“NUTRIENT USE EFFICIENCY OF DROUGHT TOLERANT RICE GENOTYPE AS INFLUENCED BY FERTILITY LEVELS UNDER RAINFED CONDITION”

M.Sc. (Ag.) THESIS

By

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COLLEGE OF AGRICULTURE
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CERTIFICATE –I

This is to certify that the thesis entitled **"NUTRIENT USE EFFICIENCY OF DROUGHT TOLERANT RICE GENOTYPE AS INFLUENCED BY FERTILITY LEVELS UNDER RAINFED CONDITION"** submitted in partial fulfilment of the requirements for the degree of **"Master of Science in Agriculture"** of the Indira Gandhi Krishi Vishwavidyalaya, Raipur, is a record of the bonafide research work carried out by **TRIBHUVAN PATEL** under my guidance and supervision. The subject of the thesis has been approved by Student's Advisory Committee and the Director of Instructions.

No part of the thesis has been submitted for any other degree or diploma (certificate awarded etc.) or has been published / published part has been fully acknowledged. All the assistance and help received during the course of the investigations have been only acknowledged by him.

Mishra 22/07/2013

Date:

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THESIS APPROVED BY THE STUDENT'S ADVISORY COMMITTEE

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Member :**Dr. G. S. Tomar** ------------------------------

Member :**Dr. A. K. Singh** ------------------------------

CERTIFICATE –II

This is to certify that the thesis entitled **"NUTRIENT USE EFFICIENCY OF DROUGHT TOLERANT RICE GENOTYPE AS INFLUENCED BY FERTILITY LEVELS UNDER RAINFED CONDITION"** submitted by **TRIBHUVAN PATEL** to the Indira Gandhi Krishi Vishwavidyalaya, Raipur in partial fulfilment of the requirements for the degree of **M.Sc. (Ag.)** in the **Department of Soil Science and Agricultural Chemistry** has been approved by external examiner and Student's Advisory Committee after oral examination.

3/9/13

Date: 3·9·13 **EXTERNAL EXAMINER**

Major Advisor 3/9/13

Head of the Department / Section 3/9/13.

Dean / Dean Faculty

Director of Instructions

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Date:

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LIST OF ABBREVIATIONS

NOTATION	DESCRIPTION
%	Per cent
CD	Critical Difference
et al.	And co-workers/and other
Fig.	Figure
g	Gram
ha^{-1}	Per hectare
K	Potassium
Kg	Kilogram
m	Meter
N	Nitrogen
No.	Number
P	Phosphorus
$\mu gCg - 1$	Micro gram carbon per gm
q	Quintal
RDF	Recommended dose of fertilizer
SEm	Standard error of mean
NS	Not significant
MT	Million Tonne
HC	Hydraulic conductivity
Mgm^{-3}	Mega gram per meter qube
cm	Centimeter

Introduction

CHAPTER -I

INRODUCTION

Rice stands first among all food grain crops of the world and is the staple food of more than half of world's population. In India also rice is the major crop in terms of area, production and consumption. Rice is growing in diversified environments even with low inputs. It occupies the enviable prime place among the food crops cultivated around the world and is grown in 147 MH with a production of 525 MT. About 90 per cent of rice grown in the world is produced and consumed in Asian countries. India has the largest area among rice growing countries and enjoys the second rank in production. India produces 73.8 m. tones of rice from an area of 43.0 m. ha with the productivity of 2915 kg ha^{-1} (Anonymous, 2006).

In Chhattisgarh, average production and consumption of rice dominate the average production and consumption of other food grain crops. Chhattisgarh contributes 5.26 per cent of total rice production of the country. The crop is cultivated in 3.68 m ha in Chhattisgarh with a production of 4.67 million tonnes and productivity of 1338 kg ha-1. In the State, it is mainly grown in rainfed condition with about 85 per cent area in Chhattisgarh plains, 73 per cent in Bastar plateau and 67 per cent in Northern-Hill zones. Chhattisgarh State is situated between 170 46' to 240 5' N latitude and 800 15' to 840 20' longitude. The climate is hot because of its position near on the tropic of cancer.

The agriculture in the state completely depends on monsoon with an annual rainfall of 1200-1400 mm. The irrigation facility in the state is also very meager (about 27 per cent) and that too, available as protective for *kharif* crops only. In general, rice is grown under diverse environmental conditions from a wide range of latitude and altitudes. It is also grown under all the 3 rice growing environments like uplands, lowlands and midlands. The major climatic factors affecting growth and yield include solar radiation, temperature and rainfall. The rainfall is particularly important in rainfed rice cultivation. When compared to other crops, the water requirement for rice crop is very high. It is often believed that standing water of at least 5 cm depth is needed for rice crop right from transplanting to flowering and grain filling stages. With increasing water crisis in many parts of the world including India, newer technologies are being developed with minimum water use for rice cultivation.

Rice is one of the most premier and staple crop of India and its production is reached up to 100 million tonnes from the cultivated area of about 40 million ha. It accounts for 42% of total food grain production and about 40% of total fertilizer consumption. Considering the future demand of rice and fertilizer consumption, relatively low use of nutrients and growing cost of rice production, fertilizer subsidies and environmental sustainability. It is important to develop non-monitory input technologies to optimum nutrient use and improve its use efficiency

Despite the importance of drought as constraints, little efforts have been devoted to developing drought tolerant rice cultivars. Most improved cultivars grown in drought prone area are originally bred for irrigated conditions and were not selected for drought tolerance. These cultivars have high yield potential but often highly prone to yield reduction under drought.

Nutrient use efficiency and grain yield of rice depend upon the level of fertilizer N applied and also on the balance use of other fertilizers, particularly P and K. Fertilizer is one of the key and costliest inputs in realizing the yield potential of high yielding varieties of cereals. Efficient fertilizer use ensures increased production, high profit and environmental protection. For a close monitoring of changes in soil with respect to fertility status on a long term basis and making balanced recommendations for the use of fertilizers and amendments, standard and stable methodology of soil testing is of prime importance.

The grain yield of rainfed rice in many Asian countries is reduced by low soil fertility. The interaction effects of drought coupled with low fertility limit the rice yield and this situation calls for the rainfed farmers to test the new genotypes under various fertility levels to sustain the optimum level of rice production.

The limited information from research conducted with irrigation and under rainfed lowland conditions suggest that both uptake of N and P and their utilization efficiency (grain yield/unit nutrient uptake) to produce grain yield are important for adoption to low soil fertility environments. Genotypic variation in utilization efficiency appears to be consistent across environments, and the efficiency can be improved by the development of cultivars that require a low nutrient concentration in the plant and a higher nutrient allocation to the grain

Selection and evaluation of drought tolerant rice genotypes for rainfed environments is usually conducted under high input (i.e. fertilizer) conditions. The fertilizer rates used by the breeders are far beyond the rates used by the farmers, because one of breeder’s most important selection targets is a high yield potential. Although yield under high and low input use is often related, the correlation is not always very strong. Thus farmer’s adoption for new variety becomes different as the performance of new variety under suboptimal nutrient conditions is least as important as their performance under optimal nutrient supplies.

Therefore, it may be useful to target the evaluation of promising lines under a range of nutrient supplies under rainfed conditions. The out come of this experiment can be used to choose germplasm which will cover well under a range of nutrient supply as well as farmer's field conditions.

Considering the future demand of rice and fertilizer use, relatively low use of nutrients, and growing cost of rice production, fertilizer subsidies and environmental sustainability, it is important to develop non-monitory input technologies to optimum nutrient use and improve its use efficiency. Identifying superior genotypes for different environments based on their differential responses and efficiency of utilizing of soil and applied nutrients is one such area which is less explored.

In view of this, it may be worthwhile to evaluate the Nutrient use efficiency of drought tolerant rice genotype as influenced by fertility levels under rainfed condition" with the following objectives:

1. To study the effect of fertility levels on rice genotypes growth yield attributes and yield under rainfed condition
2. To study the effect of fertility levels on N P and K and micro nutrient accumulation by rice genotypes under rainfed condition
3. To study the fertilizer N P and K use efficiencies as influenced by genotypes and fertility levels.

Review of Literature

CHAPTER- II

REVIEW AND LITERATURE

In this chapter, an attempt has been made to bring out a short review on the work done in India and abroad pertaining to the **"Nutrient use efficiency of drought tolerant rice genotype as influenced by fertility levels under rainfed condition".**

The review of the work done is discussed under the following heads:

2.1 Growth yield attributes and yield.

2.2 Nutrients accumulation by rice genotypes.

2.3 Nutrients use efficiencies.

2.4 Evaluation of genotypes under rainfed condition.

2.1 Growth yield attributes and yield

Uddin *et at.* (2013) reported from their experimental results that application of 80 kg N ha^{-1} produced the highest number of spikelet's and number of grains per panicle resulted highest grain yield. Similarly, 40 kg K_2O ha^{-1} resulted the highest number of total tillers and effective tillers, maximum number of total spikelets and grains panicle^{-1} which produced highest grain yield. All growth ancillary characters showed significant interaction effect of N and K except test weight.

Tabar Y. (2012) studied the effect of nitrogen and phosphorus fertilizer on growth and yield in rice cultivar (Tarom Hashemi). The results showed that tiller number, fertile tiller, total grain, 1000-grain weight and yield increased significantly with nitrogen and phosphorus fertilizer**.** Study of interaction effect of N and P-fertilizer was significant in fertile tiller and 1000-grain weight.

Fageria *et al.* (2011) reported from experiments conducted using ammonium sulfate and urea as N sources for upland rice grown on a Brazilian *Oxisol*. Maximum grain yield was achieved with the application of 380 mg N kg^{-1} by ammonium sulfate and 271 mg N kg^{-1} by urea. In the intermediate N rate range (125 to 275 mg kg^{-1}), urea was slightly better compared to ammonium sulfate for grain yield.

Metwally *et al.* (2011) evaluated the response of Egyptian hybrid rice 1 'H1' to nitrogen fertilizer beside the determination of N use efficiency and N uptake by rice grain and straw. Nitrogen fertilization significantly increased grain yield. The maximum grain yield was obtained with the application of 200 kg N ha^{-1}. Yield components were also significantly affected by N treatments. Nutrient use efficiencies were classified and expressed as agronomic efficiency, physiological efficiency, agro-physiological efficiency, apparent recovery efficiency, and utilization efficiency. Increasing N level up to 200 kg N ha^{-1} increased N use efficiency. Further, increasing the N levels decreased N use efficiencies.

Kamara *et al.* (2011) reported the response of four rain-fed lowland New Rice for Africa (NERICA) varieties (NERICA-L-12, NERICA-L-41, NERICA-L-42 and NERICA-L-56) and a popularly grown *Oryza sativa* (ITA 150) to nitrogen (0, 30, and 100 kg N ha^{-1}). Nitrogen application increased rice grain yield and yield components with the highest grain yield obtained at 100 kg N ha^{-1}. Average across N rates, NERICA –L-12 and NERICA-L- 41 produced higher grain yield than the others. The least grain yield was produced by IT 150, suggesting that it is not suitable for production in the lowland ecologies.

Two greenhouse experiments were conducted by Fageria *et al.* (2011**)** to evaluate the effect of ammonium sulfate and urea fertilization on growth, yield and yield components of lowland rice. Rice yield components, N uptake and use efficiency were significantly affected by graded dose of N fertilization from 0 to 400 mg kg^{-1} of soil by both the sources of N.

Awan *et al.* (2011) studied the effect of different nitrogen levels (110,133 & 156 kg ha^{-1}) in combination with different row spacing's (15, 22.5 & 30 cm) conducted at Rice Research Institute Kala Shah Kuku and concluded that treatment 156 kg N ha^{-1} were applied with 22.5 cm row to row and plant to plant spacing had maximum values of plant height (79.07 cm), tillers m^{-2} (594), panicle length(25.40cm), No of grains panicle^{-1} (132.97), grain yield (5461.03 kg ha^{-1}), straw yield (9662.03 kg ha^{-1}) and least value of sterility % age (5.7 %). All these parameters were statistically at par with the treatment 15cm spacing with 156 kg N ha^{-1} except panicle length. Statistically minimum values of all these parameters were recorded under the treatments 15cm spacing with 110 kg N ha^{-1} and 30 cm spacing with 110 kg N ha^{-1} except panicle length, 1000 grain weight & sterility %. Harvesting index had no significant difference among all treatments.

Fageria *et al.* (2011) indicated that lowland rice is a staple food for more than 50% of the world's population and phosphorus (P) deficiency is one of the main constraints in rice production in tropical lowlands, therefore experiment was conducted with the objective to evaluate 12 lowland rice genotypes for P use efficiency. The P rates used were 0, 22, 44, 66, and 88 kg P ha^{-1} (0, 50, 100, 150 and 200 kg P_2O_5 ha^{-1}) applied to an *Inceptisol*. The genotypes used were BRS Jaçanã, CNAi 8860, BRS Fronteira, CNAi 8879, CNAi 8880, CNAi 8886, CNAi 8885, CNAi 8569, BRSGO Guará, BRS Alvorada, BRS Jaburu and BRS Biguá. There were significant and quadratic responses of genotypes to phosphorus fertilization. Adequate P rates for maximum grain yield varied from genotype to genotype. However, across 12 genotypes, maximum grain yield was obtained with the application of 54 kg P ha^{-1}. Genotype BRS Jacana was most efficient and genotype CNAi 8569 was most inefficient in P use efficiency. Shoot dry weight and panicle number was also increased significantly and quadratically with increasing P rates in the range of 0 to 88 kg P ha^{-1}. These two plant parameters were positively associated with grain yield. Agronomic efficiency (kg grain produced per kg P applied) was significantly decreased with increasing P rates in the range of 22 to 88 kg P ha^{-1}.

Krishnamurthy *et al*. (2010) evaluated twenty eight pre-released promising rice varieties and hybrids were for their grain yield, and response to graded level of applied phosphorus in low soil-P fertility states calcareous *vertisol*. Among rice culture, four distinct patterns in grain yield response were observed with eight rice cultures at 0 P-level, six rice cultures at medium P-fertility level (20-30kg P_2O_5 ha^{-1}) where existing higher grain yield response, while five recorded higher grain yields and yield response only at higher P-level of 50-60 kg P_2O_5 ha^{-1} (65-93 kg grain kg^{-1} P_2O_5) compared to other (16-66 kg grain kg^{-1} P_2O_5).

The other cultures IET 17190, Sumati and Rajavadlu did not show any grain yield response either at 0-10 or 50-60 kg P_2O_5 ha^{-1} indicating the existence of genetic variability for P-use efficiency trait.

Sikdar *et al*. (2008) conducted a field experiment to evaluate the effect of nitrogen (N) level on the quality of aromatic rice and fertility status of the post harvest soil. The experiment comprised of three varieties *viz*., Kalizira, Badshabhog and Tulshimala and three levels of nitrogen *viz*., 40, 60 and 80 kg ha^{-1}. Kalizira was found significantly superior to Tulshimala and Badshabhog with respect to quality of grain and soil fertility of the post harvest soil. Among three N levels, 80 kg ha^{-1} performs the best to quality of aromatic rice and fertility status of the post harvest soil. The effect of interaction of varieties and N levels were not significant on the quality of aromatic rice and fertility status of the post harvest soil.

Gedam *et al*. (2008) studied that the residual effect of organic manures on growth, yield attributes and yield of rice in groundnut-rice cropping system and observed that residual effect of organic manures significantly affected the grain yield of succeeding rice. Application of poultry manure and Swastik @ 5 t/ha to groundnut increased the grain yield of rice significantly over the remaining treatments. The grain yield of rice ranged from 30.54 q/ha in control plot to 46.52 q/ha in residue of poultry manure applied to groundnut. Similarly, the direct effect of fertilizer applied to rice was significant in increasing the yield of rice. 100 % RDF recorded significantly higher grain yield as compared to 50% RDF.

Nawlakhe *et al.* (2008) conducted a field experiment during *kharif* seasons for three years to develop an integrated nutrient management system for "Sye-75" transplanted rice (*Oryza sativa L.*). Application of recommended fertilizer dose of 100: 50: 50 kg/ha of NPK recorded highest grain yield (4416 kg/ha) but it was found at par with the treatment 50% N through RDF+50% N through Glyricidia (4391 kg/ha). Highest gross monetary return (Rs. 14291/ha) and B: C ratio (1.60) was obtained with integrated nutrient management system using Glyricidia and inorganic fertilizer supplying 50% N each.

Kumar et *al.* (2008) compared rice genotype KHRS-21 with released cultivars (Hemavathi and Intan) for varying levels of nutrition and plant density. Trial consists of different levels of nutrients (Control, 50% and 100 % recommended Package) and plant density of 50 and 66 per m^2 for the above three genotypes. KHRS-21 yielded 20 per cent higher than Hemavathi and 39 per cent higher than Intan. All the cultivars tested performed better when 100 per cent recommended package was applied with 50 plants per m^2. KHRS-21 can be a supplement to Hemavathi for low land situations of hill zone.

Ndaeyo *et al*. (2008) observed that the effects of different NPK (15:15:15) fertilizer rates on the growth and yield of upland rice varieties in a high rain forest ecology of Uyo, Akwa Ibom State, Nigeria. The treatments consisted of factorial randomized complete block combinations of five rice varieties (WAB340- 8-8-2HI, WAB881-10-37-18-8-2-HI, WAB99-1-1, WAB224-8-HB, WAB189-B-B-B-8-HB) and four rates of NPK (15:15:15) fertilizer (0, 200, 400 and 600 kg ha^{-1}) and concluded that 600 kg ha^{-1} NPK fertilizer rate significantly ($P < 0.05$) increased plant height, number of leaves and tillers per plant in both years. The 400 kg ha^{-1} rate increased the number of panicles per plant, length of central panicle per plant and the overall grain yields over other rates by 4-32% and 2-21% in 2005 and 2006, respectively. Among the varieties, WAB224-8-HB produced the highest grain yield (4.73 and 4.40 t/ha) followed by WAB189-B-B-B-8-HB (4.37 and 4.20 t/ha) for both years. The interaction effects between rice variety and fertilizer rates were generally significant. The mean grain yields for both years showed that WAB224-8-HB variety performed better than other varieties by 6-24% while the grain yield in the 400 kg ha-1 plot super ceded other rates by 3-26% and hence have potentials to support upland rice production in Uyo agro ecology.

Ahmed *et al.* (2005) reported that the effect of five nitrogen levels i.e. 0, 20, 40, 60 and 80 kg ha^{-1}on different characteristics of transplanted local rice varieties i.e. Aman, Jatai and reveled that different agronomic characteristics varied significantly among the treatments. Higher N dose produced higher plant height. The highest effective tiller hill^{-1}, panicle length, filled grains panicle^{-1}, 1000-grain weight and grain yield was obtained with 40 kg N ha^{-1}. The highest and lowest biological yield was produced with 40 kg N ha^{-1}and 0-kg N ha^{-1} respectively.

Saito *et al.* (2005) found that upland traditional rice cultivars are grown with no fertilizer inputs are typically under slash-and-burn systems in the mountainous regions of northern Laos by resource-poor farmers for subsistence produces poor grain yields average only 1.7 t/ha. Therefore, a multi-site experiment was conducted in Luang Prabang province to examine cultivar and fertilizer effects on grain yield. Three traditional and three improved cultivars were grown under four fertilizer treatments: no added fertilizer, nitrogen only (N; 90 kg N/ha), phosphate only (P; 50 kg P/ha), and N and P (NP) at three locations. No severe water stress developed at any location. The two improved cultivars, IR55423-01 and B6144-MR-6-0-0 out-yielded traditional cultivars in all locations and fertilizer treatments as produced higher total dry matter and harvest index, lower plant height and more panicles than traditional cultivars. N fertilizer application increased grain yields of the two improved cultivars from 3.1 to 4.0 and traditional cultivars from 1.6 to 1.9 t/ha. Application of only P gave no effect on grain yield, and applying P with N increased grain yield only by 0.5 t/ha over N application alone on average over all cultivars at all locations. However, there was cultivar and location difference in the yield response to P applied with N. These results indicate that upland rice cultivars with high HI, which have been selected under favorable conditions, can perform well under low fertility conditions but also respond well to applied N fertilizer.

Amin *et al.* (2004) evaluated from a field experiment on the effect of increased plant density and fertilizer dose on yield of rice variety IR-6 was conducted at the farm of Faculty of Agriculture, Gomal University Dera Ismail Khan. Increased plant density significantly increase number of panicles per square meter, sterility and straw yield while increased fertilizer dose of NPK increase plant height, sterility, normal kernels, and 1000 grain weight. Interaction of increased plant density and fertilizer dose was found to be non significant except sterility percentage and straw yield. However efforts are required for increasing yield per unit area of rice.

Linquist and Sengxua (2003) reported that nitrogen (N) is the most limiting nutrient in the rainfed lowland rice soils of Laos. Indigenous N supply of these soils was low, ranging from 12 to 64 kg N/ha and was correlated with soil organic matter content. Resource-poor farmers and erratic rainfall are characteristic features of Lao rainfed lowland rice systems. Such climatic and economic factors influence farmers' ability to apply N at the 'recommended' time and therefore efficient and flexible recommendations are required. Agronomic efficiency (AE 5 kg increase in grain yield /kg N applied) was increased by 9 kg/kg N if a higher proportion of the N was applied during active tillering and panicle initiation when crop N demand is high. Under conditions of suboptimal N supply, the first N application can be applied from transplanting to 30 d after transplanting without lowering grain yield or AE (for medium duration varieties transplanted 1 month after sowing). The last N application can be made between two weeks before to one week after panicle initiation without lowering yield. These findings provide the basis for an efficient (AE of 20 to 25 kg/kg N) and flexible N management strategy for Lao rainfed lowland rice under conditions of suboptimal N supply.

Inthapanya *et al.* (2000) conducted with a large number of rainfed lowland rice genotypes under two fertilizer conditions to identify whether a genotype's ability to extract more nutrients or to use absorbed nutrients more efficiently to produce grain yield was more important in determining genotypic variation in grain yield. From the yield responses of lines to fertilizer application, 16 contrasting lines were selected, and dry matter and nutrient (N, P and K) contents were determined for grain and straw separately for crops grown under non-fertilized and fertilized (60–13–16 N–P–

K kg ha^{-1}) conditions at three locations in Laos. There were significant effects of both genotype and genotype-by-fertilizer interaction for grain yield, which were closely associated with total N and P content at maturity. There was, however, also significant genotypic variation in nutrient-use efficiency (grain yield per unit nutrient absorbed), and this also contributed to the genotypic variation for grain yield. Both N- and P-use efficiency were consistent across fertilizer levels, and hence are likely to be used as selection criteria.

Singh *et al.* (1998) conducted a field experiment in the dry season at Los Baños, Philippines, to assess the differences in grain yield and N utilization of 10 medium-duration (119±4 days after seeding [DAS]) genotypes and 10 long-duration (130±4 DAS) ones with varying acquisition and usage of soil and fertilizer N. Significant differences among genotypes were observed in grain yield and N uptake, agronomic N use efficiency [ANUE], apparent recovery [AR], The N efficient genotypes that produced high grain yield at both low and high levels of N were IR54790-B-B-38, BG380-2, BG90-2 (medium-duration), and IR3932-182-2 3-3-2, IR54853-B-B-318, and IR29723-88-2-3-3 (long-duration). Inefficient genotypes that produced low yields at low N levels but responded well to N application were IR58125-B-B-42, IR49457-33-1-2-2-2, and BG34-8 (medium-duration), and IR8192-200-3-3-1-1, IR21848-65-3-2-2, and PR106 (long-duration). IR20 (medium) and Palawan (long-duration) were N-inferior genotypes giving low yields at both low and high N levels. Increase in grain yield was highly correlated with N uptake (r^2=0.75**). The grain yield-N uptake relationship for individual genotypes indicated significant differences in slope and in the yield obtained with soil N. Differences in soil N were due to genotypic variation in N uptake and efficiency of use. The performance of efficient and inefficient genotypes over a range of soil and fertilizer N supply was consistent over three seasons of trials.

Hasanuzzaman *et al.* (2012) studied the response of hybrid rice to different levels of nitrogen and phosphorus. They noticed that the effect of nitrogen and phosphorus had significant variation in respect of yield contributing characters and yield.

2.2 Nutrients accumulation by rice genotypes

Nitrogen is the most essential element in determining the yield potential of intensified agricultural system. Additional doses of nitrogen are usually applied to increase grain yield (De Datta and Buresh, 1989). Nitrogen fertilizers are not used efficiently because rice is grown in an environment that is conducive to nitrogen losses through nitrification-denitrification, ammonia volatilization, run-off and leaching. The amount of nitrogen uptake and nitrogen use efficiency (NUE) of crop depends on the yield level and environmental conditions (Yoshida, 1983). Rice genotypes were reported to differ significantly in relation to nitrogen uptake, grain yield, nitrogen translocation efficiency and NUE (Borah and Deka, 1994). Rice genotypes were distinguished (Gourley *et al.,* 1993) as efficient, inefficient, and inferior types based on grain yield response in relation to nitrogen response. Pinto *et al.* (2001) identified N-use efficient rice genotypes under low level of available soil N and these efficient rice genotypes could be used in breeding programme to improve rice production in poor soils which would be useful for the resource poor farmers who have limited access to the use of N fertilizer.

Swain et al. (2006) conducted field experiments at Kasiadihi, Dhenkanal district, Orissa, for three years wet season 2001-03 to assess variability in N uptake and utilization by medium and late duration rice varieties. The N rates were 0, 40, 80 and 120 kg N/ha applied as urea in four equal splits at transplanting, active tiller initiation, panicle initiation and flowering stages. The grain yield response was up to 80 kg N/ha. The optimum grain yield attainable by the efficient medium duration varieties was 4.5 t/ha. The N efficient late duration varieties produced optimum grain yield of 5.8 t/ha. The relationship for total dry matter and grain yield production between N fertilized (40, 80 and 120 kg N/ha) and non-fertilized treatments were all significant, suggesting cultivar selection under optimum N fertilized conditions. The difference in optimum yield of the medium and late duration varieties was due to the differences in the amount of N uptake and its use efficiency by the plant for grain production. There was a curvilinear relationship between grain yield and N use efficiency for grain production. The relationship between N use efficiency for grain production and N contents of leaf, stem and grain at maturity was quadratic. The optimum plant N use efficiency of medium duration varieties was 49 kg grain/kg N uptake, achieved with leaf, stem and grain N contents of 10, 8 and 14 g/kg, respectively, at maturity. For late duration varieties, the optimum plant N use efficiency was 68 kg grain/kg N uptake and it was maintained with leaf and stem N content of 4.0 g/kg each and grain N content of 9.0 g/kg at maturity. The N content in plant organs could be the selection guide used to obtain efficient rice varieties.

Sudhakar *et al.* (2006) reported from the field experiment conducted on sandy clay-loam soil (Ustochrept) to assess the influence of graded fertility levels and silicon sources on yield and nutrient uptake by rice (Oryza sativa L.). Graded fertility levels up to 160-80-80-32-0.75kg/ha of N-P_2O_5-K_2O-S-Zn significantly increased grain and straw yields of rice. Highest nutrient uptake was associated with the highest fertility level of 200-100-100-40-1.00 kg/ha of N-P_2O_5-K_2O-S-Zn.

Fageria *et al*. (2010) studied on to evaluate influence of K on yield, K uptake and use efficiency of six upland rice genotypes grown on Brazilian Oxisol. The K rate used was zero (natural soil level) and 200 mg K kg^{-1} of soil. Shoot dry weight and grain yield were significantly influenced by K level and genotype treatments. However, K × genotype interactions were not significant, indicating similar responses of genotypes at two K levels for shoot dry weight and grain yield. Genotypes produced grain yield in the order of BRS Primavera > BRA 01596 > BRSMG Curinga > BRS 032033 > BRS Bonança > BRA 02582. Potassium concentration in shoot was about sixfold greater compared to grain, across two K levels and six genotypes.

Tayefe *et al.* (2011) evaluated with three rice cultivars (Hashemi, Kazemi, Khazar) to study the effects of nitrogen fertilizer on nitrogen use efficiency, yield and characteristics of nitrogen uptake in paddy soil in Guilan province, Iran. In this experiment, four treatments including: N1-control (no N fertilizer); N2- 30 kg ha^{-1} N (at transplanting time); N3- 60 kg ha^{-1} N (at transplanting, and tillering times); N4- 90 kg ha^{-1} N were compared. Results showed that total N uptake, physiological Nitrogen use efficiency (PNUE), apparent nitrogen recovery efficiency (ANRE) and agronomic nitrogen use efficiency (ANUE) was varied in different cultivars significantly and Khazar variety had the highest contents. Total N uptake, physiological N use efficiency (PNUE), agronomic nitrogen use efficiency (ANUE) was varied significantly with the increase the nitrogen. As total N uptake increased with increasing in N fertilizing contents but physiological N use efficiency (PNUE), agronomic nitrogen use efficiency (ANUE) decreased. There were significant differences in the effects of applying nitrogen fertilizer on nitrogen use efficiency and characteristics of nitrogen uptake.

Muthukumararaja *et al.* (2012) conducted an experiment to study effect of zinc on yield, zinc nutrition and zinc use efficiency of lowland rice. The results revealed that rice responded significantly to graded dose of zinc applied. The highest grain (37.53 g pot^{-1}) and straw yield (48.54 g pot^{-1}) was noticed at 5 mg Zn kg^{-1} which was about 100 % and 86% greater than control (no zinc) respectively. Similar effect was noticed on DMP. The highest zinc concentration and uptake in grain and straw and DTPA-Zn at all stages was noticed at 7.5 mg Zn kg^{-1}. The agronomic, physiological and agro-physiological apparent recovery and utilization efficiencies was highest at lower level of zinc application and decreased with Zn doses.

Pooniya *et al.* (2012) studied from a field experiment on the effects of summer green-manuring crops and zinc (Zn) fertilization on the productivity and economics of Basmati rice. They reported that a significantly higher benefit:cost ratio with SGMI and 2.0% ZEU ($ZnSO_4$ _H_2O). Overall, Sesbania aculeata green manuring and 2.0% ZEU ($ZnSO_4$ _H_2O) are excellent sources of N and Zn for improved productivity of Basmati rice.

2.3 Nutrients use efficiencies

Zhang *et al.* (2009) studied on effects of N fertilizer application rates on grain yield and physiological N use efficiency (PE) in relation to the accumulation and redistribution of biomass and N in rice (*Oryza sativa* L.) cultivars were studied at Nanjing Agricultural University, Nanjing, China. They reported that grain yields increased with the N application rate and attained plateau at 180 kg N ha^{-1} for rice cultivars at each site. Increasing N rate decreased PE for biomass and grain yield. Differences in biomass, N accumulation and N redistribution were observed at the post-heading stage among rice cultivars with differing NUEs.

Tayefe *et al.* (2011) evaluated the effects of nitrogen fertilizer on nitrogen use efficiency, yield and characteristics of nitrogen uptake in paddy soil in Guilan province, Iran . Results showed that the total N uptake increased with increasing in N fertilizing contents but physiological N use efficiency (PNUE), Agronomic Nitrogen use efficiency (ANUE) decreased. There were significant differences in the effects of applying nitrogen fertilizer on nitrogen use efficiency and characteristics of nitrogen uptake.

Fageria et *al.* (2011) conducted a field experiment for two years consecutive with the objective to evaluate 12 lowland rice genotypes for P use efficiency. The P rates used were 0, 22, 44, 66, and 88 kg P ha-1 (0, 50, 100, 150 and 200 kg P2O5 ha-1) applied to an Inceptisol. The genotypes used were BRS Jacana, CNAi 8860, BRS Fronteira, CNAi 8879, CNAi 8880, CNAi 8886, CNAi 8885, CNAi 8569, BRSGO Guara, BRS Alvorada, BRS Jaburu and BRS Bigua. There were significant and quadratic responses of genotypes to phosphorus fertilization. Adequate P rates for maximum grain yield varied from genotype to genotype. However, across 12 genotypes, maximum grain yield was obtained with the application of 54 kg P ha^{-1}. Genotype BRS Jacana was most efficient and genotype CNAi 8569 was most inefficient in P use efficiency. Agronomic efficiency (kg grain produced per kg P applied) was significantly decreased with increasing P rates in the range of 22 to 88 kg P ha^{-1}.

Arif *et al.* (2010) conducted a pot culture experiment to study the response of rice genotypes to various levels of K. The air-dried soil was mixed with the N, P and Zn fertilizers (applied @ 130, 70 & 12.5 kg ha-1 as urea, diammonium phosphate and ZnSO^4 [33%], respectively). Different K rates (0, 30, 60, 90 & 120 kg ha^{-1}) were applied to three rice genotypes previously screened and categorized for their K use efficiency *viz* IR-6 (low K-use efficient), Super basmati (medium K-use efficient) and genotype 99509 (high K-use efficient). Significant improvement in grain yield and yield components was observed with K application. Low K-use efficient genotype (IR-6) responded poorly in terms of grain yield to application of K. High K-use efficient genotype (99509) remained unaffected, whilst medium K-use efficient genotype (Super basmati) behaved moderately. Optimum K rate for maximum rice grain yield was found as 60 kg ha^{-1} for all the three rice genotypes and application beyond 60 kg K ha^{-1} had no further positive impact on various growth and yield parameters. The results implied that K-use efficient genotypes used the tissue K more efficiently.

Rahman *et al.* (2009) worked with broad bean-rice, hairy vetch-rice, naked barley-rice and fallow-rice cropping systems at Kyoto University Farm, Takatsuki, Japan during 2001-2003 to determine the effects of broad bean and hairy vetch on seasonal crop N accumulation, fertilizer N use efficiency (FNUE) and N recovery from rice-based cropping systems using 15N-labeled fertilizer. In 2002, FNUE was highest in hairy vetch-rice with N 40 kg ha^{-1} while in 2003 FNUE was highest in naked barley-rice with N 40 kg ha^{-1}. In broad bean-rice, plant nitrogen accumulation at maturity always increased and FNUE decreased in spite of increased grain yield of rice.

Jabbar *et al*. (2009) reported the results of a field experiment conducted in the 2005 wet season at the International Rice Research Institute (IRRI), Los Banos, Laguna, Philippines, to assess the differences in grain yield (GY) and nitrogen-use efficiency (NUE) of selected rice (Oryza sativa L.) genotypes, and to determine plant parameters that contribute to the improvement of NUE under irrigated and rainfed lowland conditions. Six upland, five rainfed, and eight irrigated rice genotypes were tested under two nitrogen (N) treatments (0 and 75 kg N ha^{-1}) and two water regimes (irrigated and rainfed lowland conditions). Significant differences among the genotypes were observed in grain yield, yield components, total aboveground plant N uptake (TNU), harvest index (HI), and NUE parameters. Irrigated conditions resulted in 52% higher grain yield and 51% higher TNU compared with rainfed conditions. The average yield gain due to N application was 540 kg ha^{-1} under irrigated conditions, and 484 kg ha^{-1} under rainfed conditions. The study identified GY, TNU, NUE, and HI as important plant parameters to identify N-efficient genotypes. The genotypes like PSB Rc80, CT6510-24-1-2, IR72, IR575114-PMI-5-B-1, and PSB Rc14 were performed well under rainfed conditions. These genotypes possess promising traits for improved N use and high grain yield. The most N-efficient genotypes selected in the experiment performed well inwater stress condition, indicating that they can be used in a wide variety of lowland environments.

Hassan *et al.* (2007) conducted the field experiment with three nutrient levels and five traditional *Aus* rice cultivars formed the treatments in the split plot design. Straw nitrogen (%), nitrogen uptake (straw, grain and total) and physiological nitrogen use efficiency (PNUE) showed significant differences due to variable nutrient levels at maturity while grain nitrogen per cent did not show significant difference. Gambir 2, Tarabali and Balam showed significantly higher PNUE. Goasail ranked the top in respect of grain nitrogen content.

Ohnishi *et al.* (1996) conducted experiments for improving nitrogen (N) use efficiency and yield of rainfed lowland rice, N management and cultivar at Ubon Ratchathani, Northeast Thailand. In the N experiment, Khao Dawk Mali 105 (KDML105), one of the leading cultivars in Northeast Thailand, was grown under different N management methods including different N rates in frequent split urea application and the use of organic matter and slow release fertilizer (SRF). In the cultivar experiment, 18 cultivars of different origins were compared for growth, yield and N uptake under irrigated and well-fertilized conditions. No water stress developed in any experiment. The leaf area index and dry weight increased and the harvest index decreased linearly with plant N uptake, irrespective of N management methods. Grain yield of KDML105 attained the maximum of 4 t ha^{-1} at the N uptake of about 40, 80 and 90 kg ha^{-1} at panicle initiation, heading and maturity, respectively. The frequent split N application and use of SRF improved the fertilizer N recovery efficiency (apparent fertilizer N uptake per unit applied N), although they did not substantially increase agronomic efficiency (increment of yield per unit applied N) compared with the results of previous workers. These results suggest that yield of KDML105 can be improved by optimizing the plant N uptake through increased fertilizer N recovery efficiency.

Among 18 cultivars tested, Urumamochi, Taichung65, Takanari, IR72 and Taino70 had higher yields despite their shorter growth durations compared with KDML105. Although the physiological efficiencies of N use in terms of plant dry matter production (dry matter produced per unit N uptake) were similar among all cultivars, those in terms of yield were higher in Taichung65, Takanari, IR72 and Taino70 than in KDML105 because of their higher harvest indices. Thus, these four cultivars are suggested to have two important characteristics required for cultivars adapted to rainfed lowland conditions in Northeast Thailand: the shorter growth duration to avoid late season drought and the higher physiological efficiency of N use for yield production.

Muthukumararaja *et al***.** (2012) studied on the effect of zinc on yield, zinc nutrition and zinc use efficiency of lowland rice. The results revealed that rice responded significantly to graded dose of zinc applied. The highest grain (37.53 g pot^{-1}) and straw yield (48.54 g pot^{-1}) was noticed at 5 mg Zn kg^{-1} which was about 100 % and 86% greater than control (no zinc) respectively. Similar effect was noticed on DMP. The highest zinc concentration and uptake in grain and straw and DTPA-Zn at all stages was noticed at 7.5 mg Zn kg^{-1}. The agronomic, physiological and agrophysiological apparent recovery and utilization efficiencies was highest at lower level of zinc application and decreased with Zn doses.

2.4 Evaluation of genotypes under rainfed condition

The recent rice crisis is a major concern to most of the countries in south and south-east Asia. The best strategy to deal with this crisis is to ensure that production increases faster than demand. This extra production must come from less favourable area as there is limited scope to enhance production in irrigated areas or expanding the area under rice. Drought is the number one factor limiting rice productivity in rainfed areas. In eastern India, approximately 16.2 million ha of rainfed rice grown under upland and lowland. The recent drought in India has contributed to the shortfall in production around 15 million tonnes.

Haefele *et al.* (2006) reported from studies undertaken to understand the soil fertility and fertilizer response in northeast Thailand and thereby provide a basic framework for improved nutrient management of rainfed lowland rice. They were analyzed an existing database on fertilizer trials conducted between 1995 and 1997 at eight different sites in northeast Thailand, Average annual rainfall across sites and seasons was 1300 mm, but half of all rainfed trials (12 of 23) experienced substantial water stress during the growing season. Average grain yield in N-omission plots was low (1.6 t ha^{-1}), even when compared with that of rainfed lowlands in neighboring Lao PDR. Nitrogen was clearly the most limiting element, whereas PK treatments increased yields significantly in only 6 out of 78 observations. Average agronomic efficiency of applied N was good (16 kg grain kg $^{-1}$ N), but highly variable among sites. Better nutrient availability improved crop performance at all field water stress levels occurring at the trial sites. However, yield reductions caused by water stress seemed to interact with the level of nutrient supply, that is, absolute yield differences between different fertilizer treatments decreased with increasing water stress. They concluded that efficient fertilizer use in rainfed rice of northeast Thailand can be achieved, but that existing uniform recommendations do not provide farmers with much useful advice. Therefore, they proposed a set of basic guidelines for improved nutrient management, which, after further efforts of all stakeholders involved, could contribute to increased system productivity.

Dey *et al.* (2010) conducted experiments by growing rice cultivars in rainfed upland and exposed to sever water stress (soil moisture 5.5-9.0 %) for ten days to evaluate them for drought tolerance and revealed that the cultivars IET 18645 and IET 18460 could maintain their assimilatory surface area 130.2 and 135.1 cm^2 plant^{-1} respectively even though their assimilatory unit rolled to a maximum degree (leaf rolling score were 9 in both the cases) indicating their ability to escape drought through this mechanism. They were also able to maintain water potential in the leaf tissues to a desired extent. The cv. IET 18460 produced satisfactory grain yield of 2.18 t ha^{-1}. However, cvs. IET 18645 and IET 18460 were at par with Bandana and all the three cvs, significantly registered higher grain yield compared to the check cv. Govind (1.13t ha^{-1}) IET 18645 , IET 17509 and IET 18781 exhibited strong dormancy behavior. IET 18645 showed longest grain dormancy of 28 days. Hence, IET 18645 can be identified as a potential donor for both drought tolerant upland rice cultivar and also longest grain dormancy.

Serraj *et al*. (2009) suggested that drought is the major constraint to rice production in rainfed areas across Asia and sub-Saharan Africa and in this context, increasing irrigation is generally not a viable option for alleviating drought problems in rainfed rice-growing systems. It is therefore critical that genetic management strategies for drought focus on maximum extraction of available soil moisture and its efficient use in crop establishment and growth to maximize biomass and yield. Extensive genetic variation for drought resistance exists in rice germplasm. However, the current challenge is to decipher the complexities of drought resistance in rice and exploit all available genetic resources to produce rice varieties combining drought adaptation with high yield potential, quality, and resistance to biotic stresses. The strategy described here aims at developing a pipeline for elite breeding lines and hybrids that can be integrated with efficient management practices and delivered to rice farmers. This involves the development of high-throughput, high-precision phenotyping systems to allow genes for yield components under stress to be efficiently mapped and their effects assessed on a range of drought-related traits, and then moving the most promising genes into widely grown rice mega-varieties, while scaling up gene detection and delivery for use in marker-aided breeding.

Haefele *et al.* (2008) stated that water and nutrient availability are two major constraints in most rice-based rainfed shallow lowland systems of Asia and both stresses interact and contribute to the low productivity and widespread poverty in this environment. Therefore, the study was conducted to improve the understanding of interaction between the two factors and to identify varietal characteristics beneficial for productivity in a water- and nutrient-limited rice environment, with screening 19 rice genotypes adapted to different rice environments under two water and two nutrient treatments during the wet season of 2004 and 2005 in southern Luzon, Philippines. Across all genotypes tested and in comparison with the irrigated control, rainfed conditions reduced grain yield of the treatment without N application by 69% in 2004 and by 59% in 2005. The mean nitrogen fertilizer response was highest in the dry season of 2004 and the rainfed treatment, indicating that water stress had no effect on fertilizer response. Nitrogen application reduced the relative yield loss to 49% of the irrigated treatment in 2004 and to 52% of the irrigated treatment in 2005. Internal efficiency of N (IEN) and recovery efficiency of applied N (REN) were significantly different between genotypes, but were not affected by water availability (REN) or by water and nutrient availability (IEN). In contrast, grain yield and total N uptake were affected by cultivar, N and water availability. Therefore, germplasm for rainfed environments should be screened under conditions of limited and good nitrogen and water supplies..

Zubaer *et al.* (2007) conducted an experiment to evaluate the effect of water stress at different growth stages of different T. aman rice genotypes. The experiment was conducted in CRD with three replications putting three rice genotypes at three water levels (100%, 70% and 40% FC). Plant height, numbers of tillers/hill, no. of filled grains /panicle, total dry matter/hill, 1000 grain weight , grain yield and harvest index were decreased with increasing water stress levels. Responses of the rice genotypes in different water stress varied significantly. There had been different degree of reduction to the yield contributing characters for the stress. Binadhan 4 performed better in producing tillers, leaves, total dry matter, and yield under stress than the other two genotypes. Basmoti showed the highest plant height but medium total dry matter, 1000 grain weight and yield. RD 2585 showed the lowest total dry matter, 1000 grain weight, and yield under water stress.

According to Ouk *et al.* (2006) the breeding programs for rainfed lowland rice in Southeast Asia and Eastern India focus on adaptation to a range of drought conditions as drought is a major constraint for rice production in the rainfed lowlands. However, a method of selection of drought tolerant genotypes has not been established and is considered to be one of the constraints faced by rice breeders. Drought response index (DRI) is based on grain yield adjusted for variation in potential yield and flowering date, and has been used recently, but its consistency among drought environments and hence its usefulness is not certain. In order to establish a selection method and subsequently to identify donor parents for drought resistance breeding, a series of experiments with 15 contrasting genotypes was conducted under well-watered and managed drought conditions at two sites for 5 years in Cambodia. Water level in the field was recorded and used to estimate the relative water level (WL_{REL}) around flowering as an index of the severity of water deficit at the time of flowering for each entry. This was used to determine if DRI or yield reduction was due to drought tolerance or related to the amount of available water at flowering, *i.e.* drought escape.

Grain yield reduction due to drought ranged from 12 to 46%. The drought occurred mainly during the reproductive phase, while four experiments had water stress from the early vegetative stage. There was significant variation for water availability around flowering among the nine experiments and this was associated with variation in mean yield reduction. Genotypic variation in DRI was consistent among most experiments, and genotypic mean DRI ranged from −0.54 to 0.47 (LSD 5% = 0.47). Genotypic variation in DRI was not related to WL_{REL} around flowering in the nine environments. It is concluded that selection for DRI under drought conditions would allow breeders to identify donor lines with high drought tolerance as an important component of breeding better adapted varieties for the rainfed lowlands; two genotypes were identified with high DRI and low yield reduction and were subsequently used in the breeding program in Cambodia.

Pantuwan *et al.* (2002) conducted experiments in drought-prone northeast Thailand to study the magnitude and consistency of yield responses of diverse, rainfed lowland rice genotypes to drought stress environments and also to examine ways to identify genotypes that confer drought resistance. One hundred and twenty-eight genotypes were grown under non-stress and four different types of drought stress conditions. The relationship of genotypic variation in yield under drought conditions to genetic yield potential, flowering time and flowering delay, and to a drought response index (DRI) that removed the effect of potential yield and flowering time on yield under stress was examined. Drought stress that developed prior to flowering generally delayed the time of flowering of genotypes, and the delay in flowering was negatively associated with grain yield, fertile panicle percentage and filled grain percentage. Genotypes with a longer delay in flowering time had extracted more water during the early drought period, and as a consequence, had higher water deficits. They were consistently associated with a larger yield reduction under drought and in one experiment with a smaller DRI. Genotypes, however, responded differently to the different drought stress conditions and there was no consistency in the DRI estimates for the different genotypes across the drought stress experiments. The results indicate that with the use of irrigated-control and drought test environments, genotypes with drought resistance can be identified by using DRI or delay in flowering. However, selections will differ depending on the type of drought condition.

The inconsistency of the estimates in DRI and flowering delay across different drought conditions reflects the nature of the large genotype-by-environment interactions observed for grain yield under various types of drought in rainfed lowland conditions.

Pantuwan *et al.* (2002) studies that responses of rice genotypes to drought stress may be different when characteristics of the drought stress environments differ. The performance of 128 genotypes was examined under irrigation and four different types of drought stress, to determine genotypic consistency in yield and factors determining yields under different drought stress conditions. The different drought conditions were mild drought during grain filling, short and severe drought at flowering, prolonged severe drought during the reproductive to grain filling, and prolonged mild drought during vegetative and grain filling. Genotypic grain yield under mild stress conditions was associated with yield under irrigated conditions, indicating the importance of potential yield in environments where the yield reduction was less than 50%. However, yields under irrigated conditions differed over time and locations. Under prolonged or severe drought conditions, flowering time was an important determinant of grain yield. Earlier flowering genotypes escaped the severe stress and had higher grain yields indicating large genotype by environment (G×E) interactions which have implications for plant breeding even for mild stress. It is suggested that variations in flowering time, potential yields and drought patterns need to be considered for development of drought-resistant cultivars using specific physiological traits.

Pantuwan *et al.* (2002) conducted experiments in drought-prone northeast Thailand to study the magnitude and consistency of yield responses of diverse, rainfed lowland rice genotypes to drought stress environments and also to examine ways to identify genotypes that confer drought resistance. One hundred and twenty-eight genotypes were grown under non-stress and four different types of drought stress conditions. The relationship of genotypic variation in yield under drought conditions to genetic yield potential, flowering time and flowering delay, and to a drought response index (DRI) that removed the effect of potential yield and flowering time on yield under stress was examined. Drought stress that developed prior to flowering generally delayed the time of flowering of genotypes, and the delay in flowering was negatively associated with grain yield, fertile panicle percentage and filled grain percentage. Genotypes with a longer delay in flowering time had extracted more water during the early drought period, and as a consequence, had higher water deficits. They were consistently associated with a larger yield reduction under drought and in one experiment with a smaller DRI. Genotypes, however, responded differently to the different drought stress conditions and there was no consistency in the DRI estimates for the different genotypes across the drought stress experiments. The results indicate that with the use of irrigated-control and drought test environments, genotypes with drought resistance can be identified by using DRI or delay in flowering. However, selections will differ depending on the type of drought condition. The inconsistency of the estimates in DRI and flowering delay across different drought conditions reflects the nature of the large genotype-by-environment interactions observed for grain yield under various types of drought in rainfed lowland conditions.

Materials and Methods

CHAPTER – III

MATERIALS AND METHODS

The present study entitled “Nutrient use efficiency of drought tolerant rice genotype as influenced by fertility levels under rainfed condition” was carried out during *Kharif* season, 2012 at the Instructional Farm, Indira Gandhi Krishi Vishwavidhyalaya, Raipur (CG). The details of experiment, prevailing weather conditions, material used and techniques adopted during the course of study have been briefly presented as under

3.1: Geographical situation

The experiment conducted at the Instructional farm of Indira Gandhi Krishi Vishwavidyalaya, Raipur is located at eastern part of Raipur city and situated in mid-eastern part of Chhattisgarh state and lies at 21^0 16‘N latitude and 81^0 36’ E longitudes with an attitude of 298.56 meter above the mean sea level.

3.2: Climatic and Weather Condition

The region comes under sub-humid climatic condition. The average annual rainfall of the area is 1250 mm. Major amount of precipitation occurs from the month of June to September (about 3-4 Months) which is the main rice growing season. The hottest and coolest months are May and December, respectively. Weekly meteorological data recorded from meteorological observatory during the crops period presented in Fig

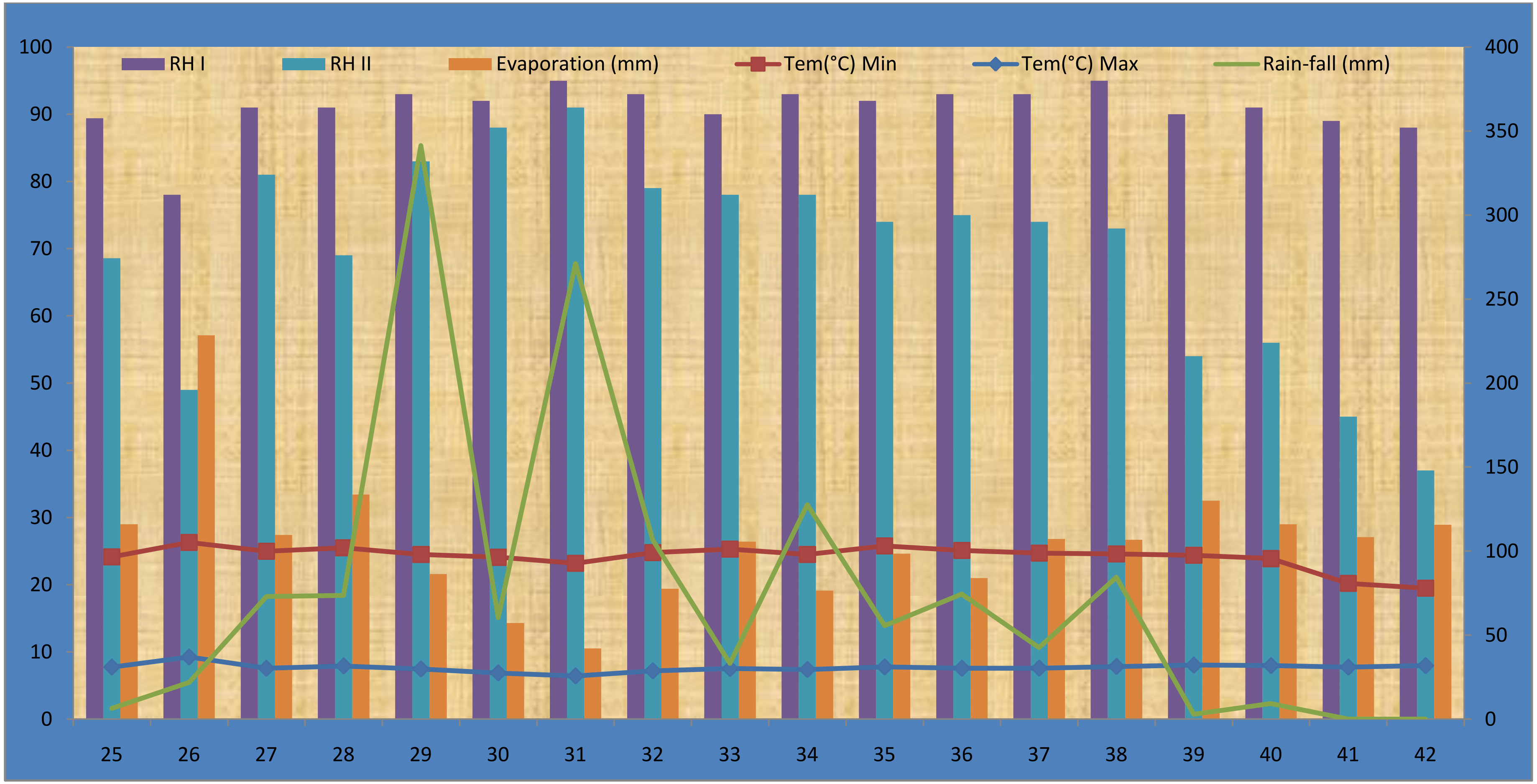


Fig.3.1 Weekly Meteorological data prevailing during crop growth period (*Kharif* 2012).

3.3: Soil

The soil of the experimental field comes under the order of Vertisol. This soil is locally known as *Kanhar* and identified as Arang II series. It is clayey in texture, dark brown to black in color, neutral to alkaline in reaction due to presence of lime concretion in lower horizon. The soil is deep to 1-1.5 meter. The structure varied from coarse angular blocky to massive and cloddy and in few cases from prismatic or columnar. Soil is represented as typical *fine montmorillonitic, hyperthermic, Udic Chromustert.* Some physico-chemical properties of experimental soil are presented in Table 3.1.

Table 3.1: Physico-chemical properties of experimental soil

Properties	**Rating/value**
pH (1:2.5)	7.34
EC (dSm^{-1})	0.26
CEC (c mol (p^{+}) kg^{-1})	38.21
Organic C (g kg^{-1})	5.80
Available N (kg ha^{-1})	273
Available P (kg ha^{-1})	14.78
Available K (kg ha^{-1})	616
Available Zn (ppm)	2.70
Available Fe (ppm)	5.97
Available Mn (ppm)	6.38
Available Cu (ppm)	1.37
Mechanical analysis	
Sand (%)	20
Silt (%)	36
Clay (%)	44
Textural class	Clay

3.4: Experimental details

The layout plan of the experiment is shown in Fig. 3.2

Location : Instructional Farm, I.G.K.V. Raipur (C.G.)

Season : *Kharif*, 2012

Soil : *Vertisols*

Crop : Rice

Seed rate : 80 kg ha^{-1}

Establishment method : Line seeding

Plot Size : 10 m^{2} (4m x 2.5m)

Row spacing : 20 cm

Date of sowing : 20-06-2012

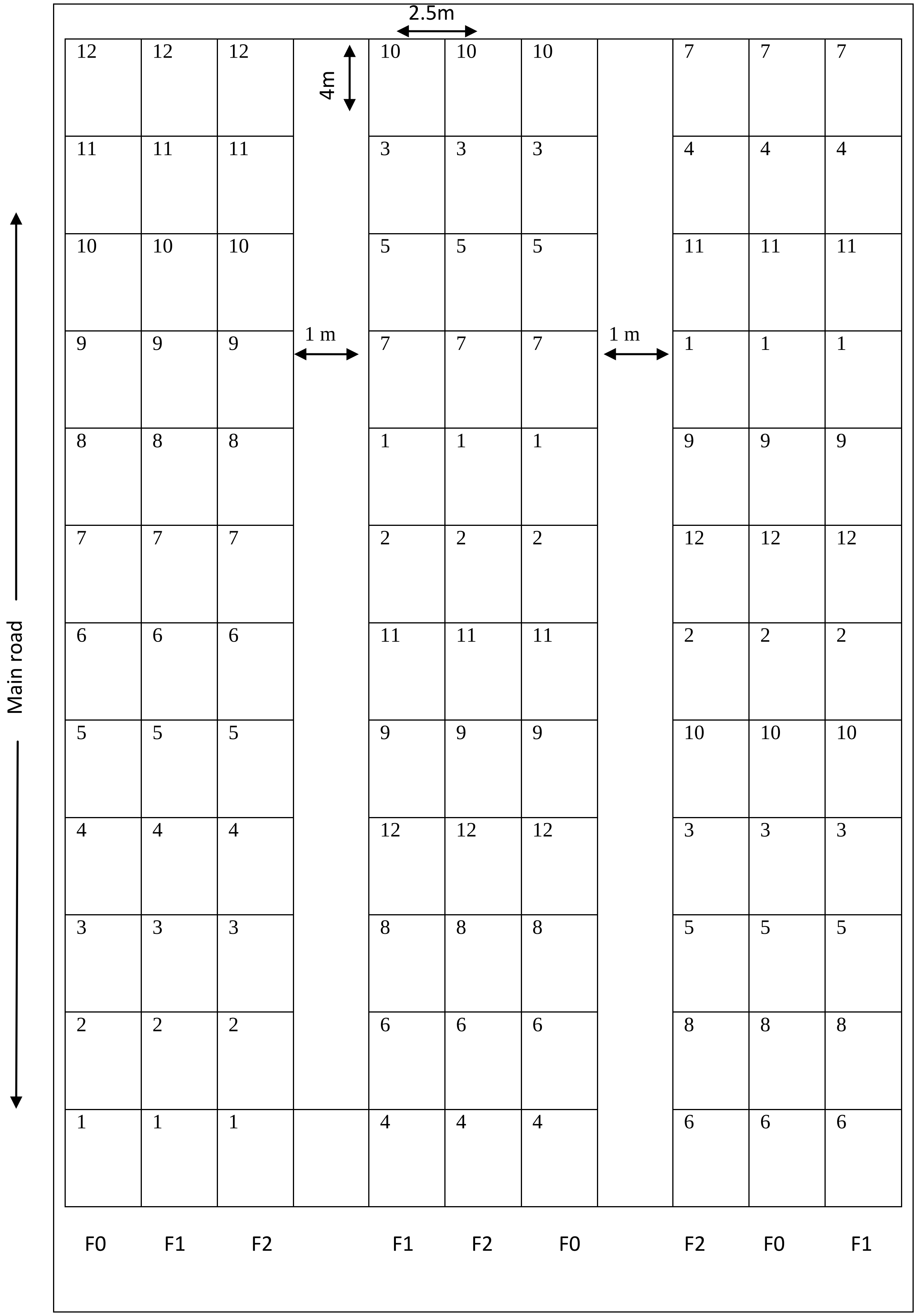
Date of harvesting : 18-10-2012

Treatment : Twelve (rice genotypes)

Replications : Three

Design : Split Plot Design

Treatment details



12	12	12		10	10	10		7	7	7
11	11	11		3	3	3		4	4	4
10	10	10		5	5	5		11	11	11
9	9	9		7	7	7		1	1	1
8	8	8		1	1	1		9	9	9
7	7	7		2	2	2		12	12	12
6	6	6		11	11	11		2	2	2
5	5	5		9	9	9		10	10	10
4	4	4		12	12	12		3	3	3
3	3	3		8	8	8		5	5	5
2	2	2		6	6	6		8	8	8
1	1	1		4	4	4		6	6	6
F0	F1	F2		F1	F2	F0		F2	F0	F1

Twelve rice genotypes having drought tolerance character were selected and taken as treatments as per the details given below:

Table: 3.2 Treatment details

Symbol No.	**Main plot:** Fertilizer treatment (three)
F_0	Low (00:00:00 NPK kgha^{-1})
F_1	Medium (45:30:20 NPK kgha^{-1})
F_2	High (90:60:40 NPK kgha^{-1})

Symbol No.	**Sub plot:** Rice genotype (Twelve)
V-1	IR-83388-B-B-108-3
V-2	IR-83388-B-B-129-3
V-3	IR-82589-B-B-84-3
V-4	IR-83383-B-B-129-4
V- 5	R-RF-65
V-6	IR-83377-B-B-93-3
V-7	R-RF-69
V-8	IR-83383-B-B-141-2
V-9	IBD-I (Local entry)
V-10	R-RF-85 (Local entry)
V-11	IR-64
V-12	MTU-1010

3.5: Field Preparation

The Experimental field was prepared by two cross ploughing followed by one harrowing and leveling by tractor drawn equipments.

3.6 Experimental materials

The crop was maintained with the same nutrient inputs in all the treatments. Three recommended fertility levels of nutrient were used as main plot i.e. 0-0-0, 45-30-20 and 90-60-40 kg N-P_2O_5-K_2O/ha and treated low, medium and high fertilty levels. 1/3 rd dose of N and full doses of P and K were applied as basal and remaining 2/3rd N was applied in two equal splits at early tillering and PI stage.

3.7 Observation Recorded

3.7.1: Pre-Sowing and post harvest soil analysis:-

3.7.1.1 pH

Soil pH was determined in 1:2.5 soils - water suspension after stirring for 30 minutes, by glass electrode pH meter as suggested by Piper (1967).

3.7.1.2 Electrical conductivity

The soil samples used for pH determination were allowed to settle overnight and electrical conductivity of the supernatant liquid was determined by solu-bridge as described by Black (1965).

3.7.1.3 Organic carbon

Organic C was determined by Walkley and Black’s rapid titration method (1934) as described by Piper (1967).

3.7.1.4 Cation Exchange Capacity (CEC)

The CEC of the soil was determined by leaching the soil with neutral normal ammonium acetate as described by Black (1965).

3.7.1.5 Mechanical analysis (soil texture*)*

The mechanical analysis of soil was carried out by International Pipette Method as described by Piper (1966).

3.7.1.6 Available nitrogen

Soil available nitrogen was determined by alkaline permanganate method as described by Subbiah and Asija (1956).

3.7.1.7 Available phosphorus

Soil available phosphorus was extracted by $NaHCO_3$ (pH 8.5) as described by Olsen *et al*. (1954) and P in extract was determined by ascorbic acid method using spectrophotometer (Watnabe and Olsen 1965).

3.7.1.8 Available potassium

Soil potassium was extracted by neutral normal ammonium acetate and determined with the help of flame photometer as described by Muhr *et al*. (1965).

3.7.1.9 Available micronutrients

The micronutrients Zn, Cu, Fe and Mn were extracted by using 0.005 M diethylene triamine penta acetic acid, 0.01 M calcium chloride dehydrate and 0.1 M trithanol amine buffered at pH 7.3 (Lindsay and Norvell, 1978) and content were analyzed using atomic absorption spectrophotometer (AAS).

3.7.2 Plant growth and yield analysis

3.7.2.1 Plant height (cm)

Plant height was measured from the base of the plant to the tip of the longest leaf. It was measured with standard meter stick in two-labeled hill at harvesting stage. The plant height was expressed in cm.

3.7.2.2 Total and effective tillers/m^2

The total number of panicle bearing effective tiller in one m^2 was recorded at the time of harvest.

3.7.2.3 Grain and straw yields

The seed and straw yields were recorded after harvesting the crop from net plot of 10 m^2 from each plot. The crop bundles were allowed to sun dry, weighted, threshed then finally seeds were cleaned and yields were recorded for all plots.

3.7.2.4 Test weight :

Thousand cleaned dried seeds were counted from each treatment and their weights were recorded by electronic balance.

3.7.3 Plant chemical analysis

Grain and straw samples were taken at harvest and allowed to sun dry for a week, then grinded and used for chemical analysis for different parameters as under

3.7.3.1 Nitrogen content

Nitrogen content analysis of grain and straw sample was done by taking 0.25 gm uniform prepared sample in digestion tube. 1 gm salt mixture (K_2SO_4 and $CuSO_4.5H_2O$ in the ratio of 10:1) was added in the tube. 05 ml. of concentrated H_2SO_4 acid was added and material was digested at 350 ^{0}C in digestion block till the material becomes colorless. Then the nitrogen in digested material was distilled by automatic KEL plus system.

3.7.3.2 Phosphorus and Potassium

One gram of grain and straw samples was taken in digestion tube and add 10 ml of di-acid mixture (Concentrated HNO_3 , $HClO_4$ and H_2SO_4 in the ratio of 9:4:1). The material was digested at 150 ^{0}C in KEL plus digestion block till the material become colorless. The digested material was transferred in to 100 ml volumetric flask by repeated washing with distilled water and made up the volume up to the mark. This digested material was used for the estimation of P and K content analysis as given below:

Phosphorus content

Phosphorus content was determined by vanadomolybdo-phosphoric acid yellow color complex method as described by Jackson (1973) - An aliquot of 10 ml was taken, 10 ml of vanado-molebdate yellow reagent was added and volume was made up to 50 ml. After half an hour color intensity was measured by Spectrophotometer.

Potassium content

Potassium content was determined by flame photometer as described by Chapman and Pratt (1961).- An aliquot of 10 ml was taken and made up to volume of 50 ml in volumetric flask and potassium content was determined by flame photometer.

3.7.3.3 Micronutrient (Fe,Mn, Cu and Zn) content in grain and straw (mg kg^{-1})

Paddy grain and Straw samples collected from individual plots at harvest were separately analyzed for Micronutrient (Fe, Mn Cu and Zn) content by atomic absorption spectroscopy (Lindsay and Norvell, 1978).

3.7.3.4 Nutrient uptake

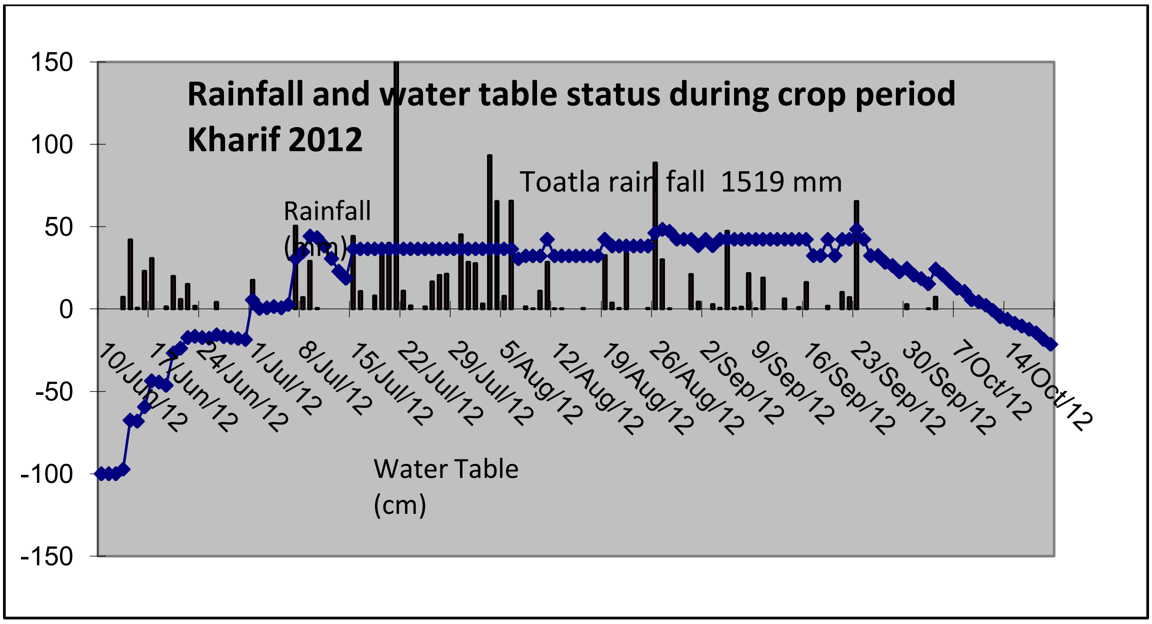
Nitrogen, phosphorus, potassium and micronutrient (Zn, Cu, Fe and Mn) uptake in seed and straw yields were computed by multiplying their respective nutrient contents with yields using of following formula:

Nutrient uptake (kg ha^{-1}) in seed and straw = Seed and straw yield x Nutrient content

3.8 Nutrients use efficiency: - It was calculated by using the following formula

$$\text{NUE} = \frac{\text{Uptake from treated plot} - \text{Uptake from control plot}}{\text{Total fertilizer applied}}$$

3.9 : Rainfall and field water status during the crop period



Piezometers were installed around the experimental field in 30, 60 and 100 cm depth to measure the water table during the crop season. Total 1519 mm rain received during the crop period up to 14th Oct., 2012. The *kharif* season 2012 was very favourable and well distributed rainfall was received and hence no terminal drought was faced by the crop up to the crop maturity

3.10 Statistical analysis

The data obtained under various characters were tabulated and statistically analysised for their test of significance using split plot design. Analysis of variance for different variables was computed with the help of IRRISTAT package version 2.1.

Results and Discussion

CHAPTER-IV

RESULTS AND DISCUSSIONS

A field experiment was conducted during *Kharif* season, 2012 in the Department of Soil Science and Agricultural Chemistry at Instructional Farm of the Indira Gandhi Krishi Vishwavidyalaya, Raipur for evaluation of nutrient use efficiency of drought tolerant rice genotypes as influenced by fertility levels under rainfed condition.

The results presented in this chapter on growth and yield parameters, nutrients uptake and their efficiencies and micronutrients content in soil and plant material have been discussed as below:

4.1: Crop growth and yield parameters

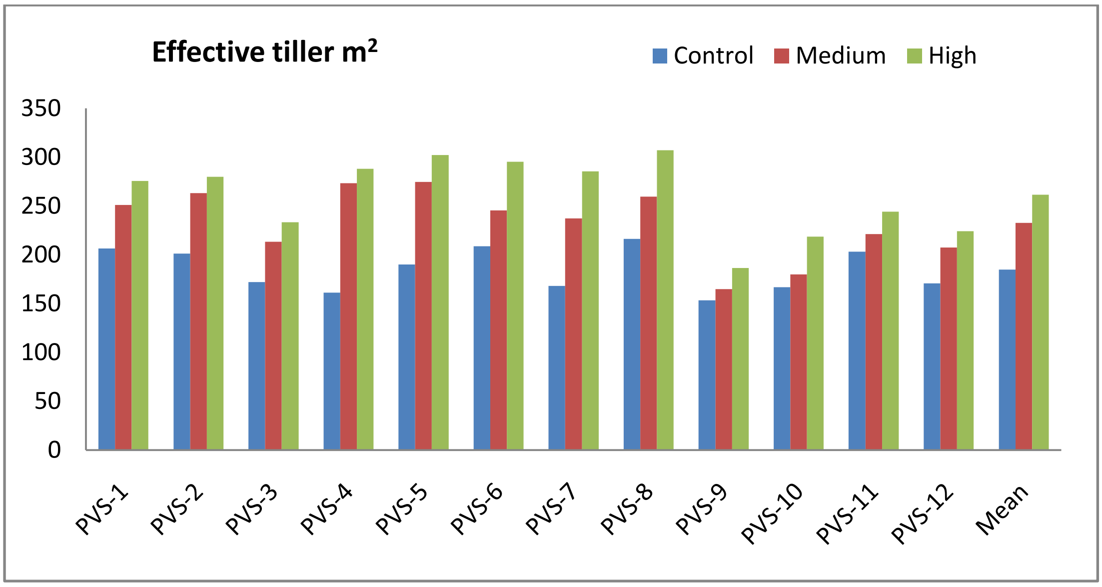
4.1.1: Effective tillers

Table 4.1.1: Effect of rice genotypes and fertility levels on effective tillers/m^2 of rice.

S.No.	Rice genotype	Symbol	Fertility levels			Mean
			Control	Medium	High	
1.	IR-83388-B-B-108-3	V1	206^{ab}	251^{abc}	276^{b}	$244^{b\text{-}e}$
2.	IR-83388-B-B-129-3	V2	201^{bc}	263^{ab}	280^{ab}	248^{bcd}
3.	IR-82589-B-B-84-3	V3	172^{cd}	213^{de}	233^{c}	206^{hi}
4.	IR-83383-B-B-129-4	V4	161^{d}	273^{a}	288^{ab}	$241^{c\text{-}f}$
5.	R-RF-65	V5	239^{a}	275^{a}	312^{a}	275^{a}
6.	IR-83377-B-B-93-3	V6	209^{ab}	$245^{a\text{-}d}$	295^{ab}	250^{bc}
7.	R-RF-69	V7	168^{d}	$237^{b\text{-}e}$	285^{ab}	$230^{d\text{-}g}$
8.	IR-83383-B-141-2	V8	216^{ab}	260^{ab}	307^{ab}	261^{ab}
9.	IBD-I-85 (Local entry)	V9	153^{d}	165^{g}	186^{d}	169^{l}
10.	R-RF-85 (Local entry)	V10	167^{d}	180^{fg}	219^{c}	189^{ijk}
11.	IR-64	V11	203^{bc}	221^{cde}	244^{c}	223^{fgh}
12	MTU-1010	V12	171^{cd}	207^{ef}	224^{c}	201^{ij}
	F-MEAN		189	233	262	228

CD $_{\text{at } 5\%}$ for T**=17.624 F**=14.217 FT**= 30.532

Fig. No. 4.1.1: Effect of rice genotypes and fertility levels on effective tillers/m^2 of rice



4.1.1: Effect of rice genotypes and fertility levels on effective tillers/m^2

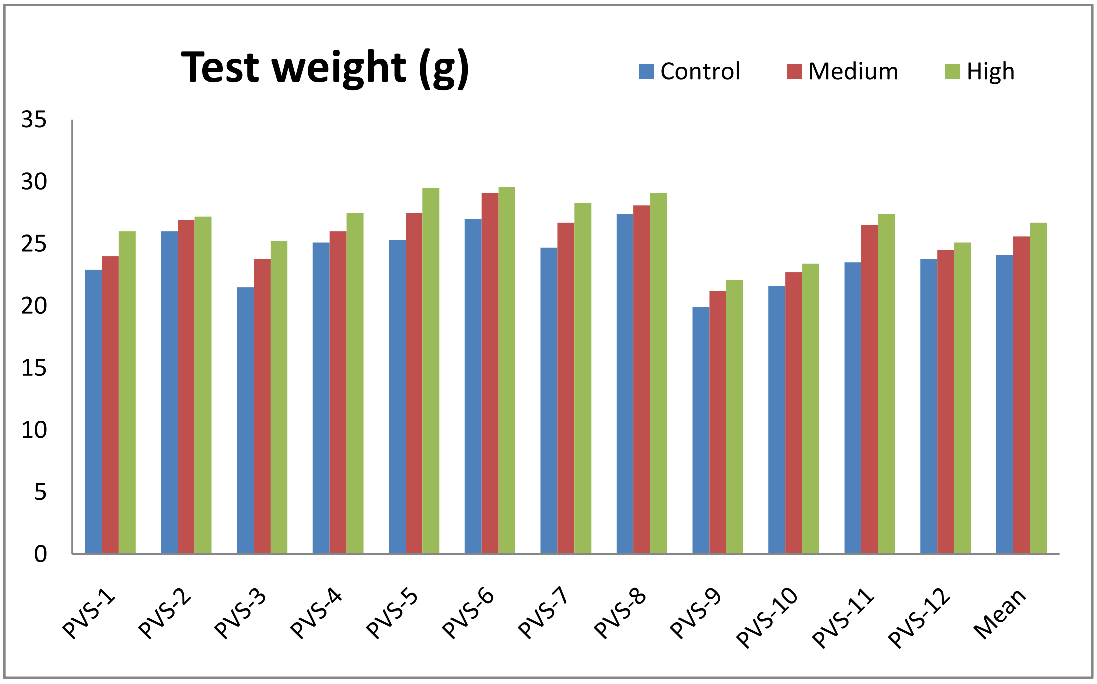
The results (Table 4.1.1 & Fig. 4.1.1) showed that the No. of effective tillers was significantly varied under different genotypes. The number of highest effective tillers were recorded in variety R-RF-65 (V5) followed by IR-83383-B-141-2 (V8), IR-83377-B-B-93-3 (V6), IR-83388-B-B-129-3 (V2), IR-83388-B-B-108-3 (V1), IR-83383-B-B-129-4 (V4), R-RF-69 (V7), IR-64 (V11), IR-82589-B-B-84-3 (V3), MTU-1010 (V12), R-RF-85 (Local entry) (V10), and IBD-I-85 (Local entry) (V9). The number of effective tillers was also significantly increased with increasing fertility levels from control to high. The effective tillers of different genotype recorded were ranged from 186-312 m^{-2} with average of 262 m^{-2} in high fertility level followed by 164-275 m^{-2} with average of 233 m^{-2} in medium fertility level and from 153-238 m^{-2} with average of 188 m^{-2} under lowest fertility level (control). Different rice genotypes have responded to the graded dose of fertilizer application created from low to high fertility level. Similar findings were also reported by Udin *et al.* (2008).and Tabar (2012).

Table 4.1.2: Effect of rice genotypes and fertility levels on Test weight

S.No.	Rice genotype	Symbol	Fertility levels			Mean
			Control	Medium	High	
1.	IR-83388-B-B-108-3	V1	22.9^{cd}	24^{def}	26.0^{bcd}	24.3^{e}
2.	IR-83388-B-B-129-3	V2	26^{ab}	26.9^{abc}	27.2^{abc}	26.7^{bc}
3.	IR-82589-B-B-84-3	V3	21.5^{de}	23.8^{ef}	25.2^{cd}	23.5^{ef}
4.	IR-83383-B-B-129-4	V4	25.1^{abc}	26^{b-e}	27.5^{abc}	26.2^{bc}
5.	R-RF-65	V5	25.3^{abc}	27.5^{ab}	29.5^{a}	27.4^{ab}
6.	IR-83377-B-B-93-3	V6	27^{a}	29.1^{a}	29.6^{a}	28.5^{a}
7.	R-RF-69	V7	24.7^{abc}	26.7^{a-d}	28.3^{ab}	26.6^{bc}
8.	IR-83383-B-141-2	V8	27.4^{a}	28.1^{ab}	29.1^{a}	28.2^{a}
9.	IBD-I-85(Local entry)	V9	19.9^{e}	21.2^{g}	22.1^{e}	21.1^{g}
10.	R-RF-85 (Local entry)	V10	21.6^{de}	22.7^{fg}	23.4^{de}	22.6^{f}
11.	IR-64	V11	23.5^{bcd}	26.5^{a-d}	27.4^{abc}	25.8^{cd}
12	MTU-1010	V12	23.8^{bcd}	24.5^{c-f}	25.1^{cd}	24.5^{de}
	F-MEAN		24.1	25.6	26.7	25.4

$CD_{\text{at }5\%}$ for T**= 1.506 F**=0.750 FxT= NS

Fig. No. 4.1.2: Effect of rice genotypes and fertility levels on test weight



4.1.2: Effect of rice genotypes and fertility levels on Test weight.

The test weight of rice was significantly affected under different genotypes and fertility levels (Table 4.1.2 & Fig. 4.1.2). Genotype IR-83377-B-B-93-3 (V6) had the highest seed weight that was on par with IR-83383-B-141-2 (V8) and R-RF-65 (V5) which had statistically at par results. The lowest test weight was observed under IBD-I-85 (V9).

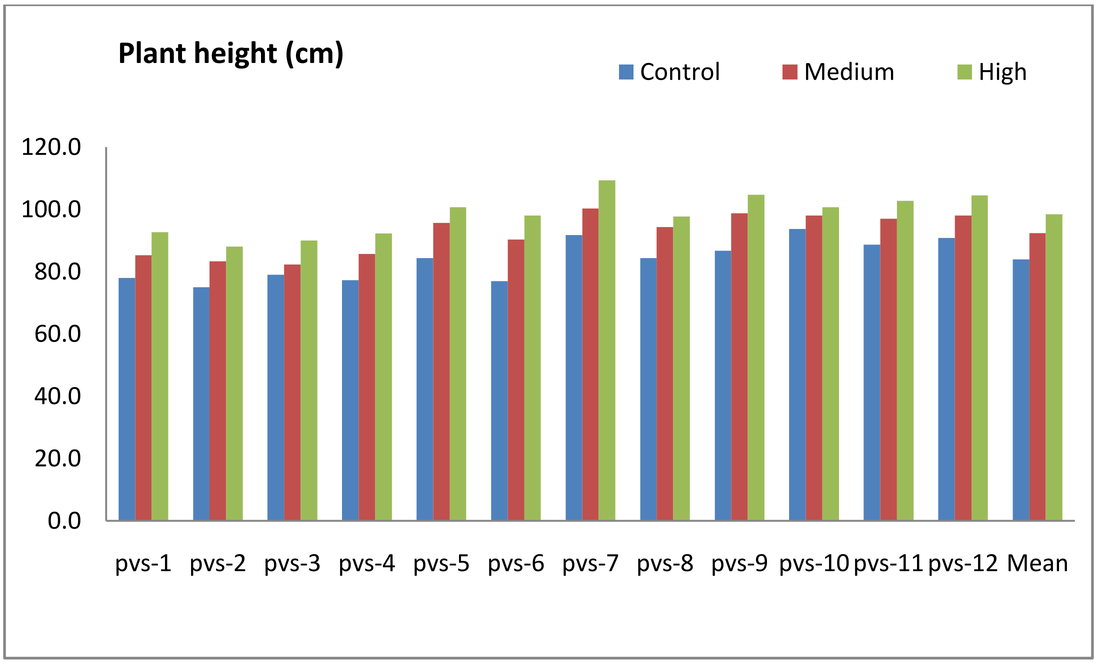
Test weight was significantly increased with increased fertility levels (Table 4.1.2 & Fig. 4.1.2). It was highest in high fertility level (26.7 g) followed by medium fertility level (25.6 g) and lowest in low fertility level (24.1 g). Interaction between rice genotypes and fertility levels were observed to be significant effect. Results reported by Tabar *et al*. (2012) and Ahmed *et al.* (2005) for increased test weight due to increased N fertility levels also confirm the findings of the experiment.

Table 4.1.3 : Effect of rice genotypes and fertility levels on Plant height.

S.No.	Rice genotype	Symbol	Fertility levels			Mean
			Control	Medium	High	
1.	IR-83388-B-B-108-3	V1	78^{de}	85.3^{cd}	92.7^{de}	85.3^{ef}
2.	IR-83388-B-B-129-3	V2	75^{e}	83.3^{d}	88^{e}	82.1^{f}
3.	IR-82589-B-B-84-3	V3	79^{de}	82.3^{d}	90^{e}	83.8^{f}
4.	IR-83383-B-B-129-4	V4	77.3^{e}	85.7^{cd}	92.3^{de}	85.1^{ef}
5.	R-RF-65	V5	84.3^{cd}	95.7^{ad}	100.7^{dc}	93.6^{cd}
6.	IR-83377-B-B-93-3	V6	77^{e}	90.3^{bc}	98^{bcd}	88.4^{e}
7.	R-RF-69	V7	91.7^{ab}	100.3^{a}	109.3^{a}	100.4^{a}
8.	IR-83383-B-141-2	V8	84.3^{cd}	94.3^{ab}	97.7^{cd}	92.1^{d}
9.	IBD-I-85 (Local entry)	V9	86.7^{bc}	98.7^{a}	104.7^{ab}	96.7^{abc}
10.	R-RF-85 (Local entry)	V10	93.7^{a}	98^{a}	100.7^{bc}	97.5^{ab}
11.	IR-64	V11	88.7^{abc}	97^{ab}	102.7^{abc}	96.1^{bc}
12	MTU-1010	V12	90.8^{abc}	98^{a}	104.5^{abc}	97.8^{ab}
	F-MEAN		83.900	92.400	98.400	91.6

CD $_{\text{at } 5\%}$ for T**= 3.5 F**=1.7 FxT= NS

Fig. No. 4.1.3 : Effect of rice genotypes and fertility levels on Plant height.



4.1.3: Effect of rice genotypes and fertility levels on Plant height

The effects of genotypes and fertility levels on plant height were found significant (Table 4.1.3 & Fig. 4.1.3). Plant height was significantly higher with R-RF-69 (V7) genotype over other genotypes like IR-64 (V11), R-RF-65 (V5), IR-83383-B-141-2 (V8), IR-83377-B-B-93-3 (V6), IR-83388-B-B-108-3 (V1), IR-83383-B-B-129-4 (V4), IR-82589-B-B-84-3 (V3) and IR-83388-B-B-129-3 (V2). Although the genotypes like MTU-1010 (V12), R-RF-85 (Local entry) (V10), R-RF-85 (Local entry) (V9) were also statistically at par in plant height with that of R-RF-69 (V7) genotype.

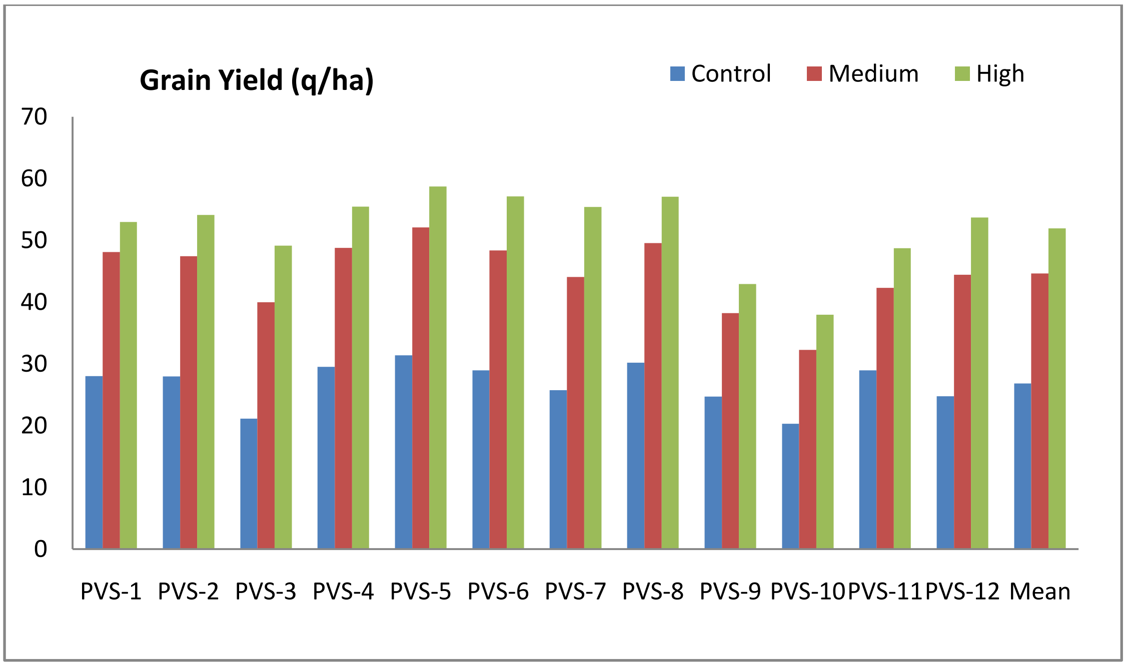
High fertility level recorded significantly higher plant height (98.400 cm) followed by medium fertility level (92.400 cm) and low fertility level (83.900 cm**).** Interaction between rice genotypes and fertility levels were found significant. The variable in plant heights by different fertility levels may be due to their genotypic variation where some genotypes has an identical plant heights. Plant height of rice genotypes increased with increasing levels of fertilizer application was also reported by Awan *et al.* (2011) and Ahmad *et al.* (2005).

Table 4.1.4 : Grain yields (q/ha) of different rice genotypes in relation to fertility levels.

S.No.	Rice genotype	Symbol	Fertility levels			Mean
			Control	Medium	High	
1.	IR-83388-B-B-108-3	V1	28.01 ^{abc}	48.09 ^{abc}	52.98 ^{bcd}	43.03 $^{b-f}$
2.	IR-83388-B-B-129-3	V2	27.98 ^{abc}	47.44 ^{abc}	54.13 ^{ab}	43.18 ^{bcde}
3.	IR-82589-B-B-84-3	V3	21.10 ^{de}	39.98 ^{de}	49.16 ^{cd}	36.75 ^{j}
4.	IR-83383-B-B-129-4	V4	29.50 ^{abc}	48.75 ^{abc}	55.46 ^{ab}	44.57 ^{bcd}
5.	R-RF-65	V5	31.39 ^{a}	52.10 ^{a}	58.71 ^{a}	47.40 ^{a}
6.	IR-83377-B-B-93-3	V6	28.95 ^{abc}	48.38 ^{abc}	57.12 ^{ab}	44.82 ^{abc}
7.	R-RF-69	V7	25.73 ^{bcd}	44.04 ^{cd}	55.38 ^{ab}	41.72 ^{efg}
8.	IR-83383-B-141-2	V8	30.21 ^{ab}	49.57 ^{ab}	57.05 ^{ab}	45.61 ^{ab}
9.	IBD-I-85 (Local entry)	V9	24.68 ^{cde}	38.20 ^{e}	42.93 ^{e}	35.27 ^{jk}
10.	R-RF-85 (Local entry)	V10	20.29 ^{e}	32.24 ^{f}	37.95 ^{f}	30.16 ^{l}
11.	IR-64	V11	28.97 ^{abc}	42.30 ^{de}	48.71 ^{d}	39.99 ^{ghi}
12	MTU-1010	V12	24.77 ^{cde}	44.45 ^{bcd}	53.70 ^{abc}	40.97 ^{efgh}
	F-MEAN		26.80	44.63	51.939	41.12

CD $_{at\ 5\%}$ for T**= 2.62 F**=1.83 FT*= 4.71

Fig. No. 4.1.4 : Grain yields (q/ha) of different rice genotypes in relation to fertility levels.



4.1.4: Grain yields (q/ha) of different rice genotypes in relation to fertility levels.

The data presented in Table 4.1.4 and depicted graphically in Fig.4.1.4 revealed that grain yields were significantly influenced by different rice genotypes and fertility levels. The average grain yield was significantly higher in R-RF-65 (V-5) as compared to those of other genotypes in the order of IR-83383-B-B-129-4 (V4), IR-83388-B-B-129-3 (V2) , IR-83388-B-B-108-3 (V1), R-RF-69 (V7), MTU-1010 (V12) , IR-64 (V11) , IR-82589 B-B-84-3 (V3). Grain yield of R-RF-65 (V-5) was also exhibited statistically on par with IR-83383-B-141-2 (V8) and IR-83377-B-B-93-3 (V6). The grain yield of 30.160 q ha^{-1} was recorded by R-RF-85 (Local entry) (V10), which was significantly lower than all other genotypes. It is interesting to note that rice genotype R-RF-65 has responded up to the highest fertility level however, its performance under low fertility level having no fertilizer application was also remarkable.

Fertility levels were also significantly increased the yield of different rice genotypes as shown in the Table 4.1.4 & Fig. 4.1.4. The highest rice yield of 51.939 q ha^{-1} was recorded under high soil fertility level (F2) followed by 44.628 q ha^{-1} in medium soil fertility level (F1) and the lowest 26.798 q ha^{-1} in low soil fertility level (F0). Interaction effect of rice genotypes with fertility levels was also found to be significant.

The grain yields of different rice genotypes did not suffer with water stress due to even distribution of rainfall throughout the crop period. Therefore, better performance of rice genotypes as compared to water stress condition in terms of grain yields recorded with increasing level of fertility status.

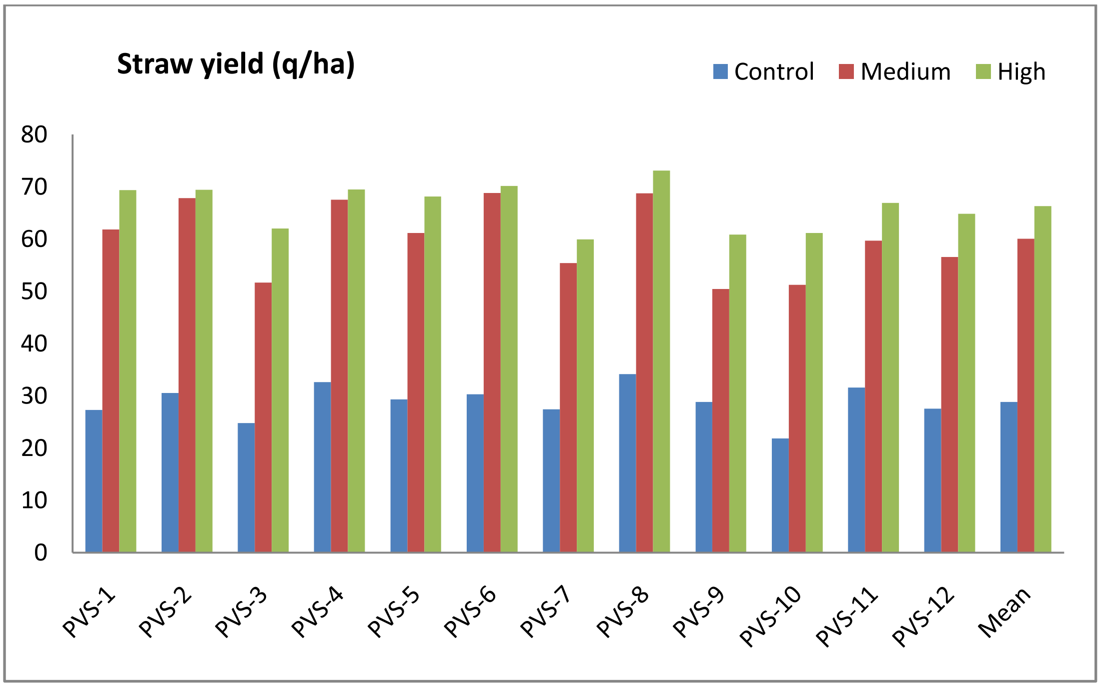
The findings of increased paddy yields by the different fertility levels are also in consonance with the results of Udin *et al.* (2013), Fageria *et al.* (2011) Metwally *et al.* (2011) and Awan *et al*. (2011), who reported increase in paddy yield of rice as the rates of NPK increased.

Table 4.1.5: Effect of rice genotypes and fertility levels on Straw yield attributes of rice.

S.No.	Rice genotype	Symbol	Fertility levels			Mean
			Control	Medium	High	
1.	IR-83388-B-B-108-3	V1	27.318 ^{abc}	61.823 ^{abc}	69.322 ^{abc}	52.821 ^{bc}
2.	IR-83388-B-B-129-3	V2	30.528 ^{ab}	67.805 ^{ab}	69.393 ^{abc}	55.908 ^{ab}
3.	IR-82589-B-B-84-3	V3	24.820 ^{bc}	51.680 ^{d}	62.015 ^{cde}	46.172 ^{de}
4.	IR-83383-B-B-129-4	V4	32.608 ^{ab}	67.520 ^{ab}	69.453 ^{abc}	56.527 ^{ab}
5.	R-RF-65	V5	29.338 ^{abc}	61.165 ^{bc}	68.108 $^{a-d}$	52.870 ^{bc}
6.	IR-83377-B-B-93-3	V6	30.318 ^{ab}	68.820 ^{a}	70.147 ^{ab}	56.428 ^{ab}
7.	R-RF-69	V7	27.408 ^{abc}	55.408 ^{cd}	59.913 ^{e}	47.576 ^{de}
8.	IR-83383-B-141-2	V8	34.165 ^{a}	68.738 ^{a}	73.108 ^{a}	58.670 ^{a}
9.	IBD-I-85 (Local entry)	V9	28.838 ^{abc}	50.420 ^{d}	60.840 ^{de}	46.699 ^{de}
10.	R-RF-85 (Local entry)	V10	21.830 ^{c}	51.248 ^{d}	61.153 ^{de}	44.743 ^{e}
11.	IR-64	V11	31.568 ^{ab}	59.680 ^{c}	66.912 $^{a-e}$	52.720 ^{bc}
12	MTU-1010	V12	27.550 ^{abc}	56.528 ^{cd}	64.843 $^{b-e}$	49.640 ^{cd}
	F-MEAN		28.857	60.069	66.267	51.731

CD $_{\text{at 5\%}}$ for T**=3.881 F**=2.674 FxT=NS

Fig. No. 4.1.5: Effect of rice genotypes and fertility levels on Straw yield attributes of rice.



4.1.5: Effect of rice genotypes and fertility levels on Straw yield attributes of rice.

The data on effect of rice genotypes and fertility levels on straw yield are presented in Table 4.1.5 & Fig. 4.1.5 and revealed that IR-83383-B-141-2 (V8) accumulated significantly higher straw yield (58.670 q ha^{-1}) followed by R-RF-65 (V5), IR-83388-B-B-108-3 (V1), IR-64 (V11), MTU-1010 (V12), R-RF-69 (V7), IBD-I-85 (Local entry) (V9), IR-82589-B-B-84-3 (V3), R-RF-85 (Local entry) (V10). Rice genotypes IR-83383-B-B-129-4 (V4), IR-83377-B-B-93-3 (V6), IR-83388-B-B-129-3 (V2) had no significant difference with IR-83383-B-141-2 (V8). The results on straw yields of different genotypes did not match with that of grain yields recorded which may be due to variable grain straw ratio genotypic characters.

Straw yield of rice cultivars significantly increased with increase in the fertility levels. High soil fertility level produced maximum straw yield (66.267 q ha^{-1}) followed by medium soil fertility level (60.069 q ha^{-1}) and low fertility level (28.857 q ha^{-1}).

Genotypes had significant effect on the growth and yield attributes and among them, R-RF-65 (V5) recorded the higher growth and yield attributes i.e. total tiller, effective tiller and their combined effect resulted the maximum rice yield. Superiority of R-RF-65 (V5) over other varieties may also seems to be on account of higher root and shoot growth, leaf area index, and efficient translocation of metabolites towards grain formation.

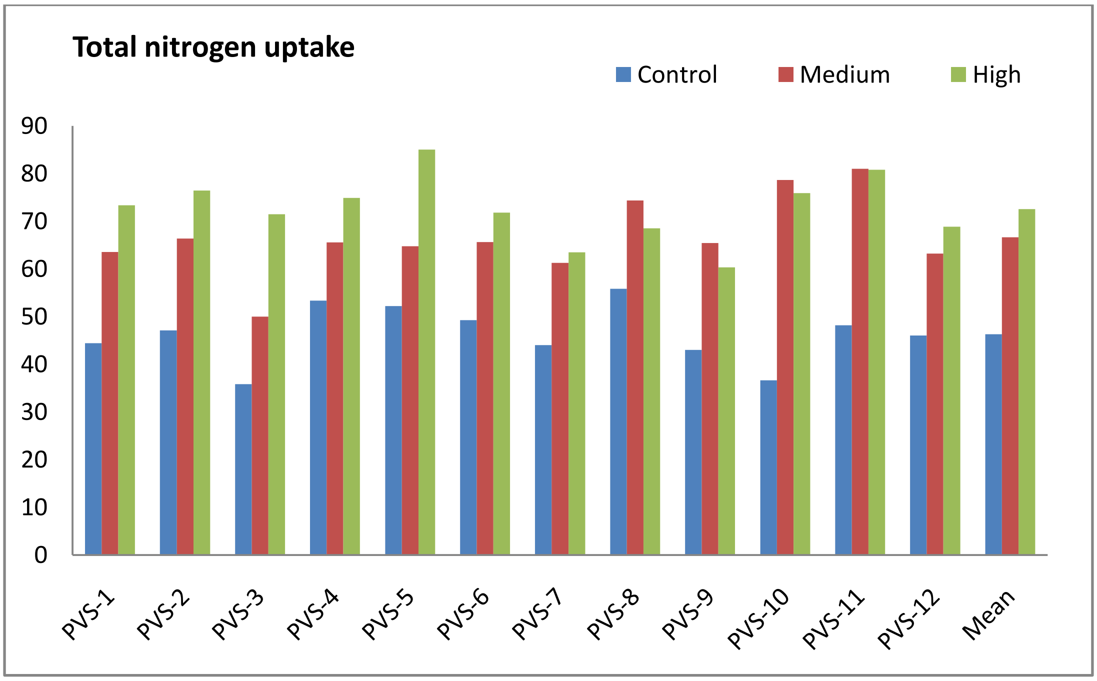
The findings of increased paddy straw yields by the different fertility levels are also in consonance with the results of Fageria *et al.* who reported increase in paddy yield of rice as the rates of NPK increased.

Table 4.2.1 : Effect of rice genotypes and fertility levels on total nitrogen uptake (kg/ha).

S.No.	Rice genotype	Symbol	Fertility levels			Mean
			Control	Medium	High	
1.	IR-83388-B-B-108-3	V1	44.428 $^{b-e}$	63.578 ^{c}	73.343 ^{bc}	60.449 $^{d-h}$
2.	IR-83388-B-B-129-3	V2	47.143 ^{abc}	66.408 ^{bc}	76.468 ^{abc}	63.339 $^{b-f}$
3.	IR-82589-B-B-84-3	V3	35.860 ^{e}	49.985 ^{d}	71.443 ^{bcd}	52.429 ^{jkl}
4.	IR-83383-B-B-129-4	V4	53.343 ^{ab}	65.580 ^{bc}	74.893 ^{bc}	64.605 ^{bcd}
5.	R-RF-65	V5	52.213 ^{abc}	64.738 ^{bc}	85.033 ^{a}	67.328 ^{ab}
6.	IR-83377-B-B-93-3	V6	49.240 ^{abc}	65.610 ^{bc}	71.820 ^{bcd}	62.223 $^{c-g}$
7.	R-RF-69	V7	44.020 $^{b-e}$	61.283 ^{c}	63.483 ^{de}	56.262 $^{h-k}$
8.	IR-83383-B-141-2	V8	55.823 ^{a}	74.357 ^{ab}	68.500 ^{cde}	66.227 ^{abc}
9.	IBD-I-85 (Local entry)	V9	43.033 ^{cde}	65.450 ^{bc}	60.348 ^{e}	56.277 ^{hij}
10.	R-RF-85 (Local entry)	V10	36.635 ^{de}	78.658 ^{a}	75.885 ^{abc}	63.726 ^{bcde}
11.	IR-64	V11	48.173 ^{abc}	81.010 ^{a}	80.838 ^{ab}	70.007 ^{a}
12	MTU-1010	V12	46.023 $^{a-d}$	63.233 ^{c}	68.833 ^{cde}	59.362 $^{e-i}$
	F-MEAN		46.327	66.657	72.574	61.853

CD $_{\text{at 5\%}}$ for T**=4.925 F**= 6.776 FxT**= 10.561

Fig. No. 4.2.1 : Effect of rice genotypes and fertility levels on total nitrogen uptake (kg/ha).



4.2.1 : Effect of rice genotypes and fertility levels on total nitrogen uptake (kg/ha).

Total nitrogen uptake was significantly affected by different rice genotypes and fertility levels (Table 4.2.1& Fig. 4.2.1). Among the genotypes, highest N uptake was observed in IR-64 (V11) which was similar to those of two other genotypes i.e. R-RF-65 (V5), IR-83383-B-141-2 (V8). Total N uptake in these three genotypes had significantly higher values as compared to those of others like IR-83383-B-B-129-4 (V4), R-RF-85 (Local entry) (V10), IR-83388-B-B-129-3(V2), IR-83377-B-B-93-3 (V6), IR-83388-B-B-108-3 (V1), MTU-1010 (V12), IBD-I-85 (Local entry) (V9) , R-RF-69 (V7) and IR-82589-B-B-84-3 (V3).

Total nitrogen uptake (Table 4.2.1 & Fig. 4.2.1) was significantly increased with application of increasing doses of fertilizers from low to high and application of high fertilizer accumulated significantly higher nitrogen (72.574 kg ha^{-1}) followed by medium (66.66 kg ha^{-1}) and low (46.33 kg ha^{-1}) in without fertilizer treatment.

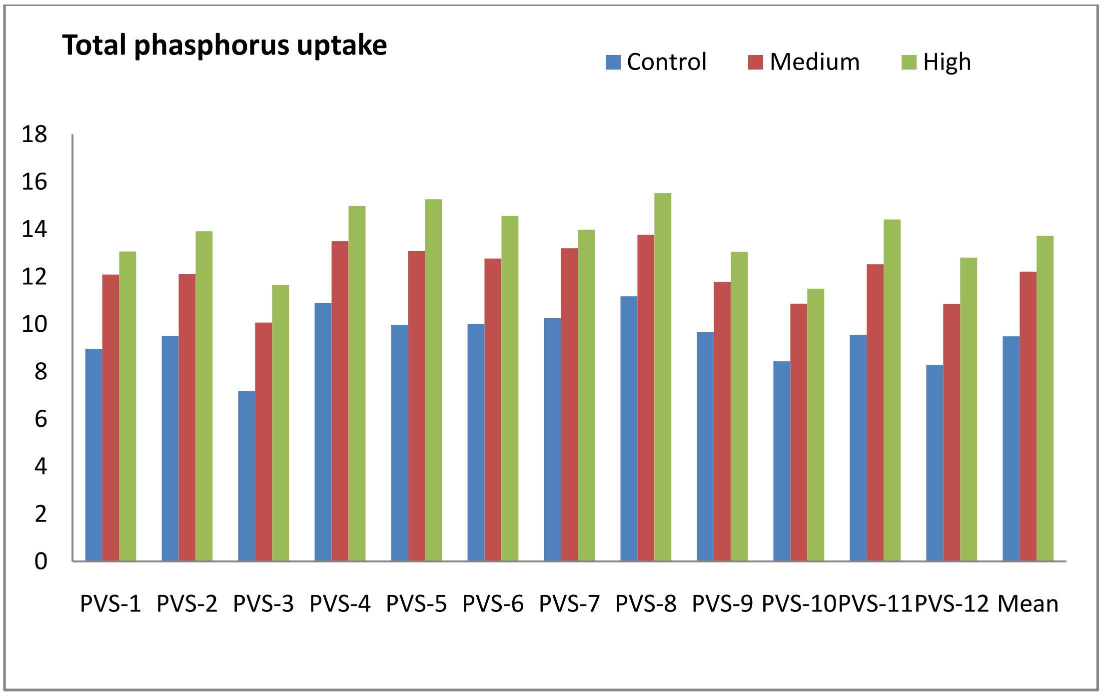
The N uptake was increased due to the better availability of nitrogen in soil and their transport to the plant from the soil and availability of nitrogen enhanced by application of higher doses of fertilizer. Interaction between rice genotypes and fertility levels found as significant. Similar result was also reported by Tayefe *et al.* (2011), Fageria *et al.* (2011) and Singh *et al.* (2010).

Table 4.2.2 : Effect of rice genotypes and fertility levels on total phosphorus uptake (kg/ha).

S.No.	Rice genotype	Symbol	Fertility levels			Mean
			Control	Medium	High	
1.	IR-83388-B-B-108-3	V1	8.953 ^{bc}	12.090 ^{abc}	13.068 ^{bcd}	11.370 ^{ef}
2.	IR-83388-B-B-129-3	V2	9.503 ^{abc}	12.108 ^{abc}	13.918 ^{abc}	11.843 ^{cde}
3.	IR-82589-B-B-84-3	V3	7.172 ^{d}	10.065 ^{d}	11.643 ^{d}	9.627 ^{h}
4.	IR-83383-B-B-129-4	V4	10.885 ^{a}	13.488 ^{ab}	14.983 ^{a}	13.118 ^{ab}
5.	R-RF-65	V5	9.967 ^{abc}	13.070 ^{ab}	15.255 ^{a}	12.764 ^{abc}
6.	IR-83377-B-B-93-3	V6	10.018 ^{abc}	12.758 ^{ab}	14.560 ^{ab}	12.445 ^{bcd}
7.	R-RF-69	V7	10.260 ^{ab}	13.203 ^{ab}	13.980 ^{abc}	12.481 ^{bc}
8.	IR-83383-B-141-2	V8	11.178 ^{a}	13.763 ^{a}	15.515 ^{a}	13.485 ^{a}
9.	IBD-I-85 (Local entry)	V9	9.655 ^{abc}	11.778 ^{bc}	13.045 ^{bcd}	11.493 ^{def}
10.	R-RF-85 (Local entry)	V10	8.432 ^{cd}	10.868 ^{cd}	11.498 ^{d}	10.266 ^{gh}
11.	IR-64	V11	9.552 ^{abc}	12.523 ^{abc}	14.408 ^{abc}	12.161 $^{b-e}$
12	MTU-1010	V12	8.280 ^{cd}	10.850 ^{cd}	12.800 ^{cd}	10.643 ^{fg}
	F-MEAN		9.488	12.213	13.723	11.808

CD $_{\text{at } 5\%}$ for T**= 0.870 F**=0.792 FxT= NS

Fig. No. 4.2.2 : Effect of rice genotypes and fertility levels on total phosphorus uptake (kg/ha).



4.2.2: Effect of rice genotypes and fertility levels on total phosphorus uptake (kg/ha).

The effects of rice genotypes and fertility levels on total phosphorus uptake was found to be significant (Table 4.2.2 & Fig. 4.2.2), The genotypes IR-83383-B-141-2 (V8), IR-83383-B-B-129-4 (V4) and R-RF-65 (V5) were statistically at par and significantly higher than IR-64 (V11) , IR-83388-B-B-129-3 (V2) , IBD-I-85 (Local entry) (V9) , IR-83388-B-B-108-3 (V1) , MTU-1010 (V12), R-RF-85 (Local entry) (V10) and IR-82589-B-B-84-3 (V3). The varieties IR-83383-B-B-129-4 (V4) was also statistically at par with R-RF-65 (V5) followed by R-RF-69 (V7) and IR-83377-B-B-93-3 (V6). P uptake increased with increasing fertilizer application from low to high fertility level. Application of high fertility level produced higher phosphorus uptake (13.723 kg ha^{-1}) followed by medium fertility level (12.213 kg ha^{-1}) and lowest in low fertility level (9.488 kg ha^{-1}).

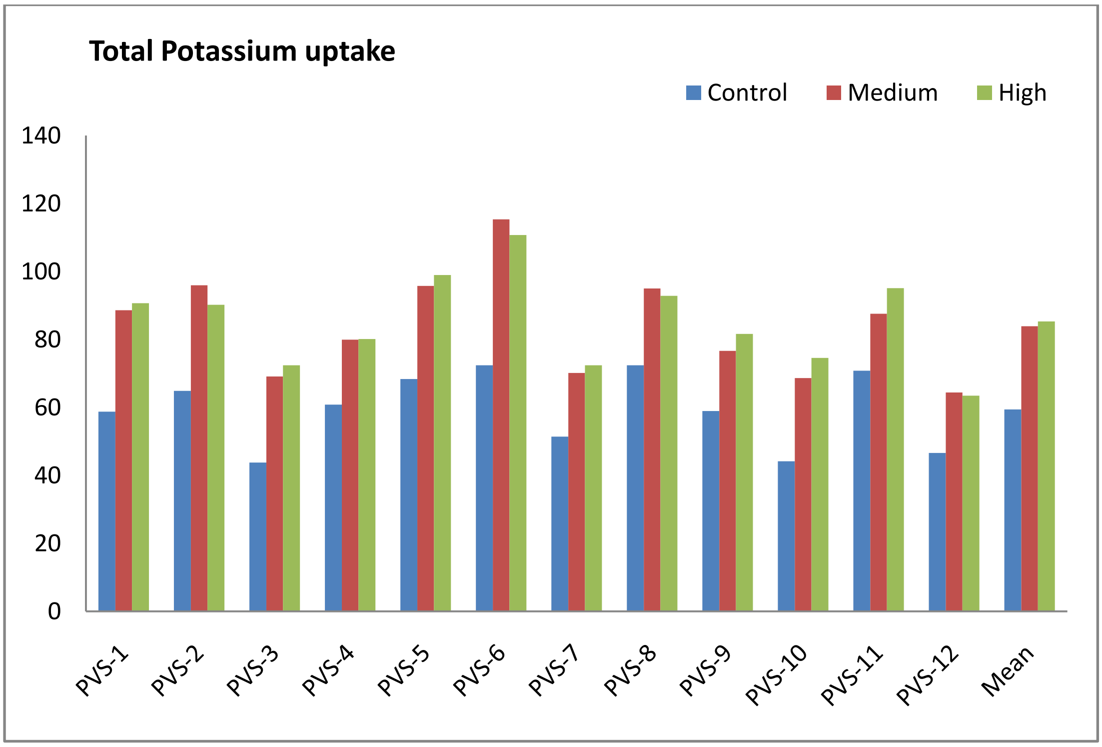
The phosphorus uptake being a function of biomass production, it was significantly increased due to increase in grain and straw yields along with their concentration in plant and with increasing N and P application levels in soil. Plants absorb proportionately more nitrogen and phosphorus from the pool of available with higher dose of application. Patel *et al*., 1997 and Bharde *et al*. (2003) also reported the synergistic effect of N in availability of P and K. Interaction between rice genotypes and fertility levels was found to be non-significant. Similar findings were also reported by Sudhakar *et al.* (2009) and Singh *et al*. (2010).

Table 4.2.3 : Effect of rice genotypes and fertility levels on total Potassium uptake (kg/ha).

S.No.	Rice genotype	Symbol	Fertility levels			Mean
			Control	Medium	High	
1.	IR-83388-B-B-108-3	V1	58.753 ^{bc}	88.580 ^{bc}	90.648 ^{bcd}	79.327 ^{cd}
2.	IR-83388-B-B-129-3	V2	64.912 ^{ab}	95.913 ^{b}	90.240 ^{bcd}	83.688 ^{bc}
3.	IR-82589-B-B-84-3	V3	43.768 ^{d}	69.080 ^{ef}	72.390 ^{ef}	61.746 ^{f}
4.	IR-83383-B-B-129-4	V4	60.848 ^{abc}	79.898 ^{cde}	80.143 ^{de}	73.629 ^{de}
5.	R-RF-65	V5	68.373 ^{ab}	95.740 ^{b}	98.962 ^{b}	87.692 ^{b}
6.	IR-83377-B-B-93-3	V6	72.440 ^{a}	115.325 ^{a}	110.760 ^{a}	99.508 ^{a}
7.	R-RF-69	V7	51.370 ^{cd}	70.145 ^{ef}	72.397 ^{ef}	64.638 ^{f}
8.	IR-83383-B-141-2	V8	72.403 ^{a}	95.033 ^{b}	92.790 ^{bc}	86.742 ^{b}
9.	IBD-I-85 (Local entry)	V9	58.895 ^{bc}	76.638 ^{de}	81.595 ^{cde}	72.376 ^{e}
10.	R-RF-85 (Local entry)	V10	44.130 ^{d}	68.673 ^{ef}	74.530 ^{ef}	62.444 ^{f}
11.	IR-64	V11	70.808 ^{a}	87.515 ^{bcd}	95.120 ^{b}	84.481 ^{bc}
12	MTU-1010	V12	46.600 ^{d}	64.388 ^{f}	63.488 ^{f}	58.158 ^{f}
	F-MEAN		59.441	83.910	85.255	76.202

CD $_{\text{at } 5\%}$ for T**=6.120 F**=6.050 FxT= NS

Fig. No. 4.2.3 : Effect of rice genotypes and fertility levels on total potassium uptake (kg/ha).



4.2.3: Effect of rice genotypes and fertility levels on total potassium uptake (kg/ha).

The effect of rice genotypes and fertility levels on total potassium uptake was observed to be significant (Table 4.2.3 & Fig. 4.2.3). The genotype IR-83377-B-B-93-3 (V6) absorbed highest potassium over other rice genotypes and lowest uptake was exhibited by MTU-1010 (V12). Variable amount of K accumulation by different genotypes showed their different genotypic characters and displayed variable test of significance, statistically.

Total potassium uptake (Table4.23 & Fig.4.23) was significantly increased with successive increase in fertility levels. Application of high fertility level recorded significantly higher potassium uptake (85.255 kg ha^{-1}) followed by medium fertility level (83.910 kg ha^{-1}) and low fertility level (59.441 kg ha^{-1}) Interaction between rice genotypes and fertility levels did not affect significantly.

Bahmaniar and Rajbar (2007) elucidated that K uptake in shoot and grain was significantly affected by cultivar and K interaction. The absorption by grain with the increase of K level was also reported by Dobermann *et al*. (1996), Fageria *et al.*(2010) , Singh *et al*. (2010) also observed increased K uptake through increasing fertility levels.

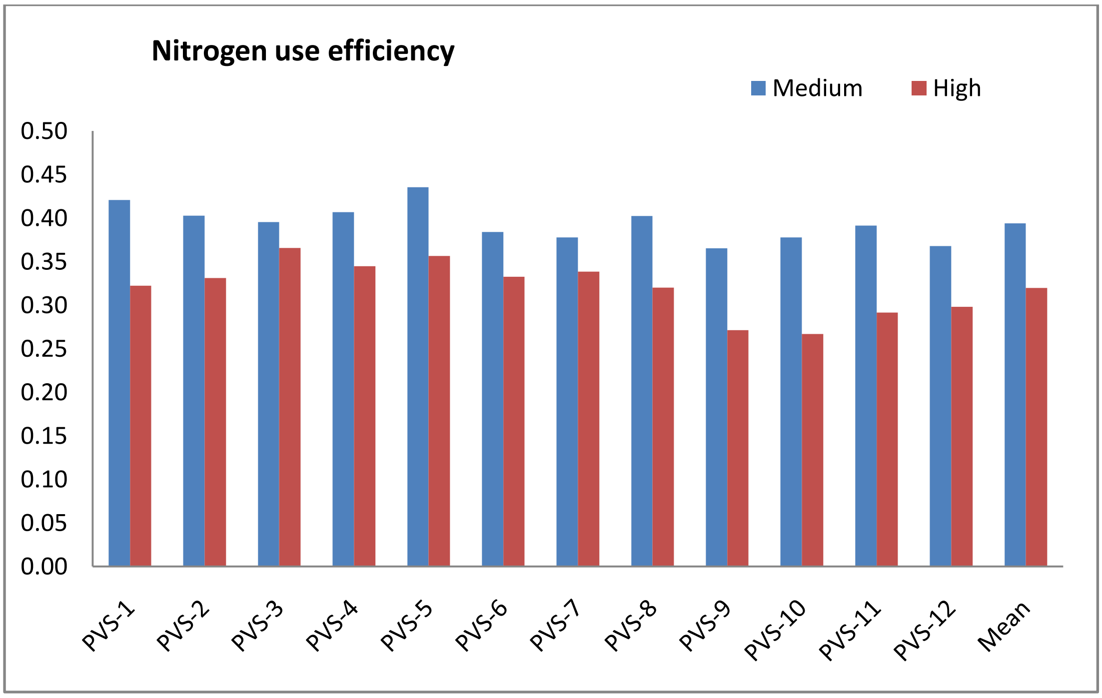
4.3: Nutrient Use Efficiency

4.3.1: Nitrogen use efficiency

Table 4.3.1: Nitrogen use efficiencies of different rice genotypes in relation to fertility levels.

S.No.	Rice genotype	Symbol	Fertility levels		Mean
			Medium	High	
1.	IR-83388-B-B-108-3	V1	0.4208	0.3223	0.3715
2.	IR-83388-B-B-129-3	V2	0.4028	0.3313	0.3670
3.	IR-82589-B-B-84-3	V3	0.3953	0.3658	0.3805
4.	IR-83383-B-B-129-4	V4	0.4068	0.3448	0.3758
5.	R-RF-65	V5	0.4355	0.3565	0.3960
6.	IR-83377-B-B-93-3	V6	0.3840	0.3325	0.3583
7.	R-RF-69	V7	0.3778	0.3383	0.3580
8.	IR-83383-B-141-2	V8	0.4023	0.3200	0.3611
9.	IBD-I-85 (Local entry)	V9	0.3653	0.2713	0.3183
10.	R-RF-85 (Local entry)	V10	0.3778	0.2668	0.3223
11.	IR-64	V11	0.3913	0.2913	0.3413
12	MTU-1010	V12	0.3680	0.2980	0.3330
	F-MEAN		0.3939	0.3199	0.3569

Fig. No. 4.3.1: Nitrogen use efficiency as influenced by rice genotypes and fertility levels



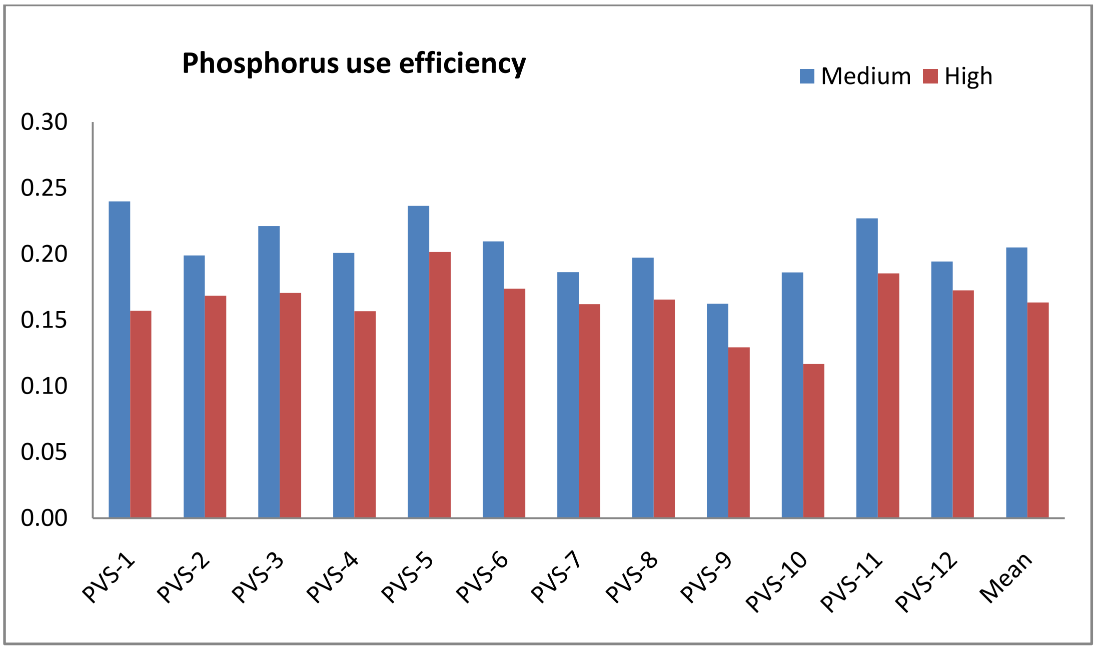
The data presented in Table 4.3.1 and depicted graphically in Fig. 4.3.1 show that nitrogen use efficiencies of different rice genotype ranged from 31.83 to 39.60 per cent with overall average value of 35.69 per cent. The highest NUE was recorded by R-RF-65 (V5) that yielded maximum grain produce. Medium fertility level exhibited higher efficiency than that of higher fertility level. Similar results on nitrogen use efficiency as influence by N, P and K levels were also reported by Zhang *et al.*(2009) and Swain *et al.* (2006).

Table 4.3.2: Phosphorus use efficiency as influenced by rice genotypes and fertility levels

S.No.	Rice genotype	Symbol	Fertility levels		Mean
			Medium	High	
1.	IR-83388-B-B-108-3	V1	0.2398	0.1570	0.1984
2.	IR-83388-B-B-129-3	V2	0.1990	0.1685	0.1838
3.	IR-82589-B-B-84-3	V3	0.2213	0.1705	0.1959
4.	IR-83383-B-B-129-4	V4	0.2008	0.1568	0.1788
5.	R-RF-65	V5	0.2365	0.2015	0.2190
6.	IR-83377-B-B-93-3	V6	0.2095	0.1738	0.1916
7.	R-RF-69	V7	0.1863	0.1620	0.1741
8.	IR-83383-B-141-2	V8	0.1973	0.1655	0.1814
9.	IBD-I-85 (Local entry)	V9	0.1623	0.1295	0.1459
10.	R-RF-85 (Local entry)	V10	0.1860	0.1168	0.1514
11.	IR-64	V11	0.2270	0.1853	0.2061
12	MTU-1010	V12	0.1943	0.1725	0.1834
	F-MEAN		0.2050	0.1633	0.1841

Table 4.3.2 and Fig. 4.3.2 showed the average phosphorus use efficiency ranged from 14.59 to 21.90 per cent with overall mean value of 18.41 per cent. Similar to NUE, R-RF-65 genotype has recorded maximum PUE and lowest by IBD-I-85 (Local entry). The doses of P application affected P use efficiency. It was higher in case of medium fertility level than that of high fertility level. Similar results on nitrogen use efficiency as influence by N, P and K levels were also reported by Fageria *et al.*2011 and Zhang *et al.* (2009).

Fig. 4.3.2: Phosphorus use efficiency as influenced by rice genotypes and fertility levels



4.3.3: Potassium use efficiency as influenced by rice genotypes and fertility levels

S.No.	Rice genotype	Symbol	Fertility levels		Mean
			Medium	High	
1.	IR-83388-B-B-108-3	V1	1.8048	0.9648	1.3848
2.	IR-83388-B-B-129-3	V2	1.8838	0.8040	1.3439
3.	IR-82589-B-B-84-3	V3	1.3803	0.8658	1.1230
4.	IR-83383-B-B-129-4	V4	1.1528	0.5835	0.8681
5.	R-RF-65	V5	1.6560	0.9250	1.2905
6.	IR-83377-B-B-93-3	V6	2.5948	1.1593	1.8770
7.	R-RF-69	V7	1.1355	0.6360	0.8858
8.	IR-83383-B-141-2	V8	1.5208	0.6923	1.1065
9.	IBD-I-85 (Local entry)	V9	1.0735	0.6863	0.8799
10.	R-RF-85 (Local entry)	V10	1.2350	0.9198	1.0774
11.	IR-64	V11	1.0648	0.7355	0.9001
12	MTU-1010	V12	1.0763	0.5108	0.7935
	F-MEAN		1.4648	0.7902	1.1275

Fig. No. 4.3.3: Potassium use efficiency as influenced by rice genotypes and fertility levels

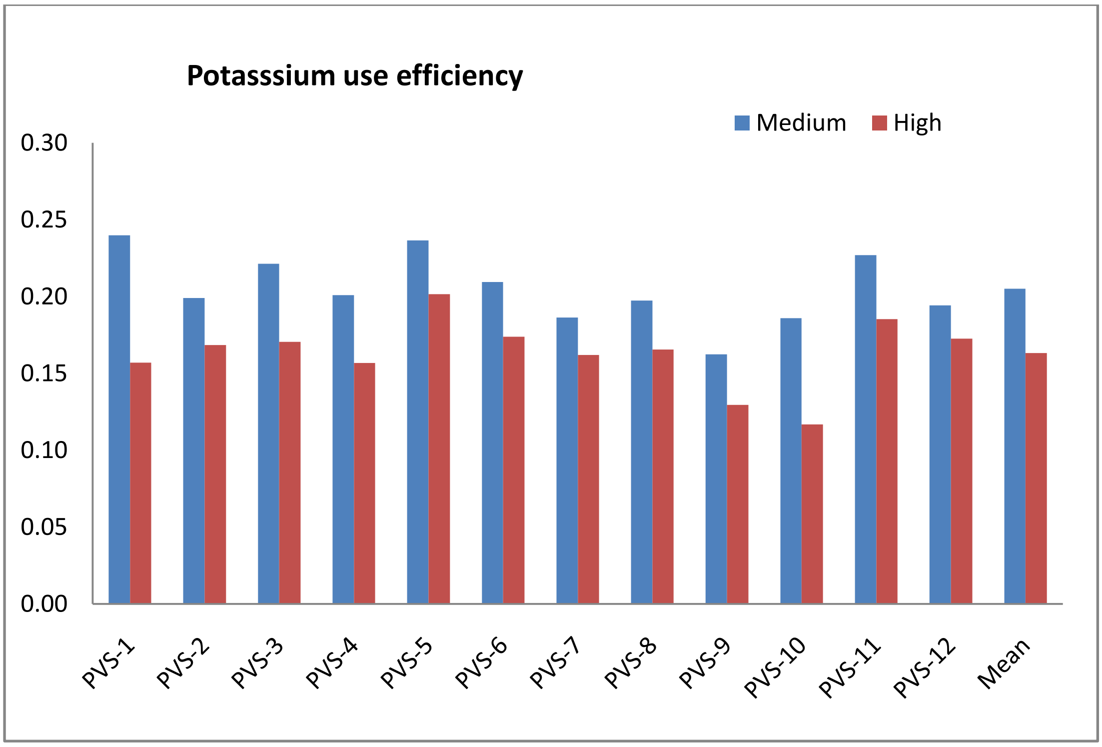


Table 4.3.3 and Fig. 4.3.3 showed the average potassium use efficiency in relation to rice genotypes and two fertility levels. Potassium use efficiency ranged from 79.35 to 138.48 per cent with overall mean value of 113 per cent. The highest potassium use efficiency was found with IR-83377-B-B-93-3 (V6) and lowest with MTU-1010 (local check). Low dose of potassium application recorded higher KUE than that of higher dose under high fertility level. Potassium use efficiencies were accounted overestimated even more than 100 per cent which shows higher K uptake than the application dose as the available K status of the experimental field soil was very high due to which crop response to the applied K was meager. Under such condition, K use efficiency estimation becomes indefinable. Similar results on nitrogen use efficiency as influence by N, P and K levels were also reported by Fageria *et al.*2010 and Zhang *et al.* (2009).

4.4 Micro Nutrient (Fe, Mn, Cu, Zn) Concentration (mg kg^{-1}) in grain and straw of different rice genotypes as influence by three fertility levels.

Table 4.4.1 gives the average Fe content (mg kg^{-1}) in grain and straw of different rice genotypes in relation to three fertility levels. Fe content significantly influenced by rice genotypes and fertility levels in grain and straw. Average Fe content in grain and straw part of different rice genotypes ranged from 113 to 131 and 171 to 253 mg kg^{-1}, respectively. Rice genotype IR-83383-B-141-2 in grain part absorbed highest Fe content and that in IR-83388-B-B-108-3 genotype had lowest Fe content. In general, Fe was accumulated more in straw part than that in grain part. Fe content was significant higher in low fertility level (control) and decreased in high fertility level in grain and Straw. High content of Fe in low fertilty level may be due to less dry matter and content decreased in high fertility level due to increase in biomass production resulting dilution effect. Interaction effect between genotypes and fertility levels did not show any statistically significant results in grain and straw. Highest yielder of the genotypes did not show the high content of Fe in grain as well as in straw. Variations in Fe concentration in different genotypes may be due to their genotypic characters.

Table 4.4.2 presents the Mn concentration in grain and straw part of different genotypes in relation to three fertility levels. There was a significant effect of Mn content in grain and straw part of the different rice genotypes coupled with fertility levels accept in grain part. Average Mn content in grain part was 4 to 5 time less than that of straw part indicating major role of Mn in vegetative part. Mn contents in grain and straw were ranged from 48-69 and 244-341 mg kg^{-1}, respectively. Mn content was higher in low fertilty level then progressively decreased to high fertility level due to increase in grain and straw yields resulting dilution effect.

Table 4.4.3 gives the Cu concentration in different rice genotypes as influenced by three fertility status. There was no significant difference in Cu content in grain with respect to different genotypes, fertility levels and their interaction. However, in rice straw, Cu content affected significantly with rice genotypes and fertility levels. Like other micro nutrients as discussed previously, Cu content in grain part was four times less than that in straw part. In low fertility level, Cu content was recorded higher than medium to high fertility levels.

Table 4.4.4 shows the average Zn content in rice grain and straw in relation to different genotypes and three fertility levels. There was significant effect of Zn content in grain and straw of different rice genotypes. However, fertility levels and interaction effects on Zn content in grain and straw did not show any significant variation. Zn content in straw part was double of what in grain part of the genotypes. Zn content varies according to the genotypic variations.

Table 4.4.: Fe Concentration (mg kg^{-1}) in grain and straw of different rice genotypes as influence by three fertility levels.

S.No.	Rice genotype	Symbol	Fe content in Grain (mg kg^{-1})				Fe content in Straw (mg kg^{-1})			
			Control	Medium	High	Mean	Control	Medium	High	Mean
1.	IR-83388-B-B-108-3	V1	118^{b}	111^{d}	109^{c}	113^{e}	258^{a}	247^{ab}	236^{abc}	247^{ab}
2.	IR-83388-B-B-129-3	V2	130^{ab}	122^{a-d}	114^{bc}	122^{cd}	251^{ab}	255^{a}	252^{a}	253^{a}
3.	IR-82589-B-B-84-3	V3	119^{b}	116^{cd}	114^{bc}	116de	196^{d}	191^{d}	193^{d}	193^{e}
4.	IR-83383-B-B-129-4	V4	136^{a}	131^{abc}	130^{ab}	132^{ab}	165^{f}	164^{e}	159^{e}	163^{g}
5.	R-RF-65	V5	137^{a}	126^{a-d}	122^{abc}	128^{abc}	225^{c}	213^{c}	196^{d}	212^{d}
6.	IR-83377-B-B-93-3	V6	138^{a}	134^{ab}	132^{a}	135^{ab}	177^{ef}	173^{e}	162^{e}	171^{fg}
7.	R-RF-69	V7	134^{ab}	132^{abc}	127^{ab}	131^{abc}	237^{bc}	231^{b}	227^{c}	231^{c}
8.	IR-83383-B-141-2	V8	141^{a}	137^{a}	132^{a}	137^{a}	250^{ab}	247^{ab}	238^{abc}	245^{ab}
9.	IBD-I-85 (Local entry)	V9	131^{ab}	128^{abc}	124^{abc}	127^{abc}	248^{ab}	241^{ab}	235^{bc}	241^{b}
10.	R-RF-85 (Local entry)	V10	133^{ab}	129^{abc}	126^{ab}	129^{abc}	251^{ab}	247^{ab}	244^{ab}	247^{ab}
11.	IR-64	V11	128^{ab}	126^{a-d}	121^{abc}	125^{bc}	182de	177de	173^{e}	177^{f}
12	MTU-1010	V12	119^{b}	117^{bcd}	113^{bc}	116de	181^{def}	177de	174^{e}	177^{f}
	F-MEAN		130	126	122	126	218	213	207	213
			CD$_{\text{at 5\%}}$ for T**=8.316 F**= 3.769 FT= NS				CD$_{\text{at 5\%}}$ for T**=8.603 F**=5.210 FxT= NS			

Table 4.4.2: Mn Concentration (mg kg^{-1}) in grain and straw of different rice genotypes as influence by three fertility levels.

S.No.	Rice genotype	Symbol	Mn content in Grain (mg kg^{-1})				Mn content in Straw (mg kg^{-1})			
			Control	Medium	High	Mean	Control	Medium	High	Mean
1.	IR-83388-B-B-108-3	V1	68^{ab}	66^{ab}	62^{ab}	66^{ab}	315^{bcd}	304^{bc}	282^{abc}	300^{c}
2.	IR-83388-B-B-129-3	V2	50^{bc}	49^{bc}	49^{b}	49^{f}	324^{abc}	307^{bc}	277^{bcd}	303^{c}
3.	IR-82589-B-B-84-3	V3	68^{abc}	65^{ab}	63^{ab}	65^{ab}	289^{c-f}	274^{d}	273^{cd}	261^{cde}
4.	IR-83383-B-B-129-4	V4	54^{abc}	55^{abc}	52^{ab}	54^{def}	290^{cde}	256^{d}	234^{ef}	260^{def}
5.	R-RF-65	V5	62^{abc}	60^{abc}	57^{ab}	60^{a-e}	335^{ab}	309^{b}	306^{ab}	316^{bc}
6.	IR-83377-B-B-93-3	V6	57^{abc}	55^{abc}	54^{ab}	55^{c-f}	358^{a}	348^{a}	318^{a}	341^{a}
7.	R-RF-69	V7	49^{c}	47^{c}	46^{b}	48^{f}	283^{def}	273^{cd}	250^{c-f}	268^{de}
8.	IR-83383-B-141-2	V8	66^{abc}	63^{abc}	62^{ab}	64^{abc}	335^{ab}	326^{ab}	314^{a}	325^{ab}
9.	IBD-I-85 (Local entry)	V9	71^{a}	68^{a}	67^{a}	69^{a}	258^{ef}	250^{d}	225^{f}	244^{f}
10.	R-RF-85 (Local entry)	V10	53^{abc}	52^{abc}	49^{ab}	51^{ef}	321^{bc}	310^{b}	302^{ab}	311^{bc}
11.	IR-64	V11	58^{abc}	57^{abc}	54^{ab}	56^{b-f}	254^{f}	252^{d}	243^{def}	250^{ef}
12	MTU-1010	V12	65^{abc}	63^{abc}	61^{ab}	63^{a-d}	308^{bcd}	298^{bc}	298^{ab}	301^{c}
	F-MEAN		60	58	56	58	306	292	276	291
			CD $_{at\ 5\%}$ for T**=8.793 F=NS FxT= NS				CD $_{at\ 5\%}$ for T**=18.63 F**=8.88 FxT= NS			

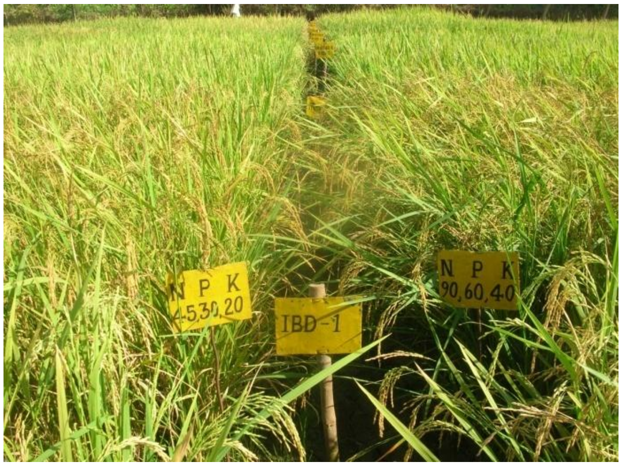
Table 4.3.3: Cu content (mg kg^{-1}) in grain and straw of different rice genotypes in relation to three fertility levels

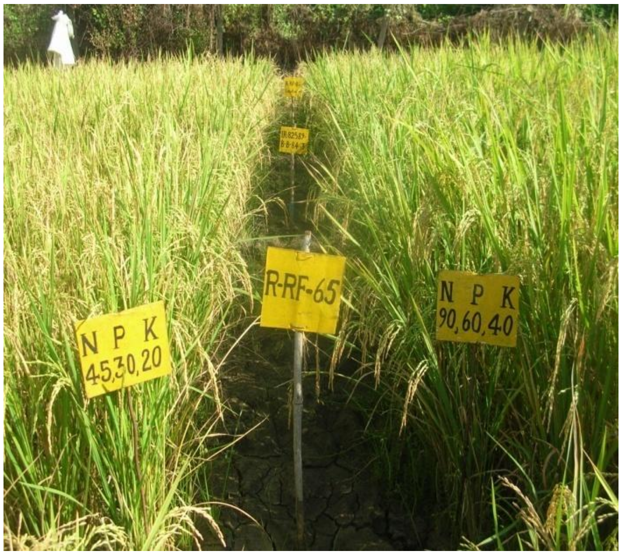
S.No.	Rice genotype	Symbol	Cu content in Grain (mg kg^{-1})				Cu content in Straw (mg kg^{-1})			
			Control	Medium	High	Mean	Control	Medium	High	Mean
1.	IR-83388-B-B-108-3	V1	6^{a}	6^{a}	6^{a}	6^{abc}	30^{ab}	29^{b}	28^{ab}	29^{b}
2.	IR-83388-B-B-129-3	V2	7^{a}	6^{a}	6^{a}	6^{abc}	29^{b}	28^{b}	28^{ab}	28^{b}
3.	IR-82589-B-B-84-3	V3	6^{a}	6^{a}	5^{a}	6^{abc}	31^{ab}	29^{ab}	26^{b}	29^{b}
4.	IR-83383-B-B-129-4	V4	7^{a}	7^{a}	6^{a}	7^{ab}	30^{ab}	29^{b}	28^{ab}	29^{b}
5.	R-RF-65	V5	6^{a}	5^{a}	5^{a}	5^{c}	30^{ab}	29^{b}	27^{ab}	29^{b}
6.	IR-83377-B-B-93-3	V6	6^{a}	6^{a}	5^{a}	6^{bc}	33^{a}	33^{a}	31^{a}	32^{a}
7.	R-RF-69	V7	7^{a}	6^{a}	7^{a}	6^{abc}	30^{ab}	29^{b}	28^{ab}	29^{b}
8.	IR-83383-B-141-2	V8	7^{a}	7^{a}	7^{a}	7^{a}	30^{ab}	29^{b}	28^{ab}	29^{b}
9.	IBD-I-85 (Local entry)	V9	6^{a}	6^{a}	6^{a}	6.11^{abc}	30^{ab}	29^{b}	28^{ab}	29^{b}
10.	R-RF-85 (Local entry)	V10	7^{a}	7^{a}	6^{a}	6^{abc}	29^{b}	28^{b}	27^{b}	28^{b}
11.	IR-64	V11	7^{a}	6^{a}	6^{a}	6^{abc}	30^{ab}	29^{b}	28^{ab}	29^{b}
12	MTU-1010	V12	7^{a}	7^{a}	7^{a}	7^{ab}	30^{ab}	28^{b}	27^{b}	28^{b}
	F-MEAN		6	6	6	6	30	29	28	29
			CD $_{\text{at } 5\%}$ for T=NS F= NS FxT= NS				CD $_{\text{at } 5\%}$ for T**=1.741 F**=0.983 FxT=NS			

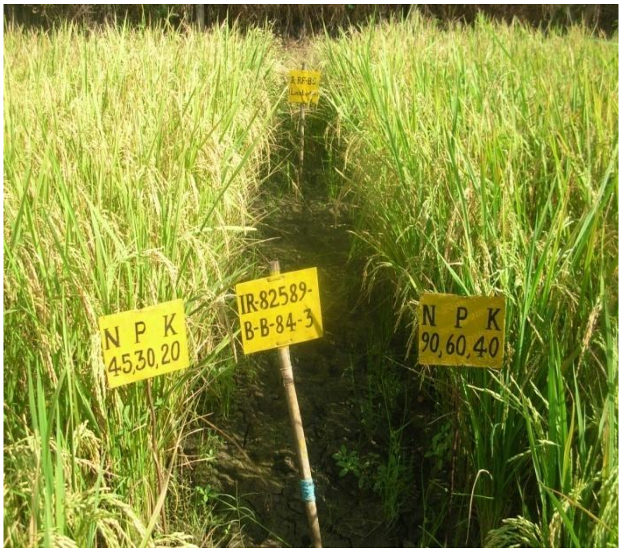
Table 4.4.4: Zn Concentration (mg kg^{-1}) in grain and straw of different rice genotypes as influence by three fertility levels.

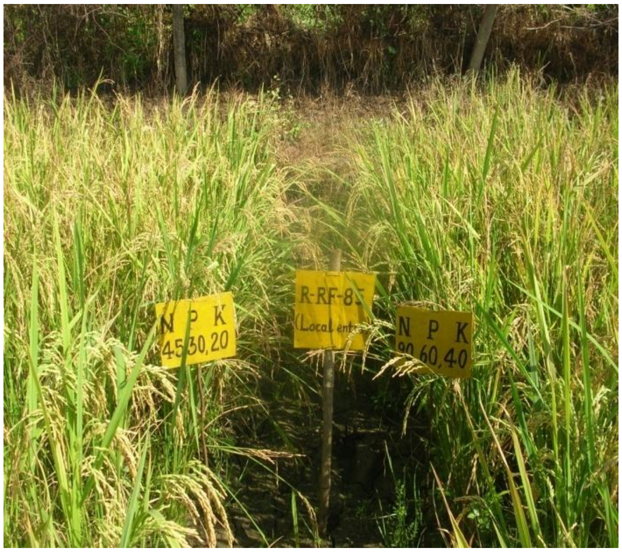
S.No.	Rice genotype	Symbol	Zn content in Grain (mg kg^{-1})				Zn content in Straw (mg kg^{-1})			
			Control	Medium	High	Mean	Control	Medium	High	Mean
1.	IR-83388-B-B-108-3	V1	58^{ab}	55^{ab}	54^{ab}	55^{ab}	110^{a}	105^{a}	102^{a}	106^{ab}
2.	IR-83388-B-B-129-3	V2	53^{ab}	50^{ab}	45^{ab}	49^{bcd}	99^{a}	98^{a}	95^{a}	98^{b}
3.	IR-82589-B-B-84-3	V3	60^{a}	60^{a}	59^{a}	60^{a}	98^{a}	96^{a}	91^{a}	95^{b}
4.	IR-83383-B-B-129-4	V4	46^{ab}	43^{b}	42^{b}	44^{d}	103^{a}	98^{a}	90^{a}	97^{b}
5.	R-RF-65	V5	53^{ab}	50^{ab}	47^{ab}	50^{bcd}	99^{a}	94^{a}	87^{a}	93^{b}
6.	IR-83377-B-B-93-3	V6	57^{ab}	55^{ab}	51^{ab}	54^{ab}	114^{a}	111^{a}	105^{a}	110^{a}
7.	R-RF-69	V7	50^{ab}	49^{ab}	48^{ab}	49^{bcd}	98^{a}	95^{a}	93^{a}	95^{b}
8.	IR-83383-B-141-2	V8	52^{ab}	51^{ab}	47^{ab}	50^{bcd}	109^{a}	103^{a}	98^{a}	104^{ab}
9.	IBD-I-85 (Local entry)	V9	44^{b}	43^{b}	41^{b}	43^{d}	107^{a}	99^{a}	94^{a}	100^{ab}
10.	R-RF-85 (Local entry)	V10	46^{ab}	45^{b}	44^{ab}	45^{cd}	110^{a}	106^{a}	101^{a}	106^{ab}
11.	IR-64	V11	50^{ab}	49^{ab}	45^{ab}	48^{bcd}	101^{a}	96^{a}	93^{a}	97^{b}
12	MTU-1010	V12	54^{ab}	52^{ab}	52^{ab}	53^{abc}	104^{a}	101^{a}	96^{a}	101^{ab}
	F-MEAN		52	50	48	50	104	100	96	100
			CD $_{at\ 5\%}$ for T**=7.184 F=NS FxT= NS				CD $_{at\ 5\%}$ for T**= 10.606 F=NS FxT= NS			

Experiment Field.






N P K
45,30,20
IR-82589-
B-B-84-3
N P K
90,60,40


N P K
45,30,20
R-RF-85
(Local ent
N P K
90,60,40


N P K
45,30,20
MTU-1010
N P K
90,60,40


MTU 1010
IR-83383-B-
B-141-2
N P K
45,30,20
N P K
90,60,40


IR-83377-B-
B-93-3
K
N P K
90,60,40


N P K
45,30,20
IR-83383-B-
B-129-4
N P K
90,60,40

Summary, Conclusion & Suggestions for Future Research Work

CHAPTER – V

SUMMARY, CONCLUSIONS AND SUGGESTIONS FOR FUTURE RESEARCH WORK

5.1 Summary and conclusions

A field experiment was carried out to to evaluate the n**utrient use efficiency of drought tolerant rice genotype as influenced by fertility levels under rainfed condition** during *kharif* season, 2012 at Instructional Farm, Indira Gandhi Krishi Vishwavidyalaya, Raipur, Chhattisgarh with the objectives

1. To find out the effect of fertility levels on growth, yield and yield attributes of rice genotypes under rainfed condition.
2. To evaluate the rice genotypes for their nutrients use efficiency under rainfed condition.

The experiment was laid out in split plot design with three main plots represented by fertility levels *viz.*, low fertility level *i.e.*00:00:00 kg ha^{-1} NPK (F_O), Medium fertility level i.e. 45:30:20 kg ha^{-1} NPK (F_1) and high fertility level i.e. 90:60:40 kg ha^{-1} NPK, (F_2) and twelve sub plots represented by rice genotypes *viz.*, IR-83388-B-B-108-3, IR-83388-B-B-129-3, IR-82589-B-B-84-3, IR-83383-B-B-129-4, R-RF-65, IR-83377-B-B-93-3, R-RF-69, IR-83383-B-B-141-2, IBD-I (Local entry), R-RF-85 (Local entry), IR-64, MTU-1010. Treatments were replicated thrice. The experimental field's soil comes in the soil's order of Vertisol, locally known as *kanhar* . Climate of the region was dry moist, sub humid with average rainfall of 1250 mm. During crop growth period, the crop received 1384 mm rainfall. The maximum temperature during crop period varied from 37 ^{o}C to 19.5 ^{o}C, while minimum temperature ranged between 26 ^{o}C to 19.2 ^{o}C. The soil was clay in texture, having pH

7.34, EC 0.26 (dSm^{-1}),CEC 38.21 (c mol (p+) kg-1) organic carbon 0.58 percent and available N, P and K 273, 14.78 and 616 kg ha^{-1}, respectively.

The results obtained in the experiment summarized and concluded as below:

The experiment was conducted to evaluate the nutrients use efficiencies under rainfed condition. However, the crop season did not suffer with water stress due to well distribution of rainfall and water table was found to be under favorable throughout the crop season. Hence, crop growth did not suffer with rainfed condition. Hence crop growth was under optimum with their full potential.

1. Number of effective tillers was significantly varied under different genotypes. The number of highest effective tillers were recorded in variety R-RF-65 followed by IR-83383-B-141-2 , IR-83377-B-B-93-3 , IR-83388-B-B-129-3 , IR-83388-B-B-108-3 , IR-83383-B-B-129-4 , R-RF-69 , IR-64 , IR-82589-B-B-84-3, MTU-1010 , R-RF-85 (Local entry), and IBD-I-85 (Local entry). The effective tillers of different genotype were ranged from 186-312 m^{-2} with average of 262 m^{-2} in high fertility level followed by 164-275 m^{-2} with average of 233 m^{-2} in medium fertility level and from 153-238 m^{-2} with average of 188 m^{-2} under lowest fertility level (control). Different rice genotypes have responded to the graded dose of fertilizer application created from low to high fertility level.
2. The test weight of rice was significantly affected under different genotypes and fertility levels . Genotype IR-83377-B-B-93-3 had the highest seed weight that was on par with IR-83383-B-141-2 and R-RF-65 which had statistically at par results. The lowest test weight was observed under IBD-I-85 .
3. Highest plant height was recorded with R-RF-69 genotype. However, MTU-1010, R-RF-85 (Local entry), R-RF-85 (Local entry) were also statistically at

par in plant height with that of R-RF-69 genotype. High fertility level recorded significantly higher plant height (98.400 cm) followed by medium fertility level (92.400 cm) and low fertility level (83.900 cm**).**

4. Grain yields were significantly influenced by different rice genotypes and fertility levels. The average grain yield was significantly higher in R-RF-65 as compared to those of other genotypes in the order of IR-83383-B-B-129-4 ,IR-83388-B-B-129-3 , IR-83388-B-B-108-3 , R-RF-69 , MTU-1010 , IR-64 , IR-82589-B-B-84-3 . Grain yield of R-RF-65 was also exhibited statistically on par with IR-83383-B-141-2 and IR-83377-B-B-93-3. The grain yield of R-RF-65 under no fertilizer dose (low fertility level) was also observed remarkably higher than other genotypes indicating thereby better performance of this genotype under nutrient stress condition. The highest rice yield of 51.939 q ha^{-1} was recorded under high soil fertility level (F2) followed by 44.628 q ha^{-1} in medium soil fertility level (F1) and the lowest 26.798 q ha^{-1} in low soil fertility level (F0). Interaction effect of rice genotypes with fertility levels was also found to be significant.
5. The straw yield of rice genotypes IR-83383-B-141-2 accumulated significantly higher straw yield (58.670 q ha^{-1}) followed by R-RF-65 , IR-83388-B-B-108-3 , IR-64 , MTU-1010 , R-RF-69 , IBD-I-85 (Local entry) , IR-82589-B-B-84-3 , R-RF-85 (Local entry) . Straw yield of rice cultivars significantly increased with increase in the fertility levels. High soil fertility level produced maximum straw yield (66.267 q ha^{-1}) followed by medium soil fertility level (60.069 q ha^{-1}) and low fertility level (28.857 q ha^{-1}).
6. The highest N uptake was observed in IR-64 which was similar to those of two other genotypes i.e. R-RF-65 ,IR-83383-B-141-2 .Total N uptake in these

three genotypes had significantly higher values as compared to those of others like IR-83383-B-B-129-4 , R-RF-85 (Local entry), IR-83388-B-B-129-3, IR-83377-B-B-93-3, IR-83388-B-B-108-3, MTU-1010, IBD-I-85 (Local entry), R-RF-69 and IR-82589-B-B-84-3. Total nitrogen uptake was significantly increased with application of increasing doses of fertilizers from low to high and application of high fertilizer accumulated significantly higher nitrogen (72.574 kg ha^{-1}) followed by medium (66.66 kg ha^{-1}) and low (46.33 kg ha^{-1}) in without fertilizer treatment.

7. The total P uptake in genotypes IR-83383-B-141-2 , IR-83383-B-B-129-4 and R-RF-65 were statistically at par and significantly higher than IR-64 , IR-83388-B-B-129-3, IBD-I-85 (Local entry), IR-83388-B-B-108-3 , MTU-1010, R-RF-85 (Local entry) and IR-82589-B-B-84-3. The varieties IR-83383-B-B-129-4 was also statistically at par with R-RF-65 followed by R-RF-69 and IR-83377-B-B-93-3. P uptake increased with increasing fertilizer application from low to high fertility level. Application of high fertility level produced higher phosphorus uptake (13.723 kg ha^{-1}) followed by medium fertility level (12.213 kg ha^{-1}) and lowest in low fertility level (9.488 kg ha^{-1}).
8. Similarly, the genotype IR-83377-B-B-93-3 absorbed highest potassium over other rice genotypes and lowest uptake was exhibited by MTU-1010 .Variable amount of K accumulation by different genotypes showed their different genotypic characters and displayed variable test of significance, statistically. Potassium uptake was significantly increased with successive increase in fertility levels. Application of high fertility level recorded significantly higher potassium uptake (85.255 kg ha^{-1}) followed by medium fertility level (83.910

kg ha^{-1}) and low fertility level (59.441 kg ha^{-1}). Interaction between rice genotypes and fertility levels did not affect significantly.

9. Nitrogen use efficiencies of different rice genotype ranged from 31.83 to 39.60 per cent with overall average value of 35.69 per cent. The highest NUE was recorded by R-RF-65 that yielded maximum grain produce. Medium fertility level exhibited higher efficiency than that of higher fertility level. Similarly, Phosphorus use efficiency ranged from 14.59 to 21.90 per cent with overall mean value of 18.41 per cent. R-RF-65 genotype has recorded maximum PUE and lowest by IBD-I-85 (Local entry). The doses of P application affected P use efficiency. It was higher in case of medium fertility level than that of high fertility level. Potassium use efficiency ranged from 79.35 to 138.48 per cent with overall mean value of 113 per cent. The highest potassium use efficiency was found with IR-83377-B-B-93-3 and lowest with MTU-1010 (local check). Low dose of potassium application recorded higher KUE than that of higher dose under high fertility level. Potassium use efficiencies were accounted overestimated even more than 100 per cent which shows higher K uptake than the application dose as the available K status of the experimental field's soil was very high due to which crop response to the applied K was meager. Under such condition, K use efficiency estimation becomes indefinable.

5.2 Suggestions for future research work

Based on the findings of the present study, the following suggestions are being made for future work.

- Based on the current study, the performance of R-RF-65 rice genotype was found to be better than the local checks hence this genotype must be tested extensively on farmer’s fields for their efficacy and potential yields under water stress condition.

- Root studies must be under taken for the promising genotypes sustaining under water stress condition.
- The results need further verification through frontline demonstrations on farmer’s field having the range of fertility variations and drought prone occurrence.

Abstract

"NUTRIENT USE EFFICIENCY OF DROUGHT TOLERANT RICE GENOTYPE AS INFLUENCED BY FERTILITY LEVELS UNDER RAINFED CONDITION"

by
Tribhuvan Patel

ABSTRACT

The present investigation was carried out at the Instructional Farm, Indira Gandhi Krishi Vishwavidyalaya, Raipur (C.G.) during *kharif* season, 2012. The experiment was conducted in Vertisol field. The experimental field's soil exhibited neutral reaction (pH 7.34), EC 0.26 (dSm^{-1}), medium status of organic C (0.58%), low in available N (273 kg ha^{-1}), medium in P (14.78 kg ha^{-1}), high in K status (616 kg ha^{-1}) and sufficient level in micronutrients (Fe, Mn, Cu, & Zn). The experiment was laid out in split plot design having three fertility levels as main plots and twelve rice genotypes as sub plot. Treatments were replicated thrice. The fertility levels were taken as low fertility level (00:00:00 kg ha^{-1} N:P:K), medium fertility level (45:30:20 kgha^{-1}N:P:K) and high fertility level (90:60:40 kg ha^{-1} N:P:K) and treatments under sub plots as rice genotypes namely IR-83388-B-B-108-3, IR-83388-B-B-129-3, IR-82589-B-B-84-3, IR-83383-B-B-129-4, R-RF-65, IR-83377-B-B-93-3, R-RF-69, IR-83383-B-B-141-2, IBD-I (Local entry), R-RF-85 (Local entry), IR-64 and MTU-1010.

Yield of different rice genotypes significantly increased with increasing level of fertility from low to high. Rice genotypes, R-RF-65, IR-83383-B-141-2, IR-83377-B-B-93-3, IR-83383-B-B-129-4, IR-83388-B-B-129-3, IR-83388-B-B-108-3, R-RF-69, MTU-1010, IR-64 and IR-82589-B-B-84-3 were recorded higher growth and yield attributes for grain and straw yields, nutrients uptake and higher nutrient use efficiencies. Overall average nutrients use efficiencies for N P and K were recorded as 35.69, 18.41 and 112.75 per cent, respectively. Rice genotype R-RF-65 registered the nutrients use efficiencies for N P and K ranged as 43.55-35.65, 23.65-20.15 and 165.60-92.50, respectively. Nutrient use efficiencies were observed higher at low fertility level and vice versa. Potassium use efficiency showed very high values which was due to less crop response to the applied K fertilizer.

Most of the genotypes tested for their nutrient use efficiencies performed better than local check. The crop season was favorable and no water stress occurred during entire period which favored the genotypes to perform their potential level.

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References

REFERENCES

Arif, M. M., Arshad, H.N., Asghar and Basra, S.M.A. 2010. Response of rice (*Oryza sativa*) genotypes varying in K use efficiency to various levels of potassium. *Int. J. Agric. Biol*., **12**: 926–930.

Amin, M., Ayyaz, M., Ahmed and Ramzan, M. 2004. Effect of increased plant density and fertilizer dose on the yield of rice variety IR-6. *Journal of Research (Science.),* **15**(1) : 09-16.

Ahamad, K., Ahamad, L.P. and Gautam, R. 2008. Evaluation of slow release nitrogen fertilizers in Rice wheat cropping system. *Journal of the Society of Soil Science.* **35(**2):35-39.

Ahmed, M., Md. Monirul Islam and Paul, S. K. 2005. Effect of Nitrogen on Yield and Other Plant Characters of Local T. Aman Rice, Var. Jatai . *Research Journal of Agriculture and Biological Sciences* **1**(2): 158-161.

Awan, T.H., Ali, R.I., Manzoor, Z., Ahmad, M. and Akhtar, M. 2011. Effect of different nitrogen levels and row spacing on the performance of newly evolved medium grain rice variety, ksk-133. *The Journal of Animal & Plant Sciences*, **21**(2): 231-234.

Azad, G. and Pandey, S. R. 1995. Urea hydrolysis in rice root zone. *Indian Journal of Agronomy*. **48**(2): 54-56.

Bahmaniar, M. A. and Rajbar, G.A. 2007. Effect on nitrogen and potassium fertilizer on rice genotype processing characteristics. *Pakistan Journal Biology scienc*e. (**10**): 829-834.

Bharde, N. M., Shivay, Y.S. and Singh, S. 2003. Effect of biogas slurry and neem oil treated urea sources on rice wheat cropping system. *Indian Journal of Agronomy*. **48**(2): 73-77.

Black, C. A. 1965. Methods of Soil Analysis. Amer. Soc.of Agro. Inc. Publ. Madison, Wisconsin, USA.

Chaudhary**,** S. K and Sinha, N.K. 2007. Effect of levels of nitrogen and zinc on grain yield and their uptake in transplanted rice. *Oryza.* **44** (1) 44-47.

Chaudhary**,** S.K. and Pandey, D. N. 2009. Response of rice genotype to levels of nitrogen in lowland. *Oryza.* **46**(1): 42-44.

Chaudhary, S.K., Thakur, S.K. and Pandey A.K. 2007. Responce of rice to nitrogen and zinc. O*ryza*, **44**(1): 31-31.

Dey, S. S., Santosh, E. E. and Sharma, D. 2010. Response of rice cultivars to phosphorus supply on an oxisol. *Indian Journal of Agronomy*. **53**(2): 70-74.

Dobermann, A., Cruz, P.C., Sta.and Cassman, K.G. 1996. Fertilizer inputs, nutrient balance, and soil nutrient-supplying power in intensive, irrigated rice systems. I. Potassium uptake and K balance. Nutrient Cycling in Agroecosystems, **46**(1): 1-10.

Fageria, N. K., Santos, A. B. and Heinemann, A. B. 2011. Lowland rice genotypes evaluation for phosphorus use efficiency in tropical lowland *Journal of Plant Nutrition*, **34**(8): 1087-1095.

Fageria, N. K., Moreira, A. and Coelho A. M. 2011. Yield and yield components of upland rice as influenced by nitrogen sources *Journal of Plant Nutrition*, **34**:361–370.

Fageria, N. K., Santos, A. B. and Coelho, A. M. 2011. Growth, yield and yield components of lowland rice as influenced by ammonium sulfate and Urea fertilization *Journal of Plant Nutrition*, **34**:371–386.

Fageria, N.K., De Morais, O. p. and Dos Santos D.A. 2010. Nitrogen use efficiency in upland rice genotypes. *Journal of Plant Nutrition*, **33**:1696–1711.

Gedam ,V. B., Powar, M. S., Rudragouda, Mahskar, N. V. and Rametke, J. R. 2008. Residual effect of organic manures on growth, yield attributes and yield of rice in groundnut-rice cropping system**.** *Res. on Crops* **9**(2):199-201**.**

Hasanuzzaman, M., Ali, M.H., Karim, M.F., Masum, S.M. and Mahmud, J.A. 2012. Response of hybrid rice to different levels of nitrogen and phosphorus. *Intl. Res. J. Appl. Basic. Sci*. **3**(12): 2522-2528.

Haq, U.P. 2002. rice varieties for rainfed upland of India. *Oryza.* **41**(2): 65-67.

Haefele, S.M. , Naklang, K., Harnpichitvitaya, D., Jearakongman, S., Skulkhu, E., Romyen, P., Phasopa, S., Tabtim, S., Suriya-arunroj, D. and Khunthasuvon, S. 2006. Factors Affecting Rice Yield and Fertilizer Response in Rainfed Lowlands of Northeast Thailand. *Field Crops Research* **98**(1) 39-51.

Haefele, S.M. , Jabbar, S.M.A., Siopongco, J.D.L.C., Tirol-Padre, A., Amarante, S.T., Sta Cruz P.C. and Cosico, W.C. 2008. Nitrogen use efficiency in selected rice (*Oryza sativa* L.) genotypes under different water regimes and nitrogen levels, *Field Crops Research*, **107** (2): 137-146.

Hassan, M. S., Khair, A., Haque, M.M. and Hamid A. 2007. Photosynthetic Haracters, Spad Value and Nitrogen Use Efficiency of Traditional *Aus* Rice (*Oryza sativa L.*) Cultivars. *Saarc J. Agri*., **5**(2):29-40.

Hassan, M. S., khair, A., Haque, M.M., Azad, A. K. Hamid, A. A. 2009. Genotypic variation in traditional rice varieties for chlorophyll content, spad value and nitrogen use efficiency bangladesh *J. Agril. Res.* **34**(3) : 505-515.

Inthapanya, P., Sipaseuth., Sihavong, P., Sihathep, V., Chanphengsay. M., Fukai, S., and Basnayake. J. 2000. Genotype differences in nutrient uptake and utilisation for grain yield production of rainfed lowland rice under fertilised and non-fertilised conditions. *Field Crops Res.*, **65**(1): 57-68.

Jabbar, S. M .A., Cruz, P. C. S., Siopongco, J. D. L. C., Cosico ,W. C, Sanchez, P. B, Amarante, S. T., Haefele, S. M . 2009. Genotypic Differences in Grain Yield and Nitrogen Uptake of Lowland Rice (Oryza sativa L.) under Irrigated and Rainfed Conditions. *Philippine Journal of Crop Science*, **34** (1):22-37.

Jackson, M. L.(1985) . Soil Chemical Analysis.

Kenneth, G. C., Dobermann, A. and Daniel T. Walters 2002. Agroecosystems, Nitrogen-use Efficiency, and Nitrogen Management. *A Journal of the Human Environment* **31(**2):132-140.

Kamara, A. Y., Ekeleme, F., Omoigui, L. O. and Chikoye, D. 2011. Influence of nitrogen fertilization on yield and yield components of rain-fed lowland NERICA rice in the northern Guinea savanna of Nigeria. *Afr. J. Agric. Res.*; **6**(13): 3092-3097.

Kumar, D.M., Anwarulla, S.M., Shadakshari, Y. G., and Kumar, D.B.M. *2008.* Response of Genotype KHRS-21 for Fertilizer Levels and Plant Density. *Karnataka J. Agric. Sci.,* **21**(2):155-158.

Krishanamurthy, B., Sreedevi, T. R., Padmavathi, G., Kmmar, R.M. and Singh, S. P. 2010. Evalution of rice genotype for phosphorus use efficiency under soil mineral conditions. *Oryza.* **47**(1): 29-33.

Linquist, B. and Sengxua, P. 2003. Efficient and flexible management of nitrogen for rainfed lowland rice. *Nutrient Cycling in Agroecosystems* **67:** 107–115.

Liu, J., Kunquan, L., Xu ,J., Liang, J., Lu, X., Yang, J. and Zhu, Q. 2003**.** Interaction of Cd and five mineral nutrients for uptake and accumulation in different rice cultivars and genotypes. *Field Crops Research*, **83**(3): 271-281.

Lindsay, W.L. and Norvell, W.A. 1978. Development of a DTPA soil test for zinc, iron, manganese and copper. *Soil Sci. Soc Amer. J.* 42, 421-428.

Masthanareddy, B. G., 2009. Nitrogen use efficiency of transplanted rice as influenced by N, P and K levels. *Journal of the Society of Soil Science.* **57** (3):345-351.

Muthukumararaja, T.M. and Sriramachandrasekharan, M.V. 2012. Effect of zinc on yield, zinc nutrition and zinc use efficiency of lowland rice. *Journal of Agricultural Technology* **8**(2): 551-561.

Muhr, G. R., Datta, N. P., Subramoney, H., Leley, V. K. and Donahue, R. L. 1965. Soil testing in India. United States Agronomy for International development mission on India, New Delhi.

Metwally, T. F., Gewaily, E. E. and Naeem, S. S. 2011. Nitrogen response curve and nitrogen use efficiency of Egyptian hybrid rice. *J. Agric. Res. Kafer El-Sheikh Univ.,* **37**(1).

Ndaeyo, N.U., Iboko, K.U. and Edem, S.O. 2008. Growth and yield performances of some upland rice cultivars as influenced by varied rates of NPK fertilizer on an *ultisol*. *Journal of Tropical Agriculture , Food, Enviroment and Extension*, **7** (3): 249-255.

Nawlakhe, J., Sharma, P.k., and Patwan , G. 2008. Primary and Secondary Nutrient uptake pattern by Rice as a guid to Fertilizer application Practices. *Indian farming* **41**(2): 5-8.

Nawlakhe, S.M. and Jiotode, D.J. 2008 . Integrated nutrient management in transplanted rice. *Res. on Crops,* **9** (2): 209-211.

Ohnishi , G.L., Ternon, P. and Allen, S. E. 1996. Fertilizer and soil N uptake by paddy rice as affected by soil N level, source and date of application. *Field Crops Research,* **75**(7): 22-26.

Olsen, S.R., Cole, C.V., Watnable, F.S. and Dean, L.A. 1954. Estimation of available phosphorous in soils by extraction with sodium carbonate. U.S.D.A. Cir. No. 933:1-10.

Ouk, M., Basnayake, J., Tsubo, M., Fuka , S. i., Fischer, K.S., Cooper, M. and Nesbitt, H. 2006. Use of drought response index for identification of drought tolerant genotypes in rainfed lowland rice. *Field Crops Research*, **99**(1): 48-58.

Pantuwan, G., S., Fukai, C. M., Rajatasereekul, S. and O'Toole, J. C. 2002. Yield response of rice (*Oryza sativa* L.) genotypes to drought under rainfed lowlands: 2. Selection of drought resistant genotypes. *Field Crops Research* , **73** (2-3): 169 – 180.

Pantuwan, G., S., Fukai, C. M., Rajatasereekul, S. and O'Toole, J. C. 2002.Yield response of rice (*Oryza sativa* L.) genotypes to different types of drought under rainfed lowlands: Part 1. Grain yield and yield components. *Field Crops Research*, **73**(2-3): 153-168.

Pooniya, V. and Shivay, Y. S. 2012. Summer green-manuring crops and zinc fertilization on productivity and economics of basmati rice (Oryza sativa L.), Archives of Agronomy and Soil Science, **58**(6): 593-616.

Patel S. R., Thakur, D. S. and Pandya, K.S. 1997. Response of rice to nitrogen levels and preconditioned urea in Inceptisol, *Fertilizer News.* **42**(8): 37-40.

Piper, C.S. 1966. Soil and Plant Analysis. Hans Publisher, Bombay. pp. 85-102.

Rahman, M. M., Amano, T. and Shiraiwa, T. 2009. Nitrogen use efficiency and recovery from N fertilizer under rice-based cropping systems. *Australian Journal of Crop Science* **3**(6):336-351.

Rany, Y. A., Narayanan, A., Devi, V.S. and Subbaramana, P. 1997. Effect on silicon application on growth and yield of rice plants. *Annals of plant physiology.* **11**(2):125-128.

Reddy, M., Shankhdhar, D., Shankhdhar, S. C. and Mani, S.C. 2010. Effect of aerobic cultivation on yield, biochemical and physiological characters of selected rice genotypes. *Oryza.* **47** (1) 22-28.

Saito, K., Linquist, B., Atlin, G.N., Phanthaboon, K., Shiraiwa, T. and Horie, T. 2005. Response of traditional and improved upland rice cultivars to N and P fertilizer in northern Laos, *Field Crops Research.*

Serraj, R., McNally, K.L. , Loedin, I. S., Kohli, A., Haefele, S. M., Atlin, G. and Kumar A. 2009. Drought Resistance Improvement in Rice: An Integrated Genetic and Resource Management Strategy. *Plant Production Science,* **14** (2011): 11-14.

Sheng, W. Q., Hong, Z. R., Xing, C. W. and H.H.P. 2004. Effect of potassium fertilizer application rates on plant potassium accumulation and grain quality of japonica rice. *Science Agriculture*. **37**: 1444-1450.

Sikdar, M.S.I., Rahman, M.M., Islam, M.S., Yeasmin, M.S. and Akhter, M.M. 2008. Effect of Nitrogen Level On Aromatic Rice Varieties And Soil Fertility Status. *Int. J. Sustain. Crop Prod.* **3**(3):49-54.

Singh, K. K., Singh, Y. V. and Sharma, S. K., 2010. Influence of biofertilizers and urea application on grain yield and quality attributed in rice cultivars. *Journal of Soil and Water Conservation.* **9** (3):271-276.

Singh, U.P. and Singh, Y. 2008. Response of boro rice cultivars to fertility levels in eastern Uttar Pradesh. O*ryza*, **45**(3): 250-251.

Singh, Y. P., Singh, R. and Gautam, A.K. 2008. Effect of Nitrogen Levels on Yield and nutrient uptake by salt tolerant rice and wheat cultivars in gypsum amended sodic soil. *Journal of the Society of Soil Science*. **56** (1): 86-91.

Singh, U., Ladha, J. K., Castillo, E. G., Punzalan,G., Tirol-Padre, A. and Duqueza, M.1998. Genotypic variation in nitrogen use efficiency in medium- and long-duration rice. *Field Crops Research,* **58** (1): 35-53.

Sudhakar, P.C., Sing J.P., Sing, Y. and Singh R. 2006. Effect of graded fertility levels and silicon sources on crop yield, uptake and nutrient-efficiency in rice. *Indian Journal of Agronomy.* **51**(3): 186-188.

Subbiah, B. V. and Asija, G. L. 1956. A rapid procedure for estimation of available nitrogen in soils. *Curr. Sci*. **25**: 259-260.

Sures, K. and Reddy, G. R. 2002. Effect of organic and inorganic sources of nutrients on growth and yield. *Oryza*. **39**(1): 57-59.

Swain, D. K., Bhaskar, B.C., krishnan, P., Rao, K. S., Nayak, S.K., and Dash, R.N. 2006. Variation in yield, N uptake and N use efficiency of medium and late duration rice varieties *Journal of Agricultural Science* . **144** :69–83.

Swarp, A. 2010. Intrigated plant nutrient supply and management strategies for enhancing soil quality, use efficiency and crop productivity. *Journal of the Society of Soil Science*. **58** (13): 25-31.

Tabar Y., 2012. Effect of Nitrogen and Phosphorus Fertilizer on Growth and Yield Rice (*Oryza Sativa* L). *Int.l j. of Agronomy and Plant Production*. **3**(12): 579-584.

Tayefe, M., Gerayzade, A., Amiri, E. and Zade, A. N. 2011. Effect of nitrogen fertilizer on nitrogen uptake, nitrogen use efficiency of rice *Intl. Conference on Biology, Environment and Chemistry IPCBEE* ,**24** :440-473.

Uddin S., Sarkar, M.A.R. and Rahman, M.M. 2013. Effect of nitrogen and potassium on yield of dry direct seeded rice cv. NERICA 1 in *aus* season *Intl. J. Agron. Plant. Prod*. **4**(1):69-75.

Watanabe, F. S. and Olsen, S. R., 1965. Test of an ascorbic acid method for determining phosphorous in water and NaHCO3 extracts from soil. *Soil Science Society of American Proceedings*, **29**:677- 678.

Zubaer, M.A., Chowdhury, A.K.M.M.B., Islam, M.Z., Ahmed, T. and Hasan , M.A. 2007. Effects of Water Stress on Growth and Yield Attributes of Aman Rice Genotypes. *Int. J. Sustain. Crop Prod.* **2**(6): 25-30

Zhang, Y. L., Fan, J. B., Wang, D. S. and Shen, Q. R. 2009. Genotypic differences in grain yield and physiological nitrogen use efficiency among rice cultivars. *Pedosphere*. **19**(6): 681–691.

Appendices

3.3 Weekly Meteorological data prevailing during crop growth period (*Kharif* 2012)

Week No.	Date	Temperature (°C)		Rain-fall (mm)	Relative Humidity (%)		Evaporation (mm)
		Max	Min		Morning	Evening	
25	18 Jun-24 Jun	31.04	24.15	6.32	89.42	68.57	29.0
26	25 Jun-01 Jul	37.0	26.3	21.8	78	49	57.1
27	02 Jul-08 Jul	30.3	25.0	72.9	91	81	27.4
28	09 Jul -15Jul	31.7	25.5	73.6	91	69	33.4
29	16 Jul -22 Jul	29.9	24.5	341.4	93	83	21.6
30	23 Jul -29 Jul	27.6	24.1	60.3	92	88	14.3
31	30Jul-05 Aug	25.8	23.2	271.1	95	91	10.5
32	06Aug-12Aug	28.8	24.8	106.8	93	79	19.4
33	13Aug-19Aug	30.2	25.3	33.2	90	78	26.4
34	20Aug -26Aug	29.6	24.5	127.6	93	78	19.1
35	27 Aug-02 Sep	31.1	25.8	55.6	92	74	24.6
36	03Sep - 09 Sep	30.3	25.1	74.4	93	75	21.0
37	10 Sep- 16 Sep	30.4	24.7	42.6	93	74	26.8
38	17 Sep-23 Sep	31.4	24.6	84.4	95	73	26.7
39	24 Sep -30 Sep	32.2	24.4	2.8	90	54	32.5
40	01 Oct - 07 0ct	31.9	23.9	9.2	91	56	29.0
41	08 Oct -14 Oct	31.0	20.2	0.0	89	45	27.1
42	15 Oct -21 Oct	31.9	19.5	0.0	88	37	28.9

3.10 Water table of the experimental field would be monitored by installing piezometer.

S.No.	Date	Rainfall mm	Water table cm
1	01-06-13	0	-100
2	02-06-13	0	-100
3	03-06-13	2.2	-100
4	04-06-13	0	-100
5	05-06-13	0	-100
6	06-06-13	0	-100
7	07-06-13	0	-100
8	08-06-13	0	-100
9	09-06-13	0	-100
10	10-06-13	0	-100
11	11-06-13	0	-100
12	12-06-13	0	-100
13	13-06-13	7.2	-97.2
14	14-06-13	42	-67.6
15	15-06-13	0.6	-68.2
16	16-06-13	23	-59.4
17	17-06-13	30.8	-43.7
18	18-06-13	0	-44.4
19	19-06-13	1.4	-46.4
20	20-06-13	20	-26.8
21	21-06-13	6	-23.8
22	22-06-13	15	-17.5
23	23-06-13	1.8	-16.6
24	24-06-13	0	-17.4
25	25-06-13	0	-17.8
26	26-06-13	4.2	-15.6
27	27-06-13	0	-16.8
28	28-06-13	0	-17.5
29	29-06-13	0	-17.9
30	30-06-13	0	-18.6
31	01-07-13	17.6	5.6
32	02-07-13	0.1	0.2

S.No.	Date	Rainfall mm	Water table cm
33	03-07-13	1	0.6
34	04-07-13	2.8	1.4
35	05-07-13	0	0.6
36	06-07-13	3.6	2.7
37	07-07-13	50.4	30.6
38	08-07-13	7	34.6
39	09-07-13	29	44.2
40	10-07-13	0.4	43.2
41	11-07-13	0	38.2
42	12-07-13	0	30.6
43	13-07-13	0	22.8
44	14-07-13	0	18.6
45	15-07-13	44.2	36.5
46	16-07-13	10.8	36.5
47	17-07-13	0	36.5
48	18-07-13	8	36.5
49	19-07-13	35	36.5
50	20-07-13	40	36.5
51	21-07-13	236.6	36.5
52	22-07-13	11	36.5
53	23-07-13	2	36.5
54	24-07-13	0	36.5
55	25-07-13	1.4	36.5
56	26-07-13	16.6	36.5
57	27-07-13	20.4	36.5
58	28-07-13	21.3	36.5
59	29-07-13	0	36.5
60	30-07-13	45.2	36.5
61	31-07-13	28.4	36.5
62	01-08-13	27.6	36.5
63	02-08-13	3.2	36.5
64	03-08-13	93.2	36.5
65	04-08-13	65.4	36.5
66	05-08-13	7.8	36.5
67	06-08-13	65.6	36.5
68	07-08-13	0	30.5
69	08-08-13	1.4	32.2
70	09-08-13	0.2	32.2
71	10-08-13	11	32.2
72	11-08-13	28.4	42.2
73	12-08-13	0.2	32.2
74	13-08-13	0.2	32.2
75	14-08-13	0	32.2
76	15-08-13	0	32.2
77	16-08-13	0.4	32.2
78	17-08-13	0	32.2
79	18-08-13	0	32.2
80	19-08-13	32.6	42.2
81	20-08-13	3.8	38.2
82	21-08-13	0.4	38.2
83	22-08-13	34.2	38.2
84	23-08-13	0	38.2
85	24-08-13	0	38.2
86	25-08-13	0.4	38.2
87	26-08-13	88.8	46.2
88	27-08-13	30	48.2
89	28-08-13	0.2	47.2
90	29-08-13	0	42.3
91	30-08-13	0	42.3
92	31-08-13	21	42.3
93	01-09-13	4.4	38.3
94	02-09-13	0	42.3
95	03-09-13	2.8	38.3
96	04-09-13	0.6	42.3
97	05-09-13	47.4	42.3
98	06-09-13	0.6	42.3
99	07-09-13	1.2	42.3
100	08-09-13	21.6	42.3
101	09-09-13	0.2	42.3
102	10-09-13	19	42.3
103	11-09-13	0	42.3
104	12-09-13	0	42.3
105	13-09-13	6.4	42.3
106	14-09-13	0	42.3
107	15-09-13	1	42.3
108	16-09-13	16.2	42.3
109	17-09-13	0	32.3
110	18-09-13	0	32.3

S.No.	Date	Rainfall mm	Water table cm
111	19-09-13	1.8	42.3
112	20-09-13	0	32.3
113	21-09-13	10.2	42.3
114	22-09-13	7	42.3
115	23-09-13	65.4	48.3
116	24-09-13	0	42.3
117	25-09-13	0	32.3
118	26-09-13	0	32.3
119	27-09-13	0	28.3
120	28-09-13	0	26.3
121	29-09-13	0	22.5
122	30-09-13	2.8	24.5
123	01-10-13	0	20.5
124	02-10-13	0	18.3
125	03-10-13	0.2	15.2
126	04-10-13	7.2	24.2
127	05-10-13	0	20.6
128	06-10-13	0	16.5
129	07-10-13	0	12.5
130	08-10-13	0	10.5
131	09-10-13	0	5.6
132	10-10-13	0	4.3
133	11-10-13	0	2.3
134	12-10-13	0	-0.8
135	13-10-13	0	-4.8
136	14-10-13	0	-6.4
137	15-10-13	0	-8.6
138	16-10-13	0	-10.4
139	17-10-13	0	-12.4
140	18-10-13	0	-14.4
141	19-10-13	0	-18.6
142	20-10-13	0	-21.4
143	21-10-13	0	-24.8
144	22-10-13	0	-26.2
145	23-10-13	0	-28.4
146	24-10-13	0	-30.5
147	25-10-13	0	-32.6
148	26-10-13	0	-35.8
149	27-10-13	0	-38.6
150	28-10-13	0	-41.4
151	29-10-13	0	-45.8
152	30-10-13	0	-49.7
153	31-10-13	0	-54.8

Table 1: Effect of different cultivars in three fertility level on N content in grain.

S.No.	Rice genotype	Symbol	Fertility level			Mean
			Control	Medium	High	
1.	IR-83388-B-B-108-3	V1	1.22 ^{b}	0.95 ^{b}	0.97 ^{a}	1.05 ^{cd}
2.	IR-83388-B-B-129-3	V2	1.26 ^{ab}	0.97 ^{b}	0.78 ^{b}	1.00 ^{d}
3.	IR-82589-B-B-84-3	V3	1.25 ^{ab}	0.97 ^{b}	0.99 ^{a}	1.07 ^{bcd}
4.	IR-83383-B-B-129-4	V4	1.30 ^{ab}	1.01 ^{ab}	1.11 ^{a}	1.14 ^{ab}
5.	R-RF-65	V5	1.28 ^{ab}	1.02 ^{ab}	1.05 ^{a}	1.12 ^{abc}
6.	IR-83377-B-B-93-3	V6	1.24 ^{ab}	0.95 ^{b}	1.00 ^{a}	1.06 ^{bcd}
7.	R-RF-69	V7	1.21 ^{b}	1.02 ^{ab}	1.04 ^{a}	1.09 ^{abc}
8.	IR-83383-B-141-2	V8	1.33 ^{ab}	1.05 ^{ab}	1.07 ^{a}	1.15 ^{ab}
9.	IBD-I-85 (Local entry)	V9	1.26 ^{ab}	1.13 ^{a}	1.12 ^{a}	1.17 ^{a}
10.	R-RF-85 (Local entry)	V10	1.30 ^{ab}	1.14 ^{a}	1.05 ^{a}	1.16 ^{a}
11.	IR-64	V11	1.25 ^{ab}	1.08 ^{ab}	1.10 ^{a}	1.14 ^{ab}
12	MTU-1010	V12	1.38 ^{a}	1.04 ^{ab}	0.97 ^{a}	1.13 ^{abc}
	F-MEAN		1.27	1.03	1.02	1.11

CD $_{\text{at 5\%}}$ for T**= 0.078, F**=0.044, FxT= NS

Table 2: Effect of different cultivars in three fertility levels on N content in Straw.

S.No.	Rice genotype	Symbol	Fertility level			Mean
			Control	Medium	High	
1.	IR-83388-B-B-108-3	V1	0.36 ^{e}	0.29 ^{b}	0.32 ^{abc}	0.32^{c}
2.	IR-83388-B-B-129-3	V2	0.39 ^{d}	0.28 ^{b}	0.30 ^{bc}	0.33^{c}
3.	IR-82589-B-B-84-3	V3	0.43 ^{c}	0.29 ^{b}	0.32 ^{abc}	0.35^{b}
4.	IR-83383-B-B-129-4	V4	0.46 ^{ab}	0.32 ^{a}	0.33 ^{ab}	0.37^{a}
5.	R-RF-65	V5	0.41 ^{cd}	0.32 ^{a}	0.33 ^{ab}	0.36^{a}
6.	IR-83377-B-B-93-3	V6	0.44 ^{bc}	0.30 ^{ab}	0.31 ^{abc}	0.35^{b}
7.	R-RF-69	V7	0.47 ^{a}	0.29 ^{b}	0.29 ^{c}	0.35^{b}
8.	IR-83383-B-141-2	V8	0.48 ^{a}	0.33 ^{a}	0.33 ^{ab}	0.38^{a}
9.	IBD-I-85 (Local entry)	V9	0.42 ^{c}	0.33 ^{a}	0.32 ^{abc}	0.36^{a}
10.	R-RF-85 (Local entry)	V10	0.47 ^{a}	0.33 ^{a}	0.34 ^{a}	0.38^{a}
11.	IR-64	V11	0.39 ^{de}	0.33 ^{a}	0.31 ^{abc}	0.34 ^{b}
12	MTU-1010	V12	0.43 ^{c}	0.28 ^{b}	0.33 ^{ab}	0.35^{b}
	F-MEAN		0.43	0.31	0.32	0.35

CD $_{\text{at } 5\%}$ for T**= 0.013 F**=0.004 FxT**= 0.03

Table 3 : Effect of different cultivars in three fertility levels on P content in Grain.

S.No.	Rice genotype	Symbol	Fertility levels			Mean
			Control	Medium	High	
1.	IR-83388-B-B-108-3	V1	0.263 ^{d}	0.200 ^{cd}	0.210 ^{bc}	0.224 ^{cde}
2.	IR-83388-B-B-129-3	V2	0.258 ^{d}	0.195 ^{d}	0.200 ^{c}	0.218 ^{de}
3.	IR-82589-B-B-84-3	V3	0.250 ^{d}	0.193 ^{d}	0.198 ^{c}	0.213 ^{e}
4.	IR-83383-B-B-129-4	V4	0.275 ^{cd}	0.208 ^{bcd}	0.210 ^{bc}	0.231 ^{bcd}
5.	R-RF-65	V5	0.250 ^{d}	0.208 ^{bcd}	0.210 ^{bc}	0.223 ^{de}
6.	IR-83377-B-B-93-3	V6	0.265 ^{cd}	0.218 ^{bcd}	0.208 ^{bc}	0.230 ^{bcd}
7.	R-RF-69	V7	0.288 ^{bc}	0.223 ^{abc}	0.210 ^{bc}	0.240 ^{b}
8.	IR-83383-B-141-2	V8	0.263 ^{d}	0.213 ^{bcd}	0.218 ^{abc}	0.231 ^{bcd}
9.	IBD-I-85 (Local entry)	V9	0.318 ^{a}	0.233 ^{ab}	0.240 ^{a}	0.263 ^{a}
10.	R-RF-85 (Local entry)	V10	0.300 ^{ab}	0.245 ^{a}	0.218 ^{abc}	0.254 ^{a}
11.	IR-64	V11	0.260 ^{d}	0.223 ^{abc}	0.230 ^{ab}	0.238 ^{bc}
12	MTU-1010	V12	0.263 ^{d}	0.200 ^{cd}	0.198 ^{c}	0.220 ^{de}
	F-MEAN		0.271	0.213	0.212	0.232

CD $_{\text{at } 5\%}$ for T**= 0.018 F**=0.011 FxT= NS

Table 4 : Effect of different cultivars in three fertility levels on P content in Straw.

S.No.	Rice genotype	Symbol	Fertility levels			Mean
			Control	Medium	High	
1.	IR-83388-B-B-108-3	V1	0.060^{jkl}	0.043^{cde}	0.030^{f}	0.044^{ki}
2.	IR-83388-B-B-129-3	V2	0.080^{e}	0.043^{cde}	0.040^{cde}	0.054^{f}
3.	IR-82589-B-B-84-3	V3	0.090^{c}	0.040^{def}	0.033^{ef}	0.054^{fg}
4.	IR-83383-B-B-129-4	V4	0.080^{ef}	0.050^{bc}	0.048^{abc}	0.059^{de}
5.	R-RF-65	V5	0.073^{i}	0.043^{cde}	0.043^{bcd}	0.053^{fgh}
6.	IR-83377-B-B-93-3	V6	0.080^{efg}	0.033^{f}	0.038^{def}	0.050^{hij}
7.	R-RF-69	V7	0.105^{ab}	0.053^{ab}	0.040^{cde}	0.066^{c}
8.	IR-83383-B-141-2	V8	0.090^{cd}	0.048^{bcd}	0.043^{bcd}	0.060^{d}
9.	IBD-I-85 (Local entry)	V9	0.080^{e-h}	0.060^{a}	0.050^{ab}	0.303^{a}
10.	R-RF-85 (Local entry)	V10	0.110^{a}	0.060^{a}	0.053^{a}	0.074^{ab}
11.	IR-64	V11	0.060^{jkl}	0.053^{ab}	0.048^{abc}	0.053^{f-i}
12	MTU-1010	V12	0.063^{j}	0.038^{ef}	0.038^{def}	0.046^{k}
	F-MEAN		0.141	0.047	0.042	0.076

CD $_{\text{at 5\%}}$ for T**=0.003 F**=0.005 FxT**= 0.005

Table 5 : Effect of different cultivars in three fertility levels on K content in Grain.

S.No.	Rice genotype	Symbol	Fertility levels			Mean
			Control	Medium	High	
1.	IR-83388-B-B-108-3	V1	0.420^{g}	0.210^{g}	0.180^{g}	0.270^{ij}
2.	IR-83388-B-B-129-3	V2	0.520^{b}	0.310^{b}	0.280^{b}	0.370^{b}
3.	IR-82589-B-B-84-3	V3	0.350^{i}	0.140^{i}	0.110^{i}	0.200^{k}
4.	IR-83383-B-B-129-4	V4	0.460^{e}	0.250^{e}	0.220^{e}	0.310^{f}
5.	R-RF-65	V5	0.580^{a}	0.370^{a}	0.340^{a}	0.430^{a}
6.	IR-83377-B-B-93-3	V6	0.460^{e}	0.250^{e}	0.220^{e}	0.310^{fh}
7.	R-RF-69	V7	0.420^{g}	0.210^{g}	0.200^{f}	0.277^{i}
8.	IR-83383-B-141-2	V8	0.380^{h}	0.170^{h}	0.140^{h}	0.230^{j}
9.	IBD-I-85 (Local entry)	V9	0.440^{f}	0.230^{f}	0.200^{f}	0.290^{h}
10.	R-RF-85 (Local entry)	V10	0.520^{b}	0.310^{b}	0.280^{b}	0.370^{bc}
11.	IR-64	V11	0.510^{c}	0.300^{c}	0.270^{c}	0.360^{cd}
12	MTU-1010	V12	0.480^{d}	0.270^{d}	0.240^{d}	0.330^{e}
	F-MEAN					

CD $_{\text{at 5\%}}$ for T**= 0.008 F**=0.003 FxT*= 0.007

Table 6 : Effect of different cultivars in three fertility levels on K content in Straw.

S.No.	Rice genotype	Symbol	Fertility levels			MEAN
			CONTROL	MEDIUM	HIGH	
1.	IR-83388-B-B-108-3	V1	1.720 ^{bc}	1.270 ^{bc}	1.170 ^{bcd}	1.387 ^{b}
2.	IR-83388-B-B-129-3	V2	1.650 ^{c}	1.200 ^{cd}	1.100 ^{cde}	1.317 ^{cd}
3.	IR-82589-B-B-84-3	V3	1.630 ^{c}	1.180 ^{cd}	1.080 ^{def}	1.297 ^{d}
4.	IR-83383-B-B-129-4	V4	1.450 ^{d}	1.000 ^{ef}	0.972 ^{fg}	1.141 ^{f}
5.	R-RF-65	V5	1.710 ^{bc}	1.260 ^{bc}	1.160 $^{b-e}$	1.377 ^{bc}
6.	IR-83377-B-B-93-3	V6	1.950 ^{a}	1.500 ^{a}	1.400 ^{a}	1.617 ^{a}
7.	R-RF-69	V7	1.480 ^{d}	1.100 ^{de}	0.888 ^{g}	1.156 ^{f}
8.	IR-83383-B-141-2	V8	1.710 ^{bc}	1.260 ^{bc}	1.160 $^{b-e}$	1.377 ^{bc}
9.	IBD-I-85 (Local entry)	V9	1.680 ^{bc}	1.348 ^{b}	1.200 ^{bc}	1.409 ^{b}
10.	R-RF-85 (Local entry)	V10	1.503 ^{d}	1.150 ^{cd}	1.050 ^{ef}	1.234 ^{e}
11.	IR-64	V11	1.780 ^{b}	1.263 ^{bc}	1.230 ^{b}	1.424 ^{b}
12	MTU-1010	V12	1.260 ^{e}	0.923 ^{f}	0.768 ^{h}	0.983 ^{g}
	F-MEAN		1.627	1.204	1.098	1.310

CD $_{\text{at 5\%}}$ for T**=0.062 F**=0.039 FxT= 0.109