36.50	8.01	16.91	11.08	16.11	47.36	401.20	15.71
9	Shoot length (cm)	86.59	54.00	118.50	82.92	126.20	10.52	12.97	65.71	1520.64	17.56
10	Root weight (g)	8.23	2.70	25.20	14.88	20.72	46.87	55.30	71.84	673.64	81.84
11	Shoot weight (g)	23.08	9.80	42.30	44.11	47.93	28.78	30.00	92.04	1312.61	56.88
12	Straw yield (g)	13.08	7.68	22.20	1.28	15.59	8.66	30.18	8.24	67.01	5.12
13	Test weight(g)	30.70	20.85	37.20	12.38	13.28	11.46	11.87	93.25	699.93	22.80
14	Phosphorus content in straw (ppm)	1.68	1.02	2.57	0.17	0.17	24.50	24.51	100.00	84.59	50.49
15	Phosphorus content in grain (ppm)	2.81	1.05	5.13	0.60	0.60	27.56	27.56	100.00	159.42	56.76

4.2(a) 14 Phosphorus content in straw (ppm):

Phosphorus content in straw showed significant variation among the genotypes at all levels of P (Table4.3 –Table4.6) viz 0, 20, 40, 60. In P_0 its mean ranged from 0.50ppm (GSR113) to 1.44ppm (Akshayadan) with a mean of 0.99 ± 0.90 ppm and CV 1.53. In P_{20} its mean ranged from 0.67 ppm (GSR119) to 1.58ppm (GSR129) with a mean of 1.08 ± 0.21 ppm and CV 0.27. In P_{40} its mean ranged from 0.60 ppm (IR60) to 1.84 ppm (GSR144) with a mean of 1.21 ± 0.25 ppm and CV 0.29. In P_{60} its mean ranged from 1.02 ppm (GSR148) to 2.57 ppm (GSR118) with a mean of 1.68 ± 0.30 ppm and CV 0.26. P content in shows significant difference among the varieties shows that, varieties have different utilization capacity for P, P content in straw increases with increase in P availability Fageria *et al.*, 1988a; Wissuwa and Ae, 2001; Fageria and Knupp, 2013.

4.2(a) 15 Phosphorus content in grain (ppm):

Phosphorus content in grain showed significant variation among the genotypes were observed for phosphorus content in grain at all levels of P (Table4.3 –Table4.6) viz 0, 20, 40, 60. In P_0 its mean ranged from 1.01 ppm (GSR104) to 2.98 ppm (GSR130) with a mean of 1.85 ± 0.16 ppm and CV1.65. In P_{20} its mean ranged from 0.83ppm (GSR121) to 3.36 ppm (Swarna) with a mean of 1.94 ± 0.35 ppm and CV0.26.in P_{40} its mean ranged from 0.56ppm (GSR128) to 4.87 ppm (Vandhana) with a mean of 2.13 ± 0.46 ppm and CV0.30. In P_{60} its mean ranged from 1.05 ppm (GSR145) to 5.13 ppm (DRRH3) with a mean of 2.81 ± 0.40 ppm and CV0.20. P content in grain showed significant difference among the varieties which indicates that, varieties have different utilization capacity for P. P content in straw increases with increase in P availability. Under critical limits P is redistributed to flag leaf from grains to maintain the source sink P homeostasis Li et al. 2015 . P content in straw increases with increase in P availability Fageria *et al.*, 1988a; Wissuwa and Ae, 2001; Fageria and Knupp, 2013.

4.2 (b) Estimation of GCV, PCV, heritability and genetic advance, genetic advance as percent of mean for the different traits under graded levels of Phosphorus Table (4.7-4.10)

4.2(b) 1 GCV, PCV

4.2(b).1.1Phenotypic coefficient of variation under P_0

PCV values ranged from 62.98% (Grain yield) to 10.41% for flag leaf width. Traits like grain yield (62.98%), shoot weight (55.66%), straw yield (48.52%) and root weight(41.26%) recorded very high PCV, whereas root length(29.01%), number of

productive tillers(24.30), phosphorus content in straw (21.83%) and phosphorus content in grain(20.75%) recorded high value of PCV and shoot length(17.78%), plant height (16.02),flag leaf length(15.14%), day to fifty percent flowering (13.48%), panicle length(13.22%),test weight (12.91%) and flag leaf width(10.14%) recorded the medium PCV.

4.2 (b) 1.2 Genotypic coefficient of variation under P₀

Genotypic coefficient of variation (GCV) values ranged from 52.45% (Shoot weight) to 4.65% (Flag leaf width). Traits like shoot weight (52.45%), grain yield (38.62%), straw yield (30.30%), root weight (28.20%), Phosphorus content in straw (21.83%), Phosphorus content in grain (20.75%), recorded high GCV. Number of productive tillers (15.91%), shoot length (15.33%), root length (14.64%),test weight (11.69%), flag leaf length (10.09%), recorded medium GCV. Whereas Plant height (9.31%), days to 50% flowering (8.73%), panicle length (7.42%) and flag leaf width (4.65%) recorded low GCV.

4.2(b) 1.3 Phenotypic coefficient of variation under P₂₀

PCV values ranged from 55.68% (Root weight) to 8.96% (panicle length). Traits like root weight (55.68%), shoot weight (40.46%), straw yield (35.68%), grain yield (33.10%), Phosphorus content in grain (32.35%) were recorded very high PCV whereas number of productive tillers (29.40%), Phosphorus content in straw (20.18%) recorded the high PCV. Flag leaf length (16.32%), test weight (14.42%), plant height (13.79%), root length (13.23%), days to 50% flowering (13.01%), shoot length (12.83%), records medium PCV and panicle length (8.96%) showed low PCV.

4.2(b) 1.4 Genotypic coefficient of variation under P₂₀

GCV values range from 37.85 % (shoot weight) to 4.89% (flag leaf width). Traits like shoot weight (37.85%), root weight (36.69%) and Phosphorus content in grain (32.34%) number of productive tillers (20.56%), straw yield (20.20%) and Phosphorus content in straw (20.18%) recorded high GCV. Grain yield (15.10%), test weight (14.05%), shoot length (10.78%), days to 50% flowering(10.47%), plant height (10.43%), flag leaf length (10.07%) were recorded medium GCV. Root length (9.75%), panicle length (5.41%) and flag leaf width(4.89%) showed low GCV.

4.2(b) 1.5 Phenotypic coefficient of variation under P₄₀

PCV values ranged from 53.66% (Root weight) to 9.85% (Panicle length). Traits like root weight (53.66%), Phosphorus content in grain (41.03%), grain yield (34.05%),

straw yield (32.44%), shoot weight(31.31%), Whereas Phosphorus content in straw (22.17%), recorded as high PCV. Number of productive tillers (19.42%), flag leaf length (18.22%), root length (15.98%), days to 50% flowering (13.71%), test weight (13.12%), flag leaf width (12.32%), plant height (12.28%), shoot length (11.31%), were recorded as medium PCV and panicle length (9.85%) records low PCV.

4.2(b)1.6 Genotypic coefficient of variation under P₄₀

GCV values range from 41.03 % (Phosphorus content in grain), to 6.19% (Panicle length). Traits like Phosphorus content in grain (41.03%), root weight (32.40%), shoot weight (30.45%), Phosphorus content in straw(22.17%), recorded high GCV. Testweight (12.37%), grain yield (11.80%), days to 50% flowering (11.26%), root length (10.23%), recorded medium GCV. Whereas flag leaf length (9.85), shoot length(9.76%), plant height(9.75%), straw yield (9.22%), flag leaf width (8.83%), number of productive tillers (8.52%) and panicle length (6.19%)showed low GCV.

4.2(b)1.7 Phenotypic coefficient of variation under P₆₀

PCV values ranged from 55.30% (Root weight) to 10.02% (Panicle length). Traits like root weight (55.30%) straw yield (30.18%) and shoot weight (30%), Phosphorus content in grain (27.56%), grain yield (25.07%), Phosphorus content in straw (24.51%) and number of productive tillers (20.54%) showed high PCV. Flag leaf length (16.99%), root length (16.11%), flag leaf width (13.06%), shoot length (12.97%), plant height (12.93%), test weight (11.87%), days to 50% flowering (11.53%), panicle length (10.02%) recorded medium PCV.

4.2(b)1.8 Genotypic coefficient of variation under P₆₀

GCV values ranged from 46.87% (Root weight) to 3.94% (Number of productive tillers). High GCV values were recorded for traits root weight (46.87%), shoot weight (28.78%), Phosphorus content in grain (27.56%) and Phosphorus content in straw (24.50%) recorded. Test weight (11.46%), root length (11.08%), shoot length (10.52%), plant height (10.23%), recorded medium GCV. Days to 50% flowering (9.06%), flag leaf length (9.00%), straw yield (8.66%), grain yield (8.65%), flag leaf width (7.60%), panicle length (6.55%), number of productive tillers (3.94%) recorded as low GCV.

The PCV was higher than GCV for most of the characters across the P levels, indicating that there is an influence of environment on the expression of the traits Ogunbayo 2014 *et al.* Konate *et al.* 2016. Similar results were reported by Dutta *et al.*, (2013); Singh *et al.*, (2014) and Tuhina-Khatun *et al.*, (2015) in rice. PCV and GCV values are almost similar

for test weight, P content in grain and P content in straw, indicating that these characters were less influenced by environment. Interestingly PCV values are high for many traits like grain yield, number of productive tillers, panicle length, root weight, shoot weight and straw yield at low level of P (P_0 and P_{20}) compared to higher level of P (P_{40} and P_{60}) indicating that genotypes responds differently for available P in the soil, and indicates that there is lot of scope for identification and improvement of genotypes which perform better in low levels of soil P. Study also indicates that for study of variability one must ensure fertility status of the soil, because different gradients of fertility influence the PCV and GCV values.

4.2(b) 2 Heritability:

4.2 (b) 2.1 Heritability under P_0 level:

Heritability values ranged from 100% (Phosphorus content in straw, Phosphorus content in grain) to 19.69% (Flag leaf width). Traits like Phosphorus content in straw(100%), Phosphorus content in grain(100%), shoot weight (88.78%), test weight(81.91%), shoot length(74.40%), recorded the high heritability and root weight (46.70%), flag leaf length (44.45%), number of productive tillers (42.84%), days to 50% flowering(41.97%), straw yield (39%), grain yield (37.61%), plant height (33.77%), panicle length(31.55%) recorded as medium heritability and root length (25.47%), flag leaf width (19.69%) recorded low heritability.

4.2 (b) 2.2 Heritability under P_{20} level

Heritability values in P_{20} ranged from 100% (Phosphorus content in straw, Phosphorus content in grain) to 14.70% (Flag leaf width). The traits like phosphorus content in straw(100%), phosphorus content in grain(100%), test weight (95.06%), shoot weight (87.52%), shoot length (70.66%), days to 50% flowering(64.80%), recorded as high heritability. Plant height (57.26%), root length (54.35%), number of productive tillers (48.91%), root weight (43.43%), flag leaf length (38.08%), panicle length (36.50%), Straw yield (32.06%). recorded as medium heritability. Grain yield (20.80%), flag leaf width (14.70%), recorded low heritability.

4.2(b) 2.3 Heritability under P_{40} level

Heritability values in P_{40} ranged from 100% (Phosphorus content in straw, Phosphorus content in grain), to 8.08% (Straw yield). Traits like phosphorus content in straw(100%), phosphorus content in grain(100%), shoot weight (94.54%), test weight (88.85%), shoot length (74.48%), %, days to 50% flowering(67.41%), plant height

(63.04%), recorded the high heritability. Flagleafwidth (51.42%), root length(40.97%), panicle length (39.49%), root weight (36.46%), recorded the medium heritability and flag leaf length (29.23%), number of productive tillers(19.27%), grain yield (12.05%), straw yield (8.08%), recorded low heritability.

4.2(b) 2.4 Heritability under P₆₀ level

Heritability values from 100% (Phosphorus content in straw, Phosphorus content in grain) to 3.68% (Number of productive tillers). Traits like phosphorus content in straw(100%), phosphorus content in grain(100%), test weight (93.25%), shoot weight(92.04%), root weight (71.84%), shoot length (65.71%), plant height (62.59%), days to 50% flowering(61.71%), recorded as high heritability. Root length (47.36%), panicle length (42.70%), flag leaf width (33.83%), recorded as medium heritability. Flag leaf length (28.07%), grain yield (11.91%), straw yield (8.24%), number of productive tillers (3.68%) recorded low heritability.

Broad sense heritability (ratio of genotypic variance to phenotypic variance) is generally expressed in per cent. Thus heritability is the heritable portion of phenotypic variance. It is a good index of transmission of characters from parents to their progenies (Falconer, 1981). The estimates of heritability helped the plant breeder in the selection of elite genotypes from diverse genetic populations, as it indicate the reliability of the phenotypic value as a guide to breeding value (Falconer and Mackay, 1996; Al-Tabbal *et al.*, 2012). In the present study high heritability estimates were found for days to fifty present flowering, plant height, flag leaf length, flag leaf width, panicle length, root length, shoot length, root weight, shoot weight, test weight, phosphorus content in grain and phosphorus content in straw. Study found that heritability for grain yield and number of productive tillers was high under low P condition but they were low for the same population under high P application. This may be because under low P condition variability for tiller number was found to be high, because different genotypes behave differentially to sustain in low P stress and uses various physiological mechanism to survive based on their genetic makeup. Under high availability of P in the soil all the genotypes produce productive tillers and there is no variability for it, there by heritability will be low. (Vejchasarn *et al.* 2016).

4.2(b) 3 Genetic advance

4.2(b) 3.1 Genetic advance under P₀ level

Genetic advance values ranged from 1781.47% (Shoot length), to 4.16% (Flag leaf

length). Traits like shoot length (1781.47%), days to 50% flowering(1249.71%), plant height (665.64%), shoot weight (571.34%), test weight (525.37%), root length (340.59%), flag leaf length (297.61%), grain yield (248.06%) , straw yield (239.97%), panicle length (152.20%), number of productive tillers (93.02%) , root weight (86.37%), phosphorus content in grain(79.01%), phosphorus content in straw(44.47%), recorded high Genetic Advance. Flag leaf width (4.16%), recorded low genetic advance.

4.2 (b) 3.2 Genetic advance under P₂₀ level

Genetic advance values ranged from 1890.80% (Days to 50% flowering), to 4.36% (Flag leaf width). Traits like days to 50% flowering(1890.80%) , shoot length (1388.80%), plant height (1176.71%), shoot weight (1036.19%), test weight (796.72%), root length (323.29%), flag leaf length (314.18%), number of productive tillers (232.05%), straw yield (231.34%), grain yield (168.64%), root weight (149.75%), panicle length (140.16%), phosphorus content in grain(129.37%), phosphorus content in straw (44.99%), recorded as high Genetic Advance. Flag leaf width observed as low (4.36%) genetic advance.

4.2(b) 3.3 Genetic advance under P₄₀ level

Genetic advance values ranged from 2003.75 % (Days to 50% flowering) to 15.50% (Flag leaf width). Traits like days to 50% flowering(2003.75%), shoot length (1472.23%), shoot weight (1384.45%), plant height (1216.41%), test weight (713.18%), root length (334.18%), flag leaf length (274.60%), root weight (209.34%), phosphorus content in grain(179.83%), panicle length (168.01%), grain yield (97.92%), number of productive tillers (73.67%), phosphorus content in straw (55.16%), straw yield (50.52%), recorded high genetic advance and flag leaf width (15.50%), recorded medium genetic advance.

4.2 (b) 3.4 Genetic advances under P₆₀ level

Genetic advance values ranged from 1532.98% (Days to 50% flowering) to 10.84% (Flag leaf width), days to 50% flowering(1532.98%) , shoot length (1520.64%), plant height (1339.68%) , shoot weight (1312.61%) , test weight (699.93%) , root weight (673.64%), root length (401.20%) , flag leaf length (266.37%) , panicle length (191.79%) , phosphorus content in grain(159.42%) , grain yield (98.13%) , phosphorus content in straw(84.59%), straw yield (67.01%) , recorded as high genetic advance. Number of productive tillers (14.54%), flag leaf width(10.84%), recorded medium genetic advance. (Abebe *et.al.*,2017).

The estimates of genetic advance helps to understand the type of gene action of various polygenic characters. Johnson *et al.* (1955) suggested that high heritability

estimates along with the high genetic advance is more helpful in predicting gain under selection than heritability estimates alone. In the present study flag leaf width showed low genetic advance but all other traits showed high genetic advance coupled with medium to high heritability. Genetic advance for yield was high under low P condition but it was less under the high available P.

4.2(b) 4 Genetic advance in percent of mean

4.2 (b) 4.1 Genetic advances in percent of mean under P₀ level

Genetic advance in percent of mean values ranged from 101.80% (Shoot weight), to 4.22% (Flag leaf width). Traits like shoot weight (101.80%) , grain yield (48.79%), phosphorus content in straw(44.98%), phosphorus content in grain(42.75%) ,root weight (39.70%) ,straw yield (38.98%), shoot length (27.24%), test weight (21.79%) , number of productive tillers (21.45%), recorded high genetic advance in percent of mean. Root length (15.22%), flag leaf length (13.86%), days to 50% flowering (11.66%), plant height (11.15%), recorded medium genetic advance in per-cent of mean. Panicle length (8.59%), flag leaf width (4.22%) recorded low Genetic advance in percent of mean. (Richardson *et al.* 2011),

4.2 (b) 4.2 Genetic advances in percent of mean under P₂₀ level

Genetic advance in percent of mean values ranged from 72.94% (Shoot weight) to 3.89% (Flag leaf width). Traits like shoot weight (72.94%) , phosphorus content in grain(66.64%) ,root weight (49.81%), phosphorus content in straw(41.57%), number of productive tillers(29.62%), test weight (28.23%),straw yield (23.57%) ,recorded high genetic advance in percent of mean. And shoot length (18.68%), days to 50% flowering (17.36%), plant height (16.26%), root length (14.81%), grain yield (14.18%), flag leaf length (12.80%) , recorded medium genetic advance in percent of mean. Panicle length (6.74%), flag leaf width (3.89%), recorded low genetic advance in percent of mean.

4.2 (b) 4.3 Genetic advance in percent of mean under P₄₀ level

Genetic advance in percent of mean values ranged from 84.52% (Phosphorus content in grain) to 5.40% (Straw yield). Traits like phosphorus content in grain (84.52%), shoot weight (60.98%), phosphorus content in straw(45.67%) , root weight (40.30%) , test weight (24.02%) ,recorded as high genetic advance in percent of mean. Days to 50% flowering(19.04%), shoot length (17.35%), plant height (15.95%), root length (13.49%), flag leaf width (13.05%) ,flag leaf length (10.97%), recorded medium genetic advance in percent of mean. Grain yield (8.45%) , panicle length (8.01%), number of

productive tillers(7.71%), straw yield (5.40%) ,recorded low Genetic advance in percent of mean. (Richardson *et al.* 2011),

4.2(b) 4.4 Genetic advance in percent of mean under P₆₀ level

Genetic advance in percent of mean values ranged from 81.84% (Root weight) to 1.56% (Number of productive tillers). Traits like root weight (81.84%) , shoot weight (56.88%) , phosphorus content in grain(56.76%), phosphorus content in straw(50.49%) and test weight (22.80%), recorded as high genetic advance in percent of mean. Shoot length (17.56%), plant height (16.67%), root length (15.71%) , days to 50% flowering(14.66%), flag leaf length (9.83%) ,flag leaf width (9.10%), panicle length (8.81%), grain yield (6.15%) ,straw yield (5.12%) and number of productive tillers(1.56%) recorded low genetic advance in per cent of mean.

Johnson et al. (1955) suggested that high heritability estimates along with the high genetic advance in percent mean is also more helpful in predicting gain under selection than heritability estimates alone. Flag leaf width and panicle length showed low genetic advance as percent of mean coupled with moderate to high heritability showed that traits are governed by non additive gene action. Grain yield under low P condition showed high heritability along with high genetic advance in percent mean, while it showed moderate heritability coupled with low to moderate genetic advance as percent mean. Grain yield is a complex trait, it is influenced by many other yield associative traits which are of additive and non additive in nature. But study reveals that under low P condition improvement is possible through selection. Similar kind of results were also observed for number of productive tillers. The traits like shoot weight, root weight, straw yield, test weight, P content in straw and P content in grain showed high genetic advance as percent mean with high heritability indicating that they are additive in nature. Similar findings have been reported by Wolie et al.. (2013), Ogunbayo et al. (2014) on rice

4.3 Character association under different graded levels of P

The degree of correlation between the traits is important in plant breeding. It can be used as tool for indirect selection. Correlation studies help the plant breeder during selection and provide help in understanding of yield components. Results of the correlation studies are summarized in the table (4.11- 4.18) and are as follows.

4.3.1 Days to 50% flowering:

4.3.1.1 Phenotypic correlation Under P₀, traits like grain yield (0.069), flag leaf length (0.065), flag leaf width (0.040), number of productive tillers (0.033), phosphorus content in

straw (0.130), straw yield (0.016) and test weight (0.047), showed positive but non-significant phenotypic correlation with days to 50% flowering. traits like phosphorus content in grain (-0.124), plant height (-0.085), panicle length (-0.102), root length (-0.025), root weight (-0.137), shoot length (-0.071) and shoot weight (-0.007) showed negative but non-significant phenotypic correlation with days to 50% flowering. (Vandamme *et al.* 2013),

4.3.1.2 Genotypic correlation was found to be positive non-significant for grain yield (0.178), flag leaf length (0.267), flag leaf width (0.177), number of productive tillers (0.165), phosphorus content in straw (0.200), plant height (0.059), panicle length (0.059), straw yield (0.107) and test weight(0.100), with days to 50% flowering. Traits like phosphorus content in grain (-0.191), root length (-0.126), root weight (-0.202), shoot length (-0.081) and shoot weight (-0.040) showed negative non-significant genotypic correlation with days to 50% flowering.

4.3.1.3 Under P₂₀, traits like grain yield (0.182), flag leaf length (0.173), flag leaf width (0.262), number of productive tillers (0.163), phosphorus content in grain (0.107), plant height (0.134), panicle length (0.174)+98+98, root length (0.168), root weight (0.114), shoot length (0.171), shoot weight (0.073) and straw yield (0.302) showed positive non-significant phenotypic correlation with days to 50% flowering. Traits like phosphorus content in straw (-0.121) and test weight (-0.067) showed negative non-significant phenotypic correlation with days to 50% flowering.

4.3.1.4 Genotypic Correlation was positive for Grain yield (0.504), Flag leaf width (0.628) and Straw yield (0.508) with Days to 50% flowering. Traits like, Flag leaf length (0.414), Number of productive tillers (0.149), Phosphorus content in grain (0.133), Plant height (0.355), Panicle length (0.387), Root length (0.272), Root weight (0.220), Shoot length (0.155) and Shoot weight (0.121) showed genotypic correlation with Days to 50% flowering. Traits like Phosphorus content in straw (-0.151) and Test weight (-0.048) showed negative non-significant genotypic correlation with Days to 50% flowering.

4.3.1.5 Phenotypic correlation Under P₄₀ observed positive non-significant for Grain yield (0.188), Flag leaf length (0.216), Flag leaf width (0.150), Phosphorus content in grain(0.030), Plant height (0.181), Panicle length (0.107), Root weight (0.047), Shoot length (0.164), Shoot weight (0.098), Straw yield (0.335) and Test weight (0.122) with Days to 50% flowering. While Number of productive tillers (-0.070), Phosphorus content in straw (-0.003) and Root length (-0.039) showed negative non-significant phenotypic

correlation with Days to 50% flowering. (Vandamme *et al.* 2013),

4.3.1.6 Genotypic correlation under P₄₀ observed positive and significant association for straw yield (0.962) with days to 50% flowering. Whereas traits like flag leaf length (0.313), flag leaf width (0.120), phosphorus content in grain (0.037), plant height (0.166), panicle length (0.147), root weight (0.233), shoot length (0.306), shoot weight (0.143) and test weight (0.143) showed positive non-significant genotypic correlation with days to 50% flowering. Traits like Phosphorus content in straw (-0.004).

Number of productive tillers (-0.124) and Root length (-0.053) showed negative non-significant genotypic correlation with Days to 50% flowering.

4.3.1.7 Phenotypic correlation under P₆₀ showed positive non-significant association for traits like grain yield (0.139), flag leaf length (0.245), flag leaf width (0.188), number of productive tillers (0.037), phosphorus content in grain (0.052), plant height (0.149), panicle length (0.248), root length (0.089), root weight (0.145), shoot length (0.216), shoot weight (0.287), straw yield (0.232) and test weight (0.120) with days to 50% flowering. Phosphorus content in straw (-0.120) showed negative non-significant phenotypic correlation with Days to 50% flowering. (Zhu and Lynch 2004).

4.3.1.8 Genotypic correlation under P₆₀ observed positive significant for flag leaf length (0.650) and straw yield (0.629) with days to 50% flowering. Traits like Flag leaf width (0.361), grain yield (0.334), phosphorus content in grain (0.066), plant height (0.218), Panicle length (0.328), Root length (0.293), Root weight (0.259), Shoot length (0.404), shoot weight (0.394) and test weight (0.137) showed positive non-significant genotypic correlation with Days to 50% flowering. Traits like, Phosphorus content in straw (-0.052) and number of productive tillers (-0.158) showed negative non-significant genotypic correlation with Days to 50% flowering.

Days to fifty percent flowering showed positive correlation with grain yield and plant height, and in most of the cases the genotypic correlation values are more than the phenotypic correlation values indicating that association is true and not because of influence of prevailing environmental factors.

4.3.2 Flag leaf length:

4.3.2.1 Under P₀: Phenotypic correlation

Traits like, plant height (0.580), panicle length (0.662), showed positive significant phenotypic correlation with flag leaf length. Traits like grain yield (0.142), days to 50% flowering (0.065), flag leaf width (0.254), number of productive tillers (0.307),

Table 4.11. Phenotypic (r_p) correlation co-efficients for yield and yield components in rice at P₀ level

Character s	DFF	FLL	FLW	GY	NT	PCG	PCS	PH	PL	RL	RW	SL	SW	SY	TW
DFF	1.000	0.065	0.040	0.069	0.033	-0.124	0.130	-0.085	-0.102	-0.025	-0.137	-0.071	-0.007	0.016	0.047
FLL		1.000	0.254	0.142	0.307	-0.033	0.008	0.580*	0.662**	0.167	0.033	0.264	0.021	0.276	0.044
FLW			1.000	0.151	0.242	-0.136	-0.019	0.206	0.229	0.023	0.032	0.035	0.000	0.127	-0.023
GY				1.000	0.488	-0.074	-0.151	0.387	0.282	0.171	-0.042	0.268	0.172	0.813**	0.016
NT					1.000	-0.042	-0.019	0.442	0.424	0.183	-0.105	0.305	0.056	0.448	-0.031
PCG						1.000	0.139	0.005	0.020	0.072	-0.023	0.083	-0.067	-0.065	0.091
PCS							1.000	-0.116	-0.014	-0.018	-0.179	-0.125	-0.190	-0.206	0.067
PH								1.000	0.774	0.120	-0.121	0.400	0.109	0.448*	0.011
PL									1.000	0.178	-0.132	0.309	-0.048	0.365	0.016
RL										1.000	-0.157	0.385	0.154	0.183	-0.041
RW											1.000	-0.093	0.077	0.029	-0.044
SL												1.000	0.521	0.307	-0.099
SW													1.000	0.152	-0.065
SY														1.000	-0.019
TW															1.000

*-Significant at 5% level of significance,**- Significant at 1% level of significance

DFF=Days to 50% flowering, PH=Plant height, NT=No of productive tillers, FLL=Flag leaf length, FLW=Flag leaf width, PL=Panicle length, RT=Root length, RW=Root weight, SL=Shoot length, SW=Shoot weight, SY=Straw yield, GY=Grain yield, TW=Test weight, PCS=Phosphorus content in straw, PCG=Phosphorus content in grain

Table 4.12. Genotypic (r_g) correlation co-efficients for yield and yield components in rice at P₀ level

Characters	DFF	FLL	FLW	GY	NT	PCG	PCS	PH	PL	RL	RW	SL	SW	SY	TW
DFF	1.000	0.267	0.177	0.178	0.165	-0.191	0.200	0.059	0.053	-0.126	-0.202	-0.081	-0.040	0.107	0.100
FLL		1.000	0.420	0.353	0.502*	-0.050	0.012	0.891**	0.851**	0.474*	-0.095	0.557*	0.042	0.597**	0.079
FLW			1.000	0.550*	0.289	-0.304	-0.041	0.126	0.012	0.053	0.053	0.219	0.106	0.593	-0.062
GY				1.000	0.804**	-0.120	-0.246	0.492*	0.396	0.501	-0.067	0.406	0.306	0.948	0.068
NT					1.000	-0.064	-0.030	0.679	0.537*	0.601**	-0.102	0.621	0.204	0.878**	0.080
PCG						1.000	0.139	0.007	0.033	0.14	-0.033	0.096	-0.071	-0.105	0.101
PCS							1.000	-0.199	-0.026	-0.037	-0.263	-0.144	-0.202	-0.330	0.074
PH								1.000	0.929**	0.671**	-0.100	0.837**	0.227	0.766**	-0.013
PL									1.000	0.837**	-0.144	0.744**	-0.051	0.786**	0.103
RL										1.000	-0.256	0.808**	0.371	0.482	-0.048
RW											1.000	-0.126	0.103	-0.056	-0.050
SL												1.000	0.646**	0.522*	-0.142
SW													1.000	0.244	-0.070
SY														1.000	-0.041
TW															1.000

*-Significant at 5% level of significance, **- Significant at 1% level of significance

DFF=Days to 50% flowering, PH=Plant height, NT=No of productive tillers, FLL=Flag leaf length, FLW=Flag leaf width, PL=Panicle length, RT=Root length, RW=Root weight, SL=Shoot length, SW=Shoot weight, SY=Straw yield, GY=Grain yield, TW=Test weight, PCS=Phosphorus content in straw, PCG=Phosphorus content in grain

Table 4.13. Phenotypic (r_p) correlation co-efficients for yield and yield components in rice at P₂₀ level

Character	DFF	FLL	FLW	GY	NT	PCG	PCS	PH	PL	RL	RW	SL	SW	SY	TW
DFF	1.000	0.173	0.262	0.182	0.163	0.107	-0.121	0.134	0.174	0.168	0.114	0.171	0.073	0.302	-0.067
FLL		1.000	0.185	0.212	-0.081	-0.049	-0.092	0.552*	0.622**	0.209	0.135	0.367	0.096	0.177	0.022
FLW			1.000	0.107	0.066	-0.025	-0.001	0.146	0.152	0.049	-0.035	0.105	0.059	0.212	0.057
GY				1.000	0.129	0.040	-0.077	0.156	0.130	0.069	0.045	0.142	0.080	0.666	-0.021
NT					1.000	0.496*	0.015	0.212	-0.099	0.175	0.089	0.137	-0.075	0.448*	0.038
PCG						1.000	0.017	0.274	0.012	0.203	0.039	0.067	-0.094	0.308	0.264
PCS							1.000	-0.087	-0.067	-0.213	-0.093	-0.147	-0.056	-0.074	-0.053
PH								1.000	0.599**	0.295	0.297	0.451*	0.092	0.277	0.094
PL									1.000	0.108	0.243	0.317	0.075	0.131	-0.016
RL										1.000	0.126	0.476*	0.328	0.193	-0.076
RW											1.000	0.182	0.239	0.106	-0.110
SL												1.000	0.381	0.188	-0.054
SW													1.000	0.024	-0.257
SY														1.000	0.064
TW															1.000

*-Significant at 5% level of significance,**- Significant at 1% level of significance

DFF=Days to 50% flowering, PH=Plant height, NT=No of productive tillers, FLL=Flag leaf length, FLW=Flag leaf width, PL=Panicle length, RT=Root length, RW=Root weight, SL=Shoot length, SW=Shoot weight, SY=Straw yield, GY=Grain yield, TW=Test weight, PCS=Phosphorus content in straw, PCG=Phosphorus content in grain

Table 4.14. Genotypic (r_g) correlation co-efficients for yield and yield components in rice at P₂₀ level

Character	DFF	FLL	FLW	GY	NT	PCG	PCS	PH	PL	RL	RW	SL	SW	SY	TW
DFF	1.000	0.414	0.628**	0.504*	0.149	0.133	-0.151	0.355	0.387	0.272	0.220	0.155	0.121	0.508*	-0.048
FLL		1.000	0.777**	0.420	-0.026	-0.081	-0.150	0.571*	0.753**	0.384	0.170	0.709*	0.160	0.355	0.022
FLW			1.000	0.596**	-0.106	-0.065	0.000	0.213	0.382	0.156	0.088	0.288	0.180	0.672**	0.230
GY				1.000	0.241	0.087	-0.170	0.338	0.211	0.200	0.216	0.476	0.304	0.607	-0.138
NT					1.000	0.712**	0.020	0.473*	-0.013	0.302	0.177	0.246	-0.136	0.882**	0.097
PCG						1.000	0.017	0.361	0.020	0.277	0.058	0.080	-0.101	0.543*	0.271
PCS							1.000	-0.115	-0.111	-0.290	-0.141	-0.175	-0.06	-0.131	-0.055
PH								1.000	0.511*	0.618**	0.517*	0.833**	0.156	0.581*	0.126
PL									1.000	0.390	0.562*	0.687**	0.268	0.262	-0.040
RL										1.000	0.385	0.583*	0.485*	0.349	-0.083
RW											1.000	0.329	0.300	0.292	-0.218
SL												1.000	0.491*	0.453*	-0.067
SW													1.000	0.042	-0.287
SY														1.000	0.094
TW															1.000

*-Significant at 5% level of significance,**- Significant at 1% level of significance

DFF=Days to 50% flowering, PH=Plant height, NT=No of productive tillers, FLL=Flag leaf length, FLW=Flag leaf width, PL=Panicle length, RT=Root length, RW=Root weight, SL=Shoot length, SW=Shoot weight, SY=Straw yield, GY=Grain yield, TW=Test weight, PCS=Phosphorus content in straw, PCG=Phosphorus content in grain

Table 4.15. Phenotypic (r_p) correlation co-efficients for yield and yield components in rice at P₄₀ level

Character	DFF	FLL	FLW	GY	NT	PCG	PCS	PH	PL	RL	RW	SL	SW	SY	TW
DFF	1.000	0.216	0.150	0.188	-0.070	0.030	-0.003	0.181	0.107	-0.039	0.047	0.164	0.098	0.335	0.122
FLL		1.000	0.245	0.305	-0.032	-0.085	-0.051	0.448	0.544*	0.108	0.163	0.443*	0.219	0.319	0.027
FLW			1.000	0.293	-0.147	-0.180	-0.001	0.269	0.342	0.122	0.022	0.246	0.334	0.232	-0.055
GY				1.000	0.123	-0.054	-0.031	0.216	0.262	0.124	0.117	0.114	0.168	0.666	0.092
NT					1.000	0.120	-0.038	0.038	-0.029	-0.050	0.074	-0.163	-0.167	0.216	0.092
PCG						1.000	0.073	0.065	-0.084	-0.051	-0.089	-0.017	-0.316	0.081	0.105
PCS							1.000	-0.089	-0.070	-0.067	0.003	0.047	0.035	0.012	0.031
PH								1.000	0.612*	0.091	0.152	0.575*	0.135	0.384	-0.020
PL									1.000	0.167	0.130	0.374	0.214	0.230	0.003
RL										1.000	0.243	0.325	0.422	0.086	0.024
RW											1.000	0.169	0.199	0.171	0.134
SL												1.000	0.425	0.218	-0.055
SW													1.000	0.100	0.088
SY														1.000	0.154
TW															1.000

*-Significant at 5% level of significance,**- Significant at 1% level of significance

DFF=Days to 50% flowering, PH=Plant height, NT=No of productive tillers, FLL=Flag leaf length, FLW=Flag leaf width, PL=Panicle length, RL=Root length, RW=Root weight, SL=Shoot length, SW=Shoot weight, SY=Straw yield, GY=Grain yield, TW=Test weight, PCS=Phosphorus content in straw, PCG=Phosphorus content in grain

Table 4.16. Genotypic (r_g) correlation co-efficients for yield and yield components in rice at P₄₀ level

Character	DFE	FLL	FLW	GY	NT	PCG	PCS	PH	PL	RL	RW	SL	SW	SY	TW
DFE	1.000	0.313	0.120	0.189	-0.124	0.037	-0.004	0.166	0.147	-0.053	0.233	0.306	0.143	0.962**	0.143
FLL		1.000	0.453	0.303	-0.852	-0.157	-0.093	0.734**	0.783**	0.010	0.799**	0.854**	0.441	1.042	0.002
FLW			1.000	0.291	-0.979	-0.253	-0.002	0.296	0.532*	0.344	-0.011	0.445*	0.473*	0.253	-0.091
GY				1.00	0.122	-0.053	-0.030	0.213	0.261	0.119	0.115	0.112	0.165	0.565	0.091
NT					1.000	0.271	-0.087	-0.144	0.603**	-0.066	0.007	-0.256	-0.302	-0.488*	0.206
PCG						1.000	0.073	0.080	-0.135	-0.079	-0.148	-0.020	-0.325	0.282	0.111
PCS							1.000	-0.112	-0.111	-0.105	0.004	0.054	0.036	0.046	0.033
PH								1.000	0.671**	0.350	0.468	0.835**	0.180	0.947**	-0.048
PL									1.000	0.308	0.286	0.634**	0.334	0.183	0.018
RL										1.000	0.578*	0.340	0.680**	0.133	0.073
RW											1.000	0.292	0.344	2.096	0.219
SL												1.000	0.505*	0.983**	-0.038
SW													1.000	0.399	0.097
SY														1.000	0.523*
TW															1.000

*-Significant at 5% level of significance,**- Significant at 1% level of significance

DFE=Days to 50% flowering, PH=Plant height, NT=No of productive tillers, FLL=Flag leaf length, FLW=Flag leaf width, PL=Panicle length, RT=Root length, RW=Root weight, SL=Shoot length, SW=Shoot weight, SY=Straw yield, GY=Grain yield, TW=Test weight, PCS=Phosphorus content in straw, PCG=Phosphorus content in grain.

Table 4.17. Phenotypic (r_p) correlation co-efficients for yield and yield components in rice at P₆₀ level

Character	DFF	FLL	FLW	GY	NT	PCG	PCS	PH	PL	RL	RW	SL	SW	SY	TW
DFF	1.000	0.245	0.188	0.139	0.037	0.052	-0.040	0.149	0.248	0.089	0.145	0.216	0.287	0.232	0.120
FLL		1.000	0.341	0.251	-0.054	-0.192	-0.005	0.395	0.503*	0.189	0.204	0.333	0.211	0.211	0.005
FLW			1.000	0.187	-0.171	-0.184	-0.005	0.068	0.095	0.115	-0.071	0.152	0.274	0.040	-0.015
GY				1.000	-0.068	-0.045	0.034	0.066	0.063	0.088	-0.032	0.027	0.121	0.607**	0.126
NT					1.000	0.067	-0.015	-0.027	-0.118	-0.150	-0.043	-0.077	-0.147	0.000	0.003
PCG						1.000	-0.077	0.007	-0.067	0.019	-0.044	-0.026	-0.175	0.009	-0.028
PCS							1.000	-0.202	-0.072	0.045	0.009	-0.162	-0.050	0.033	-0.102
PH								1.000	0.648	0.038	0.013	0.403	0.096	0.199	0.149
PL									1.000	0.107	0.098	0.353	0.187	0.099	0.060
RL										1.000	0.208	0.324	0.297	0.016	0.020
RW											1.000	0.295	0.416	0.042	0.053
SL												1.000	0.387	0.164	0.018
SW													1.000	0.095	0.077
SY														1.000	0.070
TW															1.000

*-Significant at 5% level of significance,**- Significant at 1% level of significance

DFF=Days to 50% flowering, PH=Plant height, NT=No of productive tillers, FLL=Flag leaf length, FLW=Flag leaf width, PL=Panicle length, RT=Root length, RW=Root weight, SL=Shoot length, SW=Shoot weight, SY=Straw yield, GY=Grain yield, TW=Test weight, PCS=Phosphorus content in straw, PCG=Phosphorus content in grain

Table 4.18. Genotypic (r_g) correlation co-efficients for yield and yield components in rice at P₆₀ level

Character	DFF	FLL	FLW	GY	NT	PCG	PCS	PH	PL	RL	RW	SL	SW	SY	TW
DFF	1.000	0.650**	0.361	0.33	-0.158	0.066	-0.052	0.218	0.328	0.293 ^{ns}	0.259	0.404	0.394	0.629**	0.137
FLL		1.000	0.475*	0.396	-1.036	-0.362	-0.012	0.627	0.848**	0.585*	0.554*	0.752**	0.367	0.785**	0.015
FLW			1.000	1.139	-2.265	-0.315	-0.011	0.101	-0.016	0.331 ^{ns}	-0.127	0.387	0.468	0.515	-0.022
GY				1.000	-1.288	-0.136	0.105	-0.045	0.342	0.809**	0.220	-0.047	0.415	0.060	0.235
NT					1.000	0.351	-0.074	0.125	-0.608	-1.893 ^{ns}	0.033	-0.844**	-0.711**	0.505*	-0.015
PCG						1.000	-0.077	0.008	-0.104	0.029 ^{ns}	-0.053	-0.031	-0.183	0.027	-0.029
PCS							1.000	-0.256	-0.112 ^{ns}	0.065	0.010	-0.199	-0.052	0.117	-0.106
PH								1.000	0.809**	0.134	0.093	0.626**	0.107	0.846**	0.136
PL									1.000	0.216	0.253	0.520	0.254	0.863*	0.072
RL										1.000	0.306	0.409	0.454	0.748**	0.083
RW											1.000	0.426	0.519	0.600**	0.079
SL												1.000	0.502*	0.723	0.016
SW													1.000	0.411	0.081
SY														1.000	0.061
TW															1.000

*-Significant at 5% level of significance,**- Significant at 1% level of significance

DFF=Days to 50% flowering, PH=Plant height, NT=No of productive tillers, FLL=Flag leaf length, FLW=Flag leaf width, PL=Panicle length, RT=Root length, RW=Root weight, SL=Shoot length, SW=Shoot weight, SY=Straw yield, GY=Grain yield, TW=Test weight, PCS=Phosphorus content in straw, PCG=Phosphorus content in grain

Phosphorus content in straw (0.008), root length (0.167), root weight (0.033), shoot length (0.264), shoot weight (0.021), straw yield (0.276), test weight (0.044), showed positive non-significant phenotypic correlation with flag leaf length. Traits like Phosphorus content in grain (-0.033) showed negative non-significant phenotypic correlation with flag leaf length.

4.3.2.2 Under P₀: Genotypic correlation

Traits like number of productive tillers (0.502), plant height (0.891), panicle length (0.851), root length (0.474), shoot length (0.557), straw yield (0.597), showed positive significant genotypic correlation with flag leaf length. Traits like days to 50% flowering (0.267), flag leaf width (0.420), grain yield (0.353), phosphorus content in straw (0.012), shoot weight (0.042) and test weight (0.079), showed positive non-significant genotypic correlation with flag leaf length. Traits like phosphorus content in grain (-0.050), root weight (-0.095), showed negative non-significant genotypic correlation with flag leaf length.

4.3.2.3 Under P₂₀: Phenotypic correlation

Traits like plant height (0.552), panicle length (0.622), showed positive significant phenotypic correlation with flag leaf length. Traits like grain yield (0.212), days to 50% flowering (0.173), flag leaf width (0.185), root length (0.209), root weight (0.135), shoot length (0.367), shoot weight (0.096), straw yield (0.177) and test weight (0.022) showed positive but not significant phenotypic correlation with flag leaf length. Traits like number of productive tillers (-0.081), phosphorus content in grain (-0.049), phosphorus content in straw (-0.092), showed negative non-significant phenotypic correlation with flag leaf length.

4.3.2.4 Under P₂₀: Genotypic correlation

Traits like flag leaf width (0.777), plant height (0.571), panicle length (0.753), shoot length (0.709), showed positive significant genotypic correlation with flag leaf length. Days to 50% flowering (0.414), grain yield (0.420), root weight (0.170), shoot weight (0.160), straw yield (0.355) and test weight (0.022), showed positive non significant genotypic correlation with flag leaf length. Traits like, number of productive tillers (-0.026), phosphorus content in grain (-0.081) and phosphorus content in straw (-0.150) showed negative non-significant phenotypic correlation with flag leaf length.

4.3.2.5 Under P₄₀: Phenotypic correlation

Panicle length (0.544), shoot length (0.443), showed positive significant

phenotypic correlation with flag leaf length. Traits like Grain yield (0.305), days to 50% flowering (0.216), flag leaf width (0.245), plant height (0.448), root length (0.108), root weight (0.163), shoot weight (0.219), straw yield (0.319), test weight (0.027), showed positive non-significant phenotypic correlation with flag leaf length. Traits like number of productive tillers (-0.032), phosphorus content in grain (-0.085), phosphorus content in straw (-0.051), showed negative non-significant phenotypic correlation with flag leaf length.

4.3.2.6 Under P₄₀: Genotypic correlation

Plant height (0.734), panicle length (0.783), root weight (0.799), shoot length (0.854), showed positive significant genotypic correlation with flag leaf length. Days to 50% flowering (0.313), flag leaf width (0.453), root length (0.010), shoot weight (0.441), straw yield (1.042) and test weight (0.002), showed positive non-significant genotypic correlation with flag leaf length. Traits like number of productive tillers (-0.852), phosphorus content in grain (-0.157), phosphorus content in straw (-0.093), showed negative non-significant phenotypic correlation with flag leaf length.

4.3.2.7 Under P₆₀: Phenotypic correlation

Panicle length (0.503), showed positive significant phenotypic correlation with flag leaf length. Grain yield (0.251), days to 50% flowering (0.245), flag leaf width (0.341), plant height (0.395), root length (0.189), root weight (0.204), shoot length (0.333), shoot weight (0.211), straw yield (0.211) and test weight (0.005), showed positive non-significant phenotypic correlation with flag leaf length. Number of productive tillers (-0.054), phosphorus content in grain (-0.192), phosphorus content in straw (-0.005), showed negative non-significant phenotypic correlation with flag leaf length.

4.3.2.8 Under P₆₀: Genotypic correlation

Days to 50% flowering (0.650), flag leaf width (0.475), panicle length (0.848), root length (0.585), root weight (0.554), shoot length (0.752), straw yield (0.785) showed positive significant genotypic correlation with flag leaf length. Grain yield (0.396), Plant height (0.627), shoot weight (0.367) and test weight (0.015), showed positive non-significant genotypic correlation with flag leaf length. Whereas, number of productive tillers (-1.036), phosphorus content in grain (-0.362) and phosphorus content in straw (-0.012) showed negative non-significant genotypic correlation with flag leaf length.

Flag leaf length showed positive association with the grain yield, plant height, panicle length, and also value of the genotypic correlation were higher than that of the

phenotypic correlation values indicating the association is due to genetic. These results are in agreement with the findings of Bhadru et al. (2011), Eswara reddy et al. (2013).

4.3.3 Flag leaf width

4.3.3.1 Under P₀: Phenotypic correlation

Grain yield (0.151), days to 50% flowering (0.040), flag leaf length (0.254), number of productive tillers (0.242), plant height (0.206), panicle length (0.229), root length (0.023), root weight (0.032), shoot length (0.035), shoot weight and Straw yield (0.127), showed positive non-significant phenotypic correlation with flag leaf width. Phosphorus content in grain (-0.136), phosphorus content in straw (-0.019) and test weight (-0.023), showed negative non-significant phenotypic correlation with flag leaf width.

4.3.3.2 Under P₀: Genotypic correlation

Grain yield (0.550) showed positive significant genotypic correlation with flag leaf width. Days to 50% flowering (0.177), flag leaf length (0.420), number of productive tillers (0.289), plant height (0.126), panicle length (0.012), root length (0.053), root weight (0.053), shoot length (0.219), shoot weight (0.106), straw yield (0.593) showed positive non-significant genotypic correlation with flag leaf width. Phosphorus content in grain (-0.304), phosphorus content in straw (-0.041) and test weight (-0.062) showed negative significant non-genotypic correlation with flag leaf width.

4.3.3.3 Under P₂₀: Phenotypic correlation

Grain yield (0.107), days to 50% flowering (0.262), flag leaf length (0.185), number of productive tillers (0.066), plant height (0.146), panicle length (0.152), root length (0.049), shoot length (0.105), shoot weight (0.059), straw yield (0.212) and test weight (0.057), showed positive non-significant phenotypic correlation with flag leaf width. Phosphorus content in grain (-0.025), phosphorus content in straw (-0.001), root weight (-0.035), showed negative non-significant phenotypic correlation with flag leaf width.

4.3.3.4 Under P₂₀: Genotypic correlation

Grain yield (0.596), days to 50% flowering (0.628), flag leaf length (0.777), straw yield (0.672), showed positive significant genotypic correlation with flag leaf width. Phosphorus content in straw, plant height (0.213), panicle length (0.382), root length (0.156), root weight (0.088), shoot length (0.288), shoot weight (0.180) and test weight (0.230) showed positive non-significant genotypic correlation with flag leaf width. Number of productive tillers (-0.106), phosphorus content in grain (-0.065) showed negative non-significant genotypic correlation with flag leaf width.

4.3.3.5 Under P₄₀:Phenotypic correlation

Grain yield (0.293), days to 50% flowering (0.150), flag leaf length (0.245), plant height (0.269), Panicle length (0.342), root length (0.122), root weight (0.022), shoot length (0.246), shoot weight (0.334) and straw yield (0.232), showed positive non-significant phenotypic correlation with flag leaf width. Number of productive tillers (-0.147), phosphorus content in grain (-0.180), phosphorus content in straw (-0.001) and test weight(-0.055), showed negative non-significant phenotypic correlation with flag leaf width.

4.3.3.6 Under P₄₀:Genotypic correlation

Panicle length (0.532), shoot length (0.445), shoot weight (0.473), showed positive significant genotypic correlation with flag leaf width. Days to 50% flowering (0.120), flag leaf length (0.453), Plant height (0.296), root length (0.344), straw yield (0.253), showed positive non-significant genotypic correlation with flag leaf width. Number of productive tillers (-0.979), phosphorus content in grain (-0.253), phosphorus content in straw (-0.002), root weight (-0.011) and test weight(-0.091) showed negative non-significant genotypic correlation with flag leaf width.

4.3.3.7 Under P₆₀: Phenotypic correlation

Grain yield (0.187), days to 50% flowering (0.188), flag leaf length (0.341), plant height (0.068), panicle length (0.095), root length (0.115), shoot length (0.152), shoot weight (0.274), straw yield (0.040), showed positive non-significant phenotypic correlation with flag leaf width. Whereas number of productive tillers (-0.171), phosphorus content in grain (-0.184), phosphorus content in straw (-0.005), root weight (-0.071) and test weight (-0.015), showed negative non-significant phenotypic correlation with flag leaf width.

4.3.3.8 Under P₆₀:Genotypic correlation

Flag leaf length (0.475) showed positive significant genotypic correlation with flag leaf width. Traits like grain yield (1.139), days to 50% flowering (0.361), plant height (0.101), root length (0.331), shoot length (0.387), shoot weight (0.468), straw yield (0.515) showed positive non-significant genotypic correlation with flag leaf width. Number of productive tillers (-2.265), phosphorus content in grain (-0.315), phosphorus content in straw (-0.011), panicle length (-0.016), root weight (-0.127) and test weight (-0.022) showed negative non-significant genotypic correlation with flag leaf width. The flag leaf length showed positive association with the grain yield.

4.3.4 Grain yield:

4.3.4.1 Under P₀: Phenotypic correlation

Straw yield (0.813), showed positive significant phenotypic correlation with grain yield. Days to 50% flowering (0.069), flag leaf length (0.142), flag leaf width (0.151), number of productive tillers (0.488), plant height (0.387), panicle length (0.282), root length (0.171), shoot length (0.268), shoot weight (0.172) and test weight (0.016) showed positive non-significant phenotypic correlation with grain yield. Phosphorus content in straw (-0.151), Root weight (-0.042), showed negative non-significant phenotypic correlation with grain yield.

4.3.4.2 Under P₀: Genotypic correlation

Flag leaf width (0.550), number of productive tillers (0.804), plant height (0.492), showed positive significant genotypic correlation with grain yield.. Days to 50% flowering (0.178), flag leaf length (0.353), panicle length (0.396) root length (0.501), shoot length (0.406), shoot weight (0.306), straw yield (0.948) and test weight (0.068) showed positive non-significant genotypic correlation with grain yield. Phosphorus content in grain (-0.120), phosphorus content in straw (-0.246), root weight (-0.067) showed negative non-significant genotypic correlation with grain yield.

4.3.4.3 Under P₂₀: Phenotypic correlation

Days to 50% flowering (0.182) flag leaf length (0.212), flag leaf width (0.107), number of productive tillers (0.129), phosphorus content in grain (0.040), plant height (0.156), panicle length (0.130), root length (0.069), root weight (0.045), shoot length (0.142), shoot weight (0.080), straw yield (0.666), showed positive non-significant phenotypic correlation with grain yield. Phosphorus content in straw (-0.077) and test weight(-0.021), showed negative non-significant phenotypic correlation with grain yield.

4.3.4.4 Under P₂₀:Genotypic correlation

Days to 50% flowering (0.504), flag leaf width (0.596), showed positive significant genotypic correlation with grain yield. Number of productive tillers (0.241), phosphorus content in grain (0.087), plant height (0.338), Panicle length (0.211), root length (0.200), root weight (0.216), shoot length (0.476), shoot weight (0.304), straw yield (0.607), showed positive non-significant genotypic correlation with grain yield. Phosphorus content in straw (-0.170) and test weight (-0.138) showed negative non-significant genotypic correlation with grain yield.

4.3.4.5 Under P₄₀:Phenotypic correlation

Days to 50% flowering (0.188), flag leaf length (0.305), flag leaf width (0.293),

number of productive tillers (0.123), plant height (0.216), panicle length (0.262), root length (0.124), root weight (0.117), shoot weight (0.168), straw yield (0.666) and test weight (0.092), showed positive non-significant phenotypic correlation with grain yield. Phosphorus content in grain (-0.054), phosphorus content in straw (-0.031), showed negative non-significant phenotypic correlation with grain yield.

4.3.4.7 Under P₆₀: Phenotypic correlation

Straw yield (0.607), showed positive significant phenotypic correlation with grain yield. Days to 50% flowering (0.139), flag leaf length (0.251), flag leaf width (0.187), phosphorus content in straw (0.034), plant height (0.066), panicle length (0.063), root length (0.088), shoot length (0.027), shoot weight (0.121) and test weight (0.126), showed positive non-significant phenotypic correlation with grain yield. Number of productive tillers (-0.068), phosphorus content in grain (-0.045), root weight (-0.032), showed negative non-significant phenotypic correlation with grain yield.

4.3.4.8 Under P₆₀: Genotypic correlation

Root length (0.809), showed positive significant genotypic correlation with grain yield. Days to 50% flowering (0.334), flag leaf length (0.396), flag leaf width (1.139), phosphorus content in straw (0.105), panicle length (0.342), root weight (0.220), shoot weight (0.415), straw yield (0.060) and test weight (0.235), showed positive non significant genotypic correlation with grain yield. Number of productive tillers (-1.288), phosphorus content in grain (-0.136), plant height (-0.045) and shoot length (-0.047) showed negative non significant genotypic correlation with grain yield. These results are similar to the findings of Reddy *et al.* (1997), Vange *et al.* (1999), Tara Satyavathi *et al.* (2001), Suman (2003), Patel *et al.* (2014) Girichandra tiwari *et al.* (2014), Shinde *et al.* (2015)

4.3.5 Number of productive tillers/plant:

4.3.5.1 Under P₀: Phenotypic correlation

Days to 50% flowering (0.033), flag leaf length (0.307), flag leaf width (0.242), grain yield (0.488), plant height (0.442), panicle length (0.424), root length (0.183), shoot length (0.305), shoot weight (0.056), straw yield (0.448), showed positive non-significant phenotypic correlation with number of productive tillers. Whereas phosphorus content in grain (-0.042), phosphorus content in straw (-0.019), root weight (-0.105) and test weight (-0.031) showed negative non-significant phenotypic correlation with number of productive tillers/plant.

4.3.5.2 Under P₀: Genotypic correlation

Flag leaf length (0.502), grain yield (0.804), panicle length (0.537), root length (0.601), straw yield (0.878), showed positive significant genotypic correlation with number of productive tillers. Days to 50% flowering (0.165), flag leaf width (0.289), plant height (0.679), shoot length (0.621), shoot weight (0.204) and test weight (0.080) showed positive non-significant genotypic correlation with number of productive tillers. Phosphorus content in grain (-0.064), phosphorus content in straw (-0.030) and root weight (-0.102), showed negative non-significant genotypic correlation with number of productive tillers/plant.

4.3.5.3 Under P₂₀: phenotypic correlation

Phosphorus content in grain (0.496), straw yield (0.448), showed positive significant phenotypic correlation with number of productive tillers. Days to 50% flowering (0.163), flag leaf width (0.066), grain yield (0.129), phosphorus content in straw (0.015), plant height (0.212), root length (0.175), root weight (0.089), shoot length (0.137) and test weight (0.038) showed positive non-significant phenotypic correlation with number of productive tillers. Flag leaf length (-0.081), panicle length (-0.099), shoot weight (-0.075), showed negative non-significant phenotypic correlation with Number of productive tillers/plant

4.3.5.4 Under P₂₀: Genotypic correlation

Phosphorus content in grain (0.712), plant height (0.473), straw yield (0.882), showed positive significant genotypic correlation with number of productive tillers per plant. Days to 50% flowering (0.149), grain yield (0.241), phosphorus content in straw (0.020), root length (0.302), root weight (0.177), shoot length (0.246) and test weight (0.097) showed positive non-significant genotypic correlation with number of productive tillers per plant flag leaf length (-0.026), flag leaf width (-0.106), panicle length (-0.013), shoot weight (-0.136) showed negative non-significant genotypic correlation with number of productive tillers per plant.

4.3.5.5 Under P₄₀: Phenotypic correlation

Grain yield (0.123), phosphorus content in grain (0.120), plant height (0.038), root weight (0.074), straw yield (0.216) and test weight (0.092), showed positive non-significant phenotypic correlation with number of productive tillers. Days to 50% flowering (-0.070), flag leaf length (-0.032), flag leaf width (-0.147), phosphorus content in straw (-0.038), panicle length (-0.029), root length (-0.050), shoot length (-0.163), shoot weight (-0.167) showed negative non-significant phenotypic correlation with number of productive tillers

per plant.

4.3.5.6 Under P₄₀: Genotypic correlation

Panicle length (-0.603), straw yield (-0.488), showed negative significant genotypic correlation with number of productive tillers per plant. Phosphorus content in grain (0.271), root weight (0.007) and test weight (0.206), showed positive non significant genotypic correlation with number of productive tillers. Days to 50% flowering (-0.124), flag leaf length (-0.852), flag leaf width (-0.979), phosphorus content in straw (-0.087), plant height (-0.144), root length (-0.066), shoot length (-0.256), shoot weight (-0.302) showed negative non significant genotypic correlation with number of productive tillers per plant.

4.3.5.7 Under P₆₀: Phenotypic correlation

Days to 50% flowering (0.037), phosphorus content in grain (0.067), straw yield (0.00) and test weight (0.003) showed positive non-significant phenotypic correlation with number of productive tillers per plant. Flag leaf length (-0.054), flag leaf width (-0.171), grain yield (-0.068), phosphorus content in straw (-0.015), plant height (-0.027), panicle length (-0.118), root length (-0.150), root weight (-0.043), shoot length (-0.077), shoot weight (-0.147) showed negative non-significant phenotypic correlation with number of productive tillers per plant.

4.3.5.8 Under P₆₀: Genotypic correlation

Straw yield (0.505), showed positive significant genotypic correlation with number of productive tillers per plant. Shoot length (-0.844), shootweight (-0.711) showed negative significant genotypic correlation with number of productive tillers. Phosphorus content in grain (0.351), plant height (0.125), root weight (0.033) showed positive non significant genotypic correlation with number of productive tillers per plant. Days to 50% flowering (-0.158), flag leaf length (-1.036), flag leaf width (-2.265), grain yield (-1.288), phosphorus content in straw (-0.074), panicle length (-0.608), root length (-1.893) and test weight (-0.015) showed negative non significant genotypic correlation with Number of productive tillers per plant.

These results are similiary to the finding of Roy *et al.*. (1995), Nanja Reddy *et al.*. (1995), Reddy *et al.*. (1997) Yolanda and Vijendra Das (1996) and Kavitha and Sree Rama Reddi (2001)

4.3.6 Phosphorus content in grain:

4.3. 6.1 Under P₀: Phenotypic correlation

Phosphorus content in straw (0.139), plant height (0.005), panicle length (0.020),

root length (0.072), shoot length (0.083), test weight (0.091), showed positive non-significant phenotypic correlation with phosphorus content in grain. Days to 50% flowering (-0.124), flag leaf length (-0.033), flag leaf width (-0.136), grain yield (-0.074), number of productive tillers (-0.042), root weight (-0.023), shoot weight (-0.067), straw yield (-0.065) showed negative non-significant phenotypic correlation with phosphorus content in grain.

4.3.6.2 Under P₀: Genotypic correlation

Phosphorus content in straw (0.139), plant height (0.007), panicle length (0.033), root length (0.144), shoot length (0.096) and test weight (0.101) showed positive non significant genotypic correlation with phosphorus content in grain. Days to 50% flowering (-0.191), flag leaf length (-0.050), flag leaf width (-0.304), grain yield (-0.120), number of productive tillers (-0.064), root weight (-0.033), shoot weight (-0.071) and straw yield (-0.105) showed negative non-significant genotypic correlation with Phosphorus content in grain.

4.3.6.3 Under P₂₀: Phenotypic correlation

Number of productive tillers per plant (0.496), days to 50% flowering (0.107), grain yield (0.129), phosphorus content in straw (0.017), plant height (0.274), panicle length (0.012), root length (0.203), root weight (0.039), shoot length (0.067), straw yield (0.308) and test weight (0.264), showed positive non-significant phenotypic correlation with phosphorus content in grain. flag leaf length (-0.049), flag leaf width (-0.025), shoot weight (-0.094), showed negative non-significant phenotypic correlation with phosphorus content in grain.

4.3.6.4 Under P₂₀: Genotypic correlation

Number of productive tillers per plant (0.712), straw yield (0.543), showed positive significant genotypic correlation with phosphorus content in grain. Days to 50% flowering (0.133), grain yield (0.087), phosphorus content in straw (0.017), plant height (0.361), panicle length (0.020), root length (0.277), root weight (0.058), shoot length (0.080) and test weight (0.271) showed positive non significant genotypic correlation with phosphorus content in grain. flag leaf length (-0.081), flag leaf width (-0.065), shoot weight (-0.101), showed negative non-significant genotypic correlation with phosphorus content in grain.

4.3.6.5 Under P₄₀: Phenotypic correlation

Days to 50% flowering (0.030), Number of productive tillers per plant (0.120), phosphorus content in straw (0.073), plant height (0.065), straw yield (0.081) and test weight (0.105) showed positive non-significant phenotypic correlation with phosphorus content in grain. flag leaf length (-0.085), flag leaf width (-0.180), grain yield (-0.054), panicle length (-0.084), root length (-0.051), root weight (-0.089), shoot length (-0.017), shoot weight (-0.316), showed negative non-significant phenotypic correlation with phosphorus content in grain.

4.3.6.6 Under P₄₀: Genotypic correlation

Days to 50% flowering (0.037), Number of productive tillers per plant (0.271), phosphorus content in straw (0.073), plant height (0.080), straw yield (0.282) and test weight (0.111) showed positive non-significant genotypic correlation with phosphorus content in grain. flag leaf length (-0.157), flag leaf width (-0.253), panicle length (-0.135), root length (-0.079), root weight (-0.148), shoot length (-0.020), shoot weight (-0.325), showed negative non significant genotypic correlation with phosphorus content in grain.

4.3.6.7 Under P₆₀: Phenotypic correlation

Days to 50% flowering (0.052), number of productive tillers (0.067), plant height (0.007), root length (0.019), straw yield (0.009) showed positive non-significant phenotypic correlation with phosphorus content in grain. flag leaf length (-0.192), flag leaf width (-0.184) grain yield (-0.045), phosphorus content in straw (-0.077), panicle length (-0.067), root weight (-0.044), shoot length (-0.026), shoot weight (-0.175) and test weight (-0.028) showed negative non-significant phenotypic correlation with phosphorus content in grain.

4.3.6.8 Under P₆₀: Genotypic correlation

Days to 50% flowering (0.066), number of productive tillers (0.351), plant height (0.008), root length (0.029) and straw yield (0.027) showed positive non-significant genotypic correlation with phosphorus content in grain. Flag leaf length (-0.362), flag leaf width (-0.315), grain yield (-0.136), phosphorus content in straw (-0.077), panicle length (-0.104), root weight (-0.053), shoot length (-0.031), shoot weight (-0.183) and test weight (-0.029) showed negative non-significant genotypic correlation with Phosphorus content in grain.

Phosphorus content in grain showed positive association with the phosphorus content in grain in all levels of P, while grain yield showed positive association under low P conditions but at the higher levels (P₄₀ and P₆₀) showed native association.

4.3.7 Phosphorus content in straw:

4.3.7.1 Under P₀: Phenotypic correlation

Days to 50% flowering (0.130), flag leaf length (0.008), phosphorus content in grain (0.139) and test weight (0.067), showed, positive non-significant phenotypic correlation with phosphorus content in straw. flag leaf width (-0.019), grain yield (-0.151), number of productive tillers (-0.019), plant height (-0.116), panicle length (-0.014), root length (-0.018), root weight (-0.179), shoot length (-0.125), shoot weight (-0.190), straw yield (-0.206) showed negative non-significant phenotypic correlation with phosphorus content in straw.

4.3.7.2 Under P₀: genotypic correlation

Traits like Days to 50% flowering (0.200), Flag leaf length (0.012), Phosphorus content in grain (0.139) and Test weight (0.074) showed positive non significant genotypic correlation with Phosphorus content in straw. Traits like Flag leaf width (-0.041), Grain yield (-0.246), Number of productive tillers (-0.030), Plant height (-0.199), Panicle length (-0.026), Root length (-0.037), Root weight (-0.263), Shoot length (-0.144), Shoot weight (-0.202) and Straw yield (-0.330) showed negative non significant genotypic correlation with Phosphorus content in straw.

4.3.7.3 Under P₂₀: phenotypic correlation

Number of productive tillers (0.015), phosphorus content in grain (0.017), showed positive non-significant phenotypic correlation with phosphorus content in straw. Days to 50% flowering (-0.121), flag leaf length (-0.092), flag leaf width (-0.001), grain yield (-0.077), plant height (-0.087), panicle length (-0.067), root length (-0.213), root weight (-0.093), shoot length (-0.147), shoot weight (-0.056), straw yield (-0.074), test weight (-0.053), showed negative non-significant phenotypic correlation with phosphorus content in straw.

4.3.7.4 Under P₂₀: Genotypic correlation

Flag leaf width (0.000), number of productive tillers (0.020), phosphorus content in grain (0.017), showed positive but no significant genotypic correlation with phosphorus content in straw. Days to 50% flowering (-0.151), flag leaf length (-0.150), grain yield (-0.170), plant height (-0.115), panicle length (-0.111), root length (-0.290), root weight (-0.141), shoot length (-0.175), shoot weight (-0.060), straw yield (-0.131) and test weight (-0.055) showed negative non-significant genotypic correlation with phosphorus content in straw.

4.3.7.5 Under P₄₀: phenotypic correlation

Phosphorus content in grain (0.073), root weight (0.003), shoot length (0.047), shoot weight (0.035), straw yield (0.012) and test weight (0.031) showed positive non-significant phenotypic correlation with phosphorus content in straw. Days to 50% flowering (-0.003), flag leaf length (-0.051), flag leaf width (-0.001), grain yield (-0.031), number of productive tillers (-0.038), plant height (-0.089), panicle length (-0.070), root length (-0.067) showed negative non-significant phenotypic correlation with phosphorus content in straw.

4.3.7.6 Under P₄₀: Genotypic correlation

Phosphorus content in grain (0.073), root weight (0.004), shoot length (0.054), shoot weight (0.036), straw yield (0.046) and test weight (0.033) showed positive non significant genotypic correlation with phosphorus content in straw. Days to 50% flowering (-0.004), flag leaf length (-0.093), flag leaf width (-0.002), number of productive tillers (-0.087), plant height (-0.112), panicle length (-0.111), root length (-0.105) showed negative non significant genotypic correlation with phosphorus content in straw

4.3.7.7 Under P₆₀: Phenotypic correlation

Grain yield (0.034), root length (0.045), root weight (0.009), straw yield (0.033), showed, positive non-significant phenotypic correlation with phosphorus content in straw. Days 50% flowering (-0.040), flag leaf length (-0.005), flag leaf width (-0.005), number of productive tillers (-0.015), phosphorus content in grain (-0.077), plant height (-0.202), panicle length (-0.072), shoot length (-0.162), shoot weight (-0.050), test weight (-0.102), showed negative non-significant phenotypic correlation with phosphorus content in straw.

4.3.7.8 Under P₆₀: Genotypic correlation

Grain yield (0.105), root length (0.065), root weight (0.010), straw yield (0.117), showed positive non-significant genotypic correlation with phosphorus content in straw. Days to 50% flowering (-0.052), flag leaf length (-0.012), flag leaf width (-0.011), number of productive tillers (-0.074), phosphorus content in grain (-0.077), plant height (-0.256), panicle length (-0.112) shoot length (-0.199), shoot weight (-0.052) and test weight (-0.106) showed negative non-significant genotypic correlation with phosphorus content in straw.

Phosphorus content in grain showed positive association with P content in straw in all levelss except in P₆₀, while grain yield showed negative association with P content in straw in all levelss except in P₆₀, where its values are positive.

4.3.8 Plant height:

4.3.8.1 Under P₀:Phenotypic correlation

Flag leaf length (0.580), straw yield (0.448), showed positive significant phenotypic correlation with plant height. Flag leaf width (0.206), grain yield (0.387), number of productive tillers (0.442), phosphorus content in grain (0.005), panicle length (0.774), root length (0.120), shoot length (0.400), shoot weight (0.109) and test weight (0.011) showed positive non-significant phenotypic correlation with plant height. Days to 50% flowering (-0.085), phosphorus content in straw (-0.116) root weight (-0.121), showed negative non-significant phenotypic correlation with plant height.

4.3.8.2 Under P₀:Genotypic correlation

Flag leaf length (0.891), grain yield (0.492), panicle length (0.929), root length (0.671), shoot length (0.837), straw yield (0.766) showed positive significant genotypic correlation with plant height. Days to 50% flowering (0.059), flag leaf width (0.126), number of productive tillers (0.679), phosphorus content in grain (0.007), shoot weight (0.227) showed, positive non-significant genotypic correlation with plant height. Phosphorus content in straw (-0.199), root weight (-0.100) and test weight (0.013) showed, negative non-significant genotypic correlation with plant height

4.3.8.3 Under P₂₀: Phenotypic correlation

Flag leaf length (0.552), panicle length (0.599), shoot length (0.451), showed positive significant phenotypic correlation with plant height. Days to 50% flowering (0.134), flag leaf width (0.146), grain yield (0.156), number of productive tillers (0.212), phosphorus content in grain (0.274), root length (0.295), root weight (0.297), shoot weight (0.092), Straw yield (0.277) and Test weight (0.094) showed positive non-significant phenotypic correlation with plant height. Phosphorus content in straw (-0.087) showed, negative non-significant phenotypic correlation with plant height.

4.3.8.4 Under P₂₀:Genotypic correlation

Flag leaf length (0.571), number of productive tillers (0.473), panicle length (0.511), root length (0.618), root weight (0.517), shoot length (0.833), straw yield (0.581), showed, positive significant genotypic correlation with plant height. Days to 50% flowering (0.355), flag leaf width (0.213), grain yield (0.338), phosphorus content in grain (0.361), shoot weight (0.156) and test weight (0.126) showed, positive non-significant genotypic correlation with plant height. Whereas, phosphorus content in straw (-0.115) showed positive but non-significant genotypic correlation with plant height.

4.3.8.5 Under P₄₀:Phenotypic correlation

Panicle length (0.612), shoot length (0.575), showed positive significant phenotypic correlation with plant height. Days to 50% flowering (0.181), flag leaf length (0.448), flag leaf width (0.269), grain yield (0.216), number of productive tillers (0.038), phosphorus content in grain (0.065), root length (0.091), root weight (0.152), shoot weight (0.135) and straw yield (0.384) showed positive non-significant phenotypic correlation with plant height. phosphorus content in straw (-0.089), test weight (-0.020) showed negative non-significant phenotypic correlation with plant height.

4.3.8.6 Under P₄₀:Genotypic correlation

Flag leaf length (0.734), panicle length (0.671), shoot length (0.835), straw yield (0.947), positive significant genotypic correlation with plant height. Days to 50% flowering (0.166), flag leaf width (0.296), phosphorus content in grain (0.080), root length (0.350), root weight (0.468), positive non significant genotypic correlation with plant height. Number of productive tillers (-0.144), phosphorus content in straw (-0.112), test weight (-0.048) negative non-significant genotypic correlation with plant height.

4.3.8.7 Under P₆₀:Phenotypic correlation

Days to 50% flowering (0.149), flag leaf length (0.395), flag leaf width (0.068), grain yield (0.066), phosphorus content in grain (0.007), panicle length (0.648), root length (0.038), root weight (0.013), shoot length (0.403), shoot weight (0.096), straw yield (0.199) and test weight (0.149) showed, positive non-significant phenotypic correlation with plant height. Number of productive tillers (-0.027), phosphorus content in straw (-0.202) showed negative non-significant phenotypic correlation with plant height.

4.3.8.8 Under P₆₀:Genotypic correlation

Panicle length (0.809), shoot length (0.626), straw yield (0.846), positive significant genotypic correlation with plant height. Days to 50% flowering (0.218), flag leaf length (0.627), flag leaf width (0.101), number of productive tillers (0.125), phosphorus content in grain (0.008), root length (0.134), root weight (0.093), shoot weight (0.107) and test weight (0.136) showed positive non significant genotypic correlation with plant height. Grain yield (-0.045), Phosphorus content in straw (-0.256) showed negative non significant genotypic correlation with plant height.

These results are similar to the finding of Chaubey and Singh (1994), Yolanda and Vijendra Das (1995), Reddy *et al.* (1997), Debchoudhury and Das (1998), Rao and Shrivastav (1999) Awasthi and Borthakur (1986), Ramesh Babu (1999) Tara Satyavathi *et*

al. (2001), Sakthivel (2001), Janardhanam *et al.* (2001), Madhavi Latha (2002), Suman (2003), Sinha *et al.* (2004)

4.3.9 Panicle length:

4.3.9.1 Under P₀: Phenotypic correlation

The Flag leaf length (0.662), showed positive significant phenotypic correlation with panicle length. Traits like flag leaf width (0.229), grain yield (0.282), number of productive tillers per plant (0.424), phosphorus content in grain (0.020), plant height (0.774), root length (0.178), shoot length (0.309), straw yield (0.365) and test weight (0.016) showed positive non-significant phenotypic correlation with panicle length. Whereas days to 50% flowering (-0.102), phosphorus content in straw (-0.014), root weight (-0.132), shoot weight (-0.048), showed negative non-significant phenotypic correlation with panicle length.

4.3.9.2 Under P₀: Genotypic correlation

Flagleaf length (0.851), number of productive tillers (0.537), plant height (0.929), root length (0.837), shoot length (0.744) strawyield (0.786), positive significant genotypic correlation with panicle length. Days to 50% flowering (0.53), flag leaf width (0.012), grain yield (0.396), phosphorus content in grain (0.033) and test weight (0.103) positive non significant genotypic correlation with panicle length. Phosphorus content in straw (-0.026), rootweight (-0.144), shoot weight (-0.051) showed negative non significant genotypic correlation with panicle length.

4.3.9.3 Under P₂₀: Phenotypic correlation

Flag leaf length (0.622) and plant height (0.599), showed positive significant phenotypic correlation with panicle length . Days to 50% flowering (0.174), flag leaf width (0.152), grain yield (0.130), phosphorus content in grain (0.012), root length (0.108), root weight (0.243), shoot length (0.317), shoot weight (0.075), straw yield (0.131), showed positive non-significant phenotypic correlation with panicle length. Number of productive tillers (-0.099), phosphorus content in straw (-0.067) and test weight (-0.016) showed negative non-significant phenotypic correlation with panicle length.

4.3.9.4 Under P₂₀: Genotypic correlation

Flag leaf length (0.753), plant height (0.511), root weight (0.562), shoot length (0.687) showed positive significant genotypic correlation with panicle length. Days to 50% flowering (0.387), flag leaf width (0.382), grain yield (0.211), phosphorus content in grain

(0.020), root length (0.390), shoot weight (0.268), straw yield (0.262) showed positive non-significant genotypic correlation with panicle length. Number of productive tillers (-0.013), phosphorus content in straw (-0.111), test weight (-0.040) showed negative non-significant genotypic correlation with panicle length.

4.3.9.5 Under P₄₀: Phenotypic correlation

Flag leaf length (0.544) and plant height (0.612) showed, positive significant phenotypic correlation with panicle length. Days to 50% flowering, flag leaf width (0.342), grain yield (0.262), root length (0.167), root weight (0.130), shoot length (0.374), shoot weight (0.214), straw yield (0.230) and test weight (0.003) showed positive non-significant phenotypic correlation with panicle length. Number of productive tillers (-0.029), phosphorus content in grain (-0.084), phosphorus content in straw (-0.070) showed negative non-significant phenotypic correlation with panicle length.

4.3.9.6 Under P₄₀: Genotypic correlation

Flag leaf length (0.783), flag leaf width (0.532), plant height (0.671), shoot length (0.634) showed positive significant genotypic correlation with panicle length. Number of productive tillers per plant showed negative significant genotypic correlation with panicle length. Whereas root length (0.308), root weight (0.286), shoot weight (0.334), straw yield (0.183) and test weight (0.018) showed positive non-significant genotypic correlation with panicle length. Phosphorus content in grain (-0.135), phosphorus content in straw (-0.111) showed Negative non-significant genotypic correlation with panicle length.

4.3.9.7 Under P₆₀: Phenotypic correlation

Flag leaf length (0.503) showed positive significant phenotypic correlation with panicle length. Days to 50% flowering (0.248), flag leaf length (0.095), grain yield (0.063), plant height (0.648), root length (0.107), root weight (0.098), shoot length (0.353), shoot weight (0.187), straw yield (0.099) and test weight (0.060), showed positive non-significant phenotypic correlation with panicle length. Number of productive tillers (-0.118), phosphorus content in grain (-0.067), phosphorus content in straw (-0.072), showed negative non-significant phenotypic correlation with panicle length.

4.3.9.8 Under P₆₀: Genotypic correlation

Flag leaf length (0.848), plant height (0.809), straw yield (0.863), positive significant genotypic correlation with panicle length. Days to 50% flowering (0.328), grain yield (0.342), root length (0.216), root weight (0.253), shoot length (0.520), shoot weight (0.254) and test weight (0.072), positive non-significant genotypic correlation with panicle

length. Flag leaf width (-0.016), number of productive tillers per plant (-0.608), phosphorus content in grain (-0.104), phosphorus content in straw (-0.112) showed negative non-significant genotypic correlation with panicle length. These results are in agreement with the finding of Roy *et al.* (1995), Vange *et al.* (1999), Nayak *et al.* (2001)

4.3.10 Root length:

4.3.10.1 Under P₀: Phenotypic correlation

Flag leaf length (0.167), flag leaf width (0.023), grain yield (0.171), number of productive tillers (0.183), phosphorus content in grain (0.072), plant height (0.120), panicle length (0.178), shoot length (0.385), shoot weight (0.154) and straw yield (0.183) showed positive non-significant phenotypic correlation with root length. Days to 50% flowering (-0.025), phosphorus content in straw (-0.018), root weight (-0.157), test weight (-0.041) showed negative non-significant phenotypic correlation with root length.

4.3.10.2 Under P₀: Genotypic correlation

Flag leaf length (0.474), number of productive tillers (0.601), plant height (0.671), panicle length (0.837), shoot length (0.808), showed positive significant genotypic correlation with root length. Flag leaf width (0.053), phosphorus content in grain (0.144), shoot weight (0.371) and straw yield (0.482) showed positive non-significant genotypic correlation with Root length. Days to 50% flowering (-0.126), phosphorus content in straw (-0.037), root weight (-0.256) and test weight (-0.048) showed negative non-significant genotypic correlation with root length.

4.3.10.3 Under P₂₀: Phenotypic correlation

Shoot length (0.476), showed positive significant phenotypic correlation with root length. Days to 50% flowering (0.168), flag leaf length (0.209), flag leaf width (0.049), grain yield (0.069), number of productive tillers (0.175), phosphorus content in grain (0.203), plant height (0.295), panicle length (0.108), root weight (0.126), shoot weight (0.328), straw yield (0.193), showed positive non-significant phenotypic correlation with root length. Phosphorus content in straw (-0.213) and test weight (-0.076) showed negative non-significant phenotypic correlation with root length.

4.3.10.4 Under P₂₀: Genotypic correlation

Plant height (0.618), shoot length (0.583), shoot weight (0.485), showed positive significant genotypic correlation with root length. Days to 50% flowering (0.272), flag leaf length (0.384), flag leaf width (0.156), grain yield (0.200), number of productive tillers (0.302), phosphorus content in grain (0.277), panicle length (0.390), root weight (0.385),

straw yield (0.349), showed positive non-significant genotypic correlation with root length. Phosphorus content in straw (-0.290) and test weight (-0.083), showed negative non-significant genotypic correlation with root length.

4.3.10.5 Under P₄₀: phenotypic correlation

Flag leaf length (0.108), flag leaf width (0.122), grain yield (0.124), plant height (0.091), panicle length (0.167), root weight (0.243), shoot length (0.325), shoot weight (0.422), straw yield (0.086) and test weight (0.024) showed positive non-significant phenotypic correlation with root length. Days to 50% flowering (-0.039), number of productive tillers (-0.050), phosphorus content in grain (-0.051), phosphorus content in straw (-0.067), showed negative non-significant phenotypic correlation with root length.

4.3.10.6 Under P₄₀: Genotypic correlation

Flag leaf length (0.010), flag leaf width (0.344), plant height (0.350), panicle length (0.308), root weight (0.578), shoot weight (0.680), showed positive significant genotypic correlation with root length. Days to 50% flowering (-0.053), number of productive tillers (-0.066), phosphorus content in grain (-0.079), phosphorus content in straw (-0.105), shoot length (0.340), straw yield (0.133) and test weight (0.073), showed positive non-significant genotypic correlation with root length.

4.3.10.7 Under P₆₀: phenotypic correlation

Days to 50% flowering (0.089), flag leaf length (0.189), flag leaf width (0.115), grain yield (0.088), phosphorus content in grain (0.019), phosphorus content in straw (0.045), plant height (0.038), panicle length (0.107), root weight (0.208), shoot length (0.324), shoot weight (0.297), straw yield (0.016) and test weight (0.020) showed positive non-significant phenotypic correlation with root length. Whereas Number of productive tillers (-0.150) showed, negative non-significant phenotypic correlation with root length.

4.3.10.8 Under P₆₀: Genotypic correlation

Flag leaf length (0.585), grain yield (0.809), straw yield (0.748), showed positive significant genotypic correlation with root length. root length (0.293), flag leaf width (0.331), phosphorus content in grain (0.029), phosphorus content in straw (0.065), plant height (0.134), panicle length (0.216), root weight (0.306), shoot length (0.409), shoot weight (0.454) and test weight (0.083), showed positive non-significant genotypic correlation with root length. Number of productive tillers (-1.893) showed negative non-

significant genotypic correlation with root length. Roots are very important plant parts, lengthy roots extend to rhizosphere area under the soil and thereby increase the plant foraging ability for water and nutrients. Study reveals that root length was positively associated with plant height, grain yield, and P content in grain. Root weight showed positive association with root length except in P_0 . Number of productive tillers showed positive association with root length under low P but under P_{40} and P_{60} its association was negative. It clearly shows that at sufficient availability of P plant will not put more root growth. (Cordell *et al.* 2009).

4.3.11 Root weight:

4.3.11.1 Under P_0 : Phenotypic correlation

Flag leaf length (0.033), flag leaf width (0.032), shoot weight (0.077), straw yield (0.029), showed positive non-significant phenotypic correlation with root weight. Days to 50% flowering (-0.137), grain yield (-0.042), number of productive tillers (-0.105), phosphorus content in grain (-0.023), phosphorus content in straw (-0.179), plant height (-0.121), panicle length (-0.132), root length (-0.157), shoot length (-0.093) and test weight (-0.044), showed negative non-significant phenotypic correlation with root weight.

4.3.11.2 Under P_0 : Genotypic correlation

Flag leaf width (0.053), shoot weight (0.103), showed positive non-significant genotypic correlation with root weight. Days to 50% flowering (-0.202), flag leaf length (-0.095), grain yield (-0.067), number of productive tillers (-0.102), phosphorus content in grain (-0.033), phosphorus content in straw (-0.263), plant height (-0.100), panicle length (-0.144), root length (-0.256), shoot length (-0.126), straw yield (-0.056) and test weight (-0.050) showed negative non-significant genotypic correlation with root weight.

4.3.11.3 Under P_{20} : Phenotypic correlation

Days to 50% flowering (0.114), flag leaf length (0.135), grain yield (0.045), number of productive tillers (0.089), phosphorus content in grain (0.039), plant height (0.297), panicle length (0.243), root length (0.126), shoot length (0.182), shoot weight (0.239), straw yield (0.106), showed positive non-significant phenotypic correlation with root weight. Flag leaf width (-0.035), phosphorus content in straw (-0.093) and test weight (-0.110) showed negative non-significant phenotypic correlation with root weight.

4.3.11.4 Under P₂₀: Genotypic correlation

Plant height (0.517) and panicle length (0.562), showed positive significant genotypic correlation with root weight. Days to 50% flowering (0.220), flag leaf length (0.170), flag leaf width (0.088), grain yield (0.216), number of productive tillers (0.177), phosphorus content in grain (0.058), root length (0.385), shoot length (0.329), shoot weight (0.300), straw yield (0.292), showed positive non-significant genotypic correlation with root weight. Phosphorus content in straw (-0.141), test weight (-0.218) showed, negative non-significant genotypic correlation with root weight.

4.3.11.5 Under P₄₀: Phenotypic correlation

Days to 50% flowering (0.047), flag leaf length (0.163), flag leaf width (0.022), grain yield (0.117), number of productive tillers (0.074), phosphorus content in straw (0.003), plant height (0.152), panicle length (0.130), root length (0.243), shoot length (0.169), shoot weight (0.169), straw yield (0.171) and test weight(0.134) showed positive non-significant phenotypic correlation with root weight. Phosphorus content in grain (-0.089) showed negative non-significant phenotypic correlation with root weight

4.3.11.6 Under P₄₀: Genotypic correlation

Flag leaf length (0.799) and root length (0.578), showed positive significant genotypic correlation with root weight. Days to 50% flowering (0.233), number of productive tillers per plant (0.007), phosphorus content in straw (0.004), plant height (0.468), panicle length (0.286), shoot length (0.292), shoot weight (0.344), straw yield (2.096) and test weight(0.219) showed positive non-significant genotypic correlation with root weight. Flag leaf width (-0.011) and phosphorus content in grain (-0.148) showed negative non-significant genotypic correlation with root weight.

4.3.11.7 Under P₆₀: Phenotypic correlation

Days to 50% flowering (0.145), flag leaf length (0.204), phosphorus content in straw (0.009), plant height (0.013), panicle length (0.098), root length (0.208), shoot length (0.295), shoot weight (0.416), straw yield (0.042), test weight (0.053), showed positive non-significant phenotypic correlation with root weight. Flag leaf width (-0.071), grain yield (-0.032), number of productive tillers (-0.043) and phosphorus content in grain (-0.044) showed negative non-significant phenotypic correlation with root weight.

4.3.11.8 Under P₆₀: Genotypic correlation

Flag leaf length (0.554), Straw yield (0.600), showed positive significant genotypic correlation with root weight. Days to 50% flowering (0.259), grain yield (0.220), number of

productive tillers (0.033), phosphorus content in straw (0.010), plant height (0.093), panicle length (0.253), root length (0.306), shoot length (0.426), shoot weight (0.519) and test weight (0.079), showed positive non-significant genotypic correlation with root weight. Flag leaf width (-0.127), phosphorus content in grain (-0.053) showed negative non-significant genotypic correlation with root weight.

root weight was positively associated with grain yield, plant height, panicle length, root length in all levels of P except P₀. In P₀ root weight showed negative association with grain yield, plant height, panicle length and number of productive tillers. Very low availability of P in P₀ made the plant to put more root biomass in search of nutrients, by sacrificing the growth of above ground parts. P₆₀ number of productive tillers showed positive correlation with root weight. It may be due to sufficient availability of P nearby made the plant to put less root mass in P₆₀. (Richardson *et al.* 2011),

4.3.12 Shoot length:

4.3.12.1 Under P₀: Phenotypic correlation

Flag leaf length (0.264), flag leaf width (0.035), grain yield (0.268), number of productive tillers (0.305), phosphorus content in grain (0.083), plant height (0.400), panicle length (0.309), root length (0.385), shoot weight (0.521), straw yield (0.307), showed positive non-significant phenotypic correlation with shoot length. Days to 50% flowering (-0.071), Phosphorus content in straw (-0.125), root weight (-0.093) and test weight (-0.099), showed negative non-significant phenotypic correlation with shoot length.

4.3.12.2 Under P₀: Genotypic correlation

Flag leaf length (0.557), plant height (0.837), panicle length (0.744), root length (0.808), shoot weight (0.646), straw yield (0.522), showed positive significant genotypic correlation with shoot length. Flag leaf width (0.219), grain yield (0.406), number of productive tillers per plant (0.621), phosphorus content in grain (0.096), showed positive non-significant genotypic correlation with shoot length. Days to 50% flowering (-0.081), phosphorus content in straw (-0.144), root weight (-0.126), (-0.142) showed negative non-significant genotypic correlation with shoot length.

4.3.12.3 Under P₂₀: Phenotypic correlation

Plant height (0.451) and root length (0.476) showed positive significant phenotypic correlation with shoot length. Days to 50% flowering (0.171), flag leaf length (0.367), flag leaf width (0.105), grain yield (0.142), number of productive tillers (0.137), phosphorus content in grain (0.067), panicle length (0.317), root weight (0.182), shoot weight (0.381),

straw yield (0.188), showed positive non-significant phenotypic correlation with shoot length. Phosphorus content in straw (-0.147) and test weight (-0.054), showed negative non-significant phenotypic correlation with shoot length.

4.3.12.4 Under P₂₀: Genotypic correlation

Flag leaf length (0.709), plant height (0.833), panicle length (0.687), root length (0.583), shoot weight (0.491), straw yield (0.453), showed positive significant genotypic correlation with shoot length. Days to 50% flowering (0.155), flag leaf width (0.288), grain yield (0.476), number of productive tillers (0.246), phosphorus content in grain (0.080), root weight (0.329). Phosphorus content in straw (-0.175), test weight (-0.067) showed negative non-significant genotypic correlation with shoot length.

4.3.12.5 Under P₄₀: Phenotypic correlation

Flag leaf length (0.443) and plant height (0.575) showed positive significant phenotypic correlation with shoot length. Days to 50% flowering (0.164), flag leaf width (0.246), grain yield (0.114), phosphorus content in straw (0.047), Panicle length (0.374), root length (0.325), root weight (0.169), shoot weight (0.425), straw yield (0.218), showed positive non-significant phenotypic correlation with shoot length. Number of productive tillers (-0.163), phosphorus content in grain (-0.017) test weight (-0.055), showed negative non-significant phenotypic correlation with shoot length.

4.3.12.6 Under P₄₀: Genotypic correlation

Flag leaf length (0.854), flag leaf width (0.445), plant height (0.835), panicle length (0.634), shoot weight (0.505), straw yield (0.983), showed positive significant genotypic correlation with shoot length. Days to 50% flowering (0.306), phosphorus content in straw (0.054), root length (0.340), root weight (0.292). Number of productive tillers (-0.256), phosphorus content in grain (-0.020), showed negative non-significant genotypic correlation with shoot length.

4.3.12.7 Under P₆₀: Phenotypic correlation

Days to 50% flowering (0.216), flag leaf length (0.333), flag leaf width (0.152), grain yield (0.027), plant height (0.403), panicle length (0.353), root length (0.324), root weight (0.295) shoot weight (0.387), straw yield (0.164) and test weight (0.018), showed positive non-significant phenotypic correlation with shoot length. Number of productive tillers (-0.077), phosphorus content in grain (-0.026), phosphorus content in straw (-0.162) showed negative non-significant phenotypic correlation with shoot length.

4.3.12.8 Under P₆₀: Genotypic correlation

Flag leaf length (0.752) plant height (0.626), shoot weight (0.502), showed positive significant genotypic correlation with shoot length. Number of productive tillers (-0.844), showed negative significant genotypic correlation with shoot length. Days to 50% flowering (0.404), flag leaf width (0.387), panicle length (0.520), root length (0.409), root weight (0.426), straw yield (0.723) and test weight(0.016),showed positive non-significant genotypic correlation with shoot length. Grain yield (-0.047), phosphorus content in grain (-0.031), phosphorus content in straw (-0.199) showed negative non-significant genotypic correlation with Shoot length.

plant height shoot weight, straw weight showed positive association with shoot length at all levelss of P, whereas grain yield and number of productive tillers showed positive association at P₀, P₂₀, but they showed negative association at P₄₀ and P₆₀. (Rose *et al.* 2012).

4.3.13 Shoot weight:

4.3.13.1 Under P₀: Phenotypic correlation

Flag leaf length (0.021), flag leaf width (0.000), grain yield (0.172), number of productive tillers (0.056), Plant height (0.109), root length (0.154), root weight (0.077), shoot length (0.521), straw yield (0.152),showed positive non-significant phenotypic correlation with shoot weight. Days to 50% flowering (-0.007), phosphorus content in grain (-0.067), phosphorus content in straw (-0.190), panicle length (-0.048),test weight (-0.065) showed negative non-significant phenotypic correlation with Shoot weight.

4.3.13.2Under P₀: Genotypic correlation

Shoot length (0.646),showed positive significant genotypic correlation with shoot weight. Flag leaf length (0.042), flag leaf width (0.106), grain yield (0.306), number of productive tillers (0.204), plant height (0.0.227), root length (0.371), root weight (0.103), straw yield (0.244), showed positive non-significant genotypic correlation with shoot weight . Days to 50% flowering (-0.040), phosphorus content in grain (-0.071), phosphorus content in straw (-0.202), panicle length (-0.051) and test weight(-0.070), showed negative non-significant genotypic correlation with shoot weight.

4.3.13.3 Under P₂₀: Phenotypic correlation

Days to 50% flowering (0.073), flag leaf length (0.096), flag leaf width (0.059),grain yield (0.080), plant height (0.092), panicle length (0.075), root length (0.328), root weight (0.239), shoot length (0.381), straw yield (0.024),showed positive non-significant phenotypic correlation with shoot weight. Number of productive tillers (-

0.075), phosphorus content in grain (-0.094), phosphorus content in straw (-0.056) and test weight (-0.257), showed negative non-significant phenotypic correlation with shoot weight.

4.3.13.4 Under P₂₀: Genotypic correlation

Traits like root length (0.485) and shoot length (0.491) showed positive significant genotypic correlation with shoot weight. Days to 50% flowering (0.121), flag leaf length (0.160), flag leaf width (0.180), grain yield (0.304), plant height (0.156), panicle length (0.268), root weight (0.300) and straw yield (0.042) showed positive non-significant genotypic correlation with shoot weight. Whereas number of productive tillers (-0.136), phosphorus content in grain (-0.101), phosphorus content in straw (-0.060) and test weight (-0.287), showed negative non-significant genotypic correlation with shoot weight.

4.3.13.5 Under P₄₀: Phenotypic correlation

Traits like, days to 50% flowering (0.098), flag leaf length (0.219), flag leaf width (0.334), grain yield (0.168), phosphorus content in straw (0.035), plant height (0.135), panicle length (0.214), root length (0.422), root weight (0.199), shoot length (0.425), straw yield (0.100), test weight (0.088) showed positive non-significant phenotypic correlation with shoot weight. Number of productive tillers (-0.167) and phosphorus content in grain (-0.316) showed negative non-significant phenotypic correlation with shoot weight.

4.3.13.6 Under P₄₀: Genotypic correlation

Flag leaf width (0.473), root length (0.680), shoot length (0.505), showed positive significant genotypic correlation with shoot weight. Days to 50% flowering (0.143), flag leaf length (0.441), phosphorus content in straw (0.036), plant height (0.180), panicle length (0.334), root weight (0.344), straw yield (0.399) and test weight (0.097), showed positive non-significant genotypic correlation with shoot weight. Number of productive tillers (-0.302), phosphorus content in grain (-0.325) showed negative non-significant genotypic correlation with shoot weight.

4.3.13.7 Under P₆₀: Phenotypic correlation

Days to 50% flowering (0.287), flag leaf length (0.211), flag leaf width (0.274), grain yield (0.121), plant height (0.096), panicle length (0.187), root length (0.297), root weight (0.416), shoot length (0.387), straw yield (0.095) and test weight (0.077), showed positive non-significant phenotypic correlation with shoot weight. Whereas Number of productive tillers (-0.147), phosphorus content in grain (-0.175) and phosphorus content in

straw (-0.050) showed negative non-significant phenotypic correlation with shoot weight.

4.3.13.8 Under P₆₀: Genotypic correlation

Shoot length (0.502), showed positive significant genotypic correlation with shoot weight. Number of productive tillers (-0.711) showed negative significant genotypic correlation with shoot weight. Days to 50% flowering (0.394), flag leaf length (0.367), flag leaf width (0.468), grain yield (0.415), plant height (0.107), panicle length (0.254), root length (0.454), root weight (0.519), straw yield (0.411) and test weight (0.081), showed positive non-significant genotypic correlation with shoot weight. Phosphorus content in grain (-0.183), phosphorus content in straw (-0.052) showed negative non-significant genotypic correlation with shoot weight. Shoot weight showed positive association with grain yield, Plant height and panicle length at all levels of P. number of productive tillers showed negative association with shoot weight except P₀. (Rose *et al.* 2012).

4.3.14 Straw yield:

4.3.14.1 Under P₀: Phenotypic correlation

Traits like grain yield (0.813), plant height (0.448), showed positive significant phenotypic correlation with straw yield. Days to 50% flowering (0.016), flag leaf length (0.276), flag leaf width (0.127), number of productive tillers (0.448), panicle length (0.365), root length (0.183), root weight (0.029), shoot length (0.307), shoot weight (0.152) showed positive non-significant phenotypic correlation with straw yield. Phosphorus content in grain (-0.065), phosphorus content in straw (-0.206) and test weight (-0.019), showed positive non-significant phenotypic correlation with straw yield.

4.3.14.2 Under P₀: Genotypic correlation

Flag leaf length (0.597), Number of productive tillers (0.878), Plant height (0.766), Panicle length (0.786), Shoot length (0.522), showed positive significant genotypic correlation with Straw yield. Days to 50% flowering (0.107), flag leaf width (0.593), grain yield (0.948), root length (0.482) and shoot weight (0.244) showed positive non-significant genotypic correlation with straw yield. Phosphorus content in grain (-0.105), phosphorus content in straw (-0.330), root weight (-0.056) and test weight (-0.041), showed negative non-significant genotypic correlation with straw yield.

4.3.14.3 Under P₂₀: Phenotypic correlation

Number of productive tillers (0.448), showed positive significant phenotypic correlation with straw yield. Days to 50% flowering (0.302), flag leaf length (0.177), flag leaf width (0.212), grain yield (0.666), phosphorus content in grain (0.308), plant height

(0.277), Panicle length (0.131), root length (0.193), root weight (0.106), shoot length (0.188), shoot weight (0.024) and test weight (0.064), showed positive non-significant phenotypic correlation with straw yield. Phosphorus content in straw (-0.074), showed negative non-significant phenotypic correlation with straw yield.

4.3.14.4 Under P₂₀: Genotypic correlation

Days to 50% flowering (0.508), flag leaf width (0.672), number of productive tillers (0.882), phosphorus content in grain (0.543), plant height (0.581), shoot length (0.453), showed positive significant genotypic correlation with straw yield. Flag leaf length (0.355), grain yield (0.607), panicle length (0.262), root length (0.349), root weight (0.292), shoot weight (0.042) and test weight (0.094), showed positive non-significant genotypic correlation with straw yield. Whereas phosphorus content in straw (-0.131) showed negative non-significant genotypic correlation with straw yield.

4.3.14.5 Under P₄₀: Phenotypic correlation

Days to 50% flowering (0.335), flag leaf length (0.319), flag leaf width (0.232), grain yield (0.666), number of productive tillers (0.216), phosphorus content in grain (0.081), phosphorus content in straw (0.012), plant height (0.384), panicle length (0.230), root length (0.086), root weight (0.171), shoot length (0.218), shoot weight (0.100) and test weight (0.154) showed positive non-significant phenotypic correlation with straw yield.

4.3.14.6 Under P₄₀: Genotypic correlation

Days to 50% flowering (0.962), plant height (0.947), shoot length (0.983) and test weight (0.523), showed positive significant genotypic correlation with straw yield. Traits like, number of productive tillers (-0.488) and phosphorus content in grain (0.282) showed negative significant genotypic correlation with straw yield. Traits like Flag leaf length (1.042), flag leaf width (0.253), phosphorus content in straw (0.046), panicle length (0.183), root length (0.133), root weight (2.096), shoot weight (0.399) showed positive genotypic correlation with straw yield.

4.3.14.7 Under P₆₀: Phenotypic correlation

Grain yield (0.607) showed positive significant phenotypic correlation with straw yield. Traits like days to 50% flowering (0.232), flag leaf length (0.211), flag leaf width (0.040), number of productive tillers (0.000), phosphorus content in grain (0.009), phosphorus content in straw (0.33), plant height (0.199), panicle length (0.099), root length (0.016), root weight (0.042), shoot weight and (0.095) test weight (0.070) showed positive

non-significant phenotypic correlation with Straw yield .

4.3.14.8 Under P₆₀: Genotypic correlation

Traits like days to 50% flowering (0.629), flag leaf length (0.785), number of productive tillers (0.505), plant height (0.846), panicle length (0.863), root length (0.748), root weight (0.600), showed positive significant genotypic correlation with straw yield . Traits like flag leaf width (0.515), grain yield (0.060), phosphorus content in grain (0.027), phosphorus content in straw (0.117), shoot length (0.723), shoot weight (0.411) test weight (0.061), showed positive non-significant genotypic correlation with straw yield

Straw weight showed positive correlation with grain yield, shoot length, plant height and shoot weight. Number of productive tiller showed negative correlation with straw weight at P₄₀ and P₆₀.

4.3.15 Test weight

4.3 .15.1 Under P₀:Phenotypic correlation

Traits like, days to 50% flowering (0.047), flag leaf length (0.044), grain yield (0.016), phosphorus content in grain (0.091), phosphorus content in straw (0.067), plant height (0.011), panicle length (0.016), showed positive non-significant phenotypic correlation with test weight. Traits like, flag leaf width (-0.023), number of productive tillers (-0.031), root length (-0.041), root weight (-0.044), shoot length (-0.099), shoot weight (-0.065), straw yield (-0.019) showed negative non-significant phenotypic correlation with test weight .

4.3.15.2 Under P₀:Genotypic correlation

Traits like days to 50% flowering (0.100), flag leaf length (0.079), grain yield (0.068), number of productive tillers (0.080), phosphorus content in grain (0.101), phosphorus content in straw (0.074), panicle length (0.103) showed positive non-significant genotypic correlation with test weight. Traits like flag leaf width (-0.062), plant height (-0.013), root length (-0.048), root weight (-0.050), shoot length (-0.142), shoot weight (-0.070), straw yield (-0.041) showed negative non-significant genotypic correlation with test weight.

4.3.15.3 Under P₂₀:Phenotypic correlation

Traits like flag leaf length (0.022), flag leaf width (0.057), number of productive tillers (0.038), phosphorus content in grain (0.264), plant height (0.094) and straw yield (0.064) showed positive non-significant phenotypic correlation with test weight. Traits like days to 50% flowering (-0.067), grain yield (-0.021), phosphorus content in straw (-0.053),

panicle length (-0.016), root length (-0.076), root weight (-0.110), shoot length (-0.054), shoot weight (-0.257) showed negative non-significant phenotypic correlation with test weight.

4.3.15.4 Under P₂₀: Genotypic correlation

Traits like, flag leaf length (0.022), flag leaf width (0.230), number of productive tillers (0.097), phosphorus content in grain (0.271), plant height (0.126), straw yield (0.094), showed positive non-significant genotypic correlation with test weight. Traits like, days to 50% flowering (-0.048), grain yield (-0.138), phosphorus content in straw (-0.055), panicle length (-0.040), root length (-0.083), root weight (-0.218), shoot length (-0.067) and shoot weight (-0.287) showed negative non-significant genotypic correlation with test weight.

4.3.15.5 Under P₄₀: Phenotypic correlation

Traits like days to 50% flowering (0.122), flag leaf length (0.027), grain yield (0.092), number of productive tillers (0.092), phosphorus content in grain (0.105), phosphorus content in straw (0.031), panicle length (0.003), root length (0.024), root weight (0.134), shoot weight (0.088), straw yield (0.154) showed positive non-significant phenotypic correlation with test weight. Traits like flag leaf width (-0.055), plant height (-0.020), shoot length (-0.055), showed negative non-significant phenotypic correlation with test weight.

4.3.15.6 Under P₄₀: Genotypic correlation

Traits like straw yield (0.523) showed positive significant genotypic correlation with test weight. Traits like days to 50% flowering (0.143), flag leaf length (0.002), number of productive tillers (0.206), phosphorus content in grain (0.111), phosphorus content in straw (0.033), panicle length (0.018), root length (0.073), root weight (0.219), shoot weight (0.097), showed positive non-significant genotypic correlation with test weight. Traits like, flag leaf width (-0.091), plant height (-0.048), shoot length (-0.038), showed negative non-significant genotypic correlation with test weight.

4.3.15.7 Under P₆₀: Phenotypic correlation

Traits like days to 50% flowering (0.120), flag leaf length (0.005), grain yield (0.126), number of productive tillers (0.003), plant height (0.149), panicle length (0.060), root length (0.020), root weight (0.053), shoot length (0.018), shoot weight (0.077), straw yield (0.070), showed positive non-significant phenotypic correlation with test weight. Traits like, flag leaf width (-0.015), phosphorus content in grain (-0.028), phosphorus

content in straw (-0.102), showed negative non-significant phenotypic correlation with test weight.

4.3.15.8 Under P₆₀: genotypic correlation

Traits like, days to 50% flowering (0.137), flag leaf length (0.015), grain yield (0.235), plant height (0.136), panicle length (0.072), root length (0.083), root weight (0.079), shoot length (0.016), shoot weight (0.081), straw yield (0.061), showed positive non-significant genotypic correlation with test weight. Traits like flag leaf width (-0.022), number of productive tillers (-0.015), phosphorus content in grain (-0.029), phosphorus content in straw (-0.106), showed negative non-significant genotypic correlation with test weight.

Test weight is positively correlated with grain yield at all levels of P, similar results were reported by Ogunbayo 2014. Phosphorus content in grain showed positive correlation with test weight at P₀, P₂₀ and P₄₀ but under P₆₀ it showed negative correlation. (Vandamme *et al.* 2013), (Zhu and Lynch 2004).

CHAPTER V

SUMMARY AND CONCLUSION

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SUMMARY AND CONCLUSIONS

The investigation entitled “Studies on genetic variability for low P tolerance and its use efficiency in rice” was carried out in ICAR-IIRR, Hyderabad in phosphorus sick plot with the following objectives

1. To evaluate the rice genotypes in graded level of phosphorus (P) for low P tolerance and its use efficiency
2. To estimate the genetic variability in the genotypes evaluated under graded level of phosphorus (P)
3. To study the trait association between yield and other component traits under different levels of Phosphorus (P)

The experimental material composed of 90 rice genotypes which include GSR lines, cultivated varieties and Hybrids. The genotypes were evaluated in graded level (0, 20, 40 and 60 Kg/ha) of Phosphorus (P) in factorial RBD. Data were recorded for various traits and analyzed interpreted. The salient findings of the study are summarized as follows.

- ❖ There were significant differences among the genotypes for all the character studied, except for flag leaf length, flag leaf width panicle length and straw yield. There were significant differences among the P levels; interactions were also significant for all the characters studied except for straw yield.
- ❖ PUE was estimated based on P uptake and grain content in P. the genotype GSR 134 showed high PUE while lowest PUE was found in the genotype GSR 116. Among the cultivated varieties, hybrid. The hybrid INH10002 showed highest PUE while IR-64 had low PUE.
- ❖ The estimates of variability indicated that PCV values were higher than GCV values for the all character studied at all the levels of P. it was indicated that PCV and GCV values are high for grain yield under low P condition (P_0) than under high P condition (P_{60}). Day to 50 percent flowering changed based on the P levels, among the entries. It was found that in some genotypes flowering was delayed while in some genotypes reached flowering stage earlier than normal flowering. Number of

tillers showed high to medium PCV and GCV panicle length and flag leaf length showed medium to low PCV and GCV values while flag leaf width showed low GCV and PCV values, Root length and shoot length showed medium GCV and PCV values root weight and shoot weight showed high GCV and PCV values, Straw weight showed high PCV values at all the levels of P, but GCV values are high at P₀, medium at P₂₀, and were low at P₄₀, P₆₀. Test weight showed low to medium PCV and GCV value, P content in grain, P content in straw showed medium GCV and PCV value.

- ❖ Heritability for all the traits was high at P₀ and P₂₀ except for flag leaf width, which showed medium heritability. At P₄₀ it was high for all the traits except number of productive tillers and Grain yield, which showed medium heritability. At P₆₀ heritability was low for Number of productive tillers per plant and straw yield, it was medium for grain yield and for all other traits heritability was found to high.
- ❖ Genetic advance as percent mean at P₀ was high for Grain yield, number of productive tillers Shoot length, root weight, straw yield, P content in grain and P content in straw, medium for days to fifty percent flowering, plant height, flag leaf length and flag leaf width and root length while it was low for panicle length and flag leaf width.
- ❖ Genetic advance as percent mean at P₂₀ was high for number of productive tillers per plant, root weight, straw yield, P content in grain and P straw. While medium for grain yield, days to 50 percent flowering, plant height, flag leaf length, flag leaf width, shoot length and root length. It was low for flag leaf width and panicle length.
- ❖ At P₄₀ genetic advance as percent mean was low for grain yield, number of productive tillers per plant and panicle length, while medium for days to fifty percent flowering, plant height, flag leaf length, flag leaf width, shoot length and root length for rest of the traits it was high.
- ❖ At P₆₀ genetic advance as percent mean was low to medium for all the traits except for root weight, shoot weight, P content in grain and P straw.
- ❖ Correlation studies indicated that grain yield was positively associated with all the traits except root weight, P content in grain and these traits were negatively associated with grain yield in P₀. While the plant height negatively associated days to fifty percent flowering and root weight in P₀.

- ❖ Under P_{40} level also grain yield was positively associated with all the traits except P content in grain and P content in straw. Plant height showed negative association with test weight and P content in straw, while with rest of the traits it had positive association. Days to 50 percent flowering showed positive association with all the traits except with number of productive tillers per plant.
- ❖ Under P_{60} grain yield had negative association with number of tillers per plant, P content in grain, plant height, root weight while with all other traits it had positive association. Plant height showed positive association with all other traits except P content in straw and panicle length.
- ❖ Study reveals that different rice genotypes behave differently under different levels of available P in the soil. Some genotypes were P efficient users some were less and it was also observed that variability for certain traits were also varied depending on P levels observed.

LITERATURE CITED

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- Abdourasmane, K., Konate1., Adama Zongo., Honore Kam., Ambaliou Sanni and Alain Audebert. 2016. Genetic variability and correlation analysis of rice (*Oryza sativa* L.) inbred lines based on agromorphological traits. *African Journal of Agricultural Research*. 11 (35). 3340-3346.
- Abebe, T., Alamerew, S and Tulu, L. 2017. Genetic variability, heritability and genetic advance for yield and its related traits in rainfed lowland rice (*Oryza sativa* L.) Genotypes at Fogera and Pawe, Ethiopia. *Advances in Crop Sciences and Technology*. 5: 272.
- Abhinav Sao, Motiramani, N. K., Prav, J and Deepak, G. 2004. Association analysis in certatain rice hybrids using CMS Lines. *Plant Archives*. 4 (2): 453-457.
- Akinrinde, E.A and Gaizer, T. 2006. Differences in the performance and phosphorus-use efficiency of some tropical rice (*Oryza sativa* L.) varieties. *Pakistan Journal of Nutrition*. 5 (3): 206-211.
- Akter, K., Iftexharuddula, K.M., Baskar, M.K., Kabir, M.H and Sarkar, M.Z.A. 2004. Genetic variability, correlation and path analysis in irrigated hybrid rice. *Journal of Sub Tropical Agricultural Research and Development*. 2 (1): 17-23.
- Alexandrov, N., Tai, S., Wang, W., Mansueto, L., Palis, K., Fuentes, RR., Ulat, VJ., Chebotarov, D., Zhang, G., Li, Z. 2015. SNP-Seek database of SNPs derived from 3000 rice genomes. *Nucleic Acids Res*. 43:D1023–7.
- Allard, R. W. 1960. Principles of Plant Breeding. *Published by John Wiley and Sons Inc*. New York, USA. 485.
- Aluwihare, Y.C., Ishan, M., Chamikara, M.D.M., Weebadde, C.K., sirisena, T.N., Samarasinghe, W.L.G and sooriyapathirana, S.D.S.S. 2016. Characterization and Selection of Phosphorus Deficiency Tolerant Rice Genotypes in Sri Lanka. *Rice Science*. 23(4): 184-195

- Amirthadevarathinam, A .1983 .Genetic variability, correlation and path analysis of yield components in upland rice. *Madras Agricultural Journal*. 70: 781-785.
- Ananda Kumar, C.R. 1992. Variability and character association studies in upland rice. *Oryza*. 29: 11-13.
- Ananthi, N., Jabaraj, S and Babu, R. 2006. Variability studies in two line rice (*Oryza sativa* L.). *Research on Crops*. 7 (1): 140-142.
- Anbanandan, V., Saravanan, K and Sabesan, T. 2009. Variability, heritability and genetic advance in rice. *International Journal of Plant Sciences*. 4 (1): 61-63.
- Ashwani Panwar Dhaka, R.P.S and Kumar,V.2007. Genetic variability and heritability studies in rice. *Advances in plant sciences*. 20 (1): 47-49.
- Awasthi, L.P and Pandey, V.K. 2000. Genetic variation in morphological traits of aromatic rice. *Crop Research Hisar*. 19 (2): 361-363.
- Awasthi, R.P and Borthakur, D.N. 1986. Agronomic evaluation of rice varieties in upland terraces of Meghalaya. *Indian Journal of Agricultural Sciences*. 56 (10): 700-703.
- Bagali, P.G., Shailaja, H and Shashidhar, H.E. 1999. Character association and path coefficient analysis in Indica X Japonica double haploid population in rice. *Oryza*. 36 (1): 10-12.
- Bala, A. 2001. Genetic variability, association of characters and path coefficient analysis of saline and alkaline rice genotypes under rainfed condition. *Madras Agricultural Journal*. 88 (4-6): 356-357.
- Balan, A., Muthiah and Ramachandra Boopathi, S.N.M. 1999. Genetic variability correlation and path coefficient analysis in upland early rice genotypes. *Madras Agricultural Journal*. 86 (1-3): 7-9.
- Balan, A., Muthiah, A.R and Boopathi, S.N.M.R. 2000. Genetic variability, character association and path coefficient analysis in rain fed rice, under saline condition.

Madras Agricultural Journal. 86 (1-3): 122-124.

Basvaraja, P., Rudraraya, M and Kulkarni, R.S. 1997. Genetic variability, correlation and path coefficient analysis of yield components in two F₄ population of fine grained rice. *Mysore Journal of Agricultural Sciences*. 31 (1): 1-6.

Bhadru, D., Lokanadha Reddy, D and Ramesha, M.S. 2011. Correlation and path coefficient analysis of yield and yield contributing traits in rice hybrids and their parental lines. *Electronic Journal of Plant Breeding*. 2 (1): 112-116.

Bhandarkar, S., Verma, R and Kumar, A. 2002. Genetic variability and correlation analysis in early duration rice. *Plant Archives*. 2 (1): 95-98.

Bharadwaj, C., Mishra, R., Satyavathi, C.T., Rao, S.K and Kumar, K.S. 2007. Genetic variability, heritability and genetic advance in some new plant type based crosses of rice (*Oryza sativa* L.) *Indian Journal of Agricultural Research*. 41 (3): 189-194.

Borbora, T.K and Hazarika, G.N. 1998. Study of genetic variability, heritability and genetic advance for panicle characters in rice. *Oryza* .35 (1): 19-21.

Borkakati, R.P., Chowdhury, R.K and Kurmar, K. 2005. Studies on genetic variability and correlation in some rice hybrids. *National Journal of Plant Improvement*. 7 (2): 119-121.

Bovill, W.D., Huang, C.Y., McDonald, G.K. 2013. Genetic approaches to enhancing phosphorus-use efficiency (PUE) in crops: challenges and directions. *Crop & Pasture Science*. 64:179-198.

Burton, G.W and Devane, E.H. 1953. Estimating heritability in tall fescue (*Festuca arundinaceae*) from replicated clonal material. *Agronomy Journal* .45: 478-481.

Burton, G.W. 1952. Quantitative inheritance in grasses. *Proceedings on 6th International Grassland Congress Journal*. 1: 277-283.

- Cancellier, E.L., Brandão, D.R., Silva, J., Santos, M.M., Fidelis, R.R. 2012. Phosphorus use efficiency of upland rice cultivars on Cerrado soil. *Ambience*, 8 (2): 307–318.
- Centre for Monitoring Indian Economy (CMIE), 2011-12. Statistics of paddy area and production in Andhra Pradesh.<http://www.cmie.com>.
- Chakraborty, S and Hazarika, M.K. 1994. Estimation of various genetic parameters for yield and yield components in rice. *Oryza*. 31: 226-227.
- Chaubey, P.K and Richharia, A.K. 1993. Genetic variability correlations and path coefficients. *Indian Journal of Genetics and Plant Breeding*. 53 (4): 356-360.
- Chaubey, P.K and Singh, R.P. 1994. Genetic variability correlation and path analysis of yield components in rice. *Madras Agricultural Journal*. 81 (9): 468-470.
- Chaudhary, M and Motiramani, N. K. 2003 .Variability and association among yield attributes and grain quality in traditional aromatic rice accessions. *Crop Improvement*. 30 (1): 84-90.
- Chauhan, J.S., Chauhan,V.S and Variar, M. 1993. Genetic variation and character association in rainfed upland rice. *Oryza*. 30: 116-119.
- Chikkalingaiah, Shridhara, S., Lingaraju, S and Radhakrishna, R.M. 1999. Genetic variability of plant and quality traits in promising genotypes of scented rice (*Oryza sativa* L.). *Mysore Journal of Agricultural Sciences*. 33 (4): 338-431.
- Chin, J.H., Lu, X., Haefele, S.M., Gamuyao, R., Ismail, A., Wissuwa, M and Heuer, S. 2009. Development and application of gene-based markers for the major rice QTL Phosphorus uptake. *Theoretical and Applied Genetics*.
- Chookar, S.K., Marekar, R.V and Siddiqui, M.A. 1994. Genetic variability for grain yield and yield contributing characters in rice. *Journal of Maharashtra Agricultural Universities*.19 (2): 236-238.
- Choudhary, P.K.D and Das, P.K. 1997. Genetic variability correlation and path coefficient

analysis in deep water rice. *Journal of Agricultural Science Society of North East India*. 10 (1): 155-157.

Clemens, C.M., va de Wiel ., Gerard van der Linden, c and Scholten, O.E. 2016. Improving phosphorus use efficiency in agriculture: opportunities for breeding. *Euphytica*. 207:1–22.

Cordell, D., Drangert, J.O and White, S. 2009. The story of phosphorus: Global food security and food for thought. *Glob Environ Chang* 19: 292–305. doi:10.1016/j.gloenvcha.2008.10.00.

Das, P. K., Chakrobarthy, S., Barman, B and Sarmah, K.K. 2001. Genetic variation for harvest index, grain yield and yield component in boro rice. *Oryza*. 38 (3&4): 149-150.

Das, R., Barbora, T.K., Sarma, M.K and Sarma, N.K. 2005. Genotypic variability for grain yield and flood tolerance in semi deep water rice (*Oryza sativa* L.) of Assam. *Oryza*. 42 (4): 313-314.

Debchoudhury, P.K and Das, P.K. 1998. Genetic variability, correlation and path coefficient analysis in deep water rice. *Annals of Agricultural Research*. 19 (2): 120-124.

Devi, L.S., Raina, F.A., Pandey, M.K and Kole, C.R. 2006. Genetic parameters of variation for yield and its components in rice. *Crop Research Hissar*. 32 (1): 69-71.

Dhurai, S.Y., Bhati P.K and Saroj, S.K. 2014. Studies on genetic variability for yield and quality characters in rice (*Oryza sativa* L.) under integrated fertilizer management. *The Bioscan*. 9 (2): 845-848.

Dobermann, A and Fairhurst, T. 2000. Rice: nutrient disorders & nutrient management. Potash & Phosphate Institute, Potash & Phosphate Institute of Canada and International Rice Research Institute Singapore and Los Banos.

Dutt, I., Mehla, B.S., Singh, J and Battan, K.R. 2007. Character association analysis in

rice (*Oryza sativa* L.). *National Journal of Plant Improvement*. 9 (2): 126-131.

Dutta, P., Dutta P.N and Borua P. K. 2013. Morphological Traits as Selection Indices in Rice: A Statistical View. *Univ. J. Agric. Res.* 1 (3):85-96.

Eswara Reddy, G., Suresh B.G., Sravan, T and Ashok Reddy, P. 2013. Interrelationship and cause-effect analysis of rice genotypes in north east plain zone. *The Bioscan*. 8 (4): 1141-1144.

Fageria, N.K and Baligar, V.C. 2001. Lowland rice response to nitrogen fertilization. *Communications in Soil Science and Plant Analysis*. 32: 1405–1429.

Fageria, N.K., and Baligar, V.C. 1999. Yield and yield components of lowland rice as influenced by timing of nitrogen fertilization. *Journal of Plant Nutrition*. 22: 23–32.

Fageria, N.K., Wright, R.J and Baligar, V.C. 1988. Rice cultivar evaluation for phosphorus use efficiency. *Plant and Soil*. 111:105-109.

Fageria, N.K and Baligar, V.C. 1997. Upland rice genotypes evaluation for phosphorus use efficiency. *Journal of Plant Nutrition*. 20 (4&5): 499-509.

Falconer, D.S. 1981. Introduction to quantitative genetics. Oliver and Boyd, London, 340.

Falconer, D.S. 1964. Introduction to quantitative genetics. Longmann, London and New York 294-300.

Falconer, D.S and Mackay, T. F. C. 1996. Introduction to Quantitative Genetics, Ed 4. Longmans Green, Harlow, Essex, UK.

Fageria, N.K and Santos, A.B. 2002. Low land Rice Genotypes Evaluation for Phosphorus Use Efficiency. *Journal of Plant Nutrition*. 25 (12) : 2793–2802.

Gamuyao R., Chin J. H., Pariasca-Tanaka J., Pesaresi P., Catausan S., Dalid C. et al. 2012 The protein kinase Pstol1 from traditional rice confers tolerance of phosphorus deficiency. *Nature*. 488.535–537

- Ganesan, K and Subramanian. 1990. Genetic studies of the F₂ and F₃ of tall semi-dwarf rice varieties. *International Rice Research Newsletter*. 15: 4-7.
- Gazafrodi, A.A., Honarnegad, R.F., Otokian, M.H and Alami, A. 2006. Study of correlations among agronomic traits and path analysis in rice. *Journal of Science and Technology of Agriculture and Natural Resources*. 10 (2): 99-107.
- Geetha, S., Soundaraj, A.P.M., Giridharan, S and Selvi, B. 1994. Association of yield component characters of medium duration rice genotypes. *Annals of Agricultural Research*. 15 (4): 410-412.
- Gonzales, O.M and Remirez, R. 1998. Genetic variability and path analysis in rice grown in saline soil. *International Rice Research Notes*. 23(3): 19.
- Gopinath, M., Sree Rama Reddi, N and Subramanyam, P. 1984. Studies on character association in rice (*Oryza sativa* L.). *The Andhra Agricultural Journal*. 31 (2): 102-105.
- Gravois, K.A and McNew, R.W. 1993. Genetic relationships among and selection for rice yield and yield components. *Crop Sciences*. 33: 249– 252.
- Gupta, J.C., Kotoch, P.C., Kaushik, R.P and Sharma, S.L. 1998. Cause and effect relationship of yield and its components under cold stress condition in rice (*Oryza sativa* L.). *Indian Journal of Agricultural Sciences*. 68 (1): 13-15.
- Habib, S.H., Hossain, M.K., Hoque, M.A., Khatun, M.M and Hossain, M.A. 2007. Character association and path analysis in hybrid rice. *Journal of sub Tropical Agricultural Research and Development*. 5 (3): 305-308.
- Haque, M.E., Baset, A., Zeenat, Z and Miah, N.M. 1991. Path coefficient analysis of seven characters in cold tolerant rice (*Oryza Sativa* L.). *Bangladesh Rice Journal*. 2:1-7
- Hasib, K.M. 2005. Genetic variability, interrelations and path analysis for panicle characters in scented rice. *Crop Research Hissar*. 30 (1): 37-39.

INDIASTAT. 2011-12. Area, production and productivity of rice in India and Telangana
<http://www.indiastat.com>.

Jackson, M.L. 1967. Soil Chemical Analysis. Prentice Hall of India (Private) Ltd. New Delhi, India.

Jaiswal, H.K., Srivastava, A.K and Dey, A. 2007. Variability and association studies in indigenous aromatic rice (*Oryza sativa* L.). *Oryza*. 44 (4): 351-353.

Jamal, A., Akther, M., Ahmed, E and Zahind, M.A. 2007. Genotypic and phenotypic correlations among various plant traits in rice hybrids (*Oryza sativa* L.). *Science International Lahore*. 19 (4): 287-290.

Janardhanam ,V., Nadarajan ,N and Jebaraj, S. 2001. Correlation and path analysis in rice (*Oryza sativa* L.). *Madras Agricultural Journal*. 88: 719-720.

Johnson ,H. W., Robinson, H. F and Comstock, R. E. 1955. Estimates of genetic and environmental variability in soybean. *Agronomy Journal*. 47 (7): 314-318.

Kaleem, S., Hassan, F.U and Saleem, A. 2009. Influence of environmental variations on physiological attributes of sunflower. *African Journal of Biotechnology*. 8: 3531-3539.

Kaleem, S., Ansar, M., Ali, M.A and Rashid, M. 2009. Effect of phosphorus on the yield and yield components of wheat variety “Inquilab-91” under rainfed conditions. *Sarhad J. Agric*. 25 (1): 21-24.

Karad, S.R. and Pol, K.M. 2008. Character association, genetic variability and path coefficient analysis in rice (*Oryza sativa* L.) *International journal of Agricultural Sciences*. 4 (2): 663-663.

Karim, D., Sarkar, U., Siddique, M.N.A., Miah, M.A.K and Hasnat, M.Z. 2007. Variability and genetic parameter analysis in aromatic rice. *International Journal of Sustainable Crop Production*. 2 (5): 15- 18.

- Kavitha, S and Sree Rama Reddi, N. 2001. Correlation and path analysis of yield components in rice. *The Andhra Agricultural Journal*. 48 (3-4): 311-314.
- Kaw, R.N. Aquino, R. C., Moon, H. P., Yae, J.D and Haw, N. 1999. Variability and inter-relations in rice under cold stress environments. *Oryza*. 36 (1): 1-4.
- Kishore, C., Prasad, Y., Haider, Z. A., Kumar, R and Kumar, K. 2008. Quantitative analysis of upland rice. *Oryza*. 45 (4): 268-272.
- Kishore, N.S., Babu, V.R., Ansari, N.A and Prasad, A.R. 2008. Genetic variability, heritability and genetic advance in rice (*Oryza sativa* L.) genotypes of different eco-geographical regions. *Research on Crops*. 9 (1): 147-150.
- Kishore, N.S.T., Srinivas, U., Nagabhushanam, M., Pallavi and Sameera, S.K. 2015. Genetic variability, correlation and path analysis for yield and yield components in promising rice (*Oryza sativa* L.) genotypes. *SAARC Journal of Agriculture*. 13 (1): 99-108.
- Kole, P.C., Chakraborty, N.R., Bhat, J.S. 2008. Analysis of variability, correlation and path coefficients in induced mutants of aromatic non-basmati rice. *Tropical Agricultural Research and Extension*. 11: 60-64.
- Krishnamurthy, P., Sreedevi, B., Ram, T., Padmavathi, G., Mahendra Kumar, R., Raghuveer Rao, P., Shobha Rani, N., Latha, P.C, Singh, S.P. 2010. Evaluation of rice genotypes for phosphorus use efficiency under soil mineral stress conditions. *Oryza*. 47 (1): 29-23.
- Krishnaveni, B., Shoba Rani, N. 2006. Association of grain yield with quality characteristics and other yield components in rice. *Oryza*. 43 (4): 320-322.
- Kuldeep, T., Kumar, B., Ramesh, B and Ajay, J. 2004. Genetic variability and correlations for some seedling and nature plant traits in 70 genotypes of rice. *Research on Crops*. 5 (1): 60-65.

- Kumar, M and Kumar, A. 2004. Variability and correlation studies in rice under rainfed low land condition. *Journal of Applied Biology*. 14 (2): 6-11.
- Kumar, S., Gautam, A.S and Chandel, S. 2006. Estimates of genetic parameters for quality traits in rice (*Oryza sativa* L.) in mid hills of Himachal Pradesh. *Crop Research (Hissar)*. 32 (2): 206-208.
- Kumar, P and Ramesh, B. 2008. Genetic variability and character association in rice. *Progressive Agriculture*. 8 (2): 260-262.
- Kumar, S., Singh, H.B and Sharma.J.K. 2008. Mode of gene action for grain yield, its components and grain quality traits in non segregating generations (F₁) of rice. *Oryza*. 45 (2): 152-155.
- Kundu, A., Senapathi, B.K., Bakshi, A and Mandal ,G.S. 2008. Genetic variability of panicle characters in tall indica aman rice. *Oryza*. 45 (4): 320-323.
- Lalitha, V.S.P and Sreedhar, N. 1999. Estimates of genetic parameters for quality traits in rice. *Annals of Agricultural Research*. 20 (1): 18-22.
- Laye Djouba Conde, Zhijian Chen, Hongkao Chen and Hong Liao. Effects of phosphorus availability on plant growth and soil nutrient status in the rice/soybean rotation system on newly cultivated acidic soils. 2014 . *American Journal of Agriculture and Forestry*. 2 (6) :309-316.
- Leena Kumari, S and Valarmathi, G. 1998. Relationship between grain yield, grain filling rate and duration of grain filling in rice. *Madras Agricultural Journal*. 85 (3-4): 210-211.
- Lynch, J.P, Ho, M.D. 2005. Rhizoeconomics: Carbon costs of phosphorus acquisition. *Plant and soil*. 269: 45–56.
- Lynch, J.P and Brown, K.M. 2008. Root strategies for phosphorus acquisition. In: White PJ, Hammond JP (eds) *Ecophysiol. Plant-Phosphorus Interact*. Springer, Netherlands, pp 83–116.

- Lynch, J., Chimungu, J and Brown, K. 2014. Root anatomical phenes associated with water acquisition from drying soil: targets for crop improvement. *Journal of Experimental Botany*. 65: 6155–6166.
- Madakemohekar, D.K., Mishra, A.S. Chavan and Bornare, S.S. 2015. Genetic variability, correlation and path analysis Of RIL's derived from inter sub-specific crosses for yield and its component traits in rice (*Oryza sativa* L.). *BIOINFOLET*. 12 (1 B): 190 - 193.
- Madhavi Latha, L., Sekhar, M.R., Suneetha, Y and Srinivas, T. 2005 .Genetic variability, correlation and path analysis for yield and quality traits in rice (*Oryza sativa* L.) *Research on Crops*. 6 (3): 527-537.
- Madhavi Latha, L. 2002. Studies on genetic divergence and isozyme analysis in rice (*Oryzasativa* L.). Thesis, Acharya N.G.Ranga Agricultural University, Hyderabad.
- Mahender, A., Anandan, A., Pradhan, S.K and Onkar Nath Singh, O.K. 2017. Traits-related QTLs and genes and their potential applications in rice improvement under low phosphorus condition. *Archives of Agronomy and Soil Science*. 64 (4): 449-464.
- Mahto, R.N., Yadav, M. S and Mohan, K.S. 2003. Genetic variation, character association and path analysis in rainfed upland rice. *Indian Journal of Dryland Agricultural Research and Development*. 18 (2): 196-198.
- Mall, A.K., Babu, J.D.P and Babu, G.S. 2005. Estimation of genetic variability in Rice. *Journal of Maharastra Agricultural Universities*. 30 (2): 166-168.
- Mamta Singh, Kumar, K and Singh, R.P. 2007. Study of coefficient of variation, heritability and genetic advance in hybrid rice. *Oryza*. 44 (1): 160-162.
- Manna, M., Ali, M.N., Sasmal, B.G. 2006. Variability, correlation and path coefficient analysis in some important traits of lowland rice. *Crop Research (Hisar)*. 31 (1): 153-156.
- Manonmani, S., Rangasamy, S.R and Ranganathan, B. 1996. Variability and heritability in

- early lines of Indian rice. *Madras Agricultural Journal*. 83 (1): 75-76.
- Marekar, R. V and Siddiqui. 1996. Genetic variability and correlation studies in rice. *Journal of Maharashtra Agricultural Universities*. 21 (2): 249-251.
- Marimuthu, R., Rajesekharan, S and Soundarapandian, G. 1990 .Variability, heritability and genetic advance in rice. *Madras Agricultural Journal*. 77: 443-446.
- Matthias Wissuwa. 2003, How do plants achieve tolerance to phosphorus deficiency? Small Causes with Big Effects, *Plant Physiology*. 133:1947–1958.
- Maurya, D.M., Singh, S.K and Singh, R.S. 1986. Genetic variability in 48 low land rice cultivars of Uttar Pradesh, India. *International Rice Research Newsletter*. 11 (4): 13.
- Meenakshi, T., Amirthadevarathinam, A and Backiyarani, S. 1999. Correlation and path analysis of yield and some physiological characters in rainfed rice. *Oryza*. 36 (2): 154-156.
- Mishra, D., Mishra, N.S., Das, G.B and Patra, G.J. 1996. Genetic variability, inter-relationship and performance of some scented rice genotypes. *Environment and Ecology*. 14 (1): 150-153.
- Mishra, L.K and Verma, R.K. 2002. Genetic variability for quality and yield traits in non segregating populations of rice (*Oryza sativa* L.). *Plant Archives*. 2 (2): 251-256.
- Mokate, A.S., Bendale, V.W and Birari, S.P. 1998. Variability, heritability, correlation and path analysis studies in rice (*Oryza sativa* L.). *Crop Research*. 15: 243.
- Moosavi, M., Ranjbar, G., Zarrini, H.N and Gilani, A. 2015. Correlation between morphological and physiological traits and path analysis of grain yield in rice genotypes under Khuzestan conditions. *Biological Forum*. 7 (1): 43-47.

- Mst.Tuhina- Khatun [Mohamed, M., Hanafi, Mohd Rafii Yusop, M.Y., Wong, Faezah, M., Salleh](#) and [Jannatul Ferdous](#). 2015. Genetic variation, heritability and diversity Analysis of Upland Rice (*Oryza sativa* L.) Genotypes Based on Quantitative Traits *BioMed Research International*.
- Mukherjee, A., Sarkar, S., Chakraborty, A.S., Yelne, R., Kavishetty,V., Biswas ,T., Mandal, N and Bhattacharyya, S. 2014. Phosphateacquisition efficiency andphosphate starvation tolerance locus (*PSTOL1*) in rice. *Journal of Genetice*. 93: 683–688.
- Murthy, N., Kulkarni, R.S and Uday Kumar, M. 1999. Genetic variability heritability and genetic advance for morpho-physiological traits in rice. *Oryza*. 36 (2): 159-160.
- Fageria, N.K., Knupp, A.M and Moraes, M.F. 2013. Phosphorus Nutrition of Lowland Rice in Tropical Lowland Soil. *Communications in Soil Science and Plant Analysis*. 44 (20): 2932-2940.
- Nagajyothi, B. 2001 .Studies on performance and heterosis of rice hybrids for yield, yield components and certain grain quality characters. M.Sc. (Ag.) Thesis, Acharya N.G. Ranga Agricultural University, Hyderabad.
- Nanja Reddy, Y.A., Prasad, T.G and Udaya Kumar, M. 1995. Genetic variation in yield attributes and yields of rice. *Madras Agricultural Journal*. 82 (4): 310-313.
- Nayak, A.R., Chaudhary, D and Reddy, J.N. 2003a. Genetic variability and correlation study among quality characters in scented rice. *Agricultural Science Digest*. 23 (3): 175-178.
- Nayak, A.R., Chaudhary, D and Reddy, J.N. 2002 .Genetic variability, heritability and genetic advance in scented rice. *Indian Agriculturist*. 46 (1&2): 45-47.
- Nayudu, S.R.K., Anitha and Vennila, S. 2007. Studies on variability, heritability and genetic advance for certain yield components in Rice (*Oryza sativa* L.) var. Jeeraga samba. *Crop Improvement*. 34 (2): 142-144.

- Nguyen Thi Lang and Bui Chi Buu. 2006. Mapping QTL for Phosphorus Deficiency Tolerance in Rice (*Oryza sativa* L.). *Omonrice*. 14: 1-9.
- Niranjana Murthy, Kulkarni, R.S and Uday Kumar, M. 1999. Genetic variability heritability and genetic advance for morpho-physiological traits in rice. *Oryza*. 36 (2): 159-160.
- Ogunbayo, S.A., Ojo, D.K., Sanni, K.A., Akinwale, M.G and Toulou, B. 2014. Genetic variation and heritability of yield and related traits in promising rice genotypes (*Oryza sativa* L.). *Journal of Plant Breeding and Crop Science*. 6: 153-159.
- Paikhomba, N., Kumar, A., Chaurasia, A.K and Rai, P.K. 2014. Assessment of genetic parameters for yield and yield components in hybrid rice and parents. *J Rice Res*. 2: 117. doi: 10.4172/jrr.1000117.
- Panwar, L.L. 2006. Character association and path analysis in rice. *Annals of Agricultural Research*. 27 (3): 1257-260.
- Panwar, L. L. 2005. Genetic variability, heritability and genetic advance for panicle characters in transplanted rice. *Research on Crops*. 6 (3): 505-508.
- Panwar, L.L and Mashiat Ali. 2007. Correlation and path analysis of yield and yield components in transplanted rice. *Oryza*. 44 (2): 115-120.
- Paramasivam, K., Giridharan, S and Soundararaj, K. 1995. Genetic variability and character association of derived panicle characteristics of rice genotypes. *Crop Research*. 10 (3): 285-290.
- Patel, J.R., Saiyad, M.R., Prajapati, K.N., Patel, R.A and Bhavani R.T. 2014. Genetic variability and character association studies in rainfed upland rice (*Oryza sativa* L.). *Electronic Journal of Plant Breeding*. 5 (3): 531-537.
- Patil, P.V., Sarawgi, A.K and Shrivastava, M.N. 2003. Genetic analyses of yield and quality traits in traditional aromatic accessions of rice. *Journal of Maharashtra Agricultural Universities*. 28 (3): 255-258.

Piper, C.S. 1966. Soil and plant analysis. Hans Publishers, Bombay.

Pradhyumna Rao, T., Gomathinayagam, P and Soundarapandian, G. 1996. Genetic variability and character association studies in semi- dry rice. *Madras Agricultural Journal*. 185-188.

Priya Lalitha, S.V and Sreedhar, N. 1999. Estimates of genetic parameters for quality traits in rice. *Annals of Agricultural Research*. 20 (1): 18-22.

Qifa Zhang. 2007. Strategies for developing Green super rice.16402–16409/ *PNAS* / vol. 104 / no. 42.

Rai, S.K., Suresh, B.G., Rai, P.K., Lavanya, G.R., Kumar, R and Sandhya. 2014. Genetic variability, correlation and path coefficient studies for grain yield and other yield attributing traits in rice (*Oryza sativa* L.). *International Journal of Life Sciences Research*. 2 (4): 229-234.

Rajamani, S. 1993. Genetic divergence in rice M.Sc. (Ag) Thesis submitted to Andhra Pradesh Agricultural University, Hyderabad.

Rajamanickam., Elanchezhian., Vengavasi Krishnapriya., Renu Pandey., Annangi Subba Rao., Yash Pal Abro. 2015. Physiological and molecular approaches for improving phosphorus uptake efficiency of crops. *Current Science*. 108 (7).

Ramanjaneyulu, A.V., Gouri Shankar, V., Neelima, T.L and Shashibhusahn, D. 2014. Genetic analysis of rice (*Oryza sativa* L.) genotypes under aerobic conditions on alfisolss abrao. *Journal of Breeding and Genetics*. 46 (1): 99-111.

Ramesh Babu, P. 1999. Genetic analysis of yield and grain quality attributes in Rice (*Oryza sativa* L.). Ph.D. Thesis, Acharya N.G. Ranga Agricultural University, Hyderabad.

Ramesh Kumar, V.V. 1989 .Genetic analysis of yield and its components in four rice crosses. *Journal of Research APAU*. 17 (1): 11.

Rangaswamy, R. 1995. A Text book of Agriculture stastics. New Age International pvt.Ltd, New delhi.

- Rao, S.S and Shrivastav, M.N. 1994. Genetic variation and correlation studies in rainfed upland rice. *Oryza*. 31: 288-291.
- Rao, S.S and Shrivastav, M.N. 1999. Association among yield attributes in upland rice. *Oryza*. 36 (1): 13-15.
- Raut, K.R., Harer, P.N., Yadav, P.S. 2009. Genetic variability and character association in rice (*Oryza sativa* L.). *Journal of Maharashtra Agricultural Universities*. 34 (2): 174-178
- Ravindranath, B., Peraiah, A., Sreerama Reddy, N., Subramanyam, D., Ramayya, B and Murthy, K.R.K. 1982. Interrelationships between yield and yield components in rice. *The Andhra Agricultural Journal*. 29 (4): 287-290.
- Reddy, J.N and De, R.N. 1996. Genetic variability in low land rice. *Madras Agricultural Journal*. 83 (4): 269-270.
- Reddy, J.N., De, R.N and Suriya Rao, A.V. 1997. Correlation and path analysis in low land rice under intermediate (0-50 cm) water depth. *Oryza*. 34 (3): 187-190.
- Remabai, N., Regina, A., Devika, R and Joseph, C.A. 1992. Genetic variability and association of characters in medium duration rice genotypes. *Oryza*. 29: 19-22.
- Richardson, A.E., Hocking, P.J., Simpson, R.J and George, T.S. 2009. Plant mechanisms to optimise access to soil phosphorus. *Crop and Pasture Sciences*. 60:124–143.
- Richardson, A.E., Lynch, J.P and Ryan, P.R. 2011. Plant and microbial strategies to improve the phosphorus efficiency of agriculture. *Plant and soil*. 349:121–156.
- Rose, T.J., Impa, S.M and Rose, M.T. 2012. Enhancing phosphorus and zinc acquisition efficiency in rice: a critical review of root traits and their potential utility in rice breeding. *Annals of Botany*. 112:331–345. doi:10.1093/aob/mcs217.
- Rokonuzzaman, M., Zahangir, M.S., Hussain, M.I., Hossain, M.S. 2008. Genotypic variability of the components and their effects on the rice yield: Correlation and path analysis study. *Italian Journal of Agronomy*. 3 (2): 131-134.

- Rose, T.J., Tanaka, J.P., Rose, M.T., Fukuta, Y and Wissuwa, M. 2010. Genotypic variation in grain phosphorus concentration and opportunities to improve P-use efficiency in rice. *Field crops Research*. 119 (2010): 154-160.
- Roy, A., Panwar, D.V.S and Sarma, R.N. 1995. Genetic variability and causal relationships in rice. *Madras Agricultural Journal*. 82 (4): 251-255.
- Roy, B., Hossain, M and Hossain, F. 2001. Genetic variability in yield components of rice (*Oryza sativa* L.). *Environment and Ecology*. 19 (1) : 186-189.
- Sadhukan, R.N and Chattopadhyay, P. 2000. Variability and character association between yield attributes and grain quality in aromatic rice. *Journal of Inter Academia*. 4 (4): 494-497.
- Sakthivel, P. 2001. Genetic divergence and genetic analysis of yield attributes and certain quality traits in rice (*Oryza sativa* L.). M.Sc. (Ag) Thesis, Acharya N.G.Ranga Agricultural University, Hyderabad.
- Salgotra, R.K., Katoch, P.C and Sood, M. 2005. Performance of rice hybrids for yield and quality traits in mid hills of Himachal Pradesh, India. *Oryza*. 42 (2): 93-96.
- Sankar, P.D., Sheeba, A and Anbumalarmathi, J. 2006. Variability and character association studies in rice (*Oryza sativa* L.). *Agricultural Science Digest*. 26 (3): 182- 184.
- Sanyal, S.K., Dwivedi, B.S., Singh, V.K., Majumdar, K., Datta, S.C., Pattanayak, S.K and Annapurna, K. 2015. Phosphorus Management in Crops and Cropping Systems in India. *Better Crops-South Asia*. 2015.
- Sarawgi, A.K., Rastogi, N.K and Soni, D.K. 2000. Studies on some quality parameters of indigenous rice in Madhya Pradesh. *Annals of Agricultural Research*. 21 (2): 258-261.
- Sarawgi, A.K., Rastogi, R., Verma, R and Wade, L.J. 2000. Character association in improved shallow rainfed low land rices. *Oryza*. 37 (4): 271-276.

- Sardana, S and Sasikumar. 1987. Genetic variability in cold tolerant genotypes of rice. *Oryza*. 24: 119-122.
- Sarkar, K.K., Bhutia, K.S., Senapathi, B.K., Roy, S.K., Panda, S and Mondal, A.B. 2005. Genetic variability and relationships between grain yield and its component characters in rice (*Oryza sativa* L.). *Environmental and Ecology*. 23 S (4): 702.
- Sarkar, K.K., Bhutia, K.S., Senapathi, B.K and Roy, S.K. 2007. Genetic variability and character association of quality traits in rice (*Oryza sativa* L.). *Oryza*. 44 (1): 64-67.
- Sarma, R.N and Roy, A. 1993. Studies on variability and inter-relationship of yield attributes in jhum rice. *Annals of Agricultural Research*. 14 (3): 311-316.
- Satpute, R.G. 1996. Genetic variability, correlation and path coefficient analysis in low land and upland transplanted rice. *Bhatatiya Krishi Anusandhan Patrika*. 11 (1): 49-55.
- Satya Priya Lalitha, V and Sreedhar, N. 1996. Heritability and correlation studies in rice. *The Andhra Agricultural Journal*. 43 (2-4): 158-161.
- Sawant, D.S., Patil, S.L., Jadhav, B.B and Bhawe, S.G. 1995. Genetic divergence, character association and path analysis in Rice. *Journal of Maharashtra Agricultural Universities*. 20 (3): 412-414.
- Saxena, R.R., Saxena, R.R., Motiramani, N.K., Nichal, S.S and Sahu. 2005. Studies on variability, heritability and genetic advance in scented rice germplasm accessions. *Journal of Inter Academia*. 9 (4): 487-489.
- Selvarani, M and Rangasamy, P. 1998. Correlation and path analysis in Rice. *Madras Agricultural Journal*. 85 (1): 57-58.
- Sharma, A.K and Sharma, R.N. 2007. Genetic variability and character association in early maturing rice. *Oryza*. 44 (4): 300-303.

- Shashidhar, H.E., Pasha, F., Manjunath, J., Vinod, M.S and Kanbar, A. 2005. Correlation and path coefficient analysis in traditional cultivars and double haploid lines of rainfed low land rice (*Oryza sativa* L.). *Oryza*. 42 (2): 156-159.
- Shinde, S.R., Kumar, Kamlesh and Pawar, R.M. 2015. Genetic studies in upland rice (*Oryza sativa* L.). *International Journal of Plant Sciences*. 10 (1): 33-37.
- Shivani, D and Reddy, S.R. 2000. Variability, heritability and genetic advance for morphological and physiological traits in certain rice hybrids. *Oryza*. 37 (3): 231-233.
- Shrirame, M.D and Muley, D.M. 2003. Variability and correlation studies in rice (*Oryza sativa* L.). *Journal of Soils and Crops*. 13 (1): 165-167.
- Singh, A., Singh, A.K., Singh, V., Singh, N., Singh, V.N., Shamin, M., Vikram, P and Singh, S. 2014. Genetic variability among traits associated with grain yield of rice (*Oryza sativa* L.) exposed to drought at flowering stage. *African Journal of Research*. 9 (16): 1252.
- Singh, U.K, Mishra, S.B and Jha, P.B. 2000. Variability and Interrelationship studies of some quantitative traits in Boro rice. *Oryza*. 37 (3): 187-190.
- Singh, J., Dey, K., Singh, S and Shahi, J.P. 2005. Variability, heritability, genetic advance and genetic divergence in induced mutants of irrigated basmati rice (*Oryza sativa* L.). *Oryza*. 43 (3): 210-215.
- Singh, P.K., Mishra, M.N., Hore, D.K and Panwar, A.S. 2002. Genetic variability in some indigenous low land rice genotypes of North East India. *Indian Journal of Hill Farming*. 15 (1): 113-115.
- Singh, S.P., Singhara, G.S., Parray, G.A and Bhat, G.N. 2006. Genetic variability and character association studies in rice (*Oryza sativa* L.). *Agricultural Science Digest*. 26 (3): 212-214.

- Singh, S.P., Singhara, G.S., Parray, G.A and Bhat, G.N. 2006. Genetic variability and character association studies in rice (*Oryza sativa* L.). *Agricultural Science Digest*. 26 (3): 212-214.
- Singh, M., Kumar, K and Singh, R.P. 2007. Study of coefficient of variation, heritability and genetic advance in hybrid rice. *Oryza*. 44 (1): 160-162.
- Singh, S., Dhaka, R.P.S and Malik, S.S. 1996. Heritability and genetic advance in irradiated population of rice. *Crop Research*. 11 (2): 184-188.
- Sinha, S.K., Tripathi, A.K and Bisen, U.K. 2004. Study of genetic variability and correlation coefficient analysis in midland land races of rice. *Annals of Agricultural Research*. 25 (1): 1-3.
- Siva Kumar, P and Bapu, J.R.K. 2005. Character association in inter sub specific rice hybrids involving wide compatible gene. *Crop Research. (Hissar)*. 30 (2): 208-210.
- Sivasubramanian, S and Madhava Menon, P. 1973. Genotypic and phenotypic variability in rice. *Madras Agricultural Journal*. 60: 1093-1096.
- Souroush, H.R., Mesbah, M., Hossain, Z.A and Bozorgipour, R. 2004. Genetic and phenotypic variability and cluster analysis for quantitative and qualitative traits of rice. *Seed and Plant*. 20 (2): 167- 182.
- Sukanya Subramanian and Rathinam, M. 1984. Genetic components of variation in rice. *Madras Agricultural Journal*. 71: 561-565.
- Suman, A. 2003. Studies on genetic diversity and agro-morphological characterization of rice (*Oryza sativa* L.) germplasm. Acharya N.G. Ranga Agricultural University, Hyderabad.
- Supriyo Chakraborty and Hazarika, M.K. 1994. Estimation of various genetic parameters for yield and yield components in rice. *Oryza*. 31: 226-227.
- Surender Raju, C.H. 2002. Study of genetic divergence, variability, stability, gene action and character association for certain physiological quality and yield components in rice (*Oryza sativa* L.) Ph.D. Thesis, Acharya N.G. Ranga Agricultural University,

Hyderabad.

- Suryanarayana, Y. 2000. Genetic studies on drought tolerance in rice (*Oryza sativa* L.) Ph.D. Thesis, Acharya N. G. Ranga Agricultural University, Hyderabad.
- Tara Satyavathi, C., Bharadwaj, C.H and Subramanyam, D. 2001. Variability, correlation and path analysis in rice varieties under different spacings. *Indian Journal of Agricultural Research*. 35 (2): 79-84.
- Thirumala Rao, V., Chandramohan, Y., Bhadr, D., Bharathi, D and Venkanna. 2014. Genetic variability and association analysis in rice. *International journal of applied biology and pharmaceutical technology*. 5 (2).
- Tiwari, G.C., Gupta, S.C., and Jatav, N.K. 2014. Correlation, heritability, genetic advance studies in rice (*Oryza sativa* L.). *Trends in Biosciences*. 7 (18): 2800-2805,
- Tripathi, A.K., Sinha, S.K and Bhandarkar, S. 1999. Studies on variability heritability and genetic advance of semideep water rice. *Advances in Plant Sciences*. 12 (1): 235.
- Ukaoma, A., Augustina., bokocha, P., Iwunor., Okechukwu, R and Ijeoma. 2013. Heritability and character correlation among some rice genotypes for yield and yield components. *Journal of Plant Breeding and Genetics*. 1 (2): 73-84.
- Umesh, H.k., Jaiswal, T., Sravan, Showkat, A., Waza And Rahul Bhardwaj. 2015. Estimation of genetic variability, heritability and genetic advance for yield and quality traits in some indigenous Basmati rice (*Oryza sativa* L) genotypes. *International Journal of Farm Sciences*. 5 (4): 32-40, 2015.
- Ushakumari, R., Rangaswamy, P and Gomez, S.M. 2006. Character association in wide compatible Indica-Japonica hybrids in rice. *Journal of Ecobiology*. 19 (4): 317-320.
- Vandamme, E., Renkens, M and Pypers, P. 2013. Root hairs explain P uptake efficiency of soybean genotypes grown in a P-deficient Ferralsol. *Plant and Soil*. 369:269–282.
- Vaithiyalingam, M and Nadarajan, N. 2005. Correlation and path path analysis in inter sub-specific rice hybrids. *Research on Crops*. 6 (2): 287-289.

- Vange, T and Ojo, A.A. 1997. Variability and heritability estimates of yield and yield components in some Nigerian low land rice genotypes. *International Rice Research Newsletter*.
- Vange, T., Ojo, A.A and Bellow, L.L. 1999. Genetic variability, stability and correlation studies in lowland rice (*Oryza sativa* L.) genotypes. *Indian Journal of Agricultural Sciences*. 69 (1): 30-3.
- Vejchasarn, P., Jonathan, P., Lynch., Kathleen, M and Brown. 2016. Genetic Variability in phosphorus responses of rice root phenotypes. *Rice*. 9:29.
- Veneklaas, E.J., Hans Lambers., Jason Bragg., Finnegan, P.M., Lovelock, C.E., Plaxton, W.C., Price, C.A., Scheible, W.R., Shane, M.W., White, P.J and Raven, J.A. 2012. Opportunities for improving phosphorus-use efficiency in crop plants. *New Phytologist*. 195: 306-320.
- Venkata Suresh, A. 2001. Genetic analysis for certain quantitative and qualitative traits in F₂ populations of rice (*Oryza sativa* L.). M.Sc. (Ag) Thesis, Acharya N.G. Ranga Agricultural University, Hyderabad.
- Verma, O.P., Santoshi, U.S., Dwivedi, J.L and Singh, P.P. 2000. Genetic variability, heritability and genetic advance for quantitative traits in rice. *Oryza*. 37 (2): 38-40.
- Veronica, N., Subrahmanyam, D., kiran, T.V., yugandhar, P., bhadana, V.P., padma, V., jayasree, G and Voleti, S.R. 2017. Influence of low phosphorus concentration on leaf photosynthetic characteristics and antioxidant response of rice genotypes. *Photosynthetica*. 55(2): 285-293.
- Vinod, K.K and Sigrid Heuer. 2012. Approaches towards nitrogen and phosphorus efficient rice. *AoB Plants Advance*.
- Wang, K., Kehui Cui., Guoling Liu., Weibo Xie., Huihui Yu., Junfeng Pan., Jianliang Huang., Lixiao Nie., Farooq Shah and Shaobing Peng. 2014. Identification of quantitative trait loci for phosphorus use efficiency traits in rice using a high density SNP map . *BMC Genetics*. 15:155.

- Wang, X., Shen, J., Liao, H., 2010. Acquisition or utilization, which is more critical for enhancing phosphorus efficiency in modern crops .*Plant Science*. 179 :302- 306.
- Wilfred Manuel, W and Rangaswamy, M. 1993. Correlation and path analysis in hybrid rice. *Oryza*. 30: 248.
- Williams Kwame Atakora., Mathias Fosu., Abebrese, O.S., Michael Asante and Matthias Wissuwa. 2015. Evaluation of low phosphorus tolerance of rice varieties in Northern Ghana. *Sustainable Agriculture Research*. 4 (4).
- Wissuwa, M and Ae, N. 2001. Genotypic variation for tolerance to phosphorus deficiency in rice and the potential for its exploitation in rice improvement. *Plant Breeding*. 120: 43-48.
- Wissuwa, M., Wegner, J., Ae, N and Yano, M. 2002. Substitution mapping of Pup1 major QTL increasing phosphorus uptake of rice from a phosphorus deficient soil. *Theoretical and Applied Genetics*. 105: 890–897.
- Wissuwa, M., Yano, M and Ae, N. 1998. Mapping of QTLs for phosphorus deficiency tolerance in rice (*Oryza sativa* L.). *Theoretical and Applied Genetics*. 97: 777–783.
- Wolie, A., Dessalegn, T and Belete, K. 2013. Heritability, variance components and genetic advance of some yield and yield related traits in Ethiopian collections of finger millet (*Eleusine coracana* (L.) Gaertn.) genotypes. *African Journal of Biotechnology*. 12 (36):5529-5534
- Xiang Chao., Ren Jie., Zhao Xiu-qin., Ding Zai-song., Zhang Jing., Wang Chao., Zhang Junwei., Charles Augustino Joseph., Zhang Qiang., Pang Yun-long., Gao Yong-ming and Shi Ying-yao. 2015. Genetic dissection of low phosphorus tolerance related traits using selected introgression lines in rice. *Rice Science*. 22 (6): 264-274.
- Yadav, R.K. 1992. Genetic variability, correlation studies and their implication in selection of high yielding genotypes of rice. *Advances in Plant Sciences*. 5 (Special issue): 306-312.

- Yogameenakshi, P., Nadarajan, N and Anbumalarmathi, J. 2004. Correlation and path analysis on yield and drought tolerant attributes in rice (*Oryza sativa* L.) under drought stress. *Oryza*. 41 (3&4): 68-70.
- Yolanda, J. L and Vijendra Das, L.D. 1995. Correlation and path analysis in rice (*Oryza sativa* L). *Madras Agricultural Journal*. 83 (11): 576-578.
- Yoseftabars, S. 2013. Effect of Nitrogen and phosphorus fertilizer on spikelet Structure and yield in rice (*Oryza sativa* L). *International Journal of Agriculture and Crop Sciences*. 5 (11): 1204-1208.
- Yugandhar Reddy, M., Subash Chandra Yadav., Suresh Reddy, B., Lavanya, G.R and Suresh, G. 2006. Character association and component analysis in rice. *Oryza*. 45 (3): 239- 241.
- Yugi, R., Ahadiyat., Ponendi Hidayat and Untung Susanto. 2014. Drought tolerance, phosphorus efficiency and yield characters of upland rice Lines, Emir. *Journal of Food and Agriculture*. 26 (1): 25-34.
- Zhang, Y., Anis, G.B., Wang, R., Wu, W., Ning Yu, N., Shen, X., Zhan, X., Cheng, S and Cao, L. 2018. Genetic dissection of QTL against phosphate deficiency in the hybrid rice ‘Xieyou9308’. *Plant Growth Regul.* 84:123–133.
- Zhu, J.M and Lynch, J.P. 2004. The contribution of lateral rooting to phosphorus acquisition efficiency in maize (*Zea mays*) seedlings. *Functional Plant Biology*. 31:949–958.