

**“ STABILITY ANALYSIS IN UPLAND RICE  
(*Oryza sativa* L.) ”**

*By*

**Mr. KATRAJKAR PURUSHOTTAM VITTHAL**

(Reg. No. 09/053)

*A Thesis submitted to the*

**MAHATMA PHULE KRISHI VIDYAPEETH,  
RAHURI – 413722 ; DIST. AHMEDNAGAR,  
MAHARASHTRA (INDIA)**

*In partial fulfilment of the requirements for the degree  
of*

**MASTER OF SCIENCE (Agriculture)**

*in*

**AGRICULTURAL BOTANY  
(GENETICS AND PLANT BREEDING)**

**DIVISION OF AGRICULTURAL BOTANY  
COLLEGE OF AGRICULTURE, KOLHAPUR  
MAHATMA PHULE KRISHI VIDYAPEETH,  
RAHURI – 413 722; DIST. AHMEDNAGAR (M.S.) INDIA  
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**Approved by**

**Dr. S.R.Shinde**

(Chairman and Research Guide)

**Dr.R.V.Kulkarni**

(Committee member)

**Prof.L.C.Mohatkar**

(Committee member)

**Dr.A.G.Bhoite**

(Committee member)

**Prof. M.R.Shewale**

(Committee member)

**DIVISION OF AGRICULTURAL BOTANY  
COLLEGE OF AGRICULTURE , KOLHAPUR.  
MAHATMA PHULE KRISHI VIDYAPEETH,  
RAHURI – 413 722; DIST. AHMEDNAGAR (M.S.) INDIA  
2011**

## **CANDIDATE'S DECLARATION**

**I hereby declare that this thesis or part there of**

**has not been submitted by me or any other**

**person to any other University**

**or Institute for Degree**

**or Diploma**

**Place :** College of Agriculture ,

Kolhapur.

**( Katrajkar P.V.)**

**Date :** / / 2011

**Dr. S. R. Shinde**

Associate professor of  
Agricultural Botany;  
College of Agriculture, Kolhapur.  
Mahatma Phule Krishi Vidyapeeth,  
Rahuri – 413 722; Dist. Ahmednagar,  
Maharashtra State (India).

**CERTIFICATE**

This is to certify that the thesis entitled,  
**“STABILITY ANALYSIS IN UPLAND RICE (*Oryza sativa* L.)”**  
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Vidyapeeth, Rahuri, Dist. Ahmednagar (Maharashtra State) in  
partial fulfillment of the requirements for the degree of  
**MASTER OF SCIENCE (Agriculture)** in **AGRICULTURAL  
BOTANY (GENETICS AND PLANT BREEDING)**, embodies the  
results of a piece of bonafide research carried out by  
**Mr. KATRAJKAR PURUSHOTTAM VITTHAL**, under my  
guidance and supervision and that no part of this thesis has  
been submitted for any other degree or diploma in other form.

Place : College of Agriculture,  
Kolhapur.

**Dr.S.R.Shinde**

Date :        /        /2011

(Research Guide)

**Dr. A. L. Pharande**

Associate Dean,  
College of Agriculture, Kolhapur.  
Mahatma Phule Krishi Vidyapeeth,  
Rahuri – 413 722; Dist. Ahmednagar,  
Maharashtra State (India).

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guidance and supervision of **Dr. S. R. Shinde**, Associate  
professor of Agricultural Botany; College of Agriculture,  
Kolhapur. and that no part of this thesis has been submitted  
to any other University for degree or diploma.

Place : College of Agriculture,  
Kolhapur.

**Dr.A.L.Pharande**

Date : / /2011

(Associate Dean)

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Place : College of Agriculture,  
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Date :        /        /2011

( **Katrajkar P.V** )

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## ABBREVIATIONS

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<b>Abbreviation/ symbol</b>	<b>Description</b>
CD	: Critical difference
cm	: Centimeter (s)
CV	: Coefficient of variation
d.f.	: Degrees of freedom
E	: Environment(s)
<i>et al.</i>	: Et alli (and others)
etc.	: Et cetra
G	: Genotype
g	: gram(s)
ha.	: hectare
i.e.	: id es (That is)
Kg.	: Kilogram(s)
l	: Linear
M.S.S.	: Mean sum of squares
resp.	: Respectively
S.E.	: Standard error
<i>Viz.</i>	: Videlicet (namely)
%	: Percent
/	: Per

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**ABSTRACT**

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**COLLEGE OF AGRICULTURE, KOLHAPUR.**

**MAHATMA PHULE KRISHI VIDYAPEETH,**

**RAHURI - 413722.**

---

<b>Research Guide</b>	:	<b>Dr. S.R. Shinde</b>
<b>Department</b>	:	Agricultural Botany
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---

It is necessary to test different genotypes in the target environment to evolve suitable and stable genotypes. Information on the G x E interaction and stability parameters provides a better measure of stable variety and the varietal adaptability.

A field experiment was carried out during *kharif* 2010, with ten rice genotypes. These genotypes were evaluated for eleven different expressions under six dates of sowing to study their stability.

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***Abstract contd...***

***Katrajkar P.V.***

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Genotypes x Environment interactions were found to be significant for nine out of eleven characters under study. Data was subjected to statistical analysis by following the linear regression model of Eberhart and Rusell (1966). Both linear and non linear components exhibited significance for all the traits, considered for stability analysis.

The present study indicate that sowing dates E<sub>2</sub> (30<sup>th</sup> May ) followed by E<sub>3</sub> (15<sup>th</sup> June) and E<sub>1</sub> (15<sup>th</sup>May) were most favourable for expression of yield and yield contributing traits.

It is concluded that Ratna from early maturity group, Jaya and Phule radha from mid-late group and Pusa basmati-1 and Bhogawati from late maturity group were observed to be stable for yield and yield contributing characters.

## 1. INTRODUCTION

Rice is one of the most important food crop in the world. Today rice has special position as a source of food for over 75% Asian population and 2.4 billion of world population (Sedghi-Azar *et al.*,2008). In India it is an integral part of the human traditions used in rituals and ceremonies connected with birth, marriages and funerals from ancient times. It is the main constituents of daily diet in southern and eastern India. Rice provides 20 per cent calories.(Chaudhary and Tran, 2001) It also provides vitamins like Thiamine (Vit. B<sub>1</sub>), Riboflavin (Vit. B<sub>2</sub>), Niacin (Vit. B<sub>3</sub>), Pantothenic acid (Vit.B<sub>5</sub>) and minerals like Calcium, Magnesium, Iron, Phosphorus, Zinc etc. to the world population. The following table indicates the nutritional value of the rice.

Rice: Nutritional value per 100 g.	Energy (Kcal)	CHO (g)	Sugar (g)	Dietary fiber(g)	Fat (mg)	Protein (g)	Water (g)
	365	79	0.12	1.3	500	7.12	11.6

(Source:USDA Nutrient database)

Rice (*Oryza sativa* L.) is one of the most important plant from poaceae (Graminae), originated in India. Rice plant may be characterized as an annual grass. It could normally grow between 20°C to 35°C. Globally it is grown extensively in tropical and sub-tropical regions of the world. Paddy is cultivated as a monocrop during *kharif* season under rainfed situation in two different topographical situations viz., Uplands and low lands.

Rice plant varies in size from dwarf mutants only 0.3 to 0.4 m. tall to floating varieties more than 7 m. tall. Majority

of the commercial varieties range from 1 to 2 m. in height. Vegetative organs consist of roots, culms, and leaves. A branch of the plant bearing the culm, leaves, roots and often a panicle is a tiller. (Te-tzu chang *et al*, 1965)

The botanical name for the rice grown in Asia is ***Oryza sativa* (2n=24)**. There are three most common sub-series of *Oryza sativa* as ***japonica***, ***javanica*** and ***indica***. Japonica is found in more moderate climate of Japan and Korea, where it is popularly grown and consumed domestically. It is identifiable though its relatively shorter plant height and short, roundy rice grains. When cooked, its grains are moist and slightly sticky. Javanica, ones with the larger grains, are commonly found in Indonesia and Philippines. Due to its low productivity, the cultivation of javanica is only limited to the place, they were first discovered. Indica are more common to warm, semitropical and tropical climate. It is the major rice grown all over Asia including India. Suffice it to say that indica is the world's staple food. The *Oryza glaberrima* is grown in Africa as human food, while *Oryza officinalis*, *Oryza spontanea*, *Oryza perennis* and *Oryza nivara* are wild species of rice.

Rice is grown worldwide over an area of 158.955 million hectares with a production of 685.013 million tonnes and productivity of 4.309 tonnes per hectare during 2008-09. Asia tops the list in the total area and production. The major contributors are China, India, Japan and Indonesia. India now occupies second rank in rice production next to China among the rice producing countries of the world. India contributes about 20-25 % of rice production in the world. (FAO, Regional Office for Asia and the Pacific, Bangkok, 2008).

In India rice occupies an area of 45.54 million hectares with a production of 99.18 million tonnes and productivity of 2.17 tonnes per hectare during 2008-09. The leading rice producing state in India is West Bengal followed by Andhra Pradesh and Uttar Pradesh. The next table indicates the contribution of different states in total rice production of India.

**Table.1: India rice production 2008-09:**

State	Area		Production		Productivity Kg /hactare
	Million hactares	% to All India	Million Tonnes	% to All India	
West Bengal	5.94	13.03	15.04	15.16	2533
Andhra Pradesh	4.39	9.63	14.24	14.36	3246
Uttar Pradesh	6.03	13.25	13.10	13.20	2171
Punjab	2.74	6.01	11.00	11.09	4022
Orissa	4.45	9.78	6.81	6.87	1529
Bihar	3.50	7.68	5.59	5.64	1599
Tamil Nadu	1.93	4.24	5.18	5.23	2683
Chattisgarh	3.73	8.20	4.39	4.43	1176
Assam	2.48	5.46	4.01	4.04	1614
Karnataka	1.51	3.32	3.80	3.83	2511
Jharkhand	1.68	3.70	3.42	3.45	2031
Haryana	1.21	2.66	3.30	3.33	2726
<b>Maharashtra</b>	<b>1.52</b>	<b>3.34</b>	<b>2.28</b>	<b>2.30</b>	<b>1501</b>
Madhya Pradesh	1.68	3.69	1.56	1.57	927
Gujarat	0.75	1.64	1.30	1.31	1744
Kerala	0.23	0.51	0.59	0.60	2519
Others	1.75	3.85	3.56	3.59	---
<b>All India</b>	<b>45.54</b>	<b>100.00</b>	<b>99.18</b>	<b>100.00</b>	<b>2178</b>

(Source: Directorate of Economics and Statistics (2008-09), Department of Agriculture and Cooperation, Ministry of Agriculture, Government of India )

As far as the Maharashtra state is concerned, the area under rice cultivation is 1.52 million hectares (3.34%) with annual production of 2.28 million tonnes (2.30%) and productivity of 1501 Kg. per hectares during 2008-09.

It is well known that final yield (phenotype) of a given cultivar is dependent on both genetic factors (genotype) and growth conditions (environment). Much effort has been done in breeding to improve genetic potential of rice cultivars or hybrids by optimizing plant type. However, little research has been done in understanding the effect of environmental factors on the performance of quantitative traits in upland rice genotypes. The objectives of the current experiment were to determine the relationship between yield formation and environments, and to clarify the quantitative traits closely linked with high yield under field conditions.

Keeping all the above mentioned points in view, the present study entitled “Stability analysis in upland rice (*Oryza sativa* L.)” was undertaken by using ten genotypes of rice with following objectives :

**Objectives:**

- i) To evaluate seed yield potential of different genotypes under different environmental conditions.
- ii) To estimate stability parameters for yield and its components.
- iii) To estimate G x E interaction for seed yield and its components.
- iv) To identify promising genotypes suitable for different sowing time.

## 2. REVIEW OF LITERATURE

The stability of productivity for characters of economic importance like yield and quality is of interest for the plant breeders. It is well known that some varieties of crop plant are widely adapted and others are not. Thus adaptation is the property of individual genotype permitting its survival under selection. According to Simmonds (1962), it is the property of genotypes permitting subsequent alteration of adaptation in response to changed selection pressure.

### 2.1 Genotype and environment (G x E) interactions:

G x E interactions are of major importance to plant breeder in developing improved varieties. A low level of interactions is useful for some characters so as to maximize the stability of performance over a number of environments. Environment is the sum of total of physical, chemical and biological factors.

Comstock and Moll (1963), has classified it in two categories.

- i) Micro environment
- ii) Macro environment

Micro environment is the environment of a single organism as opposed to that of another growing at the same time and same place where as Macro environment which is associated with a general location and period of time and is a collection of micro environment. They have shown

statistically, the effect of large genotype x environment interaction in reducing the process of selection.

Allard and Bradshaw (1964) coined the terms predictable and unpredictable environments. The predictable environment includes the permanent feature of the environment, such as climate, soil type, day length etc. It also includes controlled variables (Perkins and Jinks, 1971), for example, the level of fertilizer application, sowing dates, irrigated and unirrigated conditions, plant population densities etc. The unpredictable environment includes factors beyond the control of human beings i.e. amount and distribution of rainfall, the prevailing temperature.

## **2.2 Statistics and genetics of G x E interactions:**

Finlay and Wilkinson (1963), utilized technique to compare the performance of a set of cultivars grown at many sites for each variety. Varietal mean yield over environments and regression coefficients were used to classify the cultivars specially adapted to poor, better yielding environments and for general adaptability. They have indicated average phenotypic stability by a regression coefficient of unity ( $b_i = 1.0$ ). A cultivar with  $b_i < 1.0$  has above average stability,  $b_i > 1.0$  has below average stability and  $b_i = 0$  has absolute phenotypic stability which means a constant grain yield in all environments. The ideal cultivar is one that possesses genetic potential in the highest yielding environment and maximum phenotypic stability.

Eberhart and Russell (1966) observed that the corn hybrids with a regression coefficient less than 1.00 usually had means yields that were below average. Accordingly they suggested that a desired variety should have high mean, regression coefficient equal to 1.00 and variance due to regression as small as possible. Thus they modified the regression techniques, which enables partitioning of genotype x environment interaction of each variety into two parts ( $b_i$ ), the variation due to response of variety to varying environmental indices (sum of squares due to regression) and the unexplainable deviation from the regression on the environmental index. They defined both the linear ( $b_i$ ) and non linear ( $S^2_{di}$ ) component as stability parameters. They compared two types of crosses in maize. They reported that hybrid x year interactions were significantly greater for single crosses than for three way or double crosses. They further stated that some single crosses may show as much or more phenotypic stability than most stable three way or double crosses.

The approaches of Finlay and Wilkinson (1963) and Eberhart and Russell (1966) are purely statistical and component of these analysis have not been related to the parameters in biometrical genetic model. Perkins and Jinks (1968) performed the second approach which was based on the fitting of models which specify the contribution of genetic, environmental and genotype x environmental interaction to generation means and variance allowing for the contribution

of additive, dominance and epistatic gene effects to the genetic and interaction components of the model

$$Y_{ijk} = \mu + d_i + E_j + B_i E_j + e_{ij} + e_{ijk}$$

Knight (1970), reviewed the regression analysis developed by Finlay and Wilkinson to investigate genotype X environment interactions and to assess genotypes for their adaptation to a range of environments.

Freeman and Perkins (1971), proposed independent estimate of environmental index in the following two ways (a) divide the replications in to two groups, so that one group may be used for measuring the average performance of varieties, which will used for estimating environmental index (bi) use one or more varieties as check and assess environmental index on the basis of their performance. They proposed following model.

$$Y_{ijk} = m + d_i + e_{ij} + e_{ijk}$$

Bains and Gupta (1972) proposed that if the linear regression of above average genotypes upon the environmental mean is less than 1.0 with comparatively small deviation mean square, an agreeable compromise between the two definitions of Finlay and Wilkinson (1963) and Eberhart and Russell (1966) is essential.

Singh and Singh (1980), studied stability of component characters in relation with the stability of yield. They analyzed how the component characters interact. The relationship among predictable behavior of G x E interaction of the component traits and yield revealed that linear response of yield was positively and significantly associated only with the

linear response of tiller per plant whereas that of yield per spike was positively associated with that of number of grains per spike and test weight.

Dabholkar (1999) had given applicability of stability models. He suggesting that the genotype is having the general adaptability if the 'bi' value (linear component) is at unity with pooled mean above the grand mean. Further, he also suggested that the performance of the particular genotype is predictable, if that genotype is having  $S^2_{di}$  value (non-linear component) non-significant.

### **2.3 Stability analysis in rice :**

Genotypes do not give the same phenotypic performance under changing environment and different genotypes respond differently to a specified environment. This variation arising from the lack of correspondence between genetic and non-genetic effects, known as G x E interaction. In other words, the failure of a genotype to give the same phenotypic performance when grown under different environments is the reflection of G x E interactions. These are generally considered as an impediment in plant breeding as it baffles the breeder in judging the real potential of genotype when grown in different environments. Several workers considered G x E interactions as linear function of environment and proposed regression of yield of a genotype on the mean yield of all genotype in each environment to evaluate stability of

genotype. (Finlay and Wilkinson, 1963; Eberhart and Russell, 1966; Perkins and Jinks, 1968).

Eberhart and Russell (1966) redefined the technique of Finlay and Wilkinson (1963) and suggested that the interaction of genotype with environment is a function of linear and non-linear response of genotype to additive environmental variation. Thus, in addition to linear component ( $b_i$ ), they included a non-linear component ( $S^2d_i$ ) also as a stability parameter. They defined stable variety as one, which has a high mean performance, unit regression coefficient ( $b_i=1$ ) and the least deviation from regression ( $S^2d_i=0$ ).

Amirthadevarathinam (1987) evaluated a set of fifteen genotypes of dry and semi-dry paddy for stability performance for yield and four yield components under four different environments and reported that, stress conditions of moisture especially in the rainfed crop reduced the mean values with maximum reduction was observed in productive tillers followed by plant height, grain yield, days to flowering and grains per panicle. He further reported that the dry and semi-dry paddy was in general characterized by low tillering potential. The genotype-environment interaction was significant and both the linear and non-linear components were equally important. Both TKM 9 and Poongar were the high yielding genotypes with wider adaptability and high stability in addition to being specifically suitable to unfavorable environments.

Young and Virmani (1990) studied stability of rice hybrids and their parents for agronomic traits and reported that average stability for only one hybrid (IR 54752A/ IR 52). Further, they stated that stable hybrids can be developed from stable parents.

Mujumdar and Borthakur (1991) tested nine genotypes of rice for grain yield and eight other traits over five years under cold stress conditions. PK 2-1-2 and PK 12-22 were stable yielder as indicated by their regression coefficient (bi) 0.77 and 0.99, respectively. Other cultures, PK 1-1-3, PK 2-27-4 and JK 2-6 possessing regression coefficient values 1.17, 1.18 and 1.09, respectively with a reasonable amount of standard deviation could not give stable yield under these cold stresses.

Reddy and Chaudhary (1991) studied stability with respect to grain yield and their components during four successive seasons for 25 short duration rice genotypes. Significant G x E interactions was observed for grain yield, test weight, ear bearing tillers per plant, panicle length and plant height. They also found that both linear and nonlinear components of G x E interactions were significant for all the characters studied except ear bearing tillers per plant. They concluded that stability for grain yield seems to be imparted by the stability for yield components.

Mahapatra (1993) concluded stability analysis for 12 rice varieties grown under 30 environments created through the combination of date of seedling, method of planting, doses of fertilizer and growing seasons. They observed that variations due to genotypes, environments and G x E interactions were highly significant and a large portion of these interactions was due to linear regression. They also found that mean squares due to linear and non-linear components were significant.

Kulkarni and Eswari (1994) studied G x E interaction for grain yield and five yield components in 10 varieties under four ages of the seedling under transplanting condition in two years. Compared to the 30 days old seedling, the flowering duration increased by 6.5, 14.5 and 25 days when planted with 40, 50 and 60 day old seedling, respectively. They also concluded that G x E interaction for all the characters was significant except flowering and spikelet sterility.

Mahapatra and Das (1999) evaluated 12 early maturing rice varieties in respect of grain and 7 components traits for their adaptability over 30 environments. They observed high significant variation due to genotypes, environments and G x E interactions in respect of all the eight characters and a large portion of the interactions was due to linear regression. They recorded highly significant G x E interaction for linear components indicating differential response of the varieties to changing environment. They concluded that stability in grain yield was due to stability in some component traits and

plasticity in others, and that pattern of stability and plasticity in component traits differed from variety to variety.

Qayyum *et al.* (2000) evaluated 6 rice genotypes for stability in yield performance at 5 locations. They observed significant genetic differences among rice genotypes while genotype x location interaction was non-significant. The regression coefficient ( $b_i$ ) and small deviations from regression ( $S^2_{di}$ ) were significant for all genotypes except PK 4554 and Basmati 385. Basmati 385 performed best at all locations with average stability.

Chaudahari *et al.*, (2002) evaluated seven rice genotypes for the stability of yield and its components by growing them in wet season over four years during 1993-96 at Igatpuri, Maharashtra. Significant differences among the genotypes and environments suggested the presence of wide variability. Both the component of G x E interaction were significant, but the linear component was predominant for number of panicles per square meter, grains per panicle, panicle length. The linear component for grain yield was significant in only one genotype, while the non-linear component was significant in three genotypes, indicating the preponderance of non linear G x E interaction for this trait.

Kishor *et al.* (2002) studied the G x E interaction for grain yield and some associated traits in eight boro rice genotypes under four different environments in North Bihar during 1989-99. Both the linear and non-linear components of the G x E interaction were significant, but the

linear components was more predominant. Based on the stability parameters, the genotypes. PSRM-2-3-4 B-6, PSRM 1-15-3B-15 were found to stable with higher grain yield. They also concluded that the mean performance was positively correlated with linear regression (bi).

Narayana swamy and Dushyantha kumar (2003) found, Variance due to genotypes, environment and genotype x environmental interactions were significant for most of the characters studied. A linear relationship between mean performance and environment index was observed. A substantial portion of genotype x environmental interaction (linear) was significant for all the characters except days to 50 per cent flowering, 1000- grain weight and yield per hectare. Considering all the stability parameters, PSP-87, PSP - 14-2-3 and Arkavathi among selections and IR-20, Jaya, Mandya Vani and Mandya Vijaya had better stability over the environment. Among genotypes, PSP -4-2-3, PSP-87 and IR-20 are stable for yield. Based on the stability parameters and overall mean, PSP-87, PSP 4-2-3. Arkavathi, IR-20, Jaya, Mandya Vani and Mandya Vijaya were identified as elite genotypes in this study.

Belhekar *et al.* (2004), evaluated eleven elite genotype and three released varieties of rice over three locations of grain yield and its components. G x E interaction was significant for all the characters studied. E + (G x E) sum of squares were significant for all the characters. On examination of individual parameter of stability for

different genotypes and varieties, it is concluded that the RTN 148-1-2, RTN 71-2-4, SYE 36-17-14-15 of fine rice and RTN 1 of coarse rice varieties possesses average stability for given yield.

Munisonnappa *et al.*(2004) conducted a field experiment during kharif 2000, with 11 rice genotypes (7 hybrids and 4 check varieties) for eleven quantitative traits in six environments to study their stability. Genotype X environment interactions were found to be significant for ten out of eleven characters considered for stability analysis. The variance due to environment (linear) was highly significant for all the characters. Further the variance due to GXE (linear) was significant for days to fifty percent flowering, plant height, number of spikelets per panicle, thousand grain weights and grain yield per plant. Non linear component was found to be significant for all the characters except number of panicles per plant and grain yield per plant. Among seven hybrids studied four hybrids viz., DRRH-1, KRH-2, Sahyadri and KMRH- showed stability for yield with high mean. Considering different dates of sowing KRH-4 is most suitable for early kharif. While DRRH-1 and KMRH-4 are suitable for late sowing in kharif (15th August to 10th September). Of the seven hybrid studied, four hybrids viz., DRRH-1, KRH-2, Sahyadri, and KMRH-4 were consistent and high yielding compared to checks Jaya and IR30864.

Kashyap *et al.* (2005) screened 21 genotypes of aromatic rice for phenotypic stability for seed yield and its components

along with 6 checks grown in four environments. They concluded that both predictable and unpredictable components constituted to the G x E interaction for seed yield and its components except 100 seed weight.

Shanmugnathan and Ibrahim (2005) studied eleven rice hybrids in six different environments for their stability. The data were analyzed by using Eberhart and Russell (1966) approach for yield and its contributing characters. Both linear and non-linear components of G x E interaction were important for the expression of most of the traits; however linear component was larger in magnitude than the non-linear component.

Vidhufrancis *et al.* (2005) observed G x E interaction for grain yield and other yield attributes in seven rice cultures and two local checks under three different ecological situations of Kerala. Significant G x E interaction were observed for many traits. Among the linear and non-linear components of G x E interaction, linear component was predominant for days to 50 per cent flowering, volume expansion ratio and head rice recovery suggesting variation in the performance of different cultures grown over environments could be predicted. On the basis of stability parameters, culture C 26T (b) was identified as the stable culture for grain yield in three different ecological situations of Kerala.

Ali *et al* (2006) evaluated sixteen genotypes developed, through hybridization and mutation breeding techniques,

during the year 2003-04 on nine locations covering most of the area of Punjab province including Faisalabad, Toba Tek Singh and Jhang. NIAB-IRRI-9, Jhona-379 salt tolerant genotypes and super Basmati, a salt sensitive variety were included as standard checks. The tested material (six genotypes) was generated by crossing fine varieties of rice viz. Basmati-370 and Basmati-385 with three coarse varieties of rice viz. NIAB-IRRI-9, Jhona-349 and NIAB-Rice-1. The mutants (seven mutants) were derived by gamma irradiation of rice varieties, Basmati-370 and Basmati-385. The nine sets of experiments were conducted in the naturally high saline sodic soils having EC range of 9.2-18.13 d/Sm pH=8.65-9.50, and SAR=20.7-37.15. The seed yield data collected at maturity and stability parameters were computed to know genotypic x environment interaction and varieties performance. The combined analysis of variance showed highly significant variance in case of varieties, locations and varieties x locations interaction. Varieties and varieties x Environment (Lin) also showed highly significant differences. It means that genotypes exhibited different behavior in different locations / environments which is due to their different genetic make up. The behavior may be cross over (in which significant change in ranking occurs from one environment to another) or cross over nature (in which case the ranking of genotype remains constant across environments and the interaction is significant because of change in the magnitude of response) depending upon the ranking order of genotypes performance under different

environment. Only super Basmati behavior was of almost non cross over nature, while others had cross over type of interaction. Based on overall mean seed performance, mutant NIAB-Rice-4 and DM-38/88 produced significantly the highest grain yield (5.6 t/ha) followed by mutant line NIAB-Rice-5 (5.4 t/ha) and NIAB-rice-2 (5.3 t/ha). The lowest performing genotype was super Basmati (3.0 t/ha). The coarse variety Jhona-349 produced (4.8 t/ha) grain yield. Mutant line DM-38/88 showed significant regression coefficient differences from unity while mutant line NIAB-Rice-4 showed non significant difference of regression co-efficient from unity. Mutant line, NIAB-Rice-4 also showed non significant difference of standard deviation to regression co-efficient from zero. All the three parameters of stability i.e. overall mean seed yield, regression co-efficient and standard deviation to regression, provided clear evidence that mutant line NIAB-Rice-4 produced maximum stable yield compared to super Basmati.

Deshpande and Dalvi (2006) studied performance of 12 rice hybrids in respect of grain yield and other characters, under five environments in Maharashtra during wet season 1999. Variation due to genotype (G), environments (E) and G x E interaction was highly significant in all the traits. Stability parameters  $X$ ,  $b_i$  and  $S^2_d$  were estimated for yield and other characters by regression model. It was revealed that stability in yield of the hybrid appeared to differ in respect of level of stability in the component traits. They were found that, stability in grain yield was due to stability in yield

components only and plasticity in others. This pattern of stability and plasticity in component traits differ from hybrid to hybrid. Sahyadri hybrid may be rated as most promising hybrid under favorable environment.

Dushyantha and Shadakshari (2006) evaluated eighteen rice genotypes in low lands during *kharif*, 2001 season at three locations. Analysis of variance showed that, the mean sum of squares due to genotypes (G) and environment (E) differences tested against the G x E interaction were significant for all the traits studied indicating the presence of wide variability among the genotypes and environments. The G x E interaction when tested against the pooled error was significant for majority of the traits indicating that the major portion of interaction was linear in nature and the genotypes interacted considerably with the environment in expression of these traits at different locations. Both the linear and non-linear components were significant for days to 50 per cent flowering, plant height and panicle number.

Nanita Devi *et al.* (2006) evaluated ten promising rice genotypes for stability parameters in respect of grain yield and its components in four environments. The linear components of G x E interaction was significant only for three characters, *viz.*, plant height at maturity, days to 50 per cent flowering and grain yield per plot, whereas, the non-linear components was significant for all the characters. Among the genotypes, CAUR-5 and KD 2-7-6-2 produced better grain yield. However, on the basis of estimated parameters of

stability, the genotypes RCM-9 and KD-2-7-6-2 could be considered better for grain yield for general cultivation under this situation in Manipur valley.

Pande *et al.* (2006) studied, the stability of rice varieties for Bora Season of Eastern India. Twelve high yielding varieties (HYVs) of rice (*Oryza sativa* L.) were evaluated for their adaptive advantage to various dry season rice ecologies under direct seeded wetland condition for yield and its consistency. Varieties interacted with time of seeding for duration, yield and its components, disease and pest reaction as well as for milling recovery. Knowledge on thermo-sensitivity and short day effect may be helpful for seed producers as well as for commercial purpose. Duration in different varieties got delayed due to cold stress in November and December seeding and it varied in between 14 to 34 days. It was minimum in case of Vandana (14 days) and maximum in Saket 4 (34 days) due to effect of cold during growing season. Medium late variety Pusa 44 registered the highest yield (about 10 t/ha) when seeded in mid-November. IR 64, CR 749-20-2 and Lalat, which are very popular in bora areas, performed equally well under mid-December seeding. The variety Vandana may be promising for Early Ahu areas of Assam or in the areas where rice is taken after mustard or potato as a direct seeded crop. Variety Tapaswini did not flower at all when sown in mid-February till the end of the season due to non-availability of appropriate short-day requirement. Desirable grain type and tolerance to blast of Kshitish under mid-February seeding has made it popular in

the late bora areas of West Bengal. Varieties varied greatly in milling recovery - it was the highest when sown in between mid-November to mid-December, except in Saket 4 and lowest in mid-January seeding and onwards, indicating grain-filling aspect for consideration as affected by weather conditions due to different times of seeding.

Dushyanthakumar, B.M and Shadadshari, Y.G.(2007) were evaluated fifteen rice mutants of PUB local for the stability of yield and yield components by growing them in *Kharif* season during 2002 to 2004 at ZARS., Mudigere , Karnataka. Significant differences among the genotypes and environment for the five traits suggested the presence of wide variability. Both the components of genotypes x environment interaction were significant, indicating that the major portion of interaction was linear in nature and prediction over the environments was possible. Significant pooled deviations observed for all the traits, suggested that there is a considerable genotypic differences. Significant linear sensitivity with insignificant non linear sensitivity suggested that the performance of genotypes could be predicted with great precision across the environments. Based on the stability parameters, rice mutant PUBM-8 exhibited higher mean grain yield (1.23 kg/plot) , regression coefficient near unity (0.89) and deviation from regression was low (-0.19) . PUBM-24 had higher mean grain yield (2.03 kg/plot) with reduced plant height (less than 25 cm)and it is sensitive to environments .These rice mutants were ideally adoptable for both yield and stability.

Nayak,A.R. (2008) evaluated twenty nine scented rice genotypes including one non scented check Ratna for their stability parameters with respect to quality characters during four successive seasons (*rabi* 2003,*kharif* 2003, *rabi* 2004, *kharif* 2004). Significant genotypes x environment interactions were observed for all the quality characters studied. Both linear and non linear components of GXE interaction were also significant for all the characters studied. Varieties Kasturi, Basmatibahar, CR-689-424, CR-689-425, Pusa basmati-1 possessed stability in general over seasons in most of the component quality characters.

Sedghi-azar *et al.* (2008) were studied adaptability and stability of grain yield of various rice promising lines in different regions of Mazandaran province, a comparative study was undertaken for grain yield of 10 rice promising lines and two improved cultivars from 2001to 2003 in three different regions namely Amol, Sari and Tonekabon. Simple and combined analyses of variances indicated significant differences among grain yield of various lines in all regions. Experimental errors variance was uniform using Bartlet test. Except for effects of year and block × environment (year & location), all effects were significant. Results of grain yield stability analysis indicated significant effects for treatment, environment (linear) and mean squares of deviation from regression. For all lines except line No. 3 there was significant variation for effects of deviation from regression using stability parameters. The highest grain yield was produced by lines No. 7, 8 and 11, showing non significant differences

from each other. Nevertheless, for existence of significant differences among deviation from regression by zero, lines could not be recommended for a particular region. The least amount of regression slope belonged to line No. 1, 2 and 5, which were more suitable than others for unfavorable growth conditions. Overall, line No. 3 indicated the highest adaptation and stability for grain yield under different Mazandaran conditions.

Umadevi *et al.* (2008) were studied genotype x environment interaction for grain yield and their component characters in eighteen parents and their 80 hybrids of rice under three environments during summer 2008. The environment + (genotype x environment) was significant for all the characters indicating distinct nature of environments and Genotype x Environment interactions in phenotypic expression. The genotype x environment (linear) interaction component showed significance for all the characters studied except 100 grain weight and number of grains per panicle. This indicated significant differences among the genotypes for linear response to environments (bi) behavior of the genotypes could be predicted over environments more precisely and G X E interaction was outcome of the linear function of environmental components. Based on stability parameters and over all mean, five hybrids *viz.*, APMS 6 A X IR 62037 R, APMS 6 A X RR 347 R, IR 80559 A X MDU 5 R, IR 72081 A X TP 1021 R, IR 75596 A X ASD 06-8 R and IR 80154 A X TP 1021 R were stable in performance for grain yield. The parents IR 62037 R, RR 347 R, TP 1021 R and ASD 06-8 R

can be used as a male parent for developing stable hybrids over the environments.

Das *et al.*(2009) were studied the  $g \times e$  interaction of late duration rice genotypes in different models and evaluated adaptability and yield stability of 12 late duration rice genotypes (145-165 days) at Bhubaneswar, Chiplima, Jeypore and Ranital over 3 years 2003-2005, during *kharif* season. ANOVA of grain yield data of the 12 environments revealed highly significant differences among genotypes and environments and significant  $G \times E$  interaction indicated differential performance of genotypes over environments. Considering mean and the Linear Regression parameters  $b$  and  $S^2d$  values jointly, four of the seven genotypes giving above average yield showed stability of performance of which OR 1898-3-16 and Mahanadi showed adaptability to all environments, where as OR 1901-14-32 and Jagabandhu showed specific adaptation to poor environments. Stability assessment on the basis of parameters like CV, SF,  $R_1$ ,  $R_2$ , W and ASV revealed that the genotypes OR 1898-2-15, Mahanadi, Jagabandhu and OR 1901-14-32 showed stability according to 6 or 5 of the six parameters. AMMI (Additive Main and Multiplicative Interaction) analysis showed differential performance of the genotypes in the 4 locations and three of the four top yielding genotypes *viz.*, OR 1898-3-16, OR 2109-2 and Jagabandhu had small  $G \times L$  interaction, indicating their stable performance over locations. OR 1901-14-32, the highest yielder, showed high positive interaction at Jeypore and high negative interaction at Chiplima. AMMI-II

predicted yield showed that OR 1898-3-16 possessed broad adaptation to all locations. Jagabandhu and Mahanadi are better suited both for Bhubaneswar and Chiplima and OR 1901-14-32 is better suited both for Jeypore and Ranital. The genotypes OR 2119-13 and OR 2109-2 are best suited for Jeypore and Ranital locations, respectively.

Hanamaratti *et al.* (2009) were used ASTABi an AMMI based stability statistic and Rao's Index of simultaneous selection for yield and stability were estimated for 18 Near Isogenic Introgression Lines (NILs) of rice along with 4 checks over six diverse environments. Higher G x E interaction was noticed under stress environments in rainfed ecosystem. ASTABi is very useful in understanding G x E interaction and identifies the stable genotypes, which explains 95.17 per cent variation due to G x E interaction. The NIL RF-55-198 with higher yield as well as stability has been identified as suitable for rainfed condition.

Sterling *et al.* (2009) were showed that genotype × environment interaction is critical for accurate cultivar evaluation in large multi-environment trials. Cultivars that exhibit high levels of mean performance and stability across a wide range of environmental conditions are desirable for rice production. Pure-line varietal and hybrid rice cultivars are commercially produced in the U.S.; however, little research has been conducted comparing their stability for grain yield and milling quality. In this study, 15 hybrid and varietal cultivars were grown in 10 environments from 2005 to 2007 to determine the performance and stability of rough rice yield,

whole milled rice percentages, and whole-grain rice yield. Stability was analyzed using the coefficient of variation, Shukla's Stability Variance statistic with environment means as a covariate, and the Cultivar Superiority Measure. The hybrid rice cultivars XP723 and CLXL730 were ideal for high and stable rough rice and whole-grain rice yields on the basis of the cultivar superiority measure; however, for whole milled rice percentage alone, they were among the least desirable cultivars. Among the varietal cultivars, Catahoula and Jupiter were ideal cultivar selections for high and stable whole-grain rice yields. The results of this study indicate that the stability and performance of hybrid and varietal cultivars differ according to the trait of interest.

Das *et al.* (2010) studied the  $g \times e$  interaction, adaptability and yield stability of Mid-Early Rice Genotypes. Multilocation yield trials of 11 mid-early (110–125 days) rice genotypes were conducted at Bhubaneswar, Chiplitima, Jeypore and Ranital over 3 years 2003–2005, during kharif season. ANOVA of yield data of the 12 environments revealed highly significant differences among genotypes and environments and significant GxE interaction indicated differential performance of genotypes over environments. Considering mean, and the Linear Regression parameters  $b$  and  $S^2_d$  values jointly, 3 of the 6 genotypes giving above average yield showed stability of performance of which Lalat showed adaptability to all environments, while OR 2200-5 and Konark showed specific adaptation to rich environment. Stability assessment on the basis of parameters like CV, SF,

R<sub>1</sub>, R<sub>2</sub>, W and ASV revealed that the genotypes OR 1929-4, Lalat, OR 1739-47 and Bhoi showed stability of yield performance according to 6 or 5 parameters. AMMI analysis showed differential performance of the genotypes in the 4 locations and of the 6 higher yielding genotypes, Lalat, OR 2200-5 and OR 1976-11 had low G x L interaction, while OR 2006-12, OR 2172-7 and Konark had high G X L interaction. AMMI-predicted yield showed that Lalat and OR 2006-12 were high yielder and possessed broad adaptation to most locations. Genotypes showing good adaptation to specific locations were OR 2200-5 for Ranital, OR 2172-7 and OR 1916-19 for Bhubaneswar, OR 1976-11 for Chiplima and Konark for Ranital.

Das *et al* (2010) conducted experiment for integrated analysis for genotypic adaptation in rice. Development of varieties with high yield potential coupled with wide adaptability is an important plant breeding objective. The presence of genotype by environment (Gx E) interaction plays a crucial role in determining the performance of genetic materials, tested at different locations and in different years. This study was undertaken to assess yield performance, stability and adaptability of thirty-six rice genotypes of three different maturity groups evaluated over 12 environments. There were highly significant ( $P < 0.05$ ) genotype x environment interaction in three different maturity groups. The AMMI analysis of variance in the maturity groups also showed significant genotype, location and G´L. Stability in yield performance was predicted using nine stability parameters

(bi, S<sup>2</sup>di, CV, SF, R1, R2, W, S1 and ASV). The rank correlation coefficient among nine parameters indicated that the stability parameters were dissimilar in for all the maturity groups. Stability index (STI) computed by integrating all the nine stability parameters indicated that genotypes Lalat and OR 2006-12 of mid-early group, genotypes OR 1912-25, OR 2310-12 and MTU 1001 of mid-late group, and genotypes OR 1898-3-16, OR 1901-14-32, OR 2109-2, OR 2001-1, Mahanadi and Jagabandhu of late group yielded higher consistently over the 3 years in the different agroclimatic zones.

DushyanthaKumar *et al.*(2010) studied, the genotype (G) x environment (E) interaction and stability for grain yield and some associated traits was studied during the year 2002-2006 in eight Halugidda local rice mutants in the hill zone of Karnataka. Significant G x E interaction was observed for all the traits studied. The pooled deviation was significant for the majority of the traits including grain yield and considerable genotypic difference was observed. Both the linear and non-linear components of G x E interaction were significant, but the linear component was more predominant. Based on the stability parameters, rice mutants HSM-23 and HSM-27 showed higher grain yield over the population mean, with regression coefficient near unity and zero deviation from regression. Thus, they were found to be stable and may be recommended for the commercial cultivation in this region/ zone of Karnataka.

### 3. MATERIAL AND METHODS

The present investigation entitled, “Stability analysis in Upland Rice (*Oryza sativa* L.)” was conducted at the field of Division of Agricultural Botany, College of Agriculture, Kolhapur, Dist. Kolhapur, Maharashtra during *Kharif*, 2010.

#### 3.1 Experimental material and cultural practices:

The experimental material for the present study consists of ten genotypes of rice (*Oryza sativa* L.) The pedigree of the genotypes is given in table 3.1

**Table 3.1: Pedigree of rice genotypes:**

Sr.No.	Genotype	Pedigree
<b>A. Early (110 days)</b>		
1	Ratna	TKM6 X IR8
2	Karjat-184	TN1 X K540
3	Ratnagiri-73	RTN23-1 X KJT87-2
<b>B. Mid- late (115-130 days)</b>		
4	Phule radha	K540 X TN1
5	Ratnagiri-24	Zinnia 63 x TN1
6	Phule samruddhi	Indrayani x Sonsali
7	Jaya	TN1 X T141
<b>C. Late (130-150 days)</b>		
8	Indrayani	Ambemohar 157 x IR8
9	Bhogawati	Selection from Basmati composite
10	Pusa basmati-1	Pusa 167 x Karnal local

### 3.1.2 Season :

The crop was grown during *kharif* 2010 season under six different sowing dates (environments) as follow:

<b>Environment</b>	<b>Date of sowing</b>
E <sub>1</sub>	15 <sup>th</sup> May 2010
E <sub>2</sub>	30 <sup>th</sup> May 2010
E <sub>3</sub>	15 <sup>th</sup> June 2010
E <sub>4</sub>	30 <sup>th</sup> June 2010
E <sub>5</sub>	15 <sup>th</sup> July 2010
E <sub>6</sub>	30 <sup>th</sup> July 2010

### 3.1.3 Experimental design and sowing :

The experiment comprised of ten genotypes of rice laid out in randomized block design with three replications over six environments in the field. Each genotype was planted in six rows of 17 plants in each row. The field experiment was conducted at normal fertile soil. The details of the field experiment are given below :

Design	:	RBD
Genotypes	:	10
Replications	:	Three
No.of rows per plot	:	six (6)
Spacing	:	22.5 x 22.5 cm
Gross plot size	:	3.60 x 1.35 m <sup>2</sup> (6 rows)
Fertilizer dose	:	75: 30:30 N:PK Kg/ ha
Season	:	Kharif 2010

All recommended practices were carried out as and when required so as to maintain good stand of the crop.

### **3.2 Recording of observations:**

Ten plants were selected randomly from each plot for recording the observations on characters under study.

#### **I) Morphological characters:**

- i. Days to 50 % flowering
- ii. Number of tillers per plant
- iii. Length of panicle (cm)
- iv. Number of panicles per square meter
- v. Number of spikelets per panicle
- vi. Spikelet sterility (%)
- vii. Days to maturity
- viii. Yield per plant (g)
- ix. Yield per plot (Kg)
- x. 1000 grain weight (g)
- xi. Length: Breadth ratio

#### **II) Bio-chemical characters:**

- i. Protein content (%)

### **3.3 Method of recording observations :**

#### **3.3.1 Days to 50 per cent flowering :**

The number of days taken from the date of sowing to the 50 per cent of flowering was recorded as days to 50 per cent flowering.

### **3.3.2 Number of tillers per plant :**

Number of tillers per plant arises from the base of the plant i.e. at ground level were recorded at maturity.

### **3.3.3 Length of panicle (cm):**

Ten panicles selected at random from each plot of respected genotype and with the help of scale the length of each panicle is measured in cm.

### **3.3.4 Number of panicles per meter square :**

Total number of panicles per meter square were counted with the help of 1 m<sup>2</sup> square iron frame.

### **3.3.5 Number of spikelets per panicle :**

Number of spikelet (filled and unfilled) were counted from the panicle and recorded as number of spikelets per panicle.

### **3.3.6 Spikelet sterility (%) :**

It was calculated as the percentage of unfilled spikelet to the total number of spikelet. For this, five panicles per plant were selected randomly and unfilled or empty spikelets and total spikelets in those were counted.

$$\text{Spikelet sterility (\%)} = \frac{\text{Number of unfilled spikelets}}{\text{Total number of spikelets}} \times 100$$

### **3.3.7 Days to maturity:**

The number of days taken from the date of sowing to the date on which more than 90 per cent of plant showed drying up confirmed by hardness of seed to bite was taken as days to maturity.

### **3.3.8 Yield per plant (g):**

The weights of seed yield of each ten selected plants were recorded and average worked out.

### **3.3.9 Yield per plot (Kg):**

After threshing, drying, cleaning of seeds from each plot, the weight of seed yield per plot was recorded.

### **3.3.10 1000 seed weight (g):**

Weight of randomly selected 1000 seeds was recorded in grams.

### **3.3.11 Length: Breadth ratio:**

For each genotype 10 grains were selected and length and breadth of each grain was measured and L:B ratio was calculated.

### **3.3.12 Protein content (%)**

The seed of ten different genotypes of rice from E<sub>2</sub> (30<sup>th</sup> May 2010) were selected for estimation of protein. The nitrogen content of the seed was determined as per the modified Micro-Kjeldahl method. After that protein content was calculated by multiplying the nitrogen content by a factor 6.25. (Jackson, M.L., 1967)

### 3.4 Statistical analysis:

The data was collected on randomly selected ten plants per replication in each plot for each character. The collected data was subjected for testing the genotypic differences (Panse and Sukhatme, 1967).

Stability analysis was performed by model proposed by Eberhart and Russell (1966). They proposed the stability parameters to describe the performance of genotypes over different environments.

According to them the regression of each variety on an environmental index and a function of square deviation from this regression provide estimates of stability parameters.

For each genotype stability was described by three parameters *viz.*, mean performance ( $\bar{X}$ ), regression coefficient ( $b_i$ ) and the squared deviation from the regression ( $S^2d_i$ ).

These parameters are defined using the following model.

$$Y_{ij} = \mu + b_i l_j + d_{ij} \quad (i = 1, 2, \dots, t, \text{ and } j = 1, 2, \dots, S)$$

Where,

$Y_{ij}$  = Mean of  $i^{\text{th}}$  genotype in  $j^{\text{th}}$  environment.

$\mu$  = Mean of all genotypes over all environments.

$b_i$  = The regression coefficient of  $i^{\text{th}}$  genotype on the environmental index, which measures response of genotype to varying environments.

$l_j$  = The environmental index which is defined as deviation of the mean of all the genotypes

at a given environmental from the overall mean.

$$\frac{\sum_i Y_{ij}}{t} - \frac{\sum_i \sum_j Y_{ij}}{ts} \text{ with } \sum_j l_j = 0$$

$\delta_{ij}$  = The deviation from regression of the  $i^{\text{th}}$  genotype of  $j^{\text{th}}$  environment.

### 3.4.1 The stability parameters :

a) The regression coefficient ( $b_i$ ) is described as under

$$b_i = \frac{\sum Y_{ij} l_j}{\sum l_j^2}$$

where,

$\sum_{ij} l_j$  = The sum of the products.

$\sum l_j^2$  = The sum of squares of environmental index.

b) Mean square deviation ( $S^2 d_i$ ) from linear regression

$$S^2 d = \frac{\sum_j \delta^2_{ij}}{(S-2)} - \frac{S^2 e}{r}$$

Where,

$$\sum_j \delta^2_{ij} = \left( \sum_i Y_{ij}^2 l_j - \frac{Y_i^2}{t} \right) - \frac{(\sum_j Y_{ij} l_j)^2}{\sum_j l_j^2}$$

$S^2 e$  = The estimate of pooled error.

$t$  = Number of genotypes.

$S$  = Number of environments.

**1) Computation of environmental index (lj) :**

We know that  $l_j$  is defined as ,

$$l_j = \frac{\sum_j Y_{ij}}{t} - \frac{\sum_i \sum_j Y_{ij}}{ts}$$

=  $\frac{\text{Total of all genotypes of } j^{\text{th}} \text{ location}}{\text{Number of genotypes}} - \frac{\text{Grand total}}{\text{Total number of observations}}$

**2) Computation of regression coefficient (bi):**

for each genotypes,

$$b_j = \frac{\sum_j Y_{ij} l_j}{\sum_j l_j^2}$$

i For each value of regression coefficient  $\sum l_j^2$  is common equal to sum of squares environmental indices.

$$\sum l_j^2 = (l_1^2 + l_2^2 + \dots + l_j^2)$$

ii The  $\sum Y_{ij} l_j$  for each genotype of environmental index ( $l_j$ ) with corresponding mean ( $\bar{X}$ ) of that genotype at each environment.

These value were obtained in the following manner

$$\bar{X}(l_j) = \sum_j Y_{ij} l_j = S$$

where,

$\bar{X}$  = Matrix of the means

$l_j$  = Vector for environmental index

$S$  = Vector for sum of products i.e.  $\sum_j Y_{ij} l_j$

- iii The  $b_i$  value for each genotype was thus calculated by dividing  $\sum Y_{ij}l_j$  as calculated above in (ii) by  $\sum l_j^2$  obtained above under (i)

$$\text{Thus, } b_i = \frac{\sum_j Y_{ij}l_j}{\sum_j l_j^2}$$

### 3) Computation of $S^2_{di}$ :

In regression analysis it is possible to partition the variance of the dependent variable (Y) into two parts, the one which explains the linearity between dependent and independent variables (variance due to regression) and the other, which explains the variance due to deviations from linearity.

Symbolically,

$$\sigma^2_y = \sigma^2_{\text{regression}} + \sigma^2_{\text{deviation from regression}}$$

By subtracting variance due to regression from  $\sigma^2_y$  one can get the variance due to deviation from regression which in turn can be used for estimating  $S^2_{di}$  values. The variance of means over different environments was obtained as follows.

$$\sigma^2_{vi} = \sum_j Y_{ij}^2 - (Y_i^2/S)$$

where,

$\sum Y_{ij}^2$  = Sum of squares of mean of  $i^{\text{th}}$  genotype over  $j^{\text{th}}$  environment.

$Y_i$  = Sum of means of  $i^{\text{th}}$  genotype over environment.

The variance due to deviation from regression,

$$\sum_j \delta^2_{ij} \quad \text{for a genotype being}$$

$$\sum_j \delta^2_{ij} = (\sum_j Y_{ij}^2 - Y_i^2 / S) - \frac{(\sum_j Y_{ij}l_j)^2}{\sum_j l_j^2}$$

Where,

$(\sum_j Y_{ij}^2 - Y_i^2 / S)$  = The variance due to dependant variable

$(\sum_j Y_{ij}l_j)^2 / \sum_j l_j^2$  = The variance due to regression

Because,

$$\frac{(\sum_j Y_{ij}l_j)^2}{\sum_j l_j^2} = \frac{(\sum_j Y_{ij}) (\sum_j Y_{ij}l_j)}{\sum_j l_j^2}$$

$$= b_i \sum_j Y_{ij}l_j$$

Where,

$b_i$ , values have been calculated in (2) and  $\sum_j Y_{ij}l_j$  values in 2 (ii)

The  $\sum_j \delta^2_{ij}$  values may be completed as

$$\sum_j \delta^2_{ij} = \sum_j \delta^2_{vi} - b_i \sum_j Y_{ij}l_j$$

From  $\sum_j \delta^2_{ij}$ , the stability parameter  $S^2_{di}$  for each genotype was calculated as follows

$$S^2_{di} = [\sum_j \delta^2_{ij} / (S - 2)] - (S^2 e/r)$$

### 3.4.2 Analysis of variance :

The analysis of variance partitioned into three main parts,

- a) Sum of squares due to genotypes.
- b) Sum of squares due to environments +(Genotype x environment).
- c) Pooled error:

The sum of squares due to genotype x environment is further partitioned into two parts -

- i) S.S due to genotype x environment (linear) which is infact S.S due to regression.
- ii) S.S due to deviation from linearity of response (i.e. S.S due to pooled deviation).

The latter can be further partitioned into as many components as the number of genotypes with (S-2) degrees of freedom (S - represents number of environments).

The analysis of variance table for parameter was constructed as,

Source	d.f.	S.S.	M.S.S.
Genotype	(t-1)	$1/S \sum I Y_i^2 - C.F.$	MS <sub>1</sub>
Environments	(s-1)	$1/t \sum J Y_j^2 - C.F.$	MS <sub>2</sub>
Genotype X environments	(t-1)(s-1)	$\sum \sum Y_{ij}^2 - C.F. - G.S.S - E.S.S.$	MS <sub>3</sub>
Environment + (Genotype X environment)	t(s-1)	$\sum \sum Y_{ij}^2 - Y_i^2/s$	MS <sub>4</sub>
Environment (linear)	L	$1/t (\sum Y_{ij} l_j)^2 / \sum l_j^2$	
Genotype X environment (linear)	(t-1)	$\sum (\sum Y_{ij} l_j)^2 / \sum l_j^2 - E(1) S.S.$	MS <sub>5</sub>
Pooled deviation	t(s-1)	$\sum \sum^2 j_i$	MS <sub>6</sub>
Pooled error	S(r-1)(t-1)		MS <sub>7</sub>

Where,

- t = Number of genotypes
- s = Number of environments
- r = Number of replications
- G.S.S. = S.S due to genotypes
- E.S.S. = S.S due to environment

S.S due to genotypes, environment and genotype x environment were calculated as per the method of pooled analysis.

The M.S. pooled error was calculated as,

$$= \frac{(n_1 - 1) (\text{M.S. error } L_1) + \dots + (n_5 - 1) (\text{M.S. errors})}{(n_1 - 1) + (n_2 - 1) + \dots + (n_5 - 1)}$$

Where,

- M.S. error L<sub>5</sub> = Mean sum of squares due to error for 5<sup>th</sup> environment
- n<sub>1</sub> - 1 = Error d.f. in environment 1
- n<sub>2</sub> - 1 = Error d.f. in environment 2

The S.S. due to remaining sources were calculated as follows  
 S.S. due to environment (Genotype x Environment)

$$= \sum_j \sum_i Y_{ij} - \sum_i Y_i^2 / t$$

In fact,

$$\begin{aligned} & \text{S.S. (E = G X E)} \\ & = \text{S.S.E.} + \text{S.S.G. X E} \end{aligned}$$

Where,

$$S.S.E. = 1/t \left( \sum_j Y_j l_j \right)^2 / \sum_j l_j^2$$

The  $Y_j$  and  $l_j$  values are already computed and by putting appropriate values we can get S.S. environment (linear) which can also be checked as,

S.S. environment (linear)

$$= t \times \sum_j l_j^2$$

In fact,

S.S.G. x E (linear)

$$= \sum_j \left[ \frac{(\sum_i Y_{ij} l_j)^2}{(\sum_j l_j)^2} \right] - S.S.E. \text{ (linear)}$$

$$= b_i \sum_j Y_{ij} l_j \text{ for each genotype}$$

Thus by taking simply the sum of these values over all the genotypes, the first part of S.S., G x E (linear) can be obtained.

S.S. due to pooled deviation is simply the sum of S.S. due to deviation for individual genotype for (S-2) degrees of freedom each.

### 3.4.3 Test of significance :

- a) The significance of differences among genotypes and environments were tested against the M.S.S. due to GXE interaction ( $MS_3$ ). The fore more was also tested against pooled deviation ( $MS_6$ ).
- b) The G x E interaction ( $MS_3$ ) was tested against effective pooled error.
- c) The components, environment (linear). G x E (linear) was tested against pooled deviation ( $MS_6$ ).

d) Pooled deviation was tested against effective pooled error (PE/r). individual deviation from linear regression was tested as follow.

$$\frac{[(\sum \sigma^2_{ij})/(S-2)]}{\text{Pooled error}}$$

e) Stable genotype i.e. tests of significance for regression coefficient.

A genotype with unit regression coefficient ( $\delta = 1$  or not significantly deviating from unity) and deviation different from zero ( $S^2 d_i = 0$ ) is said to be stable one.

$$T \text{ test } b_i = \frac{| b_i - 1 |}{\text{S.E. } (b_i)}$$

Where,

$$\text{SE } b_i = \sqrt{\frac{\text{MSS due to pooled deviation}}{\sum_j I_j^2}}$$

## 4. EXPERIMENTAL RESULTS

The present investigation entitled "Stability analysis in upland rice (*Oryza sativa* L.)" was undertaken with a view to assess the following parameters.

- i. Seed yield potential of different genotypes of rice under different environmental conditions.
- ii. To estimate G x E interaction for seed yield and its components.
- iii. To estimate stability parameters for seed yield and its components.
- iv. To identify most promising genotypes suitable for different environmental conditions.

### 4.1 Analysis of variance :

Sr.No	Characters	Mean sum of square due to			
		Genotypes (G)	Environments (E)	G x E	Error
1	Days to 50% flowering	788.33**	367.92**	10.88**	2.10
2	Total number of tillers per plant	11.62**	216.43**	9.54**	1.55
3	Length of panicle (Cm)	21.34**	48.83**	5.65**	1.55
4	Number of panicles per square meter	8525.33**	970**	55.55*	31.27
5	Number of spiklelets per panicle	23256**	1463.6**	141.62**	31.39
6	Spikelet sterility (%)	130.43**	154.07**	6.25**	0.84
7	Days to maturity	1821.44**	1772.45**	9.79 <b>NS</b>	17.71
8	Yield per plant (g)	324.58**	1180.33**	36.37**	7.88
9	Yield per plot (Kg)	1.40**	6.77**	0.23**	6.27
10	1000 grain weight (g)	292.13**	29.69**	2.82*	1.55
11	Length:Breadth ratio	5.63**	8.85NS	5.29 <b>NS</b>	5.36

\*\* Significant at 1%      \* Significant at 5%      NS – Non significant

G x E interaction was found to be absent for days to maturity and Length: Breadth ratio, for all the environments.

## 4.2 Response of various rice genotypes to changing environments:

The mean values of the genotypes for different characters studied under six sowing dates are presented in table 4.2.1 to 4.2.12.

### 4.2.1 Days to 50% flowering:

The genotype Karjat -184 exhibited the earliness at E<sub>1</sub> (96.17), E<sub>2</sub> (91.43), E<sub>3</sub> (93.07) and E<sub>6</sub> (87.20), indicating these were the suitable environments, followed by Ratnagiri-73 for the trait under investigation. However Ratnagiri-73 showed the superiority at later sowing dates viz; E<sub>4</sub> (91.40) and E<sub>5</sub> (89.07), which was closely followed by Karjat-184.

**Table: 4.2.1: Mean performance of rice genotypes over different environments:**

Sr. No.	Genotype	Days to 50 % flowering						Mean
		E <sub>1</sub>	E <sub>2</sub>	E <sub>3</sub>	E <sub>4</sub>	E <sub>5</sub>	E <sub>6</sub>	
1	Ratna	98.33	93.77	96.97	94.07	90.43	88.87	93.74
2	Karjat-184	96.17	91.43	93.07	93.33	89.47	87.20	91.78
3	Ratnagri-73	98.33	93.63	95.00	91.40	89.07	87.70	92.52
4	Phule radha	101.77	103.67	99.33	97.67	94.33	92.33	98.18
5	Ratnagiri-24	99.67	102.67	100.33	98.00	96.00	94.33	98.50
6	Phule samruddhi	108.33	111.67	108.67	109.67	103.33	101.33	107.17
7	Jaya	109.33	112.67	106.67	102.67	104.67	101.67	106.28
8	Indrayani	115.00	113.50	109.33	107.67	104.67	106.67	109.47
9	Bhogawati	110.03	113.67	107.33	102.67	105.33	102.33	106.89
10	Pusa basmati-I	104.67	106.67	99.00	102.33	97.00	95.33	100.83
	Mean	104.16	104.33	101.57	99.95	97.43	95.78	100.54
	S.E.±	0.89	1.06	1.21	0.20	0.66	0.53	0.86
	CD@5%	2.65	3.16	3.62	0.59	1.96	1.59	2.40

The genotype Karjat-184 (91.78) was observed to be earliest; while Indrayani was late (109.47) as far as mean performance is concerned.

**4.2.2. Number of tillers per plant (hill):**

The genotype Bhogawati had shown consistency at E<sub>1</sub> (25.93) and E<sub>6</sub> (20.97) for the character under study, which was followed by Ratnagiri-73 (24.80) and Ratnagiri-24 (18.43) respectively. Ratna had expressed superior performance at E<sub>2</sub> (26.87) and E<sub>3</sub> (25.93), followed by Pusa basmati-1 (25.80) and Jaya (25.77) respectively. Karjat-184 (20.37) followed by Phule radha (19.27) had produced higher number of tillers per plant at E<sub>5</sub>. The genotypes Phule samruddhi and Pusa basmati-1 were superior at E<sub>4</sub>.

**Table: 4.2.2 : Mean performance of rice genotypes over different environments:**

Sr. No.	Genotype	Number of tillers per plant (hill)						
		E <sub>1</sub>	E <sub>2</sub>	E <sub>3</sub>	E <sub>4</sub>	E <sub>5</sub>	E <sub>6</sub>	Mean
1	Ratna	24.00	26.87	25.93	20.77	18.83	16.70	22.18
2	Karjat-184	22.47	25.00	20.90	19.27	20.37	17.10	20.85
3	Ratnagri-73	24.80	21.33	25.07	20.13	18.13	16.30	20.96
4	Phule radha	21.07	24.50	26.80	20.80	19.27	17.43	21.64
5	Ratnagiri-24	19.07	22.70	24.60	19.23	16.47	18.43	20.08
6	Phule Samruddhi	20.13	23.40	19.60	21.00	19.13	16.90	20.03
7	Jaya	23.77	19.90	25.77	20.23	19.03	17.00	20.95
8	Indrayani	22.93	24.97	19.97	19.47	17.93	16.63	20.32
9	Bhogawati	25.93	23.17	25.37	20.43	18.00	20.97	22.31
10	Pusa basmati-1	22.57	25.80	21.73	21.00	19.17	16.70	21.16
	Mean	22.67	23.76	23.57	20.23	18.63	17.42	21.05
	S.E.±	0.74	0.62	0.72	0.74	0.83	0.60	0.78
	CD@5%	2.22	1.86	2.15	NS	NS	1.79	2.18

Bhogawati had maintained its dominance by producing maximum number of tillers (22.31), while Phule samruddhi expressed poor performance (20.03) when mean performance was estimated.

### 4.3.3. Length of panicle (cm):

The genotype Bhogawati had more panicle length at E<sub>1</sub> (26.03) and E<sub>3</sub> (25.00), followed by Pusa basmati-1 (25.07) and Jaya (24.97) respectively. Whereas Pusa basmati-1 had produced superior performance at E<sub>2</sub> (27.17), E<sub>4</sub> (21.13) and E<sub>5</sub> (23.94) for the trait, followed by K-184 (25.7) at E<sub>2</sub>, Phule samruddhi (21.03) at E<sub>4</sub> and Bhogawati (23.13) at E<sub>5</sub> respectively. The genotype Karjat-184 (21.70) followed by Ratnagiri-24 (21.41) were superior at E<sub>6</sub> for the character under investigation.

**Table: 4.2.3 : Mean performance of rice genotypes over different environments:**

Sr. No.	Genotype	Length of panicle (cm)						Mean
		E <sub>1</sub>	E <sub>2</sub>	E <sub>3</sub>	E <sub>4</sub>	E <sub>5</sub>	E <sub>6</sub>	
1	Ratna	20.50	23.90	21.66	19.97	20.80	18.87	20.95
2	Karjat-184	23.34	25.70	21.33	19.80	22.70	21.70	22.43
3	Ratnagri-73	20.83	21.60	23.97	19.03	20.13	18.37	20.66
4	Phule radha	19.70	20.83	22.90	19.97	19.87	20.63	20.65
5	Ratnagiri-24	19.57	20.50	23.03	20.90	18.67	21.41	20.68
6	Phule Samruddhi	20.93	23.03	21.47	21.03	19.03	20.43	20.99
7	Jaya	21.07	22.90	24.97	20.03	20.76	19.13	21.48
8	Indrayani	20.91	23.07	20.27	19.94	20.90	19.38	20.74
9	Bhogawati	26.03	23.07	25.00	20.93	23.13	20.24	23.07
10	Pusa basmati-1	25.07	27.17	22.90	21.13	23.94	20.97	23.53
	Mean	21.79	23.18	22.75	20.27	20.99	20.11	21.51
	S.E.±	0.74	0.62	0.72	0.74	0.83	0.60	0.59
	CD@5%	2.22	1.86	2.15	NS	2.49	1.79	1.65

The mean performance of the Pusa basmati-1 (23.53) and Bhogawati (23.07) were superior, while Phule radha had the shortest panicle length (20.65) among all the genotypes.

#### 4.2.4. Number of spikelets per panicle:

The genotype Phule radha had exhibited stable performance under all the variable environments, by producing higher number of spikelets per panicle viz; E<sub>1</sub> (249.50), E<sub>2</sub> (258.67), E<sub>3</sub> (266.90), E<sub>4</sub> (244.10), E<sub>5</sub> (239.43) and E<sub>6</sub> (245.76). This was followed by Ratnagiri-24 viz; 205.57, 217.40, 226.76, 221.00, 194.83 and 210.24 respectively.

**Table: 4.2.4 : Mean performance of rice genotypes over different Environments :**

Sr.No	Genotype	Number of spikelets per panicle						
		E1	E2	E3	E4	E5	E6	Mean
1	Ratna	173.50	196.66	178.80	153.63	169.24	149.64	170.24
2	Karjat-184	157.97	170.74	154.00	147.97	153.37	139.57	153.94
3	Ratnagri-73	134.17	137.83	141.36	128.43	137.07	124.03	133.82
4	Phule radha	249.50	258.67	266.90	244.10	239.43	245.76	250.73
5	Ratnagiri-24	205.57	217.40	226.76	221.00	194.83	210.24	212.63
6	Phule Samruddhi	154.26	166.87	157.83	155.60	148.90	150.97	155.74
7	Jaya	151.67	158.44	164.80	149.00	153.94	143.60	153.57
8	Indrayani	151.03	155.77	143.60	140.00	147.37	137.60	145.90
9	Bhogawati	154.37	142.73	148.90	137.64	145.37	138.63	144.61
10	Pusa basmati-1	167.23	173.77	162.00	158.13	159.67	155.20	162.67
	Mean	169.93	177.89	174.50	163.55	164.92	159.52	168.38
	S.E.±	3.04	3.14	3.46	3.12	3.38	3.22	2.72
	CD@5%	9.03	9.34	10.28	9.27	10.07	9.59	7.61

The genotype Phule radha (250.73) had maximum, while Ratnagiri-73 (133.82) had minimum spikelets per panicle, when performance of all environments was considered.

#### 4.2.5. Spikelet sterility (%):

The genotype Jaya had shown promise for lower spikelet sterility at E<sub>1</sub> (7.77), E<sub>2</sub> (3.66), E<sub>3</sub> (5.51) and E<sub>6</sub> (9.90), followed by K-184 at E<sub>1</sub> (9.53) and E<sub>6</sub> (11.14), Phule samruddhi at E<sub>2</sub> (6.83) and Ratnagiri-73 at E<sub>3</sub> (5.54). Ratnagiri-73 had the lower spikelet sterility at E<sub>4</sub> (8.33) and E<sub>5</sub> (11.04) followed by Ratna (8.90) at E<sub>4</sub> and Jaya (11.17) at E<sub>5</sub> respectively.

**Table: 4.2.5 : Mean performance of rice genotypes over different environments :**

Sr. No	Genotype	Spikelet sterility (%)						Mean
		E <sub>1</sub>	E <sub>2</sub>	E <sub>3</sub>	E <sub>4</sub>	E <sub>5</sub>	E <sub>6</sub>	
1	Ratna	9.92	7.87	6.80	8.90	11.44	14.17	9.85
2	Karjat-184	9.53	7.73	9.47	11.80	12.90	11.14	10.43
3	Ratnagiri-73	10.50	8.24	5.54	8.33	11.04	12.54	9.36
4	Phule radha	15.77	12.54	14.04	17.07	19.73	21.77	16.82
5	Ratnagiri-24	14.77	12.86	11.28	14.30	16.87	18.90	14.83
6	Phule Samruddhi	11.27	6.83	9.84	11.74	13.14	11.30	10.69
7	Jaya	7.77	3.66	5.51	9.70	11.17	9.90	7.95
8	Indrayani	13.53	12.20	9.00	15.80	17.24	13.13	13.48
9	Bhogawati	10.87	7.80	9.75	12.20	15.20	11.84	11.28
10	Pusa basmati-1	13.40	10.10	9.07	13.97	11.23	15.60	12.23
	Mean	11.73	8.98	9.03	12.38	14.00	14.03	11.69
	S.E.±	0.47	0.49	0.55	0.55	0.62	0.46	0.64
	CD@5%	1.40	1.48	1.63	1.63	1.85	1.37	1.79

The minimum percent of spikelet sterility is expressed by Jaya (7.95), followed by Ratnagiri-73 (9.36). However Phule radha (16.82) had the maximum spikelet sterility.

#### 4.2.6. Panicles per square meter :

The genotype Bhogawati had maintained its consistency for the trait at E<sub>1</sub> (457.73), E<sub>2</sub> (449.60), E<sub>4</sub> (444.70), E<sub>5</sub> (440.54) and E<sub>6</sub> (438.63), followed by Jaya at E<sub>1</sub> (449.37), E<sub>5</sub> (439.50) and E<sub>6</sub> (435.50). However Pusa basmati-1 at E<sub>2</sub> (448.87) and Indrayani at E<sub>4</sub> (444.37) maintained second position. Jaya (455.53) followed by Bhogawati (454.50) had the superiority at E<sub>3</sub>.

**Table: 4.2.6 : Mean performance of rice genotypes over different environments :**

Sr. No.	Genotype	Panicles per square meter						
		E <sub>1</sub>	E <sub>2</sub>	E <sub>3</sub>	E <sub>4</sub>	E <sub>5</sub>	E <sub>6</sub>	Mean
1	Ratna	432.40	445.00	440.23	429.47	438.37	425.94	435.23
2	Karjat-184	401.50	409.30	396.53	393.57	397.37	389.44	397.95
3	Ratnagri-73	446.44	440.57	448.76	438.33	431.64	428.50	439.04
4	Phule radha	438.50	444.00	452.67	441.44	435.67	431.50	440.63
5	Ratnagiri-24	386.57	391.50	396.43	382.67	377.50	380.30	385.83
6	Phule Samruddhi	410.76	419.50	408.43	416.20	406.50	401.40	410.47
7	Jaya	449.37	443.84	455.53	442.13	439.50	435.50	444.31
8	Indrayani	444.60	448.50	441.60	444.37	438.50	435.43	442.17
9	Bhogawati	457.73	449.60	454.40	444.70	440.54	438.63	447.60
10	Pusa basmati-1	441.50	448.87	437.90	434.36	431.57	430.53	437.46
	Mean	430.94	434.07	433.25	426.72	423.71	419.72	428.07
	S.E.±	3.04	3.14	3.46	3.12	3.38	3.23	1.99
	CD@5%	9.03	9.35	10.28	9.28	10.06	9.60	5.57

Bhogawati maintained its higher position by producing maximum number of panicles per meter square (447.60), while Ratnagiri-24 remained at bottom with 385.83 panicles per meter square.

#### 4.2.7. Days to maturity:

The genotype Karjat-184 exhibited earliness at E<sub>1</sub> (117.67) and E<sub>6</sub> (102.33), followed by Ratna 120.33 and 103.33 respectively. Ratnagiri-73 matured earlier at E<sub>2</sub> (117.67), E<sub>3</sub> (114.33), E<sub>4</sub> (108.33) and E<sub>5</sub> (105.67), followed by Karjat-184. 121.67, 114.33, 110.33 and 106.67 respectively at these environments.

**Table: 4.2.7 : Mean performance of rice genotypes over different environments :**

Sr. No	Genotype	Days to maturity						
		E <sub>1</sub>	E <sub>2</sub>	E <sub>3</sub>	E <sub>4</sub>	E <sub>5</sub>	E <sub>6</sub>	Mean
1	Ratna	120.33	123.67	117.33	110.44	108.17	103.33	113.88
2	Karjat-184	117.67	121.67	114.33	110.33	106.67	102.33	112.17
3	Ratnagri-73	122.67	117.67	114.33	108.33	105.67	103.67	112.06
4	Phule radha	134.67	130.33	125.67	122.67	120.33	116.67	125.06
5	Ratnagiri-24	131.33	136.33	127.50	123.44	121.67	118.33	126.43
6	Phule Samruddhi	137.50	133.67	129.67	125.67	122.67	119.33	128.08
7	Jaya	139.67	135.67	132.33	127.33	121.67	117.67	129.06
8	Indrayani	150.67	145.33	140.33	136.33	131.67	127.33	138.61
9	Bhogawati	148.67	144.67	139.33	133.33	128.33	124.67	136.50
10	Pusa basmati-1	148.33	143.33	138.33	131.67	128.33	124.33	135.72
	Mean	135.15	133.23	127.92	122.95	119.52	115.77	125.76
	S.E.±	2.28	2.36	2.61	2.34	2.53	2.41	0.67
	CD@5%	6.80	7.02	7.77	6.96	7.54	7.18	1.87

The genotype Ratnagiri-73 was earliest (112.06), while Indrayani had shown late maturity (138.61) as far as mean performance is concerned.

**4.2.8. Yield per plant (g):**

The genotype Jaya had displayed consistency for the given trait at E<sub>1</sub> (58.60), E<sub>3</sub> (62.50), E<sub>4</sub> (53.66), E<sub>5</sub> (47.10) and E<sub>6</sub> (43.60), followed by Bhogawati at E<sub>1</sub> (57.84), Phule radha at E<sub>3</sub> (57.27) and Pusa basmati-1 at E<sub>4</sub> (47.27) and E<sub>6</sub> (39.54). However Ratna (60.63) followed by Pusa basmati-1 (59.16) had exhibited superior performance at E<sub>2</sub>.

**Table: 4.2.8 : Mean performance of rice genotypes over different environments :**

Sr. No.	Genotype	Yield per plant (hill) (g)						
		E <sub>1</sub>	E <sub>2</sub>	E <sub>3</sub>	E <sub>4</sub>	E <sub>5</sub>	E <sub>6</sub>	Mean
1	Ratna	51.20	60.63	56.06	44.70	40.57	37.69	48.48
2	Karjat-184	45.44	48.71	41.90	38.50	36.14	33.64	40.72
3	Ratnagri-73	50.77	46.20	53.46	42.77	37.17	34.30	44.11
4	Phule Radha	45.67	50.94	57.27	42.64	40.34	37.17	45.67
5	Ratnagiri-24	38.13	43.80	48.33	36.20	30.57	34.73	38.63
6	Phule Samruddhi	43.70	51.72	41.80	46.10	38.80	35.30	42.90
7	Jaya	58.26	51.30	62.50	53.66	47.10	43.60	52.74
8	Indrayani	50.17	54.26	45.16	43.14	39.24	36.27	44.71
9	Bhogawati	57.84	51.01	55.80	46.73	42.33	38.00	48.62
10	Pusa basmati-1	54.10	59.16	49.94	47.27	43.73	39.54	48.96
	Mean	49.53	51.77	51.22	44.17	39.60	37.02	45.55
	S.E.±	1.57	1.58	1.71	1.57	1.70	1.62	1.54
	CD@5%	4.66	4.72	5.08	4.68	5.05	4.83	4.31

The genotype Jaya showed consistency for grain yield (52.74), followed by Pusa basmati-1 (48.96). However the mean performance of the Ratnagiri-24 was found to be lowest (38.63).

Similar trend was observed for yield per plot.

**Table: 4.2.9 : Mean performance of rice genotypes over different environments :**

Sr. No.	Genotype	Yield per plot (Kg)						Mean
		E <sub>1</sub>	E <sub>2</sub>	E <sub>3</sub>	E <sub>4</sub>	E <sub>5</sub>	E <sub>6</sub>	
1	Ratna	3.50	4.33	3.82	3.17	2.77	2.50	3.35
2	Karjat-184	3.25	3.54	2.86	2.63	2.53	2.20	2.84
3	Ratnagri-73	3.50	3.26	3.77	3.02	2.56	2.28	3.07
4	Phule Radha	3.16	3.50	3.73	2.90	2.77	2.18	3.04
5	Ratnagiri-24	2.61	3.09	3.43	2.47	2.14	2.44	2.70
6	Phule Samruddhi	3.09	3.58	2.90	3.36	2.70	2.37	3.00
7	Jaya	4.01	3.50	4.38	3.67	3.25	3.04	3.64
8	Indrayani	3.48	3.87	3.12	3.00	2.73	2.22	3.07
9	Bhogawati	4.01	3.30	3.83	3.28	2.96	2.32	3.28
10	Pusa basmati-1	3.75	4.21	3.49	2.97	3.11	2.78	3.39
	Mean	3.44	3.62	3.53	3.05	2.75	2.43	3.14
	S.E.±	0.11	0.14	0.13	0.18	0.15	0.13	0.12
	CD@5%	0.33	0.41	0.41	0.54	0.45	0.39	0.33

#### 4.2.10. 1000 grain weight (g):

The genotype Jaya produced higher thousand grain weight at E<sub>1</sub> (26.80), E<sub>2</sub> (28.10), E<sub>3</sub> (30.33), E<sub>4</sub> (28.33), E<sub>5</sub> (27.30) and E<sub>6</sub> (26.13), followed by Ratnagiri-73 at E<sub>1</sub> (23.40), E<sub>2</sub> (26.33), E<sub>4</sub> (25.43), E<sub>5</sub> (24.27) and E<sub>6</sub> (23.23), however Bhogawati had recorded higher grain weight at E<sub>3</sub> (24.76).

**Table: 4.2.10 : Mean performance of rice genotypes over different environments :**

Sr.No.	Genotype	1000 grain weight (g)						Mean
		E <sub>1</sub>	E <sub>2</sub>	E <sub>3</sub>	E <sub>4</sub>	E <sub>5</sub>	E <sub>6</sub>	
1	Ratna	21.93	20.01	20.40	22.23	19.70	20.93	20.87
2	Karjat-184	20.83	23.23	21.27	22.50	22.43	20.53	21.80
3	Ratnagri-73	23.40	26.33	24.43	25.43	24.27	23.23	24.52
4	Phule Radha	14.23	16.07	14.70	15.97	14.13	14.88	15.00
5	Ratnagiri-24	13.47	15.30	14.37	15.40	14.07	13.10	14.28
6	Phule Samruddhi	20.73	22.26	23.73	22.13	21.63	20.23	21.79
7	Jaya	26.80	28.10	30.33	28.33	27.30	26.13	27.83
8	Indrayani	21.53	25.13	22.83	23.80	22.43	21.17	22.82
9	Bhogawati	19.95	21.49	24.76	22.13	21.47	19.27	21.51
10	Pusa basmati-1	18.20	20.56	22.87	20.86	19.77	17.67	19.99
	Mean	20.11	21.85	21.97	21.88	20.72	19.71	21.04
	S.E.±	0.74	0.62	0.72	0.74	0.83	0.60	0.38
	CD@5%	2.22	1.86	2.15	2.20	2.49	1.79	1.06

The mean performance of Jaya was superior (27.83) for the character under study, followed by Ratnagiri-73 (24.52). However, Ratnagiri-24 had lowest mean thousand grain weight (14.28).

**4.2.11. Length: Breadth ratio:**

The genotype Bhogawati had displayed the superiority for the given trait at E<sub>1</sub> (4.05), E<sub>3</sub> (4.02), E<sub>5</sub> (3.86) and E<sub>6</sub> (3.95), followed by Indrayani at E<sub>1</sub> (3.79), Pusa basmati-1 at E<sub>3</sub> (3.88), E<sub>5</sub> (3.82) and E<sub>6</sub> (3.85). Pusa basmati-1 had displayed the superior performance at E<sub>2</sub> (4.10) and E<sub>4</sub> (3.96) followed by Indrayani at E<sub>2</sub> (3.81) and Bhogawati at E<sub>4</sub> (3.86).

**Table: 4.2.11 : Mean performance of rice genotypes over different environments :**

Sr.No.	Genotype	Length:Breadth ratio						Mean
		E <sub>1</sub>	E <sub>2</sub>	E <sub>3</sub>	E <sub>4</sub>	E <sub>5</sub>	E <sub>6</sub>	
1	Ratna	3.37	3.01	3.42	3.19	3.28	3.06	3.22
2	Karjat-184	2.57	2.65	2.64	2.46	2.47	2.55	2.56
3	Ratnagri-73	2.78	2.52	2.92	2.47	2.44	2.74	2.64
4	Phule radha	3.25	2.91	3.25	3.19	3.12	3.20	3.15
5	Ratnagiri-24	2.96	2.84	2.73	2.79	2.85	2.64	2.80
6	Phule Samruddhi	3.23	3.05	3.09	3.21	2.98	3.06	3.10
7	Jaya	2.38	2.28	2.40	2.30	2.25	2.36	2.33
8	Indrayani	3.79	3.81	3.67	3.84	3.79	3.65	3.76
9	Bhogawati	4.05	3.55	4.02	3.86	3.86	3.95	3.88
10	Pusa basmati-1	3.52	4.10	3.88	3.96	3.82	3.85	3.86
	Mean	3.19	3.07	3.20	3.13	3.09	3.11	3.13
	S.E.±	0.10	0.17	0.12	0.11	0.13	0.13	4.84
	CD@5%	0.30	0.51	0.38	0.34	0.40	0.39	13.55

The genotype Bhogawati had produced slender (fine) grains with L:B ratio (3.88) and it was at par with Pusa basmati-1 (3.86). However Jaya produced bold grains (2.33), as far the mean performance is concerned.

#### 4.2.12. Protein content (%):

The nitrogen content of ten genotypes was estimated by modified Micro-Kjeldhal method. Protein content was calculated by multiplying nitrogen content by factor 6.25. Pusa basmati-1 had the highest (6.82%), while Ratnagiri-73 had the lowest protein (5.60%) among all the genotypes under study at E<sub>2</sub> (30<sup>th</sup> May 2010).

**Table: 4.2.12 : Protein content (%):**

Sr.No.	Genotype	Protein (%)
1	Ratna	6.12
2	Karjat-184	5.95
3	Ratnagiri-73	5.60
4	Phule radha	6.65
5	Ratnagiri-24	6.47
6	Phule Samruddhi	6.30
7	Jaya	6.12
8	Indrayani	5.77
9	Bhogawati	6.30
10	Pusa basmati-1	6.82

### 4.3 Stability analysis:

#### 4.3.1 Analysis of variance (Pooled):

The analysis of variance representing the mean sum of square due to different sources of variation as per Eberhart and Russell (1966) is presented in Table 4.3.1

Pooled analysis of variance over six different environments showed that, genotypic variances (G) and Environmental variances (E) were significant for all the

characters viz; days to 50 % flowering, length of panicle, number of spikelets per panicle, spikelet sterility, panicles per meter square, 1000 grain weight and yield per plant when tested against g x e interaction, pooled deviation and pooled error. Genotypic variances(G) for number of tillers per plant and yield per plot was observed to be significant against pooled deviation and pooled error but non significant against G x E.

G x E interactions were significant for all the traits when tested against pooled deviation and pooled error. Partitioning of E + (G x E) interaction showed that, G x E (linear) and E (linear) components were significant for all the character when tested against pooled deviation and pooled error, indicating genotypes differed for their linear response to environments. Pooled deviation effects for all the traits were significant, when tested against pooled error, which showed deviation from linear relationship.

ANOVA FOR STABILITY AS PER EBERHART AND RESELL  
MODEL

#### **4.4 Estimates of environmental indices (I<sub>j</sub>):**

Estimates of environmental indices (I<sub>j</sub>) are presented in Table 4.4, which revealed that environment E<sub>1</sub> (15<sup>th</sup> May) was favourable for eight characters i.e. Number of tillers per plant, Length of panicle (cm), Number of panicles per meter square, Number of spikelets per panicle, Spikelet sterility (%), Yield per plant (g), Yield per plot (Kg) and Length:Breadth ratio.

Environment E<sub>2</sub> (30<sup>th</sup> May ) was favourable for eight characters i.e. Number of tillers per plant, Length of panicle(cm), Number of panicles per meter square, Number of spikelets per panicle, Spikelet sterility (%), Yield per plant (g), Yield per plot (kg) and 1000 grain weight (g). It was unfavorable for three characters i.e. Days to 50% flowering, Days to maturity and Length: Breadth ratio.

Environment E<sub>3</sub> (15<sup>th</sup> June) was favourable for all characters i.e. Number of tillers per plant, Length of panicle(cm), Number of panicles per meter square, Number of spikelets per panicle, Length: Breadth ratio, 1000 grains weight (g). Spikelet sterility (%), Yield per plant (g), Yield per plot (kg) except Days to maturity and Days to 50% flowering.

Environment E<sub>4</sub> (30<sup>th</sup> June) was favourable for characters *viz.*, Days to 50% flowering, Days to maturity and 1000 grain weight (g).

Environment E<sub>5</sub> (15<sup>th</sup> July) and E<sub>6</sub> (30<sup>th</sup> July) were favourable for only days to 50% flowering and Days to maturity.

**Table 4.4 : Estimation of environment index (I<sub>j</sub>) under different environments**

Sr. No.	Characters	Environmental index (I <sub>j</sub> )					
		E <sub>1</sub>	E <sub>2</sub>	E <sub>3</sub>	E <sub>4</sub>	E <sub>5</sub>	E <sub>6</sub>
1	Days to 50 % flowering	3.62	3.79	1.03	-0.58	-3.11	-4.75
2	Number of tillers per plant(hill)	1.62	2.71	2.52	-0.82	-2.41	-3.63
3	Length of panicle (cm)	0.27	1.66	1.23	-1.25	-0.53	-1.41
4	Number of spikelets per panicle	1.55	9.51	6.12	-4.83	-3.46	-8.86
5	Spikelet sterility (%)	0.04	-2.71	-2.66	0.69	2.31	2.34
6	Days to maturity	9.39	7.47	2.16	-2.81	-6.23	-9.99
7	L:B ratio	0.06	-0.06	0.07	0.00	-0.04	-0.02
8	Panicles per Square meter	2.87	6.00	5.18	-1.35	-4.36	-8.35
9	1000 grain weight (g)	-0.93	0.81	0.92	0.84	-0.32	-1.33
10	Yield per plant (g)	3.98	6.22	5.67	-1.38	-5.95	-8.53
11	Yield per plot (Kg)	0.30	0.48	0.39	-0.09	-0.39	-0.71

In general environment E<sub>2</sub> (30<sup>th</sup> May) was most favourable for yield and yield contributing characters followed by E<sub>3</sub> (15<sup>th</sup> June) and E<sub>1</sub> (15<sup>th</sup> May).

#### 4.5 Stability parameters for individual characters :

Since G x E interaction was detected for all the characters (except-Days to maturity and L:B ratio) the stability parameters in respect of these traits were estimated and are presented in Table 4.3.1. The non-significant bi values were considered as around unity irrespective of their high or low numerical values. According to Eberhart and Russell (1996) a stable genotype is one which shows, (i) high mean yield (ii) a regression co-efficient (bi=1) equal to unity and (iii) a mean square deviation from regression (S<sup>2</sup>di=0) near to zero.

#### 4.5.1. Days to 50% flowering :

Mean days to 50% flowering ranged from 91.77 (Karjat-184) to 109.47 (Indrayani) with a population mean of 100.53 days.

**Table-4.5.1 : Estimates of the stability parameters for days to 50 % flowering :**

Sr. No.	Genotype	Days to 50 % flowering		
		X	bi	S <sup>2</sup> di
1	Ratna	93.739	0.871	3.868
2	Karjat-184	91.778	0.718	3.453
3	Ratnagri-73	92.522	1.015*	2.524
4	Phule radha	98.183	1.226**	-0.718
5	Ratnagiri-24	98.500	0.813**	0.263
6	Phule samruddhi	107.167	0.996	3.412
7	Jaya	106.278	1.058	3.566
8	Indrayani	109.472	1.053*	2.171
9	Bhogawati	106.894	1.087	5.073
10	Pusa basmati-1	100.833	1.164*	2.959
	Mean	100.536	--	--
	S.E.±	0.865	0.247	--

\* , \*\* = Significant at 5% and 1% level of significant, respectively

The genotypes Ratna and Karjat-184 had non significant regression coefficient (bi=0.87 and 0.71 resp.) with non-significant deviation from regression (S<sup>2</sup>d=3.86 and 3.45 respectively) and superior mean performances ( 93.73 and 91.77 resp.), indicating their average stability for this character i.e. these genotypes perform better under all environments, in respect of earliness which is desirable.

The genotypes Ratnagri-73 and Phule radha had significant regression coefficient (bi=1.01 and 1.22 resp.) with non significant deviation from regression (S<sup>2</sup>d=2.52 and -0.71 resp.) and superior mean performances (92.52 and 98.18 days resp.) indicating their stability for favourable environment i.e. below average stability.

The genotype Ratnagiri-24 had significant regression coefficient (bi=0.81) with non-significant deviation from regression (S<sup>2</sup>d=0.26) and superior mean performance (98.50 days) indicating its stability for stress environment i.e. above average stability.

#### 4.5.2. Number of tillers per plant :

Mean number of tillers per plant ranged from 20.02 (Phule samruddhi) to 22.31 (Bhogawati) with a population mean of 21.04.

**Table-4.5.2 : Estimates of the stability parameters for number of tillers per plant:**

Sr.No.	Genotype	Number of tillers per plant		
		$\bar{X}$	$b_i$	$S^2d_i$
1	Ratna	22.183	1.505**	-0.305
2	Karjat-184	20.850	0.834	2.359
3	Ratnagiri-73	20.961	1.166	2.759
4	Phule radha	21.644	1.152*	2.301
5	Ratnagiri-24	20.083	0.895	3.458*
6	Phule samruddhi	20.028	0.581	2.201
7	Jaya	20.950	0.927	4.730
8	Indrayani	20.317	0.993	2.726
9	Bhogawati	22.311	0.908	3.821
10	Pusa basmati-1	21.161	1.039*	1.677
	Mean	21.048	--	--
	S.E.±	0.786	0.292	--

\*, \*\* = Significant at 5% and 1% level of significance, respectively

The genotypes Ratnagiri-73, Jaya and Bhogawati had non significant regression coefficient ( $b_i=1.16, 0.92$  and  $0.90$  resp.) with non-significant deviation from regression ( $S^2d=2.75, 4.73$  and  $3.82$  resp.) and superior mean performance ( $20.96, 20.95,$  and  $22.31$  resp.) indicating their average stability for this character i.e. these genotypes perform better under all environments.

The genotypes Ratna, Phule radha and Pusa basmati-1 had significant regression coefficient ( $b_i=1.50, 1.15$  and  $1.03$  resp.) with non-significant deviation from regression ( $S^2d=-0.30, 2.30$  and  $1.67$  resp.) and superior mean performances ( $22.18, 21.64$  and  $21.16$  resp.) indicating their stability for favourable environment i.e. below average stability.

### 4.5.3. Length of panicle (cm) :

Mean length of panicle ranged from 20.64 (Phule radha) which was at par with genotype Ratnagiri-73 (20.65 cm) to 23.52 (Pusa basmati-1) with a population mean of 21.51 cm.

**Table-4.5.3 : Estimates of the stability parameters for length of panicle :**

Sr.No.	Genotype	Length of panicle ( cm)		
		X	bi	S <sup>2</sup> di
1	Ratna	20.950	1.212*	0.166
2	Karjat-184	22.427	1.042	2.333
3	Ratnagri-73	20.656	1.376	0.629
4	Phule radha	20.649	0.502	0.734
5	Ratnagiri-24	20.680	0.250	2.208
6	Phule samruddhi	20.988	0.703	0.606
7	Jaya	21.477	1.476	0.664
8	Indrayani	20.745	0.755	0.362
9	Bhogawati	23.066	1.203	2.803
10	Pusa basmati-1	23.529	1.482	2.131
	Mean	21.516	--	--
	S.E.±	0.597	0.468	--

\* , \*\* = Significant at 5% and 1% level of significance , respectively

The genotypes Karjat-184, Bhogawati and Pusa basmati-1 had non-significant regression coefficient (bi=1.04, 1.20 and 1.48 resp.) with non-significant deviation from regression (S<sup>2</sup>d=2.33, 2.80 and 2.13 resp.) and superior mean performances (22.42, 3.06, and 23.52 resp.) indicating their average stability for this character i.e. these genotypes perform better under all environments.

#### 4.5.4. Number of spikelets per panicle:

Mean number of spikelets per panicle ranged from 133.81(Ratnagiri-73) to 250.72 (Phule radha) with a population mean of 168.38.

**Table-4.5.4 : Estimates of the stability parameters for number of spikelets per panicle:**

Sr.No	Genotype	Number of spikelets per panicle		
		X	bi	S <sup>2</sup> di
1	Ratna	170.244	2.356**	22.622
2	Karjat-184	153.936	1.330*	17.693
3	Ratnagri-73	133.815	0.764	6.881
4	Phule radha	250.726	1.179	36.122
5	Ratnagiri-24	212.633	0.669	129.210**
6	Phule samruddhi	155.738	0.750	6.023
7	Jaya	153.573	0.906	8.671
8	Indrayani	145.896	0.757	14.113
9	Bhogawati	144.606	0.440	29.010
10	Pusa basmati-1	162.667	0.848	3.890
	Mean	168.383	--	--
	S.E.±	2.724	0.390	--

\* , \*\* = Significant at 5% and 1% level of significance, respectively

The genotype Phule radha had non significant regression coefficient (bi=1.17) with non-significant deviation from regression (S<sup>2</sup>d=36.12) and superior mean performance (250.72) indicating it's average stability for this character i.e. this genotype perform better under all environments.

The genotype Ratna had significant regression coefficient (bi=2.35) with non-significant deviation from regression (S<sup>2</sup>d=22.62) and superior mean performance (170.24) indicating it's stability for favourable environment i.e. below average stability.

The genotype Ratnagiri-24 exhibited significant value of S<sup>2</sup>di (129.21) indicating it's unpredictability for the given character.

#### 4.5.5. Spikelet sterility (%) :

The spikelet sterility ranged from 7.95% (Jaya) to 16.81% (Phule radha) with a population mean of 11.69%.

**Table-4.5.5 : Estimates of the stability parameters for spikelet sterility:**

\*, \*\* = Significant at 5% and 1% level of significance, respectively

Sr.No.	Genotype	Spikelet sterility (%)		
		X	bi	S <sup>2</sup> di
1	Ratna	9.849	1.035	1.659
2	Karjat-184	10.429	0.706	0.890
3	Ratnagiri-73	9.363	0.929	1.958
4	Phule radha	16.819	1.457**	1.140
5	Ratnagiri-24	14.829	1.116*	1.103
6	Phule samruddhi	10.686	0.800	1.459
7	Jaya	7.952	1.218**	0.582
8	Indrayani	13.483	0.967	4.043**
9	Bhogawati	11.277	0.953	1.677
10	Pusa basmati-1	12.231	0.818	3.234**
	Mean	11.691	--	--
	S.E.±	0.642	0.283	--

The genotypes Ratna, Karjat-184, Ratnagiri-73, Phule samruddhi and Bhogawati had non-significant regression coefficient ( $b_i=1.03, 0.70, 0.92, 0.80$  and  $0.95$  resp.) with non-significant deviation from regression ( $S^2d=1.65, 0.89, 1.95, 1.45$  and  $1.67$  resp.) and superior mean performances ( $9.84, 10.42, 9.36, 10.68$  and  $11.27$  resp.) indicating their average stability for this character i.e. these genotypes perform better under all environments.

The genotype Jaya had significant regression coefficient ( $b_i=1.21$ ) with non-significant deviation from regression ( $S^2d=0.58$ ) and superior mean performance ( $7.95\%$ ) indicating it's stability for favourable environment i.e. below average stability.

The genotypes Indrayani and Pusa basmati-1 exhibited significant values of  $S^2d_i$  ( $4.04$  and  $3.23$ ) indicating their unpredictability for the given character.

#### 4.5.6. Panicles per square meter:

Mean number of panicles per square meter ranged from 385.82(Ratnagiri-24) to 447.59(Bhogawati) with a population mean of 428.06.

**Table-4.5.6 : Estimates of the stability parameters for panicles per meter square :**

Sr.No.	Genotype	Panicles per square meter		
		X	bi	S <sup>2</sup> di
1	Ratna	435.234	0.916	20.956
2	Karjat-184	397.951	0.931	14.197
3	Ratnagri-73	439.040	1.250	6.753
4	Phule radha	440.629	1.072	11.274
5	Ratnagiri-24	385.828	1.100	5.263
6	Phule samruddhi	410.465	0.803	18.438
7	Jaya	444.310	1.035	11.410
8	Indrayani	442.168	0.688	-1.298
9	Bhogawati	447.599	1.150	9.849
10	Pusa basmati-1	437.456	1.052	5.389
	Mean	428.068	--	--
	S.E.±	1.993	0.350	--

\* , \*\* = Significant at 5% and 1% level of significance , respectively

The genotypes Ratna, Ratnagiri-73, Phule radha, Jaya , Indrayani, Bhogawati and Pusa basmati-1 had non significant regression coefficients (bi=0.91, 1.25, 1.07, 1.03, 0.68, 1.15 and 1.05 resp.) with non-significant deviation from regression (S<sup>2</sup>d=20.95, 6.75, 11.27, 11.41, -1.29, 9.84 and 5.38 resp.) and superior mean performances (435.23, 439.04, 440.62, 444.31, 442.16, 447.59 and 437.45 resp.) indicating their average stability for this character i.e. these genotypes perform better under all environments.

**4.5.7. Yield per plant (g) :**

Mean yield per plant ranged from 38.62 (Ratnagiri-24) to 52.73 (Jaya) with a population mean of 45.55.

**Table-4.5.7 : Estimates of the stability parameters for yield per plant:**

Sr.No.	Genotype	Yield per plant (g)		
		X	bi	S <sup>2</sup> di
1	Ratna	48.476	1.392**	3.769
2	Karjat-184	40.721	0.843*	3.451
3	Ratnagri-73	44.110	1.115*	6.988
4	Phule radha	45.669	1.052*	11.146
5	Ratnagiri-24	38.628	0.863	12.698
6	Phule samruddhi	42.904	0.694	14.942
7	Jaya	52.739	0.908	18.004
8	Indrayani	44.708	0.968*	7.682
9	Bhogawati	48.617	1.133*	8.973
10	Pusa basmati-1	48.956	1.033	7.640
	Mean	45.552	--	--
	S.E.±	1.548	0.246	--

\* , \*\* = Significant at 5% and 1% level of significance, respectively

The genotypes Jaya and Pusa basmati-1 had non significant regression coefficient ( $b_i=0.90$  and  $1.03$  resp.) with non significant deviation from regression ( $S^2d=18.00$  and  $7.64$  resp.) and superior mean performance ( $52.73$  and  $48.95$  resp.) indicating their average stability for this character i.e. this genotypes perform better under all environments.

The genotypes Ratna, Phule radha and Bhogawati had significant regression coefficients ( $b_i=1.39$ ,  $1.05$  and  $1.13$  resp.) with non significant deviations from regression ( $S^2d=3.76$ ,  $11.14$  and  $8.97$ ) and superior mean performance ( $48.47$ ,  $45.66$  and  $48.61$ ) indicating their stability for favourable environment i.e. below average stability.

#### 4.5.8. Yield per plot (Kg) :

Mean yield per plot (Kg) ranged from 2.69 (Ratnagiri-24) to 3.64 (Jaya) with a population mean of 3.13

**Table-4.5.8 : Estimates of the stability parameters for yield per plot:**

Sr.No.	Genotype	Yield per plot ( Kg)		
		X	bi	S <sup>2</sup> di
1	Ratna	3.347	1.365**	0.027
2	Karjat-184	2.835	0.936*	0.033
3	Ratnagri-73	3.067	1.109**	0.029
4	Phule radha	3.040	1.108**	0.015
5	Ratnagiri-24	2.696	0.769	0.094
6	Phule samruddhi	3.001	0.705	0.081
7	Jaya	3.641	0.801	0.100
8	Indrayani	3.069	1.115*	0.039
9	Bhogawati	3.283	1.103*	0.100
10	Pusa basmati-1	3.386	0.991	0.060
	Mean	3.136	--	--
	S.E.±	0.126	0.265	--

\*, \*\* = Significant at 5% and 1% level of significance, respectively

The genotypes Jaya and Pusa basmati-1 had non significant regression coefficients ( $b_i=0.80$  and  $0.99$  resp.) with non-significant deviations from regression ( $S^2d=0.10$  and  $0.06$  resp.) and superior mean performance ( $3.64$  and  $3.38$  resp.) indicating their average stability for this character i.e. these genotypes perform better under all environments.

The genotypes Ratna and Bhogawati had significant regression coefficients ( $b_i=1.36$  and  $1.10$  resp.) with non significant deviations from regression ( $S^2d=0.02$  and  $0.10$  resp.) and superior mean performances ( $3.34$  and  $3.28$  resp.) indicating their stability for favourable environment i.e. below average stability.

#### 4.5.9. 1000 grain weight (g) :

Mean 1000 grain weight ranged from 14.28 (Ratnagiri-24) to 27.83 (Jaya) with a population mean of 21.04.

**Table-4.5.9 : Estimates of the stability parameters for 1000 grain weight:**

Sr.No.	Genotype	1000 grain weight (g)		
		X	bi	S <sup>2</sup> di
1	Ratna	20.869	-0.139	0.782
2	Karjat-184	21.800	0.733	0.253
3	Ratnagri-73	24.517	1.007	-0.002
4	Phule radha	14.997	0.515	0.029
5	Ratnagiri-24	14.283	0.856*	-0.330
6	Phule samruddhi	21.788	1.126*	-0.171
7	Jaya	27.834	1.282	0.146
8	Indrayani	22.816	1.256	0.238
9	Bhogawati	21.510	1.609	0.878
10	Pusa basmati-1	19.987	1.755*	0.170
	Mean	21.040	--	--
	S.E.±	0.380	0.382	--

\* , \*\* = Significant at 5% and 1% level of significance, respectively

The genotypes Karjat-184, Ratnagiri-73, Jaya, Indrayani and Bhogawati had non significant regression coefficients (bi=0.73, 1.00, 1.28, 1.25 and 1.60 resp.) with non-significant deviations from regression (S<sup>2</sup>d=0.25, -0.002, 0.14, 0.23 and 0.87 resp.) and superior mean performances (21.80, 24.51, 27.83, 22.81 and 21.51 resp.) indicating their average stability for this character i.e. these genotypes perform better under all environments.

The genotype Phule samruddhi had significant regression coefficient (bi=1.12) with non-significant deviation from regression (S<sup>2</sup>d=-0.17) and superior mean performance (21.78 g) indicating it's stability for favourable environment i.e. below average stability.

## 5. DISCUSSION

In the task of developing improved genotypes, assessment of genotype x environment interaction forms an important tool in the hands of plant breeders. Many times, the interaction effects have camouflaged the value of genotype and this has considerably affected the selection criteria in breeding programme. Young and Virmani (1990) observed varying magnitude of G x E interaction, stressed the need to evaluate genotypes across environments. With this background, an experiment was conducted with an objective to assess stable and high yielding rice genotypes for different dates of sowing during *kharif* season 2010.

### 5.1 Pooled analysis of variance:

Analysis of variance for stability parameters was done (Table 4.3.1) by following model of Eberhart and Rusell (1966). Which revealed the presence of significant variation due to environment (E) for all the characters, indicating considerable additive environmental variance. Genotypic variances (G) were significant for all the traits, which indicated prevalence of lot of genetic variability among the rice genotypes under study. These results are in agreement with the results reported by Munisonnappa *et al.* (2004); Sedghi azar *et al.* (2008); Hanamaratti *et al.* (2009) and Das *et al.* (2010).

The G x E interaction when tested against pooled deviation and pooled error was found to be significant for all the traits, explaining that the major portion of interaction was

linear in nature and prediction over environments was possible. The similar results were reported by Luren *et al* (2000); Sarawgi *et al.* (2000) and Satit *et al.* (2000).

Further partitioning of  $E + (G \times E)$  into  $E(\text{linear})$  was found to be significant for all the traits, indicating differences between environments and their influence on genotypes for expression of these traits. This is in accordance with previous reports made by Sawant *et al.* (2005); Panwar *et al.* (2008) and Umadevi *et al.* (2008). The  $G \times E$  (linear) component showed significance for all the characters. This revealed the linear relationship for expression of these traits with different environments. The similar trend was observed by Mahapatra and Das (1999) and Nanitadevi *et al.* (2006).

Pooled deviation tested against pooled error found to be significant for all the traits, indicating presence of non predictable components for grain yield and yield related traits. These results are in agreement with the previous findings reported by Shantakumar (1997); Narayana swamy and Dushyanthakumar *et al* (2003); Munisonnappa *et al.* (2004) and Hanamaratti *et al.* (2009).

Thus in present study, both linear and non-linear components were significant for yield and yield contributing characters. Similar findings were reported by Kulkarni *et al.* (2000); Senapati *et al.* (2002) and Dushanthakumar *et al* (2010).

## **5.2 Response of rice genotypes to changing environments:**

The mean performance of individual character is presented in table 4.2.1.to 4.2.12, while stability parameters are in table 4.5.1 to 4.5.9

Eberhart and Rusell (1966) defined a stable genotype as the one which showed high mean, regression coefficient around unity ( $b_i=1$ ) and deviation from regression near to zero ( $S^2d_i=0$ ). Accordingly, the mean and deviation from regression of each genotype was considered for stability and linear regression ( $b_i$ ) was used for varietal response.

- i. Genotypes with high mean, regression coefficient around unity ( $b_i=1$ ) and non significant deviation from regression ( $S^2d_i$ ) are average stable. i.e. suitable over all environmental conditions and they are considered as stable genotypes.
- ii. Genotypes with high mean, regression coefficient more than unity ( $b_i \geq 1$ ) and non significant deviation from regression ( $S^2d_i$ ) are considered below average stability. i.e. suitable over rich environmental conditions but give poor yield in unfavourable environment.
- iii. Genotypes with high mean, regression coefficient less than unity ( $b_i \leq 1$ ) and non significant deviation from regression ( $S^2d_i$ ) are considered above average stability. i.e. suitable over poor environmental conditions.
- iv. Genotypes with any value of regression coefficient ( $b_i$ ) with significant deviation from regression ( $S^2d_i$ ) are unpredictable.

### **5.2.1 Days to 50% flowering:**

The genotype Karjat-184 (91.78 days) was observed to be earliest, while Indrayani (109.47 days) was late among all the genotypes.

The genotypes Ratna and Karjat-184 were average stable, indicating their adaptability to all environments. Ratnagiri-24 was suitable for poor environment i.e. above average stability. While Ratnagiri-73 and Phule radha were suitable for rich environments i.e. below average stability, for the trait under study.

For the given trait, both linear (G x E) and non linear (Pooled deviation) found to be significant, which indicates that expression of the trait under study was found to be influenced by predictable and unpredictable components of environment. Similar findings were reported earlier by Dushanthkumar *et al.* (2010) and Senapati *et al.* (2002).

### **5.2.2 Number of tillers per plant (hill):**

Bhogawati had maintained its dominance by producing maximum number of tillers (22.31), while Ratnagiri-24 expressed poor performance (20.08) among all the genotypes under study.

The genotypes Ratnagiri-73, Jaya and Bhogawati were average stable, expressing that they produce stable number of tillers under all environments. Ratna, Phule radha and Pusa basmati-1 exhibited below average stability for the given trait i.e. performs well under favourable environmental conditions.

The linear and non linear component of environment greatly affects the number of tillers per plant. Similar trend

was reported earlier by Narayana swamy and Dushantha kumar (2003); Pande and Singh (2006) and Umadevi *et al.* (2008).

### **5.2.3 Length of panicle (cm):**

The genotype Pusa basmati-1 (25.053) and Bhogawati (23.07) were superior, while Phule radha (20.63) had the shortest panicle as compared to other genotypes.

Karjat-184, Bhogawati and Pusa basmati-1 were average stable i.e. panicle length remains stable over variable environmental conditions.

The expression of the given trait was controlled by the predictable and non predictable components of environment. These findings are in agreement with earlier observations reported by Munisonnappa *et al.* (2004); Dushanthakumar and Shadakshari (2008); Umadevi *et al.* (2008); Hanamaratti *et al.* (2009) and Dushanthakumar *et al.* (2010).

### **5.2.4 Number of spikelets per panicle:**

The genotype Phule radha (250.73) had produced maximum, while Ratnagiri-73 (133.82) had produced minimum number of spikelets per panicle over rest of the genotypes under investigation.

Phule radha showed the average stability for this trait, indicating its stable performance over different environments. Ratna had the below average stability for the trait, revealing that it is suitable for better environment for stable performance of given character. Number of spikelets per panicle was found to be largely influenced by the linear and non linear components of environment. These are similar to

the findings of Munisonnappa *et al.* (2004); Gouri Shankar *et al.* (2008) and Umadevi *et al.* (2008).

#### **5.2.5 Spikelet sterility (%):**

The minimum percent of spikelet sterility had expressed by Jaya (7.95), whereas Phule radha (16.82) had the maximum spikelet sterility.

The genotypes Ratna, Ratnagiri-73, Karjat-184, Phule samruddhi and Bhogawati were found to be average stable. Jaya found to be suitable for the better environment, as it shows the below average stability.

The magnitude of spikelet sterility was found to be significantly influenced by the predictable (linear) and unpredictable (non linear) components of environment. These results confirm the findings of Munisonnappa *et al.* (2004).

#### **5.2.6 Panicles per square meter :**

Bhogawati had maintained its consistency by producing maximum panicles (447.60), while Ratnagiri-24 remained at bottom with 385.83 panicles per square meter , when compared to other genotypes.

The genotypes Ratna, Ratnagiri-73, Phule radha, Jaya, Indrayani, Bhogawati and Pusa basmati-1 were stable for the trait under study.

Present study revealed that production of panicles was found to be varied due to linear and non linear components of genotype x environment interaction. This is in agreement with results of Dushanthakumar and Shadakshari (2007); Hanamaratti *et al.* (2009) and Dushanthakumar *et al.* (2010).

### **5.2.7 Days to maturity:**

The genotype Ratnagiri-73 found to be earliest (112.06), while Indrayani required maximum days to maturity (138.61) among all the genotypes.

Genotype x Environment interaction was observed to be absent for this trait, indicating that this character was not influenced by changing environments. Similar observations were reported by Dinesh Kumar (1987); Hedge (1996); Mahapatra and Sujantha Das (1999) and Lohithaswa *et al.* (1999).

### **5.2.8 Yield per plant (g):**

The genotypes Jaya (52.74) showed consistency for such an important trait, followed by Pusa basmati-1 (48.96). The high yield potential was found to be favoured by low spikelet sterility and higher thousand grain weight in Jaya, while in Pusa basmati-1 more number of tillers and panicle length.

The genotypes Ratna, Phule radha and Bhogawati were found to be suitable for rich environments i.e. below average stability.

Jaya and Pusa basmati-1 exhibited average stability showing their consistency for yield over wide range of environment. Nayak (2008) reported stability of Pusa basmati-1 for yield. Narayanaswamy and Dushanthakumar (2003) and Munisonnappa *et al.* (2004) reported stability of Jaya for yield and yield contributing characters like thousand grain weight and tillers per plant.

Yield and yield contributing traits of crop are influenced by genotype (G), environment (E), and their interaction (GxE).

Every factor of the environment has a potential to cause differential performance, associated with interaction (GxE). These findings are in accordance with the earlier reports made by Fehr (1987); Mahapatra (1993); Mishra and Mahapatra (1998); Kulkarni *et al.* (2000); Senapati *et al.* (2002); Narayanaswamy and Dushanthakumar (2003); Munisonnappa *et al.* (2004); Tokok Haryantho *et al.* (2008); Umadevi *et al.* (2008); Hanamaratti *et al.* (2009) and Das *et al.* (2010).

### **5.2.9 Length : Breadth ratio:**

The genotypes Pusa basmati-1(3.86) and Bhogawati (3.88) produced slender (fine) grains, indicating their superiority for quality. Jaya (2.33) had the bold grains as far mean performance considered.

Genotype x Environment interaction was observed to be absent for the trait under study. These results are in conformity with results obtained by Dineshkumar (1987); Senanayake and Vijayratne (1990); Bay an Long (1994); Shantakumar (1997); Lohithaswa *et al.* (1999) and Nayak (2008).

### **5.2.10 1000 grain weight (g):**

The genotypes Jaya (27.83) and Ratnagiri-73 (24.52) were found to be superior for grain weight. However Ratnagiri-24 had reported lowest seed weight (14.28).

The genotype Phule samruddhi displayed the below average stability, indicating ability to produce stable performance under better environment for the trait studied.

Karjat-184, Ratnagiri-73, Jaya, Indrayani and Bhogawati were found to be elite for grain weight over wide range of environment.

The character under study, showed the differential performance due to the linear and non linear components of the environment. This is in agreement with previous reports made by Narayanaswamy and Dushanthakumar (2003); Munisonnappa *et al.* (2004); Gourishankar *et al.* (2008); Parry *et al.* (2008); Tokok hayantho *et al.* (2008) and Umadevi *et al.* (2008).

#### **5.2.11 Protein content (%):**

The protein content of rice is one of the most important quality parameter. The protein present in rice is called as *Oryzenin*. In present study protein content of ten rice genotypes was estimated. Pusa basmati-1 contains maximum protein (6.82%), while Ratnagiri-73 shows lower protein content (5.60%) ,over rest of the genotypes. Similar reports on rice protein content were made by Juliano and Villareal (1993) and Jian ping sun *et al.* (2008).

**Table-5.1: Nature of stability of rice genotypes under different environments:**

Sr. No	Character	Genotypes showing stability		
		Average wider stability (bi=1) (suitable for all environments)	Above average (bi<1) (suitable for stress environment)	Below average (bi>1) (suitable for favourable environment)
1	Days to 50 % flowering	Ratna , Karjat-184	Ratnagiri-24	Ratnagiri-73 , Phule radha
2	Number of tillers per plant (hill)	Ratnagiri-73, Jaya, Bhogawati	---	Ratna, Phule radha, Pusa basmati-I
3	Length of panicle (cm)	Karjat-184, Bhogawati, Pusa basmati-I	---	---
4	Number of spikelets per panicle	Phule radha	---	Ratna
5	Spikelet sterility (%)	Ratna, Ratnagiri-73, Karjat-184, Phule Samruddhi, Bhogawati.	---	Jaya
6	Panicles per square meter	Ratna, Ratnagiri-73, Phule-radha, Jaya, Indrayani, Bhogawati, Pusa basmati-I	---	---
7	1000 grain weight (g)	Karjat-184, Ratnagiri-73, Jaya, Indrayani, Bhogawati.	---	Phule samruddhi
8	Yield per plant (g)	Jaya, Pusa basmati-1	---	Ratna, Phule radha, Bhogawati
9	Yield per plot (Kg)	Jaya, Pusa basmati-I	---	Ratna, Bhogawati

## 6. SUMMARY AND CONCLUSIONS

Rice (*Oryza sativa* L.) is the world's most important staple food crop. It is widely cultivated in varying rainfall, altitudes and climatic conditions in India. Grafius (1956) emphasized that, studies on individual components can lead to simplification in genetic explanation of yield stability. The present study aims to investigate the stability of the component traits in relation to stability of grain yield.

The findings obtained were summarized under following points.

### **6.1 Analysis of variance:**

Analysis of variance showed significance for nine characters, while G x E component found to be absent for days to maturity and L:B ratio.

### **6.2 Pooled analysis of variance:**

As per the Eberhart and Rusell (1966) model, both the linear (g x e) and non linear (pooled deviation) components were significant for nine quantitative characters. This indicates that, expression of these traits was under influence of predictable and unpredictable components of environment.

### **6.3 Estimation of environmental index:**

The present study indicate that sowing date E<sub>2</sub> (30<sup>th</sup> May) followed by E<sub>3</sub> (15<sup>th</sup> June) and E<sub>1</sub> (15<sup>th</sup> May) were most favourable for expression of yield and yield contributing traits.

#### **6.4 Response of rice genotypes to changing environments:**

The genotypes Karjat-184 and Ratnagiri-73 were earliest. Ratna and Karjat-184 showed average stability, while Ratnagiri-73 and Phule radha exhibited below average stability. Ratnagiri-24 had displayed above average stability for days to 50 % flowering.

Bhogawati was found to be best for number of tillers per plant. Ratnagiri-73, Jaya and Bhogawati were average stable, while Ratna, Phule radha and Pusa basmati-1 were exhibited below average stability for the same trait under study.

Pusa basmati-1 and Bhogawati were found to be superior and average stable for panicle length. Also Karjat-184 displayed stable performance for the same trait.

Phule radha was observed to be superior and stable for number of spikelets per panicle, while Ratna showed below average stability for the same character under investigation.

The genotype Jaya had the lowest spikelet sterility. It was found to be below average stability. However Ratna, Ratnagiri-73, Phule samruddhi, Karjat-184 and Bhogawati were exhibited average stability for the character under study.

The maximum number of panicles per square meter was reported by genotype Bhogawati. Ratna, Ratnagiri-73, Phule radha, Jaya, Indrayani, Bhogawati and Pusa basmati-1 were found to be stable for number of panicles per square meter.

The genotype Jaya found to be superior for grain yield among all the genotypes. Pusa basmati-1 and Jaya were

exhibited average stability. However Ratna, Phule radha and Bhogawati showed below average stability for grain yield.

Jaya exhibited the highest thousand grain weight. The genotypes Karjat-184, Ratnagiri-73, Jaya, Indrayani and Bhogawati were elite for seed weight.

Pusa basmati-1 and Bhogawati were produced slender (fine) grains. The studied rice genotypes contains protein ranging from 5.60 % to 6.82%, But Pusa basmati-1 had highest protein content (6.82%) among them.

### **6.5 Conclusions:**

1. Stability analysis indicates that, the environment E<sub>2</sub> (30<sup>th</sup> May) followed by E<sub>3</sub> (15<sup>th</sup> June) and E<sub>1</sub> (15<sup>th</sup> May) found to be most suitable for better expression of yield and yield contributing characters.
2. None of the genotype was found to be average stable for all the characters.
3. The genotypes showed differential stability performance for all the characters.
4. Linear and non-linear components of G x E interactions were highly significant for all the characters.
5. The genotypes Jaya, Pusa basmati-1, Bhogawati, Ratna and Phule radha were found to be promising for yield and yield contributing traits, which can be used for commercial cultivation, between 30<sup>th</sup> May to 15<sup>th</sup> June.

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\* Original not seen.

## 8. VITA

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**Mr. KATRAJKAR PURUSHOTTAM VITTHAL**

A candidate for the degree  
of  
**MASTER OF SCIENCE (AGRICULTURE)**  
in  
**AGRICULTURAL BOTANY**  
**(GENETICS AND PLANT BREEDING)**

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**Title of thesis** : “Stability analysis in Upland Rice  
(*Oryza sativa* L.)”

**Major field** : Genetics and Plant Breeding

### **Biographical information**

**Personal** : Born on 2<sup>nd</sup> December. 1985, at Kusadgaon,  
Tal Jamkhed, Dist. Ahmednagar (M.S.),  
Son of Sau. Shalan and Shri. Vitthal kisan  
Katrajkar.

**Educational** : Passed S.S.C from Maharashtra Vidyalaya  
Sadashiv peth,Pune-30, in 2001 with first  
class (63.67 %)

: Passed H.S.C. from Shree Chhatrapati  
Shivaji Junior College,Shrigonda Tal-  
Shrigonda,Dist. Ahmednagar in 2004 with  
distinction (76.17 %)

Received Bachelor of Science (Agriculture)  
degree with first class (79.95%) in 2008 from  
college of Agriculture, Kolhapur.

**Address** : A/P Kusadgaon Tal. Jamkhed ,  
Dist : Ahmednagar