# STUDIES ON GENETIC DIVERSITY FOR DROUGHT TOLERANCE IN LOCAL LAND RACES OF RICE (*Oryza sativa* L.) UNDER AEROBIC CONDITION

**NAVYA, G. T.**

**MA1TAE0127**

***DEPARTMENT OF GENETICS AND PLANT BREEDING***

***COLLEGE OF AGRICULTURE, SHIVAMOGGA***

**UNIVERSITY OF AGRICULTURAL AND HORTICULTURAL SCIENCES**

**SHIVAMOGGA**

**JULY, 2017**

# STUDIES ON GENETIC DIVERSITY FOR DROUGHT TOLERANCE IN LOCAL LAND RACES OF RICE (*Oryza sativa* L.) UNDER AEROBIC CONDITION

**NAVYA, G. T.**
**MA1TAE0127**

Thesis submitted to the

**UNIVERSITY OF AGRICULTURAL AND HORTICULTURAL SCIENCES**
**SHIVAMOGGA**

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

*Master of Science* (Agriculture)
in
***GENETICS AND PLANT BREEDING***

**Shivamogga** **July, 2017**

**DEPARTMENT OF GENETICS AND PLANT BREEDING**
**COLLEGE OF AGRICULTURE, SHIVAMOGGA**

**UNIVERSITY OF AGRICULTURAL AND HORTICULTURAL SCIENCES SHIVAMOGGA**

# CERTIFICATE

This is to certify that the thesis entitled **"STUDIES ON GENETIC DIVERSITY FOR DROUGHT TOLERANCE IN LOCAL LAND RACES OF RICE (*Oryza sativa* L.)UNDER AEROBIC CONDITION"** submittedin partial fulfillment of the requirementsfor the award of the degree of **MASTER OF SCIENCE (AGRICULTURE)** in **GENETICS AND PLANT BREEDING** to the College of Agriculture, Shivamogga, University of Agricultural and Horticultural Sciences, Shivamogga is a bonafide record of research work carried out by **Ms. NAVYA G. T, ID. No. MA1TAE0127(navyagt@gmail.com)** during the period of study in this university under my guidance and supervision and no part of this thesis has previously formed the basis for the award of any other degree, diploma, associateship, fellowship or any other similar titles.

**Shivamogga**
**July, 2017**

**(B. M. DUSHYANTHA KUMAR)**

APPROVED BY:

Chairman : **(B. M. DUSHYANTHA KUMAR)**

Members : **1.** **(S. GANGAPRASAD)**

**2.** **(S. P. NATARAJU)**

**3.** **(SRIDEVI A. JAKKERAL)**

## ACKNOWLEDGEMENT

*I feel the immense pleasure to express my deep sense of gratitude and profound indeptedness to **Dr. B. M. Dushyantha Kumar**, Professor and Head, Department of Genetics and Plant Breeding, College of Agriculture, UAHS, Shivamogga and chairperson of my Advisory Committee for valuable guidance, constant supervision, vivid encouragement and affectionate dealing throughout the period of investigation and during preparation of the manuscript. It was a great pleasure and privilege for me is associated with him and I find no words to express my sincere thanks for all his kindness.*

*I wish to express my deep sense of gratitude to **Dr. S. Ganga Prasad**, Professor, Department of Genetics and Plant Breeding. **Dr. S. P. Nataraju**, Professor, Department of crop physiology. **Mrs. Sridevi A. Jakkeral**, Jr. Breeder, ZAHRS, Brahmavar my Advisory Committee members for their constant encouragement, suggestions and valuable guidance during the course of my study and investigation.*

*I express my whole hearted thanks to **Dr. Pranesh** farmer Assistant professor (contract), Department of Genetics and Plant Breeding ,**Dr. Satisha T. N.** Assistant professor (contract), Department of Genetics and Plant Breeding and **Dr. Nagaraju C. H.** Assistant professor (contract), Department of Genetics and Plant Breeding,and my seniors **Nishanth sir, Sheshaiah sir, Raghavendra sir and Pavan sir** for their valuable suggestions.*

*I owe thanks from depth of my heart to my dear friends **Lahari, Vittal, Ashwini, Sheela, Jyoti, Megha G., Megha H., Nikhila, Shubha, Chandru, Veerasena Reddy and all my senior and junior friends.***

*I wish to express my sincere and heartfull thanks to field assistant **Sri. Maheshwarappa, RA Schin sir, SRF Pradeep sir** and non teaching staff our bleloved **Suvarnamma, Smt. Gayatri and field workers Rajayya, Rangappa, Sarojamma, Neelamma** for their valuable support throughout study period.*

*I greatly acknowledge COA **Shivamogga**, for providing facilities to carry out my research work.Also express my thanks to**Mr. Shiva Kumar** (Sri Guru Raghavendra Digital copier) and **Snehamilana Xerox centre** for thesis frame work and also to all the teaching and non teaching staff members*

*...any omission in this small manuscript does not mean lack of gratitude.*

Navya G T

***Shivamogga**, 2017* (Navya G T)

**Studies on genetic diversity for drought tolerance in local land races of rice (*Oryza sativa* L.) under aerobic condition**

**(NAVYA, G. T.)**

## ABSTRACT

Rice is the principle food crop for more than half of the world's population. The frequent occurrences of abiotic stress are the key to decreased productivity of rice. Drought is identified as the major abiotic stress affecting the yield of rice.The present study was undertaken to evaluate 49 local land races of rice including checks in field and PVC pipes for screening drought tolerant genotypes, assessing genetic variability, correlation, path coefficients and genetic divergence under control and drought condition. ANOVA revealed highly significant difference for all the characters. Yield per plant was significantly and positively associated with productive tillers per plant, number of spikelets per panicle, number of filled grains per panicle, seed filling per cent and test weight. Physiological characters like chlorophyll content, relative water content, proline content, root length, root to shoot ratio and root volume showed significant positive correlation with yield under drought condition. Phenotypic path-coefficient analysis revealed that test weight in drought and number of spikelets per panicle under control showed highest direct effect on yield per plant and among physiological characters root length under drought and control condition exhibited highest direct effect on yield. Using Mahalanobis' $D^2$ statistics, genotypes were grouped into eightclusters, wide genetic variability was indicated by the intra and inter cluster distances. Maximum inter cluster distance was observed between cluster IV and cluster VIII under drought condition and between cluster VII and VIII under control condition. Based on yield and yield attributes results under both drought and control conditions the genotypes Sannavaalya, Manjakaime, JGL-1798, Gangadace, Madras sanna and Najarbadwere recommended for drought tolerance breeding programme as well as adoption under drought stress condition.

Department of Genetics and Plant Breeding
UAHS, Shivamogga
July, 2017

Navya, G. T.
(navyagt@gmail.com)

B. M. Dushyantha Kumar
(dushyanth123@yahoo.com)

# “ಏರೋಬಿಕ್ ಸ್ಥಿತಿಯಲ್ಲಿ ಭತ್ತದ ಸ್ಥಳೀಯ ಭೂ ತಳಿಗಳೊಂದಿಗೆ ಬರ ಸಹಿಷ್ಣುತೆಗಾಗಿ ಅನುವಂಶಿಕ ವೈವಿಧ್ಯತೆಯ ಮೇಲಿನ ಅಧ್ಯಯನ”

(ನವ್ಯ, ಜಿ. ಟಿ.)

ಸಾರಾಂಶ

ವಿಶ್ವದ ಜನಸಂಖ್ಯೆಯ ಅರ್ಧಕ್ಕಿಂತ ಹೆಚ್ಚು ಜನರಿಗೆ ಭತ್ತ ಆಹಾರ ಬೆಳೆಯಾಗಿದೆ. ಆಗಾಗ್ಗೆ ಸಂಭವಿಸುವ ಅಜೈವಿಕ ಒತ್ತಡಗಳು ಭತ್ತದ ಉತ್ಪಾದಕತೆಯನ್ನು ಕಡಿಮೆ ಮಾಡುವ ಪ್ರಮುಖ ಅಂಶಗಳು. ಬರವು ಭತ್ತದ ಇಳುವರಿಯನ್ನು ಬಾಧಿಸುವ ಪ್ರಮುಖ ಅಜೀವಕ ಒತ್ತಡವೆಂದು ಗುರುತಿಸಲಾಗಿದೆ. ಪ್ರಸ್ತುತ ಅಧ್ಯಯನದಲ್ಲಿ ೪೯ ಸ್ಥಳೀಯ ಭೂ ಪ್ರದೇಶಗಳ ಭತ್ತದ ತಳಿಗಳನ್ನು ಪರೀಕ್ಷಿಸಿ, ಬರ ಸಹಿಷ್ಣು ತಳಿಗಳನ್ನು ಗುರುತಿಸಲು ಪಿವಿಸಿ ಕೊಳವೆಗಳ ತಪಾಸಣೆ ಸೇರಿದಂತೆ, ತಳಿಯ ವ್ಯತ್ಯಾಸ, ಪರಸ್ಪರ ಸಂಬಂಧ, ಮಾರ್ಗಗುಣಾಂಕಗಳನ್ನು ನಿಯಂತ್ರಣದ ಪರಿಸ್ಥಿತಿ ಮತ್ತು ಬರ ಪರಿಸ್ಥಿತಿಗಳಲ್ಲಿ ಅನುವಂಶೀಕ ವೈವಿಧ್ಯತೆಗಳನ್ನು ಅಂದಾಜು ಮಾಡಲಾಗಿದೆ. ಅನೋವಾ ಪರೀಕ್ಷೆಯು ಎಲ್ಲಾ ಗುಣಲಕ್ಷಣಗಳಿಗೆ ಹೆಚ್ಚು ಗಮನಾರ್ಹ ವ್ಯತ್ಯಾಸವನ್ನು ಬಹಿರಂಗಪಡಿಸಿತು. ಪ್ರತಿ ಗಿಡದ ಇಳುವರಿಯು ಪ್ರತಿ ಗಿಡದ ಫಲದಾಯಕ ತೆಂಡೆಗಳ ಸಂಖ್ಯೆ, ಪ್ರತಿ ತೆಂಡೆಯ ತುಂಬಿದ ಧಾನ್ಯಗಳ ಸಂಖ್ಯೆ, ಬೀಜ ಭರ್ತಿ ಶೇಕಡಾ ಮತ್ತು ೧೦೦೦ ಬೀಜಗಳ ತೂಕಗಳಿಗೆ ಗಮನಾರ್ಹವಾಗಿ ಮತ್ತು ಸಕಾರಾತ್ಮಕವಾಗಿ ಸಂಬಂಧಿಸಿದೆ. ಪತ್ರಹರಿತ್ತು ಅಂಶ, ಸಾಪೇಕ್ಷ ನೀರಿನ ಅಂಶ, ಪ್ರೋಲಿನ್ ಅಂಶ, ಬೇರಿನ ಉದ್ದ, ಬೇರು ಮತ್ತು ಗಿಡದ ಉದ್ದದ ಅನುಪಾತ ಅಂಶಗಳು ಬರ ಪರಿಸ್ಥಿತಿಯಡಿಯಲ್ಲಿ ಇಳುವರಿಯೊಂದಿಗೆ ಗಮನಾರ್ಹ ಧನಾತ್ಮಕ ಸಂಬಂಧವನ್ನು ತೋರಿಸಿದೆ. ಫೀನೋಟೈಪಿಕ್ ಪಥ ಗುಣಾಂಕ ವಿಶ್ಲೇಷಣೆಯು ೧೦೦೦ ಬೀಜಗಳ ತೂಕವು ಬರ ಪರಿಸ್ಥಿತಿಯಲ್ಲಿ ಮತ್ತು ಪ್ರತಿ ತೆಂಡೆಯ ಧಾನ್ಯಗಳ ಸಂಖ್ಯೆಯು ನಿಯಂತ್ರಣದ ಪರಿಸ್ಥಿತಿಯಲ್ಲಿ ಗಿಡದ ಇಳುವರಿಯೊಂದಿಗೆ ನೇರ ಪರಿಣಾಮವನ್ನು ಪ್ರದರ್ಶಿಸುತ್ತದೆ. ಮಹಾಲನೋಬಿಸ್ ಡಿ$^{೨}$ ಅಂಕಿ ಅಂಶಗಳನ್ನು ಬಳಸಿಕೊಂಡು, ಈ ೪೯ ತಳಿಗಳನ್ನು ಎಂಟು ಗುಂಪುಗಳಾಗಿ ವಿಂಗಡಿಸಲಾಯಿತು. ಅಂತರ ಹಾಗೂ ಅಂತಃ ಗುಂಪುಗಳ ದೂರದಲ್ಲಿ ವಿಸ್ತಾರವಾದ ಅನುವಂಶೀಯ ವ್ಯತ್ಯಾಸವನ್ನು ಗಮನಿಸಲಾಯಿತು, ಗುಂಪು ೪ ಮತ್ತು ೮ರ ನಡುವೆ ಬರ ಪರಿಸ್ಥಿತಿಯಲ್ಲಿ ಮತ್ತು ನಿಯಂತ್ರಣ ಸ್ಥಿತಿಯಲ್ಲಿ ಗುಂಪು ೭ ಮತ್ತು ೮ರ ನಡುವೆ ಗರಿಷ್ಠ ಅಂತರ ಗುಂಪುಗಳ ದೂರವನ್ನು ಗಮನಿಸಲಾಗಿದೆ. ಇಳುವರಿ ಮತ್ತು ಇಳುವರಿ ಸಂಬಂಧಿತ ಗುಣಲಕ್ಷಣಗಳ ಆಧಾರದ ಮೇಲೆ ಬರ ಮತ್ತು ನಿಯಂತ್ರಣ ಪರಿಸ್ಥಿತಿಗಳ ಆಧಾರದ ಮೇಲೆ ಫಲಿತಾಂಶಗಳು ಸಣ್ಣವಲ್ಯ, ಮಂಜಕೈಮೆ, ಜೆ.ಜಿ.ಎಲ್ – ೧೭೯೮, ಗಂಗಾಡೇಸ್, ಮದ್ರಾಸ್ ಸಣ್ಣ ಮತ್ತ ನಜರ್‌ಬಾದ್ ಬರ ಅಥವಾ ಜಲಕ್ಷಾಮದ ತಳಿ ಅಭಿವೃದ್ಧಿ ಕಾರ್ಯಕ್ರಮಕ್ಕೆ ಮತ್ತು ಬರ ಪರಿಸ್ಥಿತಿಗೆ ಒಳಗಾಗುವ ಪ್ರದೇಶಗಳಿಗೆ ಶಿಫಾರಸ್ಸು ಮಾಡಬಹುದಾಗಿದೆ.

ಅನುವಂಶೀಯತೆ ಮತ್ತು ಸಸ್ಯತಳಿ ಅಭಿವೃದ್ಧಿ ಶಾಸ್ತ್ರ ವಿಭಾಗ
ಕೃಷಿ ಮತ್ತು ತೋಟಗಾರಿಕಾ ವಿಶ್ವವಿದ್ಯಾಲಯ, ಶಿವಮೊಗ್ಗ
ಜುಲೈ, ೨೦೧೭

Navya GT
ನವ್ಯ, ಜಿ.ಟಿ.
(navyagt@gmail.com)

ದುಶ್ಯಂತ ಕುಮಾರ್, ಬಿ.ಎಂ.
(dushyanth123@yahoo.com)

## CONTENTS

# LIST OF TABLES

## LIST OF PLATES

## LIST OF APPENDICES

# *Introduction*

# I INTRODUCTION

Rice (*Oryza sativa* L.) is the primary staple food crop for about 65 per cent of the world population and influences the livelihoods and economies of several billion people. It provides 27 per cent of dietary energy and 20 per cent of dietary protein in the developing countries (Singh and Singh., 2007).Hence the rice cultivation, products, landscapes and traditions attached to it are an integral part of the world's cultural heritage in simple words "Rice is Life". As a tribute to a commodity that is a lifeline for millions of farmers the United Nations General Assembly designated 2004 as the International year of Rice (Alexander Sarris., 2004).

Rice is cultivated in all the continents of the world except Antarctica. Asia is the major producer and consumer of rice. In India the crop is cultivated in an area of 44.1 million hectares, with a production of 105.50 million tonnes and productivity of 2391.00 kg/ ha (2014-15). In 2016 the production of rice decreased to 104.4 million tonnes. It is grown in an area of 13.26 lakh hectares with production of 35.41 lakh tonnes and productivity of 26.70 quintal/ ha in Karnataka (Anonymous. 2016).

Rice is a unique crop grown under diverse ecological regions ranging from irrigated to rainfed, upland to lowland and deep water system. The frequent occurrences of abiotic stresses have been identified as the key to the low rice productivity of rainfed ecosystem. Among all the abiotic stresses, salinity, drought, submergence and mineral toxicity are the most important limiting factors affecting rice production. In Asia, rice cultivation generally follows a bimodal rainfall pattern, thus the drought stress during the growing season can be classified into three types, namely early stress (early in the growing season), intermittent stress (in the middle of the growing season) and late stress (in the late growing season) (Chang *et al*., 1979). About 23 million hectares of rainfed rice in Asia are estimated to be drought prone, and drought is becoming an increasing problem even in traditionally irrigated areas of India (Pandey *et al*., 2005).

There is a global consensus that current climate is changing mainly due to the anthropogenic emissions of greenhouse gases. There is widespread concern over long term climate changes and change in climate variability through occurrence of extreme weather events such as cyclone, floods, drought and sea level raise *etc*. The impact of climate change on cropping pattern in dry land regions have emerged as a critical concern in recent years (Naveen *et al.,* 2011). Drought is "a shortfall of water availability sufficient to cause loss in yield" or a period of no rainfall or irrigation that affects crop growth. Yield of rainfed lowland rice, which occupies about 25 per cent of the world's rice areas, are drastically reducing by drought due to unpredictable, insufficient and uneven rainfall during the growing period (Zulqarnain Haider *et al*., 2013). So, the need to accelerate breeding for increased yield potential and better adaptation under drought stress is of great concern.

The population continues to grow and the pressure on resources is also increasing. In order to feed the growing population, there is a need to breed for drought tolerant, high yielding and stable rice varieties. There are numerous local land races which are the important components of germplasm serve as the source of drought tolerance which can be used as donors. Breeding for drought tolerance is a difficult task because drought tolerance is a complex trait involving morphological, physiological, biochemical and molecular mechanisms. Hence, study of traits associated with improved performance of the plants under water stress condition will help in screening and selection of tolerant genotypes and using these traits in breeding programs.

Genetic diversity is a pre-requisite for crop improvement program to develop the superior recombinants. Genetic diversity is the total number of genetic characteristics in the genetic makeup of a species. It serves as a way for populations to adapt to changing environments. Information on the nature and degree of genetic divergence would help the plant breeder in choosing the right parents for breeding program. The $D^2$ technique is based on multivariate analysis developed by Mahalanobis (1936) had found to be a potent tool in quantifying the degree of divergence in germplasm.

Plants have evolved several adaptive mechanisms which classified into four categories to overcome the effect of stress. Three of these adaptations are developmental traits (*e.g*. time of flowering), structural traits (*e.g*. leaf waxiness) and physiological mechanisms (*e.g*. maintaining high relative water content) involve complex interaction. The fourth one is the metabolic responses such as alteration in metabolism and accumulation of organic osmolytes, most commonly proline (Jabasingh and Saravana. 2013). The root characteristics also play an important role in drought tolerance, depending on the genotypes, the roots have the ability to undergo developmental changes at different extents to better adapt to water stress. Hence, it is essential to study the degree of association between these mechanisms with yield attributing characters. A study of correlation and path analysis thus help to identify suitable selection criteria for improving yield.

Keeping all these in views, the present study was planned to assess genetic variability, diversity and physiological traits and their association with drought tolerance in the local land races of rice under aerobic condition by meeting the following objectives

1. Screening for drought tolerant rice genotypes
2. Studies on physiological parameters for drought tolerance
3. Genetic divergence studies among rice genotypes
4. Correlation and path analysis among root traits and yield attributing characters

# Review of Literature

# II REVIEW OF LITERATURE

Rice is the major staple food crop of the world, cultivated under diverse ecologies ranging from irrigated to rainfed, upland to lowland and deep water system. The frequent occurrence of abiotic stresses has been identified as the key to low rice productivity of rainfed ecosystem. Drought is the most severe abiotic constraint reducing production and productivity of rice. So, to feed the growing population and to maintain food security there is a need for breeding drought tolerant stable high yielding varieties and hybrids of rice with highest water use efficiency.

The literature relevant to the present research is reviewed and presented under the following headings.

2.1. Screening for drought tolerant rice genotypes

2.2. Contribution of physiological parameters for drought tolerance

2.3. Genetic divergence and correlation among rice genotypes

2.4. Association among root traits and yield attributing characters

## 2.1. Screening for drought tolerant rice genotypes

Screening of rice germplasm, differentiate among genotypes and helps in identifying the tolerant genotypes, degree of yield reduction and the strategy adopted by the plant to survive under water stress situation.

Abd Allah *et al.* (2010) evaluated 33 local and exotic rice entries under normal as well as drought condition. The genotypes viz. Giza 178, Giza 182, GZ5121, GZ 6296-12-1-2-1-1, GZ 8310-7-3-2-1, GZ 8367-11-8-3-2, GZ 8372-5-3-2-1, GZ 8375-2-1-2-1, GZ 8450-19-6-5-3, GZ 8452-7-6-5-2, GZ 1368-S-4, Augusto and SIS R215 were found best entries under drought conditions they possess many desirable traits which were useful for drought tolerance in rice.

Gana (2011) screened 109 rice varieties for drought tolerance and result indicated that most varieties had scores between 4-6 that was at susceptible level. Two varieties had score of 2 and eight had score of 3. At 28 days of stress Danboto had a score of 4 and was better than other varieties. Thirteen entries were selected for both drought tolerance and recovery. Danboto a local variety was the best variety with drought score of 4 and recovery score of 2. These entries were expected to provide higher yields after severe drought than those entries with high susceptibility.

Mina *et al.* (2011) studied thirty different genotypes of native, breeded and upland cultivars and reported the genotypes Domsephid, Deylamany, Hasansaraei, Sadri, Anbarboo and Domsiah had highest sensitivity referring to drought stress and produced the lowest grain yield. The genotypes, IR24, Nemat, Sephidroud, Kadoos and Bejar (variety from Iran) and Vandana, upland cultivar (originally from India) had the highest tolerance to drought stress and produced the highest grain yield.

Fangjun *et al.* (2012) evaluated the responses of eight accessions of *Oryza rufipogon* and one accesstion of *O. officinalis* by measuring the morphological and physiological traits, and reported wild rice accessions showed differential abilities to tolerate and recover from the water deficit. The accession of *O. officinalis* had much stronger drought tolerance than all *O. rufipogon* accessions. Two *O. rufipogon* accessions (Or03, Or08) from Hainan (as a tropical island) had the best performance under drought stress, while two other accessions of (Or15, Or33) from Guangdong and Jiangxi provinces were sensitive to water deficit and they reported that then *O. Rufipogon* accessions from tropical area have stronger drought resistance than accessions from sub-tropical areas.

Akram *et al.* (2013) studied drought stress for three rice cultivars *viz*., Basmati-Super, Shaheen-Basmati and Basmati-385 and they reported the cultivar, Shaheen-Basmati exhibited comparatively more tolerance to drought stress at all the three growth stages (panicle initiation, anthesis and grain filling stage) under study with less reduction in various physiological and agronomic traits. They observed less increase in transpiration rate and sterile tillers per hill were observed in Shaheen-Basmati under drought stress at all the three stages.

Sumontip and Prapaporn (2013) studied drought tolerance in seven rice cultivars, namely KDML 105, IR58821, CT9993, IR62266, IR57514, IR52561 and BT. Based on degree of tolerance three groups of cultivars were recognized and identified CT9993 rice cultivar as a highly drought-tolerant cultivar. The moderately drought-tolerant cultivars included KDML 105, IR58821, IR57514, IR52561 and BT. IR62266 cultivar was considered sensitive to drought.

Kumar *et al.* (2014) evaluated 75 rice genotypes and selected the genotypes with high DTE and STI and low SSI and TOL were identified as drought tolerant genotypes. Based on preliminary screening, rice genotypes IR55419-04, IR84895-B-B-127-CRA-5-1-1, IR83376-B-B-24-2, IR83387-B-B-40-1 and IR83373-B-B-24-3 showed low SSI and TOL and high DTE and STI values were identified as drought tolerant genotypes.

Mahender *et al.* (2014) reported significant variation for traits like shoot length, root length and tiller number/plant in all the treatments studied and noticed fourteen genotypes with higher levels tolerance similar to controls.

Santosh *et al*. (2014) conducted a field experiment under reproductive stage drought stress condition with the objective to determine the effect of water deficit stress on yield and yield attributes of 75 rice genotypes and reported IR 84895-B-B-127-CRA-5-1-1, IR 83387-B-B-40-1, IR 83376-B-B-24-2, IR55419-04 and IR 83373-

B-B-24-3 genotypes showed superiority in terms of grain yield, 1000 grain weight, total plant biomass, RWC, leaf area index and proline content.

Santosh *et al.* (2015) conducted a field screening of twelve rice genotypes under drought stress and irrigated non-stress condition. Reported significant yield decline in almost in all rice genotypes grown under water stress condition compared to irrigated situation. Out of these twelve rice genotypes, IR88964-24-2-1-4, IR88966-43-1-1-4 and IR8896-11-2-2-3 showed superior in terms of grain yield and yield attributes.

**2.2. Contribution of physiological parameters for drought tolerance**

In response to drought, rice plants adopt few morphological, physiological and metabolic traits alteration. Understanding these mechanisms that enable plant to adapt to drought and maintain growth and productivity during stress condition will help in screening and selection of tolerant genotypes and using these traits in breeding programme (Zaharieva *et al*., 2001).

Manickavelu *et al.*(2006) conducted variability studies in rice and showed the traits *viz*., days to 70 per cent relative water content, leaf rolling, leaf drying, harvest index, biomass yield and grain yield offer high scope for improvement for drought tolerance by way of simple selection technique.

Suriyan cha-um *et al.*(2010) studied four indica rice varieties and reported, reduced relative water content under reduced soil water content and increased proline content in leaf sheath in PT1 and IR20 genotypes. Panicle length and fertile grains in KDML105 and NSG19 were stabilized, leading to greater productivity than in PT1 and IR20. From the results, KDML105 and NSG19 were identified as water deficit-tolerant, PT1 and IR20 as water deficit-susceptible genotypes.

Fangjun *et al.* (2012) evaluated eight wild rice accessions and reported that, accession Or08 had decreased leaf water potential and increased proline content when compared to other accessions. There was larger leaf chlorophyll content increase in Oo01, Or08and Or34than in the others. After drought stress for 20 days, four accessions (Or06, Or15, and Or33and Or34) had rolled leaves while this symptom starts to appear in plants of Or01and Or05. There wasn’t any typical leaf rolling in other wildrice accessions.

Kuixian *et al.* (2012) reported 78and 8 per cent reduction in osmotic potential of leaves in drought susceptible rice cultivar Zhenshan97B and tolerant rice cultivar IRAT109, respectively, extensive deeper root growth was observed in IRAT109.

Luis *et al.* (2012) reported that tolerant genotypes accumulated higher amount of Proline and kept higher RWC and the photosynthetic rate reduction was higher than in susceptible genotype under stressed conditions.

Roel *et al.* (2012) studied rice genotypes CT9993 (upland japonica) and IR62266 (lowland indica) which were grown in greenhouse and subjected to continuously waterlogged (CWL) and transient waterlogged-to-droughted (W-D) conditions with different soil moisture contents (SMC). Under waterlogged-to-droughted, CT9993 had progressive reductions in shoot biomass with decreasing SMC down to 20 per cent, before it further reduced to 5 per cent SMC. In contrast, IR62266 had progressive reductions in shoot biomass with decreasing SMC down to 15%. Furthermore, CT9993 also maintained stomatal conductance and transpiration, unlike IR62266, during the progressive drying. On the other hand, photosynthesis increased in IR62266 unlike in CT9993, which was maintained, thereby improving its water use efficiency under W-D down to 5 per cent SMC.

Akram *et al.*(2013) studied three rice cultivars Basmati-Super, Shaheen-Basmati and Basmati-385 and reported the growth stage panicle initiation was the most sensitive one exhibiting more adverse effects on all the physiological and agronomic parameters under study., photosynthetic rate, RWC and stomatal conductance showed strong and positive correlation with WUE whereas, transpiration rate expressed negative correlation with WUE. Similarly, all the physiological and yield component traits except transpiration rate and number of sterile grains per panicle reported strong and positive correlation with paddy yield.

Jabasingh and Saravana Babu (2013) reported increased proline level in the rice leaves in response to water stress. Among all different type of soil proportions, proline content was least in red soil + clay and gradually increased in other types of soil proportions and higher in red soil + sand soil and noticedincreased proline in the stressed plants to adapt and overcome the water stress conditions.

Sumontip and Prapaporn (2013) studied seven rice cultivars, severe drought stress resulted in significant differences in the relative leaf water content (RLWC) among the cultivars and observed RLWC reduction to 92.9, 92.3 and 86.1 per cent in CT9993, BT andIR62266 respectively. During the night- time, no significant differences in the RLWC were observed among all the cultivars under normal conditions with values ranging from 99.7 to99.9%. Significant differences in the RLWC was noticed under severe drought stress conditions. KDML 105, IR62266 and IR52561 accumulated a large amount of proline compared with the normal level of proline found in CT9993 and BT, resulting in no significant differences among the cultivars.

Kumar *et al.* (2014) reported significant yield reduction under drought stress in majority of the rice genotypes studied. Drought stress at reproductive stage caused reduction in grain yield (55.31%), leaf area (34.87%), number of spikelet (15.9%), spikelet fertility (17.13%), plant height (8.87%), relative water content (31.57 %) and harvest index (29.2%), while increase in sterility percentage (51.5%) and proline content (55.9%). The variation in SSI values ranged from 0.39 – 1.34, DTE from 26.10 to78.54 per cent, STI ranged from 0.22 to 0.74 and TOL varied from 0.91 to 3.54.

Lum *et al.* (2014) studied eight rice genotypes under different drought levels at germination and early seedling growth and observed, Pulot Wangi tolerated PEG at the highest drought level (-8 bar) and showed no significantly difference relation to control. Noticed, drought-sensitive variety, Kusam markedly affected even at the lowest drought level used. Reported, the activity of antioxidant enzymes catalase, peroxidase and superoxide dismutase in the drought-tolerant varieties increased markedly during drought stress, while decreased by drought stress in the drought sensitive variety. Concluded that the activities of antioxidant enzymes and proline accumulation were associated with the dry mass production and consequently with the drought tolerance of the upland rice varieties.

Mahender *et al.*(2014) reported among the physiological traits, high relative water content (> 75 %) under severe drought stress was observed in ten rice genotypes while ten genotypes recorded higher levels of proline accumulation under stress. From the pooled data they concluded that eight genotypes and control CR-143-2-2 possess high levels of tolerance to drought stress.

Maisura Mohamed *et al* .(2014) reported that drought stress leads todecrease in grain yield per hill, chlorophyll a content and chlorophyll a/b ratio, and an increment of proline and total sugar accumulation. Tolerant varieties (Ciherang, Way Apo Buru and Jatiluhur) accumulated proline over a longer time and increased accumulation of total sugar at the stage of pre anthesis. Jatiluhur varieties showed less reduction in grain yield under drought stress (40.7%) than other varities

Phung (2014) studied physiological responses of rice to drought and reported morphological responses as leaf rolling and drying after exposure to water deficit. Together with the loss of water relation (relative water content and shoot water potential), reactive oxygen species (H2O2 and malondialdehyde level) accumulated in the leaves of rice seedlings which led to apparent reduction in photosynthetic efficiency but only slight reduction of chlorophyll content.

Santosh *et al.* (2014) reported reduction in relative water content (31.57%), membrane stability index (25.80%), grain yield (55.31%), number of effective tillers (37.70%), plant bio-mass (23.65 %) and increase in grain sterility (51.5%) and proline content (55.9%) in rice genotypes.

Santosh *et al.* (2015) reported significant variation among genotypes for leaf rolling, leaf drying, stress recovery and relative water content under drought stress conditions. The tolerant lines maintained high leaf water status, membrane stability and plant biomass under reproductive stage drought condition. Based on yield and yield attributes results under drought and irrigated condition, rice genotypes IR88964-24-2-1-4, IR88966-43-1-1-4 and IR88964-11-2-2-3 were identified as drought resistant.

### 2.3. Divergence and correlation among rice genotypes

The nature and degree of genetic divergence information would help the plant breeder in choosing the right parents for breeding program.

Islam *et al.* (2004) studied diversity in 62 rice genotypes using Mahalanobis $D^2$ – statistics and reported that the genotypes were grouped into five clusters. The cluster II and IV contained the highest number of genotypes (16) and the cluster I contained the lowest (7). The highest intra cluster distance was noticed for cluster I and the lowest for cluster III. The highest inter cluster distance was observed between cluster I and cluster IV followed by cluster I and cluster V, cluster I and cluster III, cluster III and cluster IV and lowest between cluster IV and cluster V. The highest cluster means for yield and other three yield attributing characters were obtained from cluster I, six highest and two second highest means for yield attributing characters were found in cluster III, and concluded that more emphasis should be given on cluster I for selecting genotypes as parents for crossing with the genotypes of cluster III, which may produce new recombinants with desired traits.

Manickavelu *et al.*(2006) conducted correlation and path analysis and indicated that, to get high yielding combined with drought tolerance emphasis should give selection pressure on relative water content, panicle length, grains per panicle, harvest index, biomass yield, root/shoot ratio and root length and low scores of leaf rolling, leaf drying and drought recovery rate.

Mostajeran and Rahimi-Eichi (2009) reported that Zayandeh-Rood cultivar which originated from local cultivars, had higher ability in solute accumulation i.e proline and total carbohydrates than the other new lines. Due to correlation between drought tolerance of Zayandeh-Rood and solute accumulation, suggested the solute accumulation was one of the mechanisms for drought tolerance in rice.

Mina *et al.* (2011) studied thirty different genotypes of native, breeded and upland cultivars and reported that analysis of variance showed significant differences among genotypes in respect of all vegetative and morphological traits. Genotypes were divided into three groups by cluster analysis based on all studied traits with minimum variance method (Ward’s Method) and noticed significant differences among groups in respect of all morphological and physiological characteristics.

Chanbeni *et al.* (2012) studied 70 rice genotypes using Mahalanobis $D^2$ – statistics by considering 13 quantitative characters.Mahalanobis$D^2$ analysis revealed considerable amount of diversity and the genotypes were grouped into nine clusters. Cluster I and cluster III constituted maximum number of genotypes (12 each). The genotypes falling in cluster VII (2907) had the maximum divergence followed by cluster V (2027) and cluster I (1762). The inter cluster distance was maximum between cluster VI and VII (18054) followed by cluster III and IX (12520), suggesting that the genotypes constituted in these clusters may be used as parents for future hybridization programme. Traits like spikelets per panicle; plant height and biological yield were the major contributors to genetic divergence.

Luis *et al.* (2012) reported significant correlation among proline content with photosynthetic rate and stomatal conductance.

Uday (2013) studied sixty four rice land races and using Mahalanobis $D^2$ statistics, grouped genotypes into eight and twelve in control and ten and thirteen clusters in low-moisture stress under field and PVC pipes respectively. Wide genetic variability was indicated by the intra and inter cluster distances. Based on cluster means, cluster VI and IV in control and cluster II and XII in low-moisture stresses ranked first under both field and pipes respectively.

Aishwarya *et al.* (2014) studied forty one rice genotypes and reported significant differences among the genotypes for all the characters studied. The forty-one genotypes were grouped into seven heterogeneous clusters. Among these clusters, Cluster I had maximum number of genotypes (9). On the basis of mean performance genotypes CR 264-26-1-2-2 and RP 5213-69-13-3-4-1-2-B were found to be the best genotypes in Allahabad agro-climatic conditions. The characters such as grain yield, harvest index, number of panicles per plant and biological yield per plant should be given top priority for effective selection.

Bhadra and Roy (2014) estimated genetic diversity in 40 rice genotypes under aluminium toxic environment using Mahalanobis $D^2$ statistics. The genotypes were grouped into five clusters. The relative divergence of each cluster from other clusters displayed higher order of divergence between cluster IV and V (D=34.292) followed by clusters III and IV (D=31.029), clusters II and V (D=30.829), and clusters I and V (D=28.858). Highly divergent genotypes deem to produce wide variability that may help further selection for genetic improvement.

Manjappa *et al*. (2014) studied 250 $F_2$ genotypes derived from Moroberekan/IR64, japonica/indica rice cross and reported high PCV than GCV for all the characters except for culm angle indicating the influence of environment on the characters. High heritability coupled with high GAM was observed for grain yield traits; grain yield per plant, biomass yield per plant, harvest index, productive tillers per plant and drought traits; leaf rolling (LR), spikelet fertility, panicle exsertion and plant vigor (PV) and hence offered good scope for selection. $F_2$ population has recovered maximum superior transgressive segregants for PV (73.2%), followed by (65.5%), panicle length (49.8%) and test weight (49.8%).

Muhammad *et al.* (2014) assessed twenty rice lines and the mean value of the root shoot traits of each genotype was analyzed at different levels of significance. The highest correlation was found between root length, shoot length(r = 0.856, r = 0.896) and shoot length and root number (r = 0.825, r = 0.818) in stress and normal condition respectively.

Ramanjaneyulu *et al.*(2014) evaluated low land rice genotypes and noticed significant and positive correlation of grain yield with number of tillers/plant (1.11), number of productive tillers/plant (0.99), number of grains/spikelet (0.84) and spikelet length (0.59), indicating that grain yield and these traits have the same physiological basis for expression. The genotypes were grouped into 4 clusters indicated the existence of a significant amount of variability. The maximum intra-cluster distance (D: 0.773) was observed in cluster III. The yield attribute 1000-grain weight exhibited the maximum contribution to total genetic divergence (57.78%), followed by grain yield (15.56%), number of grains/spikelet (11.11%), straw yield (6.67%) and spikelet length (4.44%).

Ranawake and Hewage (2014) tested thirty four traditional rice genotypes for drought tolerance and obtained 53 percent seedling survivability and Pearson's correlation analysis showed 0.9256 of positive correlation in survival rates of drought.

Santosh Kumar *et al.* (2014) reported significant and positive correlations between yield and physiological attributes like proline content, leaf area index, relative water content and plant biomass under drought stress condition and concluded that the physiological traits have direct or indirect effect on yield performance of rice genotypes under water stressed environment at reproductive stage.

Pham *et al.*(2015) analyzed forty four rice genotypes for drought tolerance and reported that, The drought tolerance at seeding stage (DTS) was significantly proportional to drought tolerance at vegetative stage (DTV) (r = 0.60). In addition, DTS and DTV had strong significant positive correlation to leaf roll (r = 0.87 and 0.54, respectively). Means of unfilled grains and tilling per panicle were proportionally correlated to DTS (r = 0.22 and 0.25, respectively), and DTV (r = 0.20 and 0.36, respectively). Weight of 1000 grains and filled grains were recorded no correlation to DTS and DTV. At a homologous coefficient of 16.85 integrated from cluster analysis of agro-morphological, quantitative characteristics and drought tolerant scores, the rice cultivars were divided into five groups.

Tuhina-Khatun *et al.* (2015) evaluated forty three rice genotypes and reported that all genotypes exhibited a wide and significant variation for 22 traits. Cluster analysis based on 22 traits grouped the 43 rice genotypes into five clusters. Cluster II was the largest and consisted of 20 genotypes mostly originating from the Philippines and suggested best traits for selection were number of filled grains/panicle and yields/plant (g), which showed high heritability and high genetic advance and concluded that the traits used as a selection criterion for hybridization programmes.

Guimaraes *et al.*(2016) evaluated forty one genotypes for drought tolerance and multivariate analysis, The genotypes with and without water stress were classified into six and seven clusters, respectively, based on the average yield in the two years of experimentation. The most productive cluster under water stress comprised the genotypes AB062041, Douradao, Guarani, BRS Aimore and Tangara.

Islam *et al.* (2016) studied 113 aromatic and fine local rice genotypes. The test genotypes were evaluated for 19 growth traits and yield components. All the quantitative traits varied significantly among the test genotypes. Grain yield was significantly and positively correlated with days to flowering, days to maturity, panicle length, filled grains per panicle and 1000 grain weight. According to $D^2$cluster analysis, 113 test genotypes formed 10 clusters and concluded that Selection of parents from the clusters V and X followed by hybridization would possibly result in desirable heterosis for the development of heterotic rice hybrids.

Ha *et al.* (2016) conducted path analysis and noticed number of panicles/clusters had the highest and a direct positive effect on the grain yield, followed by the number of filled-grain/panicle, and the harvest index compared to other component traits. These traits could be used as selection criteria for high yield and drought tolerance in populations of rice genotypes.

Sridhar *et al.* (2016) studied sixty four traditional rice cultivars and reported fourteen clusters based on $D^2$ statistics. Of which cluster I (44) had more number of cultivars followed by cluster III (8) and remaining were solitary. Maximum inter cluster $D^2$distance was observed between cluster X and XIV (2056.50) inferring, crosses between these two clusters could exploit maximum heterosis. Whereas, maximum intra cluster distance was observed in cluster III (225.63) indicating, hybridization involving genotypes within the same cluster may result in good cross combinations. Days to maturity contributed maximum (36.41%) towards divergence, followed by straw yield per plant (19.54%). Genotypes such as Sannamundaga, Kaasebai and Champakali which are genetically variable and high yielders over local check varieties could be utilized in crop improvement programme for enhancement both qualitative and quantitative traits. Plant height (0.1977) and test weight (0.2559) showed positive and significant correlation with grain yield at phenotypic level. Phenotypic path coefficient analysis had revealed the highest positive and direct effect of days to maturity (0.5107) followed by harvest index (0.3110) on grain yield. So, selection based on these traits could help to bring simultaneous improvement of yield and its components.

Thippeswamy *et al.*(2016) assessed fifty five rice genotypes for association analysis and noticed positive and high correlation between yield and days to flowering, effective bearing tillers per plant, plant height and panicle length. All genotypes were grouped into five clusters, Cluster I had highest number of genotypes (42), followed by Cluster II (9), Cluster III (2) and two mono-genotypic clusters (cluster IV and V).Cluster III had two maintainers of different grain types and its genetic distance with other clusters, indicates possibility of development of heterotic hybrids by using restorers of cluster II and IV. Highest genetic distance was observed between mono-genotypic (JGL11470) cluster V and two genotypic cluster III (JMS2 and CMS23B). Genotypes selected from these clusters may be used for development of maintainer lines with medium slender grain type.

### 2.4. Association among root traits and yield attributing characters

Genetic correlation among root traits and yield attributing traits provide the information on extent and direction of association of plant traits under drought stress condition.

Kanbar *et al.* (2002) reported significant positive correlation between plant height and root charecters. Maximum root length, number of roots, root volume, root dry weight and number of tillers were observed to be interrelated.

Price *et al.* (2002) studied 140 recombinant inbred lines and their parents Azucena and Bala. All the genotypes were screened for root growth in thin glass-sided soil filled chambers and reported that Azucena has thicker roots and more roots at depth compared to Bala, which slowed shoot growth sooner and became less water-stressed than Azucena. Azucena has root traits that potentially contribute to drought resistance while Bala has a number of shoot related mechanisms that makes it adapt to drought environment.

Dwivedi (2007) reported that high yielding varietie including IR20, Narendra118, Narendra 359 etc. have smallest roots while Kalkari, Blackgora and N22 had the longest root. The genotype Moreberekan had extremely long and thick root.

Kanbar *et al.* (2009) based on canonical correlation studies conducted under contrasting moisture regimes, suggested that maximum root length, ratio of root to shoot by weight and length and root dry weight conferred an advantage to grain yield under stress.

Roel *et al.* (2009) studied a line CSSL47 selected from Nipponbare (Japonica type) and reported that CSSL47 showed greater shoot dry matter production than Nipponb are under transient waterlogged-to-drought (W–D) conditions. This was due to CSSL47's greater root system development through more initiation of L type lateral roots that effectively maintained soil water uptake. This in turn sustained higher stomatal conductance, transpiration and photosynthesis.

Ganapathy *et al.* (2010) evaluate genetic potentiality of eight lines and five testers along with 40 hybrids of rice were evaluated under PVC pipes for root traits and Observations were recorded on seven important root traits viz., root length, root volume, root length density, total number of roots, root thickness, root dry weight and root: shoot ratio. Five genotypes viz., Norungan, CT 9993, Moroberekan, Nootripathu and MDU 5 showed significantly superior mean values than grand mean for most of the root traits. Therefore, these genotypes were used as potential donors in drought resistance breeding programme. Among the hybrids, CT 9993 / ASD 18, Moroberekan / ASD 16, CT 9993 / IR 50, Moroberekan / Co 47, Noungan / ASD 16, Nootripathu / MDU and Nootripathu / CO47 were identified as outstanding ones for improving drought tolerance as they registered significant higher mean value for majority of the root traits.

Sedeek *et al.* (2010) Studied variation for root morphology in four upland rice accessions originated from Cote de Ivoire (IRAT112, IRAT170, WAB450-I-B-P-105-HB and Yun Len62) compared with three Egyptian rice varieties (Giza177, Sakha101 and GZ7456-13-6-5-3) and Significant variation was observed in most of the investigated root traits such as root length, root volume, root thickness and root dry weight among the upland rice accessions and Egyptian rice varieties.

Mana Kano-Nakata *et al.* (2011) reported that, there was no significant difference among the genotypes in shoot growth and root development, while CSSL45 and CSSL50 showed greater shoot dry weight than Nipponbare under water deficit conditions. This was due to their abilities to promote root system development as compared with Nipponbare, which facilitated greater water extraction than Nipponbare.

Amelia *et al.* (2012) reported that drought-resistant genotypes had the lowest night-time bleeding rates of sap from the root system in the field. Diurnal fluctuation predominated as the strongest source of variation for bleeding rates in the field and root hydraulic conductivity in the greenhouse and was related to expression trends of various PIP and TIP aquaporins. Root anatomy was generally more responsive to drought treatments in drought treatments in drought-resistant genotypes.

Fangjun *et al.* (2012) reported six *O. rufipogon* accessions (Or01, Or03, Or05, Or06, Or08and Or15) had maximum root length (depth) of≥80cm under CK or drought condition, i.e. the root system reached the bottom of the PVC tubes. *O. officinalis* accession (Oo01) had root length of 50cm under CK and 80cm under drought stress. The remaining two accessions (Or33and Or34) had the root lengths from 70cm under CK to about 80cm under drought stress. Therefore, there was about

50% increase of root length (depth) after drought treatment in Oo01, less than 15% in Or33 and Or34, and little in other accessions. The maximum root length was significantly high in Oo01, Or03, Or06 and Or08; moderate in Or01, Or05 and Or34, and low in Or15 and Or33 under drought stress. Root dry weight and root volume had similar patterns of variance.

Roel *et al.* (2012) studied two rice genotypes CT9993 (upland Japonica) and IR62266 (lowland Indica) and reported that both genotypes showed similar pattern of root growth under waterlogged-to-drought condition CT9993 had higher ability than IR62266 for plastic root growth at deeper soil layers , where soil moisture tended to be higher during progressive drought.

Zulqamain *et al.,* (2013) reported that genotypes responded differently under same level of stress. Results revealed that as a response to drought, all the genotypes showed 42 per cent average increase in seedling root length, 39 per cent average decrease in seedling shoot length. They concluded that seedling root-to- shoot length ratio followed by seedling root length contributes majorly in yield per plant under drought stress.

# *Material and Methods*

# III MATERIAL AND METHODS

The details of the materials used and methodology followed in the present investigation has been presented under following subheadings.

## 3.1 Experiment I: Phenotypic evaluation of local land races of rice in field under control and drought stress aerobic condition

*3.1.1 Experimental material and site*

The present study was conducted during summer 2016 at College of Agriculture, University of Agricultural and Horticultural Sciences, Shivamogga in the field experiment plots of department of Genetics and Plant Breeding. The experimental material consisting of 46 local land races of rice and three checks Anagha (resistant check), Jyothi (susceptible check) and Poustic 9. Genotypes included in the study are mentioned in appendix I.

*3.1.2 Experimental methods*

*3.1.3 Experimental layout*

The experiment was laid out in Randomized Complete Block Design (RCBD) with two replications under control and water stress condition. The normal package of practices of aerobic rice cultivation was followed except for irrigation schedule, Moisture stress was imposed 30 days after sowing by withholding irrigation and only lifesaving flash irrigation was given when plants showed wilting symptoms, whereas in control condition regular irrigation was given without creation of any stress. The spacing maintained was 20cm between rows and 10cm between plants within a row.

*3.1.4 Methods of sampling and observations recorded*

Observations were recorded on five randomly selected plants from each line on 15 metric characters. The average of observations recorded on these five plants was considered for statistical analysis. The characters on which observations were recorded are described below.

*3.1.4.1 Days to 50 per cent flowering*

The number of days taken by each genotype from sowing to 50 per cent plant flowering was observed and recorded.

*3.1.4.2 Days to maturity*

The total number of days taken by each genotype from sowing to physiological maturity was observed and recorded.

*3.1.4.3 Total number of tillers per plant*

Both productive and non-productive tillers per hill were counted and recorded.

*3.1.4.4 Number of productive tillers per plant*

The number of tillers bearing panicle per hill were counted and recorded.

*3.1.4.5 Number of spikelets per panicle*

Number of spikelets per panicle was counted both filled and chaffy seeds in five panicles from each plant were recorded as average.

*3.1.4.6 Number of seeds per panicle*

Number of filled grains per panicle in five panicles from each plant was recorded as average.

*3.1.4.7 Panicle length (cm)*

Length of panicle from the base of panicle to the tip of panicle was measured and recorded in centimeters.

*3.1.4.8 Plant height (cm)*

Plant height at maturity from the base of the plant to the tip of the panicle was measured and recorded in centimeters.

*3.1.4.9 Yield per plant (g)*

The total grain weight per plant was recorded in grams.

*3.1.4.10 Seed filling percent*

Seed filling percent was calculated by counting spikelets per panicle and filled grains and convert into per cent.

*3.1.4.11 Test weight (g)*

Weight of thousand randomly selected seeds weight was measured and recorded in grams.

*3.1.4.12 Chlorophyll content*

Chlorophyll content was measured using SPAD chlorophyll meter (KONICA MINOLTA, SPAD 502 PLUS, Version: 1.20.0000) in random five leaves of each genotype at flowering stage and readings were recorded.

*3.1.4.13 Relative water content (%)*

Relative water content was recorded after 30 days of withholding the irrigation in water stress condition and also in the control condition. leaf sample was collected and its fresh weight was recorded then leaf sample was immersed in water over night and added maximum water to it then the next day turgid weight was recorded and leaves were kept for drying in hot air oven then dry weight was recorded in grams and relative water content was calculated using the formula given by (Weatherley. 1950).

$$\text{Relative water content (\%)} = \frac{\text{Fresh weight} - \text{Dry weight}}{\text{Turgid weight} - \text{Dry weight}} \times 100$$

*3.1.4.14 Leaf rolling scores*

The plants were scored for leaf rolling, 30 days after induction of water stress using 0-9 standard evaluation system of rice which is given below. Leaf rolling score description (Gana. 2011).

| **Scale** | **Description** |
|---|---|
| 0 | Leaves healthy. |
| 1 | Leaves starts to fold. |
| 3 | Leaves folding (V- shaped) |
| 5 | Leaves fully cupped (U- shaped) |
| 7 | Leaves margins touching (O- shaped) |
| 9 | Leaves tightly rolled. |

*3.1.4.15 Proline estimation (µ mole /g FW)*

Proline was estimated in leaves of plants subjected to water stress and control conditionusing Bates *et al.* (1973) method. 0.5 g of leaf sample was collected and homogenized with 10ml 3 percent aqueous Sulpho-salicilic acid in pestle and morter then filtered. Filtrate volume was made up to 25ml then 2ml was pipetted out into test tubes. 2ml of filtrate was reacted with 2ml acid ninhydrin and 2ml of glacial acetic acid for one hour at $100^0$C, and the reaction terminated in an ice bath. The reaction mixture was extracted with 4ml toluene, mixed vigorously with a test tube stirrer for 15-20 sec. the chromophore containing tolune was aspirated from the aqueous phase, warmed to room temperature and the obserbance read at 520nm in a spectrophotometer. The proline concentration was determined from a standard curve and calculated on a fresh weight basis as follows:

$$\text{Proline } (\mu\text{mole/g FW}) = \frac{(\mu\text{g proline/ml} \times \text{ml toluene})/115.5\mu\text{g/ mole}}{\text{g sample}}$$

**3.2 Experiment II: Root studies in local land races of rice using PVC pipes under drought stress and control condition**

*3.2.1. Experimental material and site*

The present study was conducted during Rabi 2016-17 using the same 49 rice land races including checks in PVC pipes at Department of Genetics and Plant Breeding, College of Agriculture, UAHS, Shivamogga.

*3.2.2 Experimental layout*

The experiment was laid out incompletely Randomized Design (CRD). PVC pipes of 100 cm length and 20 cm diameter were used. The pipes were filled with a mixture of red soil and FYM. Seeds were directly sown in the pipes. After 30 days irrigation was withheld to create water stress whereas, for control regular irrigation was given without creating stress.

*3.2.3 Recording of observations*

At the time of flowering, the pipes were carefully removed and immersed in water for few hours to loosen the soil then washed with a jet of water. Then the plants were carefully removed and washed with water without damaging the roots then plants were kept in bucket containing water for recording observations.

The following observations on root characteristics were recorded on sample plants of each genotype.

*3.2.3.1 Plant height (cm)*

Plant height was measured from base of the plant to tip of the boot leaf and recorded in centimeters.

*3.2.3.2 Maximum root length (cm)*

Root length was measured from collar region to the tip of the longest root and recorded in centimeters.

*3.2.3.3 Root volume (ml)*

Root volume was measured in ml by water displacement method.

*3.2.3.4 Root to shoot ratio*

Root to shoot ratio was calculated by dividing root length by shoot length.

**3.3 Statistical analysis**

*3.3.1. Analysis of variance (ANOVA)*

The data of mean value for all the characters were analyzed for the variance following randomized block design. Analysis was done by using WINDOSTAT software.

| **Source of variation** | **Degree of freedom** | **Sum of squares** | **Mean sum of squares** | **Variance ratio/ F- Value** |
|---|---|---|---|---|
| Replication | (r-1) | SSR | MSR | |
| Treatments | (t-1) | SST | MST | MST/MSE |
| Error | (r-1) (t-1) | SSE | MSE | |
| Total | (rt-1) | TSS | | |

Where,

r = number of replications

t = number of treatments

The significance was tested using Fisher (1936) table. And Standard error of mean (SEm), critical difference (CD) and coefficient of variation (CV) were calculated using standard formulae comparing means of the genotypes.

$$\mathrm{CV} = \frac{\mathrm{SD}}{\mathrm{Mean}} \times 100$$

$$\mathrm{CD} = \mathrm{SEm} \times t_{\propto} \text{ at } 5\%$$

*3.3.2. Estimation of genetic parameters*

Genotypic and phenotypic variance were estimated using the formula,

$$\text{Genotypic variance}(\sigma_g^2) = \frac{\text{MSS (genotype)} - \text{MSS(error)}}{\text{Number of replications}}$$

$$\text{Phenotypic variance}(\sigma_p^2) = (\sigma_g^2) + \text{MSS(error)}$$

*3.3.3. Coefficient of variability*

The coefficient of variability was calculated at phenotypic and genotypic levels for all the characters by using the formulae given by Burton and De Vane (1953).

*Phenotypic coefficient of variation (PCV)*

$$\mathrm{PCV} = \frac{\sigma_p}{\bar{X}} \text{ X } 100$$

*Genotypic coefficient of variation (GCV)*

$$GCV = \frac{\sigma_g}{\bar{X}} \times 100$$

Where, $\bar{X}$ = grand mean of the character

$\sigma_p$ = phenotypic standard deviation

$\sigma_g$ = genotypic standard deviation

*3.3.4. Broad sense heritability ($h^2$)*

Formula given by Lush (1945) was used to calculate broad sense heritability.

$$h^2 = \frac{\sigma_g^2}{\sigma_p^2} \times 100$$

Where,

$h^2$= heritability (broad sense)

$\sigma_g^2$ = Genotypic variance

$\sigma_p^2$ = Phenotypic variance

Heritability was classified as low (0 – 30%), moderate (30.1 – 60%) and high (> 60%) as given by Robinson and Comstock (1949).

*3.3.5. Genetic advance (GA)*

*3.3.5.1 Predicted Genetic Advance*

Predicted genetic advance was calculated using the formula given by Johnson *et al.* (1995)

$$\mathrm{GA} = \mathrm{h}^2 . \mathrm{K} . \sigma_\mathrm{P}$$

Where, $h^2$ = Heritability

K = Selection differential at given intensity

$\sigma_\mathrm{P}$ = Phenotypic standard deviation

*3.2.5.2. Genetic advance as percent mean (GAM)*

The genetic advance as percent mean was calculated using the formula given below.

$$\mathrm{GAM} = \frac{\mathrm{GA}}{\bar{\bar{\mathrm{X}}}} \times 100$$

Where,

GA = Genetic advance

$\bar{\mathrm{X}}$ = General mean

The genetic advance as percent of mean was classified as suggested by Johnson *et al.* (1955) as low (0 – 10%), moderate (10.1 – 20%) and high (>20%).

*3.3.6. Correlation coefficients*

To study the degree of association of characters with yield and yield attributing characters correlation coefficient was calculated.

Genotypic and phenotypic coefficient of correlation between yield attributing traits, physiological traits and root characteristics was calculated by using variance and covariance components as suggested by Jibouri (1958). The analysis was done by using the WINDOSTAT software.

$$r_{g(x,y)} = \frac{Cov_{g(x,y)}}{\sqrt{\sigma^2_{gx} . \sigma^2_{gy}}}$$

$$r_{p(x,y)} = \frac{Cov_{p(x,y)}}{\sqrt{\sigma^2_{px} . \sigma^2_{py}}}$$

Where,

$r_p$ and $r_g$ are phenotypic and genotypic correlations, respectively.

$Cov_p(x,y)$ and $Cov_g(x,y)$ are phenotypic and genotypic covariance between the characters, x and

y.$\sigma^2_{px}$ and $\sigma^2_{py}$ are the phenotypic variances of the characters x and y.

$\sigma^2_{gx}$and $\sigma^2_{gy}$ are the genotypic variances of the characters x and y.

The calculated value of r was compared with table r value with (n-2) degree of freedom at 5 and 1 percent of significance.

*3.3.7. Path coefficient analysis*

To study the direct or indirect effect of yield attributing traits to yield was calculated using correlation coefficients as given by Wright (1921). Analysis was done using WINDOSTAT software (Version 9.2).

$P_{01} + P_{02}\, r_{12} + \ldots\ldots\ldots\ldots\ldots P_{0p}\, r_{1p} = r_{01}$

$P_{01}\, r_{21} + P_{02}\, r_{22} \ldots\ldots\ldots\ldots\ldots P_{0p}\, r_{2p} = r_{02}$

$P_{0p}\, r_{1p} + P_{0p}\, r_{2p} \ldots\ldots\ldots\ldots\ldots P_{0p} = r_{0p}$

Where,

$P_{01}$, $P_{02,}$ $P_{0p}$ are the direct path coefficients of variables 1, 2, 3…….p on the dependent variable 0.$r_{12,}$ $r_{13\ldots\ldots\ldots}$p$r_{1p\ldots\ldots}r_{r(p\,-\,1)}$ are the possible correlation coefficients between various independent variables and $r_{01}$, $r_{02\ldots\ldots}r_{0p}$ are the correlations between dependent and independent variables. The indirect effects of the $i^{th}$ variable via $j^{th}$ variable were obtained $p_{0j}$ X $r_{ij.}$

The contribution of the remaining unknown factors was measured as the residual factor and calculated as,

$P^2_{0x} = 1 – (P^2_{01} + 2P_{01}P_{02}r_{12} + 2\ P_0P_{03}r_{13} + \ldots..+P^2_{02} + 2P_{02}P_{03}r_{13} + \ldots\ldots.+P^2_{0p})$

Residual factor ($R^2$) = $\sqrt{P^2_{0x}}$

The direct and indirect effects are rated as given below following the method of Lenka and Mishra (1973).

| | |
|---|---|
| 0.00 – 0.09 **:** Negligible | 0.10 – 0.19 **:** Low |
| 0.20 - 0.29 **:** Moderate | 0.30 – 0.99 **:** High |
| | > 1.00**:** Very high |

*3.3.8. Genetic diversity*

Genetic diversity between the populations was assessed using Mahalanobis' (1936) $D^2$ statistics using WINDOSTAT software (Version 9.2). The distance between the two clusters was calculated using the formula,

$$D^2 = \Sigma\Sigma\lambda ij\sigma ai\sigma aj.$$

Where,

$D^2$ = square of generalized distance

$\lambda ij$= reciprocal of the common dispersal matrix

$\sigma ai$= ($\mu i1$ -$\mu i2$)

$\sigma aj$= ($\mu j1$ -$\mu j2$)

$\mu$ = general mean

Since, the formula for computation requires inversion of higher order determinant, transformation of the original correlated unstandardized character mean (Xs) to standardized uncorrelated variable (Ys) was done to simplify the computational procedure. The $D^2$ values were obtained as the corresponding uncorrelated (Ys) values of any two uncorrelated genotypes (Rao, 1952)

*3.3.8.2. Clustering of $D^2$ values*

All the (n-1)/2 $D^2$ values were clustered using Tocher's method as described by Rao (1952).

*Intra cluster distance:*

The intra cluster distances were calculated by the formula given by Singh and Chaudhary (1977).

$$\text{Square of intra cluster distance} = \sum \frac{D_i^2}{N}$$

Where,

$\sum D_i^2$ was the sum of distance between all possible combinations of the entries included in a cluster.

n = number of all possible combinations.

*Inter cluster distance:*

The inter cluster distances were calculated by the formula described by Singh and Chaudhary (1977).

$$\text{Square of inter cluster distance} = \sum \frac{D_i^2}{n_i n_j}$$

Where,

$\sum D_i^2$ is the sum of distance between all possible combinations of the ($n_i n_j$) number of entries included in a cluster.

$n_i$ = number of lines in cluster i.

$n_j$ = number of lines in cluster j.

# *Experimental Results*

# IV EXPERIMENTAL RESULTS

The experimental results are present in this chapter under the following sub headings.

4.1 Genetic variability for yield and yield attributing characters under drought and control conditions

4.2 Correlation and path coefficient analysis among yield and yield attributing characters and also with physiological characters

4.3 Genetic divergence among yield and yield attributing characters

4.4 Per cent difference for physiological parameters contributing to drought tolerance between stress and control condition

## 4.1 Genetic variability for yield and yield attributing characters

The mean values of the eleven yield attributing characters are given in Appendix II. The analysis of variance under drought and control conditions are presented in table 1 and table 2 respectively. The analysis of variance are given for eleven yield attributing morphological characters were statistically analyzed and found to be significant for all the characters under both drought and control conditions.

The genetic variability parameters viz., mean, range, phenotypic coefficient of variation (PCV), genotypic coefficient of variation (GCV), broad sense heritability and genetic advance per cent mean (GAM) for all the traits under drought and control condition are presented in Table 3.

### *4.1.1 Days to 50 per cent flowering*

The mean for number of variation of 45 days to 50 per cent flowering was 79 days with a range of 50 to 105 days. The earliest flowering at 50 days was observed in line Tonnur and late flowering at 105 days was recorded by Sambamasanna. It recorded moderate PCV and GCV values of 13.08 and 12.57 per cent respectively. High heritability estimate of 92.3 per cent with expected genetic advance average mean of 24.88 per cent were observed for this trait under drought condition.

The mean number of days to 50 per cent flowering was 94.96 days with a range of 77 to 120 days under control condition. The Lalkaderice was the earliest line to flower at 77 days and Vijayananded was the late to flower at 120 days. The moderate PCV and GCV of 10.15 and 10.06per cent recorded respectively. High heritability (98.1%) and high GAM (20.52%) were recorded for this trait.

**Table 1: Analysis of variance for yield and yield attributing characters in local land races of rice under drought conditions.**

| Source of variation | df | Days to 50% flowering | Days to maturity | Total tillers/plant | Productive tillers/plant | Spikelets / panicle | Filled grains / panicle | Panicle length | Plant height | Yield / plant | Seed filling per centage | Test weight |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Replication** | 1 | 26.54 | 2.29 | 71.11 | 0.25 | 62.08 | 119.02 | 15.44 | 67.06 | 0.34 | 54.64 | 0.0009 |
| **Treatments** | 48 | 205.65** | 205.89** | 33.45** | 29.26** | 1625.42** | 2539.74** | 7.53** | 226.76** | 92.73** | 1312.51** | 29.50** |
| **Error** | 48 | 8.18 | 4.35 | 14.49 | 1.56 | 33.74 | 828.97 | 2.24 | 112.55 | 1.65 | 23.01 | 0.83 |
| **CD (5%)** | | 5.75 | 4.19 | 7.65 | 2.51 | 11.68 | 8.35 | 3.01 | 21.33 | 2.58 | 9.64 | 1.83 |
| **CV (%)** | | 3.61 | 1.88 | 22.00 | 10.84 | 7.18 | 11.41 | 7.88 | 12.42 | 18.28 | 11.73 | 5.65 |

**Table 2: Analysis of variance for yield and yield attributing characters in local land races of rice undercontrol conditions.**

| Source of variation | df | Days to 50% flowering | Days to maturity | Total tillers/plant | Productive tillers/plant | Spikelets / panicle | Filled grains / panicle | Panicle length | Plant height | Yield / plant | Seed filling per centage | Test weight |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Replication** | 1 | 0.82 | 1.46 | 7.43 | 9.80 | 149.39 | 164.90 | 23.33 | 132.81 | 37.38 | 80.22 | 0.24 |
| **Treatments** | 48 | 184.38** | 177.91** | 23.41** | 20.92** | 1894.14** | 1660.37** | 9.07* | 433.83** | 65.99** | 16.13 | 16.77** |
| **Error** | 48 | 1.78 | 2.99 | 4.79 | 3.80 | 91.12 | 122.79 | 5.60 | 80.60 | 9.77 | 13.66 | 0.51 |
| **CD (5%)** | | 2.68 | 3.47 | 4.40 | 3.92 | 19.19 | 22.28 | 4.75 | 18.05 | 6.28 | 7.70 | 1.44 |
| **CV (%)** | | 1.40 | 1.33 | 14.82 | 13.94 | 8.87 | 11.15 | 10.74 | 8.00 | 8.14 | 4.00 | 3.42 |

** Significance at 1% and * significance at 5%

**Table 3: Estimates of mean, range, phenotypic and genotypic variability, heritability and genetic advance mean for yield and yield attributing characters in local land races of rice under drought and control conditions**

| Sl. No | Characters | Mean ± SE | | Range | | PCV (%) | | GCV (%) | | $h^2$(broad sense%) | | GAM (%) | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | C | S | C | S | C | S | C | S | C | S | C | S |
| 1 | **Days to 50% flowering** | 94.96±0.94 | 79.05±2.02 | 77.00-120.00 | 50.50-105.50 | 10.15 | 13.08 | 10.06 | 12.57 | 98.10 | 92.30 | 20.52 | 24.88 |
| 2 | **Days to maturity** | 129.26±1.22 | 110.64±1.47 | 110-149 | 90.00-135.50 | 7.35 | 9.26 | 7.23 | 9.07 | 96.70 | 95.90 | 14.65 | 18.29 |
| 3 | **No. of tillers / plant** | 14.76±1.54 | 17.30±2.69 | 10.00-24.00 | 10.00-27.00 | 25.43 | 28.29 | 20.66 | 17.79 | 66.00 | 39.50 | 34.59 | 23.04 |
| 4 | **No. of productive tillers/ plant** | 13.98±1.37 | 11.54±0.88 | 9.50-22.50 | 2.50-18.00 | 25.13 | 34.02 | 20.91 | 32.24 | 69.20 | 89.80 | 35.84 | 62.96 |
| 5 | **Spikelets per panicle** | 107.54±6.75 | 80.87±4.10 | 71.50-245.00 | 42.00-210.00 | 29.29 | 35.61 | 27.92 | 34.88 | 90.80 | 95.90 | 54.81 | 70.37 |
| 6 | **Filled grains per panicle** | 99.30±7.83 | 36.40±2.93 | 64.00-225.00 | 3.00-195.00 | 30.06 | 98.20 | 27.92 | 97.54 | 86.20 | 98.60 | 53.41 | 199.57 |
| 7 | **Panicle length (cm)** | 22.02±1.67 | 18.99±1.05 | 17.51-28.83 | 13.77-22.27 | 12.29 | 11.63 | 5.98 | 8.56 | 23.60 | 54.10 | 5.99 | 12.97 |
| 8 | **Plant height (cm)** | 112.16±6.34 | 85.37±7.50 | 77.50-139.15 | 49.34-108.95 | 14.29 | 15.25 | 11.84 | 8.85 | 68.70 | 33.70 | 20.22 | 10.57 |
| 9 | **Yield per plant (g)** | 38.37±2.21 | 7.03±0.90 | 24.62-48.75 | 0.45-24.75 | 16.03 | 97.72 | 13.81 | 95.99 | 74.19 | 96.50 | 24.51 | 194.25 |
| 10 | **Seed filling per centage** | 92.24±2.61 | 40.88±3.39 | 83.70-97.47 | 6.25- 92.95 | 4.18 | 63.20 | 1.20 | 62.10 | 97.98 | 96.55 | 71.32 | 125.72 |
| 11 | **Test weight (g)** | 20.97±0.50 | 16.14±0.64 | 15.75-26.75 | 12.03-26.25 | 14.01 | 24.13 | 13.59 | 23.45 | 94.00 | 94.50 | 27.15 | 46.97 |

***C – Control, S – Drought condition**

*4.1.2 Days to maturity*

The mean of 111 days with a range of 90 to 135.5 days to maturity was recorded in drought condition. The early matured line was Tonnur at 90 days and line to mature late was Sambamasanna (135.5 days). The low values of PCV and GCV 9.26 and 9.07 per cent respectively were recorded. High heritability estimates of 95.9 per cent with moderate GAM of 18.29 per cent were observed for this trait.

The mean number of days to maturity was 129.26 days with a range of 110 to 149 days. The earliest maturity at 110 days was observed in line Lalkade rice and late maturing at 149 days was observed in the line Hasudi. The low PCV and GCV values of 7.35 and 7.23 per cent recorded respectively. High heritability estimate of 96.7 per cent with moderate genetic advance mean of 18.29 per cent were observed for this trait under control condition.

*4.1.3 Number of tillers per plant*

The mean number of tillers recorded under drought was 17.3 with a range of 10 to 27 tillers per plant. The highest number of tillers per plant was observed in Doddiga (27 tillers per plant) and least in Rajamani (10 tillers per plant). High value of PCV (28.29%) with moderate GCV (17.79%) was recorded. Moderate heritability estimates of 39.50 per cent with high GAM (23.04%) were recorded for this trait.

The range of 10 to 24 tillers per plant and mean of 14.76 tillers per plant was recorded under control condition. The highest number of tillers per plant was observed in Navara (24 tillers per plant) and least in JGL 1798(10 tillers per plant). The high PCV and GCV of 25.43 and 20.66per cent respectively was recorded. High heritability estimates of 66 per cent with high genetic advance mean of 34.59 per cent were observed for this trait.

*4.1.4 Number of productive tillers per plant*

The mean number of productive tillers per plant was 11.54 tillers with a range of 2.50 to 18.00. The lowest number of productive tillers per plant of 2.50 was observed in Sambamasanna and the highest number of productive tillers per plant of 18 was recorded in Rajakaime. The high PCV (34.02 %) and GCV (32.24 %) along with high heritability (89.80 %) with high GAM (62.96%) were recorded for this trait under drought condition.

The number of productive tillers per plant under control condition was ranged from 9.50 to 22.50 and a mean of 13.98 tillers. The lowest number of productive tillers per plant was observed in Mottaikar (9.5) and highest in Navara and Doddiga (22.5). The high PCV (25.13 %) and GCV (20.91 %) with high heritability (69.20 %) and high GAM (35.84 %) were recorded for this trait under control condition.

*4.1.5 Number of spikelets per panicle*

The mean number of spikelets per panicle under drought condition was 80.87 with a range of 42.00 to 210.00 numbers of spikelets per panicle. The highest number of spikelets per panicle of 210.00was observed in the line Anagha and least in Baiganmanju 42.00spikelets per panicle. The high genetic variability PCV (35.61 %), GCV (34.88 %), heritability (95.9 %) and GAM (70.37 %) were recorded for this trait.

The number of spikelets per panicle was ranged from 71.50 to 245.00 with a mean of 107.54. The highest number of spikelets per panicle 245 was observed in the line Anagha and least in Ktaru (71.5). The high PCV (29.29 %), GCV (27.92 %) was recorded along with high heritability (90.8%) and GAM (54.81 %) were recorded for this trait.

*4.1.6 Number of filled grains per panicle*

The mean number of filled grains per panicle was 36.40 grains per panicle with a range of 3.00 to 195.00 grains per panicle. The least number of 3 grains per panicle was observed in Shashti and highest in Anagha (195.00). The high PCV (98.2 %), GCV (97.54 %) heritability (98.6 %) and GAM (199.57 %) were recorded for this trait under drought condition.

The number of filled grains per panicle was ranged from 64.00 to 225.00 with a mean of 99.30 grains per panicle. The least number of 64.00 grains per panicle was observed in Ktaru and highest in Anagha (225.00). The high PCV (29.29 %), GCV (27.92 %) with high heritability (86.20 %) and genetic advance mean (53.41 %) were recorded for this trait under control condition.

*4.1.7 Panicle length*

The panicle length under drought condition ranged from 13.77cm to 22.27 cm with mean of 18.99 cm. The highest panicle length of 22.27cm was recorded in Sannavaalya and lowest in Moradhi (13.77). The moderate PCV (11.63 %) and low GCV (8.56 %) were recorded along with moderate heritability (54.1 %) and moderate GAM (12.97 %) was recorded for this trait.

The mean panicle length under control condition was 22.02 cm with a range of 17.51cm to 28.83cm. The highest panicle length of 28.83cm was recorded in Akkalu and lowest Lalkade rice (17.51). The moderate PCV (12.29) and low GCV (5.98) were recorded along with low heritability (23.6 %) GAM (5.99 %) was recorded for this trait.

*4.1.8 Plant height*

The plant height under drought condition ranged from 49.34 cm to 108.95 cm and mean of 85.37 cm was observed. The highest plant height was recorded in

Gangadace (108.95 cm) and lowest in Poustic-9 (49.34 cm). The moderate PCV (15.25 %) and low GCV (8.85 %) were recorded along with moderate heritability (33.7 %) and GAM (10.57 %) was recorded for this trait.

The mean plant height recorded under control was 112.16cm with a range of 77.5cm to 139.15cm. The highest plant height of 139.15cm was recorded in Tonnur and lowest plant height of 77.5 cm in Poustic-9. The moderate PCV (14.29 %) and GCV (11.84 %) were recorded with high heritability of 68.7 per cent and GAM of 20.22 per cent were recorded for this trait.

*4.1.9 Yield per plant*

The mean yield of 7.03g per plant with a range of 0.45g to 24.75g/plant was recorded under drought condition. The highest yield was recorded in Sannavalya (24.75 g) and lowest in Shashti (0.45 g). The highest PCV (97.72 %) and GCV (95.99 %) and also high heritability (96.5 %) with GAM (194.25 %) were observed for this trait.

The 38.37 g mean yield per plant was recorded under control condition with a range of 24.62 g/plant to 48.75 g/plant. The highest yield of 48.75 g/plant was recoded in Rasakadari and lowest yield of 24.62g/plant in Lalkade rice. The moderate PCV (16.03 %) and GCV (13.81 %) with high heritability (74.19 %) and GAM (24.51 %) were recorded for this trait.

*4.1.10 Seed filling per cent*

The observed mean of seed filling per cent of 40.88 with a range of 6.25 to 92.95 per cent was observed. The highest seed filling per cent of 92.95 was recorded in Anagha and lowest was recorded in Shashti (6.25). The high PCV (63.20 %), GCV (62.10 %) with high heritability (96.55 %) and GAM (125.72 %) were recorded for this trait under drought condition.

The seed filling per cent under control condition ranged from 83.70 to 97.47 per cent with a mean of 92.24 was observed. The highest seed filling per cent of 97.47 was recorded in Tonnur and lowest seed filling per cent of 83.7 was recorded in Navara. The low PCV (4.18 %) and GCV (1.20 %) were observed with high heritability (97.98 %) and GAM (71.32 %) were recorded for this trait.

*4.1.11 Test weight*

The mean test weight of 16.14 g with a range of 12.03 to 26.25 g was observed. The highest test weight was recorded in Sannavalya (26.25g) and lowest in Shashti (12.03 g).The high PCV (24.13 %), GCV (23.45 %) with high heritability (94.5 %) and GAM (46.97 %) were recorded for this trait under drought condition.

The test weight ranged from 15.75 to 26.75 g and mean of 20.97 g was recorded. The highest test weight of 26.75 g was recorded in JGL 1798 and lowest test weight of 15.7 5g was recorded in Tonnur. The moderate PCV (14.01 %) and GCV (13.59 %) with high heritability (94 %) and GAM (27.15 %) were recorded for this trait under control condition.

## 4.2 Correlation and path coefficient analysis among yield and yield attributing characters also with physiological characters

### *4.2.1 Correlation and path coefficient analysis among yield and yield attributing characters*

Phenotypic correlation for yield with 10 yield attributing characters were recorded. The results on association among the traits under both drought and control conditions were presented in Table 4.

#### *4.2.1.1 Correlation of yield with other characters*

The significant and positive association at phenotypic level was found between grain yield with productive tillers per plant (0.282), spikelets per panicle (0.628), number of filled grains per panicle (0.879), seed filling per cent (0.865), test weight (0.906). Rest characters did not show any association.

The significant positive association at phenotypic level was found between yield with days to fifty per cent flowering (0.275) and seed filling per cent (0.305). However for the traits like *viz.*, days to maturity (0.172), number of total tillers per plant (0.074), number of productive tillers per plant (0.086), spikelets per panicle (0.161), number of filled grains per panicle (0.191), panicle length (0.054), plant height (0.029) and test weight (0.012) showed non-significant positive association with yield per plant under control condition.

#### *4.2.1.2 Correlation among yield attributing characters*

##### *4.2.1.2.1 Days to 50 per cent flowering*

Days to 50 per cent flowering showed significant positive correlations at phenotypic level under drought condition with days to maturity (0.920),whereas it showed non-significant positive correlation with number of filled grains per panicle (0.021), seed filling per cent (0.066) and negative significant correlation with number of total tillers per plant (-0.271), number of productive tillers per plant (-0.273). However, it showed negative non-significant correlation with number of spikelets per panicle (-0.030), panicle length (-0.095), plant height (-0.083), and test weight (-0.030).

Under control condition days to 50 per cent flowering showed significant positive correlation at phenotypic level with days to maturity (0.911) and plant height (0.229). Non-significant positive correlation with panicle length (0.091) and seed filling per cent (0.026) whereas significant negative correlation was observed for spikelets per panicle (-0.325), number of filled grains per panicle (-0.312). The number of tillers per plant (-0.054), number of productive tillers per plant (-0.062) and test weight (-0.189) showed negative non-significant correlation.

**Table 4: Estimation of phenotypic correlation between yield and yield attributing characters under drought and control conditions.**

| TRAITS | $X_1$ | $X_2$ | $X_3$ | $X_4$ | $X_5$ | $X_6$ | $X_7$ | $X_8$ | $X_9$ | $X_{10}$ | $X_{11}$ |
|---|---|---|---|---|---|---|---|---|---|---|---|
| **$X_1$** | **1.000** | 0.920** | -0.271** | -0.273** | -0.030 | 0.021 | -0.095 | -0.083 | 0.066 | -0.030 | 0.029 |
| **$X_2$** | 0.911** | **1.000** | -0.289** | -0.283** | -0.067 | 0.014 | -0.156 | -0.160 | 0.090 | -0.049 | 0.022 |
| **$X_3$** | -0.054 | -0.059 | **1.000** | 0.586** | 0.067 | -0.065 | 0.286** | -0.003 | -0.072 | 0.021 | 0.034 |
| **$X_4$** | -0.062 | -0.079 | 0.958 | **1.000** | 0.281** | 0.180 | 0.181 | -0.162 | 0.152 | 0.202* | 0.282* |
| **$X_5$** | -0.325** | -0.316** | 0.067 | 0.100 | **1.000** | 0.801 | 0.312** | -0.175 | 0.459** | 0.488** | 0.628** |
| **$X_6$** | -0.312** | -0.306** | 0.081 | 0.121 | 0.992 | **1.000** | 0.118 | -0.172 | 0.861 | 0.773 | 0.879** |
| **$X_7$** | 0.091 | 0.042 | 0.115 | 0.091 | 0.062 | 0.101 | **1.000** | -0.015 | -0.018 | 0.043 | 0.062 |
| **$X_8$** | 0.229* | 0.265** | 0.038 | 0.008 | -0.294** | -0.275** | 0.434 | **1.000** | -0.142 | -0.039 | -0.150 |
| **$X_9$** | 0.026 | 0.005 | 0.078 | 0.124 | 0.155 | 0.269** | 0.348 | 0.212* | **1.000** | 0.778** | 0.865** |
| **$X_{10}$** | -0.189 | -0.253* | -0.053 | 0.019 | 0.327** | 0.322** | -0.091 | -0.267** | -0.015 | **1.000** | 0.906** |
| **$X_{11}$** | 0.275** | 0.172 | 0.074 | 0.087 | 0.161 | 0.191 | 0.054 | 0.029 | 0.305** | 0.012 | **1.000** |

**Significance at 1% and *Significance at 5%.(Above diagonal drought; below diagonal control condition)

Where,

$X_1$ - Days to 50 per cent flowering
$X_2$ –Days to maturity
$X_3$ – No. of tillers per plant
$X_4$ – No. of productive tillers per plant
$X_5$ – No. of spikelets per panicle
$X_6$ –No. filled grains per panicle
$X_7$ – Panicle length (cm)
$X_8$ – Plant height (cm)
$X_9$ – Seed filling per cent
$X_{10}$– Test weight (g)
$X_{11}$ – Yield per plant(g)

*4.2.1.2.2 Days to maturity*

Days to maturity under drought condition showed non-significant positive correlation with number of filled grains per panicle (0.014), seed filling per cent (0.090), significant negative correlation was observed for number of tillers per plant (-0.289), number of productive tillers per plant (-0.283) whereas, it showed non-significant negative correlation with spikelets per panicle (-0.067), panicle length (-0.156), plant height (-0.160) and test weight (-0.049).

Days to maturity under control condition showed significant positive correlation with plant height (0.265), significant negative correlation with number of spikelets per panicle (-0.316), number of filled grains per panicle (-0.306) and test weight (-0.253). Non-significant positive correlation with panicle length (0.042), seed filling per cent (0.005) and non-significant negative correlation with number of total tillers per plant (-0.059) and productive tillers per plant (-0.079).

*4.2.1.2.3 Number of tillers per plant*

Number of total tillers per plant showed significant positive correlations at phenotypic level under drought condition with productive tillers per plant (0.586), panicle length (0.286) and non-significant positive correlation with number of spikelets per panicle (0.067) and test weight (0.021)whereas, filled grains per panicle (-0.065), plant height (-0.003) and seed filling per cent (-0.072) showed non-significant negative correlation.

Under control condition this trait showed significant positive correlation with number of productive tillers per plant (0.958) and non-significant positive correlation with number of spikelets per panicle (0.067), panicle length (0.115), plant height (0.038) and seed filling per cent (0.078) whereas test weight (-0.053) showed non-significant negative correlation.

*4.2.1.2.4 Number of productive tillers per plant*

Number of productive tillers per plant showed significant positive correlations at phenotypic level under drought condition with number of spikelets per panicle (0.281), test weight (0.202), and non-significant positive correlation with number of filled grains per panicle (0.180), panicle length (0.181) and seed filling per cent (0.152). Whereas, plant height (-0.162) showed non-significant negative correlation.

The trait number of productive tillers per plant showed non-significant positive correlation with traits spikelets per panicle (0.100), number of filled grains per panicle (0.121), panicle length (0.091), plant height (0.008), seed filling per cent (0.124) and test weight (0.019) under control condition.

*4.2.1.2.5 Number of spikelets per panicle*

Number of spikelets per panicle showed significant positive correlations under drought condition with number of filled grains per panicle (0.801), panicle length (0.312), seed filling per cent (0.459) and test weight (0.488). Whereas, plant height (-0.175) showed non-significant negative correlation.

Number of spikelets per panicle exhibited significant positive correlations at phenotypic level under control condition with number of filled grains per panicle (0.992) and test weight (0.327). Non-significant positive correlation with panicle length (0.062) and seed filling per cent (0.155) whereas, plant height (-0.294) showed significant negative correlation under control condition.

*4.2.1.2.6 Number of filled grains per panicle*

Number of filled grains per panicle showed significant positive correlations at phenotypic level under drought condition with seed filling per cent (0.861), test weight (0.773) and panicle length (0.118) showed non-significant positive correlation. Whereas, plant height (-0.172) exhibited non-significant negative correlation.

The trait number of filled grains per panicle showed significant positive correlation at phenotypic level under control condition with seed filling per cent (0.269), test weight (0.322) and panicle length (0.101) showed non-significant positive correlation. Whereas, plant height (-0.275) exhibited significant negative correlation.

*4.2.1.2.7 Panicle length*

Test weight (0.043) exhibited significant positive correlation with plant height (-0.015) and seed filling per cent (-0.018) showed non-significant negative correlation with panicle length under drought condition.

Panicle length showed significant positive correlation at phenotypic level under control condition with plant height (0.434) and seed filling per cent (0.348) whereas, test weight (-0.091) showed non-significant negative correlation

*4.2.1.2.8 Plant height*

Plant height showed non-significant negative correlation at phenotypic level under drought condition with seed filling per cent (-0.142) and test weight (-0.039).

Under control condition plant height showed significant positive correlation at phenotypic level with seed filling per cent (0.212) whereas, test weight (-0.267) showed significant negative correlation.

*4.2.1.2.9 Seed filling per cent*

Seed filling per cent showed significant positive correlation at phenotypic level under drought condition with test weight (0.778) whereas, in controlled condition it showed non-significant negative correlation test weight (-0.015).

*4.2.1.3 Path coefficient analysis*

The results obtained under drought and control condition are presented in the table 5 and table 6 respectively. The direct and indirect effects of different traits on yield per plant are presented below.

*4.2.1.3.1 Direct effect of yield attributing characters on yield per plant at phenotypic level*

Totally eight out of ten characters had positive and direct effect on yield per plant under drought condition *viz*., days to 50 per cent flowering (0.034), days to maturity (0.014), number of total tillers per plant (0.013), number of productive tillers per plant (0.079), number of spikelets per panicle (0.179), filled grains per panicle (0.028), seed filling per cent (0.332) and test weight (0.523) showed direct positive effect on yield whereas, panicle length (-0.026) and plant height (-0.029) had negative direct effects on grain yield.

Five out of ten characters had positive and direct effect on yield per plant at phenotypic level under control condition. The characters which showed positive direct effect on yield were days to 50 per cent flowering (0.766), number of tillers per plant (0.159), number of spikelets per panicle (1.158), plant height (0.015) and seed filling per cent (0.4029)whereas, days to maturity (-0.452), number of productive tillers per plant (-0.094), filled grains per panicle (-0.940), panicle length (-0.132) and test weight (-0.012) exhibited negative direct effects on yield per plant.

Test weight (0.523) under drought and number of spikelets per panicle (1.158) under control condition showed the highest positive direct effect whereas, plant height (-0.029) under drought and number of filled grains per panicle (-0.940) under control condition exhibited the highest negative direct effect on yield.

*4.2.1.3.2 Indirect effect of yield attributing traits on yield per plant*

*4.2.1.3.2.1 Days to 50 per cent flowering*

The indirect positive effect on yield per plant was exhibited by days to 50 per cent flowering under drought condition through days to maturity (0.0315), filled grains per panicle (0.0007) and seed filling per cent (0.0023). However, it showed negative effect on yield through number of tillers per plant (-0.0093), productive tillers per plant (-0.0093), panicle length (-0.0033), plant height (-0.0028), spikelets per panicle (-0.0010) and test weight (-0.0011).

**Table 5: Estimates of direct and indirect effects of yield components on yield at phenotypic level under drought condition.**

| Traits | $X_1$ | $X_2$ | $X_3$ | $X_4$ | $X_5$ | $X_6$ | $X_7$ | $X_8$ | $X_9$ | $X_{10}$ |
|---|---|---|---|---|---|---|---|---|---|---|
| $X_1$ | **0.0342** | 0.0315 | -0.0093 | -0.0093 | -0.0010 | 0.0007 | -0.0033 | -0.0028 | 0.0023 | -0.0011 |
| $X_2$ | 0.0135 | **0.0146** | -0.0042 | -0.0041 | -0.0010 | 0.0002 | -0.0023 | -0.0023 | 0.0013 | -0.0007 |
| $X_3$ | -0.0038 | 0.0040 | **0.0139** | 0.0082 | 0.0009 | -0.0009 | 0.0040 | -0.0001 | -0.0010 | 0.0003 |
| $X_4$ | -0.0206 | -0.0214 | 0.0442 | **0.0754** | 0.0212 | 0.0136 | 0.0137 | -0.0123 | 0.0115 | 0.0153 |
| $X_5$ | -0.0054 | -0.0121 | 0.0121 | 0.0505 | **0.1795** | 0.1438 | 0.0560 | -0.0314 | 0.0824 | 0.0877 |
| $X_6$ | 0.0006 | 0.0004 | -0.0019 | 0.0052 | 0.0230 | **0.0287** | 0.0034 | -0.0049 | 0.0247 | 0.0222 |
| $X_7$ | 0.0025 | 0.0041 | -0.0075 | -0.0048 | -0.0082 | -0.0031 | **-0.0263** | 0.0004 | 0.0005 | -0.0011 |
| $X_8$ | 0.0024 | 0.0047 | 0.0001 | 0.0047 | 0.0051 | 0.0050 | 0.0004 | **-0.0292** | 0.0041 | 0.0011 |
| $X_9$ | 0.0221 | 0.0301 | -0.0239 | 0.0506 | 0.1527 | 0.2865 | -0.0062 | -0.0473 | **0.3325** | 0.2587 |
| $X_{10}$ | -0.0161 | -0.0260 | 0.0115 | 0.1061 | 0.2559 | 0.4048 | 0.0228 | -0.0206 | 0.4074 | **0.5236** |
| **r value** | **0.0294** | **0.0299** | **0.035** | **0.2825** | **0.6281** | **0.8793** | **0.0622** | **-0.1505** | **0.8657** | **0.906** |

**Residual effect=0.27**

Where,

$X_1$ - Days to 50 per cent flowering
$X_2$ –Days to maturity
$X_3$ – No. of total tillers per plant
$X_4$ – No. of productive tillers per plant
$X_5$ – No. of spikelets per panicle
$X_6$ –No. filled grains per panicle
$X_7$ – Panicle length (cm)
$X_8$ – Plant height (cm)
$X_9$ – Seed filling per cent
$X_{10}$– Test weight (g)

**Table 6: Estimates of direct and indirect effects of yield components on yield at phenotypic level under control condition.**

| Traits | $X_1$ | $X_2$ | $X_3$ | $X_4$ | $X_5$ | $X_6$ | $X_7$ | $X_8$ | $X_9$ | $X_{10}$ |
|---|---|---|---|---|---|---|---|---|---|---|
| $X_1$ | **0.7666** | 0.6985 | -0.0417 | -0.0475 | -0.2498 | -0.2398 | 0.0699 | 0.1755 | 0.0200 | -0.1453 |
| $X_2$ | -0.4121 | **-0.4523** | 0.0271 | 0.0359 | 0.1430 | 0.1385 | -0.0193 | -0.1200 | -0.0023 | 0.1147 |
| $X_3$ | -0.0087 | -0.0096 | **0.1599** | 0.1532 | 0.0107 | 0.0130 | 0.0185 | 0.0062 | 0.0125 | -0.0086 |
| $X_4$ | 0.0059 | 0.0075 | -0.0906 | **-0.0946** | -0.0095 | -0.0115 | -0.0087 | -0.0008 | -0.0117 | -0.0018 |
| $X_5$ | -0.3773 | -0.3661 | 0.0777 | 0.1164 | **1.1580** | 1.1487 | 0.0728 | -0.3410 | 0.1796 | 0.3787 |
| $X_6$ | 0.2943 | 0.2881 | -0.0764 | -0.1141 | -0.9332 | **-0.9407** | -0.0956 | 0.2592 | -0.2534 | -0.3031 |
| $X_7$ | -0.0120 | -0.0056 | -0.0153 | -0.0121 | -0.0083 | -0.0134 | **-0.1321** | -0.0574 | -0.0460 | 0.0121 |
| $X_8$ | 0.0035 | 0.0041 | 0.0006 | 0.0001 | -0.0046 | -0.0043 | 0.0067 | **0.0155** | 0.0033 | -0.0041 |
| $X_9$ | 0.0105 | 0.0021 | 0.0315 | 0.0501 | 0.0625 | 0.1085 | 0.1403 | 0.0857 | **0.4029** | -0.0063 |
| $X_{10}$ | 0.0045 | 0.0060 | 0.0013 | -0.0005 | -0.0078 | -0.0077 | 0.0022 | 0.0064 | 0.0004 | **-0.0238** |
| **r value** | **0.2752** | **0.1727** | **0.0741** | **0.0869** | **0.161** | **0.1913** | **0.0547** | **0.0293** | **0.3053** | **0.0125** |

**Residual effect=0.68**

Where,

$X_1$ - Days to 50 per cent flowering

$X_2$ –Days to maturity

$X_3$ – No. of total tillers per plant

$X_4$ – No. of productive tillers per plant

$X_5$ – No. of spikelets per panicle

$X_6$ –No. filled grains per panicle

$X_7$ – Panicle length (cm)

$X_8$ – Plant height(cm)

$X_9$ – Seed filling per cent

$X_{10}$– Test weight (g)

The indirect positive effect on yield was exhibited by days to 50 per cent flowering under control condition *via.* Days to maturity (0.698), panicle length (0.069), plant height (0.175) and Seed filling per cent (0.020). However, it showed negative effect on yield through number of tillers per plant (-0.041), number of productive tillers per plant (-0.047), Number of filled grains per panicle (-0.239), number of spikelets per panicle (-0.249) and test weight (-0.145).

*4.2.1.3.2.2 Days to maturity*

Under drought condition days to maturity had the indirect and positive effect on yield *via.* Days to 50 per cent flowering (0.0315), number of filled grains per panicle (0.0002), and seed filling per cent (0.0013). While negative influence through number of tillers per plant (-0.0042), number of productive tillers per plant (-0.0041), number of spikelets per panicle (-0.0010), panicle length (-0.0023), plant height (-0.0023) and test weight (-0.0007).

This character had the indirect positive effect on yield under control condition through number of tillers per plant (0.0271), number of productive tillers per plant (0.0359), number of spikelets per panicle (0.1430), number of filled grains per panicle (0.1385) and test weight (0.1147). While negative influence on yield was exhibited through days to 50 per cent flowering (-0.4121), panicle length (-0.0193), plant height (-0.1200) and seed filling per cent (-0.0023).

*4.2.1.3.2.3 Total number of tillers per plant*

The indirect positive effect on yield was exhibited by number total tillers per plant *via.* Days to maturity (0.0040), number of productive tillers per plant (0.0082), number of spikelets per panicle (0.0009), panicle length (0.0040) and test weight (0.0003)whereas, the trait exhibited indirect negative effect through, days to 50 per cent flowering (-0.0038), number of filled grains per panicle (-0.0009), plant height (-0.0001) and seed filling per cent (-0.0010) under drought condition.

This character under control condition had indirect positive effect on yield through, number of productive tillers per plant (0.1532), spikelets per panicle (0.0107), number of grains per panicle (0.0130), panicle length (0.0185), plant height (0.0062) and seed filling per cent. Whereas, it exhibited negative effect on yield *via.,* days to 50 per cent flowering (-0.0087), days to maturity (-0.0096) and test weight (-0.0086).

*4.2.1.3.2.4 Number of productive tillers per plant*

Number of productive tillers per plant showed the indirect positive effect on yield through number of tillers per plant (0.0442), number of spikelets per panicle (0.0212), number of filled grains per panicle (0.0136), panicle length (0.0137), seed filling per cent (0.0115) and test weight (0.0153). However, it showed negative indirect effect *via*., days to fifty per cent flowering (-0.0206) days to maturity (-0.0214) and plant height (-0.0123) under drought condition.

Under control condition number of productive tillers per plant exhibited the indirect positive effect on yield through days to 50 per cent flowering (0.0059), and days to maturity (0.0075).However it showed negative indirect effect *via*. number of tillers per plant (-0.0906), number of spikelets per panicle (-0.0095), number of filled grains per panicle (-0.0115), panicle length (-0.0087), seed filling per cent (-0.0117) test weight (-0.0018) and plant height (-0.0008).

*4.2.1.3.2.5 Number of spikelets per panicle*

Number of spikelets per panicle under drought condition showed indirect positive effect on yield through number of tillers per plant (0.0121), number of productive tillers per plant (0.0505), number of filled grains per panicle (0.1438), panicle length (0.0560), seed filling per cent (0.0824) and test weight (0.0877) whereas, it had indirect negative effect on yield through days to maturity (-0.0121) and plant height (-0.0314).

The character under control condition had indirect positive effect on yield through number of tillers per plant (0.0777), number of productive tillers per plant (0.1164), number of grains per panicle (1.1487), panicle length (0.0728), seed filling per cent (0.1796) and test weight (0.3787) whereas, it had indirect negative effect on yield *via.* days to 50 per cent flowering (-0.3773), days to maturity (-0.3661)and plant height (-0.3410).

*4.2.1.3.2.6 Number of filled grains per panicle*

Number of grains per panicle under drought condition showed indirect positive effect on yield through days to 50 per cent flowering (0.0006), days to maturity (0.0004), productive tillers per plant (0.0052), number of spikelets per panicle (0.0230), panicle length (0.0034), seed filling per cent (0.0247) and test weight (0.0222). However, it had negative effect on yield through number of total tillers per plant (-0.0019) and plant height (-0.0049).

Under control condition this character had indirect positive effect on yield *via.* days to 50 per cent flower (0.2943), days to maturity (0.2881), and plant height (0.2592). Whereas it had indirect negative effect on yield through number of total tillers per plant (-0.0764), productive tillers per plant (-0.1141), number of spikelets per panicle (-0.9332), panicle length (-0.0956), seed filling per cent (-0.2534) and test weight (-0.3031).

*4.2.1.3.2.7 Panicle length*

Panicle length had indirect positive effect on yield under drought condition through, days to 50 per cent flowering (0.0025), days to maturity (0.0041), plant height (0.0004) and seed filling per cent (0.0005) however, it had indirect negative effect on yield *via.* number of tillers per plant (-0.0075), number of productive tillers per plant (-0.0048), number spikelets per panicle (-0.0082), number of filled grains per panicle (-0.0031) and test weight (-0.0011).

Under control condition panicle length had indirect positive effect on yield *via.* test weight (0.012). Whereas it had indirect negative effect on yield through days to 50 per cent maturity (-0.012), days to maturity (-0.005), number of tillers per plant (-0.015), number of productive tillers per plant (-0.012), spikelets per panicle (-0.003), number of filledgrains per panicle (-0.013), plant height (-0.057) and seed filling per cent (-0.046).

*4.2.1.3.2.8 Plant height*

Plant height had an indirect positive effect on yield under drought condition through all the characters, days to 50 per cent maturity (0.002), days to maturity (0.004), number of tillers per plant (0.0001), number of productive tillers per plant (0.004), spikelets per panicle (0.005), number of filled grains per panicle (0.005), panicle length (0.0004), seed filling per cent (0.004) and test weight (0.001).

Under control condition panicle length had indirect positive effect on yield *via.*, days to 50 per cent maturity (0.003), days to maturity (0.004), number of tillers per plant (0.0006), number of productive tillers per plant (0.0001), panicle length (0.006) and seed filling per cent (0.003). However, it had indirect negative effect on yield through spikelets per panicle (-0.0046), number of filled grains per panicle (-0.0043) and test weight (-0.0041).

*4.2.1.3.2.9 Seed filling per cent*

Under drought condition seed filling per cent exhibited indirect positive effect on yield through days to 50 per cent flowering (0.0221), days to maturity (0.0301), number of productive tillers per plant (0.0506), number of spikelets per panicle (0.1527), number of filled grains per panicle (0.2865), and test weight (0.2587). However it had indirect negative effect on yield *via.* Number of total tillers per plant (-0.0239), panicle length (-0.0062) and plant height (-0.0473).

Under control condition seed filling per cent exhibited indirect positive effect on yield through days to 50 per cent flowering (0.0105), days to maturity (0.0021), number of total tillers per plant (0.0315),number of productive tillers per plant (0.0501), number of spikelets per panicle (0.0625), number of filled grains per panicle (0.1085), panicle length (0.1403) and plant height (0..0857). However it had indirect negative effect on yield *via.*test weight (-0.0063).

*4.2.1.3.2.10 Test weight*

Test weight exhibited indirect positive effect on yield through number of total tillers per plant (0.0115), number of productive tillers per plant (0.1061), number of spikelets per panicle (0.2559), number of filled grains per panicle (0.4048), panicle length (0.0228), and seed filling per cent (0.4074). Whereas it had indirect negative effect on yield *via.*, days to 50 per cent flowering (-0.0161), days to maturity (-0.0260), and plant height (-0.0206) under drought condition.

Under control condition test weight had indirect positive effect on yield *via.*, Days to 50 per cent flowering (0.0045), days to maturity (0.0060), number of total tillers per plant (0.0013), panicle length (0.0022), plant height (0.0064), and seed filling per cent (0.0004). Whereas it had indirect negative effect through, number of productive tillers per plant (-0.0005), number of spikelets per panicle (-0.0078) and number of filled grains per panicle (-0.0077).

*4.2.2 Correlation and path coefficient analysis for yield and physiological characters*

Phenotypic correlation was worked out among 8 physiological and root characters to know the nature of association between yield and physiological parameters under drought and control condition are presented in the table 7.

*4.2.2.1 Correlation of yield with physiological characters*

Significant and positive association at phenotypic level under drought condition was found between yield per plant with chlorophyll content (0.599), relative water content (0.693), proline content (0.805), root length (0.816), root to shoot ratio (0.68), root volume (0.777) and significant negative association with leaf rolling (-0.687) whereas non-significant negative association was observed with shoot length (-0.080).

Under control condition significant and positive association at phenotypic level was not found between yield per plant and other physiological parameters. Whereas non-significant positive association was found with chlorophyll content (0.144), root length (0.072), root to shoot ratio (0.069), root volume (0.061) and non-significant negative association with relative water content (-0.040), proline content (-0.025), leaf rolling (-0.039) and shoot length (-0.0886).

*4.2.2.2 Correlation among physiological parameters*

*4.2.2.2.1 Chlorophyll content*

Chlorophyll content showed significant positive correlations at phenotypic level under drought condition with relative water content (0.544), proline content (0.558), root length (0.558), root to shoot ratio (0.435) and root volume (0.508). Whereas it showed significant negative association with leaf rolling (-0.477) and non-significant negative correlation with shoot length (-0.002).

**Table 7: Estimation of phenotypic correlation between yield and physiological characters under drought and control condition.**

| **Traits** | **$X_1$** | **$X_2$** | **$X_3$** | **$X_4$** | **$X_5$** | **$X_6$** | **$X_7$** | **$X_8$** | **$X_9$** |
|---|---|---|---|---|---|---|---|---|---|
| **$X_1$** | **1.000** | 0.544** | 0.558** | -0.477** | 0.558** | -0.002 | 0.435** | 0.508** | 0.599** |
| **$X_2$** | -0.044 | **1.000** | 0.679** | -0.505** | 0.660** | 0.022 | 0.524** | 0.616** | 0.693** |
| **$X_3$** | 0.063 | 0.069 | **1.000** | -0.518** | 0.623** | 0.019 | 0.471** | 0.624** | 0.805** |
| **$X_4$** | -0.232* | 0.191 | -0.379** | **1.000** | -0.757** | 0.129 | -0.653** | -0.670** | -0.687** |
| **$X_5$** | 0.026 | 0.239* | 0.375** | -0.012 | **1.000** | -0.112 | 0.861** | 0.790** | 0.816** |
| **$X_6$** | 0.029 | 0.163 | 0.036 | -0.242* | -0.123 | **1.000** | -0.572** | -0.071 | -0.080 |
| **$X_7$** | 0.039 | 0.074 | 0.250* | 0.108 | 0.725** | -0.712** | **1.000** | 0.665 | 0.679** |
| **$X_8$** | -0.032 | 0.279** | 0.370** | -0.219* | 0.347** | 0.089 | 0.177 | **1.000** | 0.777** |
| **$X_9$** | 0.144 | -0.040 | -0.025 | -0.039 | 0.072 | -0.088 | 0.069 | 0.061 | **1.000** |

**Significance at 1%, *Significance at 5%. (Above diagonal drought; below diagonal control condition)

Where,

$X_1$–Chlorophyll content (SPAD reading)
$X_2$ – Relative water content (%)
$X_3$ – Prolinecontent (μmole/g FW)
$X_4$ – leaf rolling
$X_5$ – Root length (cm)
$X_6$ –Shoot length (cm)
$X_7$ – Root to shoot ratio
$X_8$ – Root volume (ml)
$X_9$ – Yield per plant (g)

Under control condition chlorophyll content showed significant negative correlation at phenotypic level with leaf rolling (-0.232) and non-significant positive correlation with proline content (0.036), root length (0.026), shoot length (0.029), root to shoot ratio (0.039) however, it showed non-significant negative association with relative water content (-0.044) and root volume (-0.032).

*4.2.2.2.2 Relative water content*

Relative water content showed significant positive correlation at phenotypic level under drought condition with proline content (0.679), root length (0.660), root to shoot ratio (0.435), root volume (0.616)and significant negative association with leaf rolling (-0.505). Whereas shoot length (0.022) showed non-significant positive association.

Under control condition relative water content showed significant positive correlation at phenotypic level with root length (0.239), root volume (0.279) and non-significant positive correlation with proline content (0.069), leaf rolling (0.191), shoot length (0.163), root to shoot length (0.074).

*4.2.2.2.3 Proline content*

Proline content showed significant positive correlation at phenotypic level under drought condition with root length (0.623), root to shoot ratio (0.471) and root volume (0.624). leaf rolling (-0.518) showed significant negative association whereas shoot length (0.019) exhibited non-significant positive association.

Proline content under control condition exhibited significant positive correlation at phenotypic level with root length (0.375), root to shoot ratio (0.250) and root volume (0.370). Whereas shoot length (0.036) showed non-significant positive association and leaf rolling (-0.379) showed significant negative association.

*4.2.2.2.4 Leaf rolling*

Under drought condition leaf rolling exhibited significant negative correlation at phenotypic level with root length (-0.757), root to shoot ratio (-0.653) and root volume (-0.670). Whereas shoot length (0.129) showed non-significant positive correlation.

Leaf rolling exhibited non-significant positive correlation with root to shoot ratio (0.108), whereas significant negative association with shoot length (-0.242), root volume (-0.219) and non-significant negative association with root length (-0.012) at phenotypic level under control condition.

*4.2.2.2.5 Root length*

Root length showed significant positive correlation at phenotypic level under drought condition with root to shoot ratio (0.861) and root volume (0.790). Whereas shoot length (-0.112) showed non-significant negative correlation.

Under control condition root length exhibited significant positive correlation at phenotypic level with root to shoot ratio (0.725) and root volume (0.347). Whereas shoot length (-0.123) showed non-significant negative correlation.

*4.2.2.2.6 Shoot length*

Shoot length under drought condition exhibited significant negative correlation at phenotypic level with root to shoot ratio (-0.572), whereas root volume (-0.071) showed non-significant negative association.

Under control condition shoot length exhibited significant negative correlation at phenotypic level with root to shoot ratio (-0.712) and root volume (0.089) showed non-significant positive association.

*4.2.2.2.7 Root to shoot ratio*

Under drought condition root to shoot ratio exhibited significant positive correlation at phenotypic level with root volume (0.665).

Root to shoot ratio under control condition exhibited non-significant positive association with root volume (0.177).

*4.2.2.3 Path coefficient analysis*

Path coefficient analysis was done at phenotypic level taking the yield per plant as a dependent character and other physiological characters chlorophyll content, relative water content, proline content, leaf rolling, root length, shoot length, root to shoot ratio and root volume as independent characters. The results obtained under drought and control condition are presented in table 8 and table 9 respectively and the direct and indirect effects of different physiological characters on yield are present below.

*4.2.2.3.1 Direct effect of physiological parameter on yield at phenotypic level*

Five out of eight parameters had positive direct effect on yield at phenotypic level under drought condition. The characters which showed positive direct effects are chlorophyll content (0.0508), relative water content (0.0425), proline content (0.4037), root length (0.457) and root volume (0.175). Other characters leaf rolling (-0.069), shoot length (-0.117) and root to shoot ratio (-0.177) had negative direct effects on yield.

**Table 8: Estimates of direct and indirect effects of physiological parameters on yield at phenotypic level under drought condition**

| Traits | $X_1$ | $X_2$ | $X_3$ | $X_4$ | $X_5$ | $X_6$ | $X_7$ | $X_8$ |
|---|---|---|---|---|---|---|---|---|
| **$X_1$** | **0.0508** | 0.0277 | 0.0284 | -0.0243 | 0.0284 | -0.0001 | 0.0222 | 0.0259 |
| **$X_2$** | 0.0231 | **0.0425** | 0.0288 | -0.0215 | 0.0280 | 0.0010 | 0.0223 | 0.0262 |
| **$X_3$** | 0.2255 | 0.2743 | **0.4037** | -0.2094 | 0.2515 | 0.0078 | 0.1901 | 0.2522 |
| **$X_4$** | 0.0330 | 0.0349 | 0.0358 | **-0.0691** | 0.0523 | -0.0089 | 0.0451 | 0.0463 |
| **$X_5$** | 0.2552 | 0.3017 | 0.2847 | -0.3462 | **0.4570** | -0.0515 | 0.3936 | 0.3612 |
| **$X_6$** | 0.0003 | -0.0027 | -0.0023 | -0.0152 | 0.0133 | **-0.1177** | 0.0679 | 0.0084 |
| **$X_7$** | -0.0775 | -0.0933 | -0.0838 | 0.1162 | -0.1532 | 0.1019 | **-0.1779** | -0.1183 |
| **$X_8$** | 0.0892 | 0.1081 | 0.1096 | -0.1176 | 0.1387 | -0.0126 | 0.1167 | **0.1755** |
| **r value** | **0.5996** | **0.6932** | **0.8049** | **-0.6871** | **0.816** | **-0.0801** | **0.68** | **0.7774** |

**Residual effect= 0.41**

Where,

$X_1$–Chlorophyll content (SPAD reading)
$X_2$ – Relative water content (%)
$X_3$ – Proline content (µmole/g FW)
$X_4$ – leaf rolling
$X_5$ – Root length (cm)
$X_6$ –Shoot length (cm)
$X_7$ – Root to shoot ratio
$X_8$ – Root volume (ml)

**Table 9: Estimates of direct and indirect effects of physiological parameters on yield at phenotypic level under control condition**

| Traits | $X_1$ | $X_2$ | $X_3$ | $X_4$ | $X_5$ | $X_6$ | $X_7$ | $X_8$ |
|---|---|---|---|---|---|---|---|---|
| $X_1$ | **0.1610** | -0.0072 | 0.0102 | -0.0374 | 0.0043 | 0.0047 | 0.0064 | -0.0052 |
| $X_2$ | 0.0014 | **-0.0308** | -0.0021 | -0.0059 | -0.0074 | -0.0050 | -0.0023 | -0.0086 |
| $X_3$ | -0.0059 | -0.0064 | **-0.0927** | 0.0352 | -0.0348 | -0.0034 | -0.0232 | -0.0344 |
| $X_4$ | 0.0123 | -0.0102 | 0.0201 | **-0.0531** | 0.0007 | 0.0129 | -0.0058 | 0.0117 |
| $X_5$ | 0.0102 | 0.0925 | 0.1446 | -0.0049 | **0.3855** | -0.0476 | 0.2798 | 0.1339 |
| $X_6$ | -0.0119 | -0.0665 | -0.0148 | 0.0989 | 0.0504 | **-0.4082** | 0.2908 | -0.0367 |
| $X_7$ | -0.0195 | -0.0367 | -0.1234 | -0.0534 | -0.3570 | 0.3505 | **-0.4920** | -0.0871 |
| $X_8$ | -0.0028 | 0.0246 | 0.0326 | -0.0193 | 0.0306 | 0.0079 | 0.0156 | **0.0880** |
| **r value** | **0.1448** | **-0.0407** | **-0.0255** | **-0.0399** | **0.0723** | **-0.0882** | **0.0693** | **0.0616** |

**Residual effect=0.96**

Where,

$X_1$–Chlorophyll content (SPAD reading)
$X_2$ – Relative water content (%)
$X_3$ – Proline content (µmole/g FW)
$X_4$ – leaf rolling
$X_5$ – Root length (cm)
$X_6$ –Shoot length (cm)
$X_7$ – Root to shoot ratio
$X_8$ – Root volume (ml)

Under control condition three out of eight parameters had positive direct effect on yield at phenotypic level. Chlorophyll content (0.161), root length (0.385) and root volume (0.088) had exhibited positive direct effect on yield. Whereas relative water content (-0.030), proline content (-0.092), leaf rolling (-0.053), shoot length (-0.408) and root to shoot ratio (-0.492) had exhibited negative direct effects on yield.

Root length (0.457; 0.385) in drought and control condition had the highest positive direct effect, whereas root to shoot ratio (-0.177; -0.492) in drought and control condition had the highest negative effect on yield.

*4.2.2.3.2 Indirect effect of physiological parameters on yield*

*4.2.2.3.2.1 Chlorophyll content*

The indirect positive effect on yield was exhibited by chlorophyll content under drought condition through, Relative water content (0.027), proline content (0.028), root length (0.028), root to shoot ratio (0.022) and root volume (0.025). However, it had negative effect on yield *via.* leaf rolling (-0.024) and shoot length (-0.0001).

The indirect positive effect on yield was exhibited by chlorophyll content *via.,* Proline content (0.010), root length (0.004), shoot length (0.004) and root to shoot ratio (0.006). However it had indirect negative effect on yield through relative water content (-0.007), leaf rolling (-0.037) and root volume (-0.005) under control condition.

*4.2.2.3.2.2 Relative water content*

The indirect and positive effect on yield was exhibited by relative water content under drought condition through, chlorophyll content (0.023), proline content (0.028), root length (0.028), shoot length (0.001), root to shoot ratio (0.022) and root volume (0.026). However it had indirect negative effect on yield through leaf rolling (-0.021).

Under control condition relative water content had the indirect and positive effect on yield through chlorophyll content (0.001). Whereas it had indirect negative effect on yield *via.*, Proline content (-0.002), leaf rolling (-0.005), root length (-0.007), shoot length (-0.005), root to shoot ratio (-0.002) and root volume (-0.008).

*4.2.2.3.2.3 Proline content*

Under drought condition the proline content had indirect positive effect on yield through relative water content (0.274), chlorophyll content (0.225), root length (0.251), shoot length (0.007), root to shoot ratio (0.190), root volume (0.252). Whereas it had indirect negative effect on yield through leaf rolling (-0.209).

The indirect and positive effect on yield was exhibited by proline content under control condition through leaf rolling (0.035) and indirect negative effect on yield through chlorophyll content (-0.005), relative water content (-0.006), root length (-0.034), shoot length (-0.003), root to shoot ratio (-0.023) and root volume (-0.034).

*4.2.2.3.2.4 Leaf rolling*

The indirect and positive effect on yield was exhibited by leaf rolling under drought condition through chlorophyll content (0.033), relative water content (0.034), proline content (0.035), root length (0.052), root to shoot ratio (0.045) and root volume (0.046).Whereas it had indirect negative effect on yield *via.* Shoot length (-0.008).

Under control condition the leaf rolling had indirect positive effect on yield through chlorophyll content (0.012), proline content (0.020), root length (0.0007), shoot length (0.012) and root volume (0.011). However it had indirect negative effect on yield through relative water content (-0.010) and root to shoot ratio (-0.005).

*4.2.2.3.2.5 Root length*

The indirect and positive effect on yield was exhibited by root length under drought condition through chlorophyll content (0.255), relative water content (0.301), proline content (0.284), root to shoot ratio (0.393) and root volume (0.361). However it had indirect negative effect on yield *via.* Leaf rolling (-0.346) and shoot length (-0.051).

The indirect and positive effect on yield was exhibited by root length under control condition through chlorophyll content (0.010), relative water content (0.092), proline content (0.144), root to shoot ratio (0.279) and root volume (0.133). Whereas it had indirect negative effect on yield through leaf rolling (-0.004) and shoot length (-0.047).

*4.2.2.3.2.6 Shoot length*

Under drought condition shoot length exhibited indirect positive effect on yield *via.* Chlorophyll content (0.0003), root length (0.013), root to shoot ratio (0.067) and root volume (0.008). However it had indirect negative effect on yield through relative water content (-0.002), proline content (-0.002), and leaf rolling (-0.015).

Shoot length had indirect positive effect on yield through, leaf rolling (0.098), root length (0.0504) and root to shoot ratio (0.2908). However it had indirect negative effect on yield through chlorophyll content (-0.011), relative water content (-0.066), proline content (-0.014) and root volume (-0.036) under control condition.

*4.2.2.3.2.7 Root to shoot ratio*

Root to shoot ratio under drought condition had indirect positive effect on yield through leaf rolling (0.116), shoot length (0.101).However it had indirect negative effect on yield *via.* Chlorophyll content (-0.077), relative water content (-0.093), proline content (-0.083), root length (-0.153) and root volume (-0.118).

The indirect positive effect was exhibited by root to shoot ratio under control condition through, shoot length (0.350). Whereas it had indirect negative effect on yield *via.* Chlorophyll content (-0.019), relative water content (-0.036), proline content (-0.123), leaf rolling (-0.053), root length (-0.357) and root volume (-0.087).

*4.2.2.3.2.8 Root volume*

Root volume under drought condition exhibited indirect positive effect on yield through, chlorophyll content (0.089), relative water content (0.108), proline content (0.109), root length (0.138) and root to shoot ratio (0.116). However it had indirect negative effect on yield *via.* Leaf rolling (-0.117) and shoot length (-0.012).

Root volume had an indirect positive effect on yield through relative water content (0.024), proline content (0.032), root length (0.030), shoot length (0.007) and root to shoot ratio (0.015). However it had indirect negative effect on yield *via.* Chlorophyll content (-0.002) and leaf rolling (-0.019) under control condition.

**4.3 Genetic divergence among yield and yield attributing characters.**

Genetic diversity analysis helps to study the nature of divergence among studied genotypes and help to identify the genetically diverse genotypes for their uses in recombinant breeding programme. Present study also work out genetic diversity among 49 genotypes by following Mahalanobis' $D^2$ analysis with yield and its attributing traits under drought and controlled conditions.

*4.3.1 Cluster constellation*

The 49 genotypes of rice were distributed into eight clusters under both drought and controlled condition is present in table 10 and table 11 respectively. Cluster pattern under drought condition revealed that, cluster V constitutes of 13 genotypes forming the largest cluster followed by cluster VI (12 genotypes), cluster II (9 genotypes), cluster III (5 genotypes), cluster VIII (4 genotypes), cluster I (3 genotypes), cluster VII (2 genotypes), and cluster IV (1 genotype).

Cluster pattern under control condition revealed that, cluster VI constitutes of 14 genotypes forming the largest cluster followed by cluster VII (10 genotypes), cluster II (8 genotypes), cluster IV (6 genotypes), cluster VIII (4 genotypes), cluster I and cluster V (3 genotypes each) and cluster III (1 genotype).

**Table 10: Clustering pattern of 49 rice genotypes under drought condition**

| Clusters | No. of Genotypes | Genotypes name |
|---|---|---|
| I | 3 | Madras sanna, JGL 1798, Rasakadari |
| II | 9 | Lalkade rice, Tonnur, Doppavaalya, Hasudi, Baiganmanju, Doddiga, Malgudisanna, Velaiponni, Sannabatha |
| III | 5 | Selumsanna, Delhi bog batta, Navara, Sambamasanna, Shashti |
| IV | 1 | Anagha |
| V | 13 | Kangalli, Karangarav, Kallurandikar, Karuraikalanji, Honasu, Gilisalle, Rajakaime, Gandhasale, Vijaynanded, Sharavatikempakki, Thogarsi, Kagga, Jyothi |
| VI | 12 | Kaduvalai, Moradhi, Akkalu, Sandukaar, Champakali, Naarikela, Rajamani, Bangla rice, Mottaikar, Ambimohari, Kataru, Kemputadi. |
| VII | 2 | Manjakaime, Gangadace. |
| VIII | 4 | Sannavalya, Najarbad, Bettadeyan, Poustic 9. |

**Table 11: Clustering pattern of 49 rice genotypes under control condition**

| Clusters | No. of Genotypes | Genotypes name |
|---|---|---|
| I | 3 | Anagha, Rasakadari, Jyothi. |
| II | 8 | Akkalu, Kangalli, Naarikela, Sambamasanna,Shashti,Hasudi,Honasu,Kataru. |
| III | 1 | Vijaynanded. |
| IV | 6 | Sannavalya, Rajakaimae,Gangadace,Najarbad,Bettadeyan, Poustic 9. |
| V | 3 | Lalkaderice,Tonnur,Doddiga. |
| VI | 14 | Selumsanna,Navara,Doppavaalya,Karangarav,Kallurandikaar,Champakali,Karuraikalanji,Rajamani, Bangla rice,Gandhasale,Ambimohari, Sannabatha, Thogarsi, Kagga. |
| VII | 10 | Kaduvalai,Moradhi,Sandukaar,Manjakaime, Gilisalle,Malgudisanna,Kemputadi,Baiganmanju, Mottaikar, Sharavatikempakki. |
| VIII | 4 | Madras sanna, Delhi bog batta, JGL 1798,Velaiponni. |

### *4.3.2 Intra and Inter cluster relation*

The average $D^2$ values of intra and inter clusters distances under drought and control condition are presented in table 12 and table 13 respectively.

Under drought condition the intra cluster distance ranged from 0.00 to 107.67. The maximum intra-cluster distance was recorded in cluster V (107.67) followed by cluster II (59.53) and cluster I (54.19).

In case of control condition the intra cluster distance ranged from 0.00 to 70.41. The maximum intra-cluster distance was recorded in cluster IV (70.41) followed by cluster I (57.58) and cluster II (51.60).

Diversity among clusters under drought condition; varied from 85.38 to 1466.23. Cluster IV and cluster VIII exhibited maximum inter cluster distance (1466.23) followed by cluster I and cluster VIII (1450.79). The lowest inter cluster distance was recorded between cluster I and cluster III (85.38) followed by cluster I and cluster II (101.22).

Diversity among clusters under control condition, varied from 51.95 to 1104.91. Cluster VII and cluster VIII (1104.91) showed maximum inter cluster distance followed by cluster IV and cluster VIII (912.28). The lowest inter cluster distance was recorded between cluster V and cluster VI (51.95) followed by cluster VI and cluster VII (90.94).

### *4.3.3 Cluster means*

Cluster means of eleven characters studied under drought and control condition are presented in table 14 and table 15 respectively.

Genotypes studied under drought condition exhibited a wide range of variation for all the characters. Highest mean value for days to 50 per cent flowering was recorded in the cluster VII (98) and lowest mean value in the cluster II (62.13). Whereas in control condition highest mean was recorded in cluster VIII (120) and lowest in cluster IV (79.25).

Highest mean value for days to maturity under drought condition was recorded in cluster VII (129) and lowest mean value in the cluster II and cluster VI (95). However in control condition highest mean was recorded in cluster VIII (146) and lowest in cluster III and VII (113.50).

Under drought condition highest mean value for number of total tillers per plant was recorded in cluster VI (20.50) and lowest in the cluster VII (11). Whereas in control condition highest mean value was recorded in cluster VIII (146), and lowest in cluster III (10).

**Table 12: Average inter and intra cluster distances for yield and yield attributing characters in 49 rice genotypes evaluated under drought condition**

| Cluster | I | II | III | IV | V | VI | VII | VIII |
|---|---|---|---|---|---|---|---|---|
| **I** | **54.19** | 101.22 | 85.38 | 145.62 | 229.65 | 404.26 | 433.57 | 1450.79 |
| **II** | | **59.53** | 139.50 | 309.48 | 249.59 | 310.44 | 548.17 | 1439.23 |
| **III** | | | **0.00** | 106.38 | 122.39 | 295.20 | 244.86 | 1218.57 |
| **IV** | | | | **0.00** | 274.08 | 596.48 | 310.48 | 1466.23 |
| **V** | | | | | **107.67** | 168.79 | 157.53 | 812.82 |
| **VI** | | | | | | **0.00** | 329.98 | 548.06 |
| **VII** | | | | | | | **0.00** | 643.18 |
| **VIII** | | | | | | | | **0.00** |

***Diagonal values indicate intra cluster distances**

**Table 13: Average inter and intra cluster distances for yield and yield attributing characters in 49 rice genotypes evaluated under control condition**

| Cluster | I | II | III | IV | V | VI | VII | VIII |
|---|---|---|---|---|---|---|---|---|
| **I** | **57.58** | 169.25 | 109.13 | 176.16 | 176.72 | 180.70 | 398.25 | 399.77 |
| **II** | | **51.60** | 161.50 | 495.16 | 343.89 | 429.47 | 741.12 | 153.80 |
| **III** | | | **0.00** | 353.96 | 173.98 | 160.64 | 412.23 | 230.97 |
| **IV** | | | | **70.41** | 224.60 | 176.55 | 288.86 | 912.28 |
| **V** | | | | | **0.00** | 51.95 | 106.67 | 602.38 |
| **VI** | | | | | | **0.00** | 90.94 | 685.52 |
| **VII** | | | | | | | **0.00** | 1104.91 |
| **VIII** | | | | | | | | **0.00** |

***Diagonal values indicate intra cluster distances**

***Above diagonal values indicate inter cluster distances**

**Table 14: Cluster means for yield and yield attributing characters in 49 rice genotypes evaluated under drought condition**

| Cluster/ character | $X_1$ | $X_2$ | $X_3$ | $X_4$ | $X_5$ | $X_6$ | $X_7$ | $X_8$ | $X_9$ | $X_{10}$ | $X_{11}$ |
|---|---|---|---|---|---|---|---|---|---|---|---|
| **I** | 76.95 | 108.23 | 18.07 | 11.66 | 72.32 | 19.34 | 19.24 | 87.62 | 3.89 | 27.34 | 14.91 |
| **II** | 62.13 | 95.00 | 18.25 | 13.75 | 73.63 | 33.75 | 17.72 | 80.83 | 6.03 | 47.93 | 15.72 |
| **III** | 83.50 | 114.50 | 16.00 | 10.50 | 75.00 | 47.50 | 20.75 | 104.30 | 7.30 | 63.39 | 14.75 |
| **IV** | 95.08 | 126.58 | 14.00 | 7.25 | 64.92 | 19.83 | 18.09 | 86.47 | 3.09 | 31.50 | 13.62 |
| **V** | 81.93 | 115.29 | 17.86 | 13.57 | 104.57 | 78.07 | 18.98 | 75.68 | 16.91 | 75.87 | 20.33 |
| **VI** | 68.00 | 95.00 | 20.50 | 16.50 | 134.00 | 108.00 | 21.53 | 108.95 | 21.25 | 80.61 | 21.25 |
| **VII** | 98.00 | 129.00 | 11.00 | 7.00 | 103.00 | 91.50 | 17.13 | 70.50 | 21.75 | 89.01 | 24.83 |
| **VIII** | 77.00 | 106.00 | 12.50 | 11.50 | 210.00 | 195.00 | 20.50 | 74.17 | 24.25 | 92.95 | 25.80 |

Where,

$X_1$ - Days to 50 per cent flowering
$X_2$ –Days to maturity
$X_3$ – No. of total tillers per plant
$X_4$ – No. of productive tillers per plant
$X_5$ – No. of spikelets per panicle
$X_6$ –No. filled grains per panicle
$X_7$ – Panicle length (cm)
$X_8$ – Plant height (cm)
$X_9$ – Yield per plant (g)
$X_{10}$ – Seed filling per cent
$X_{11}$ – Test weight (g)

**Table 15: Cluster means for yield and yield attributing characters in 49 rice genotypes evaluated under control condition**

| Cluster/ character | $X_1$ | $X_2$ | $X_3$ | $X_4$ | $X_5$ | $X_6$ | $X_7$ | $X_8$ | $X_9$ | $X_{10}$ | $X_{11}$ |
|---|---|---|---|---|---|---|---|---|---|---|---|
| **I** | 92.75 | 127.20 | 14.28 | 13.57 | 100.87 | 92.73 | 22.17 | 112.77 | 37.43 | 91.80 | 21.36 |
| **II** | 107.65 | 142.15 | 14.35 | 13.25 | 95.05 | 87.50 | 22.11 | 119.82 | 39.43 | 91.91 | 18.66 |
| **III** | 100.00 | 131.50 | 10.00 | 10.00 | 117.50 | 110.00 | 22.65 | 94.75 | 44.75 | 93.62 | 26.75 |
| **IV** | 79.25 | 113.75 | 19.00 | 18.00 | 118.50 | 111.88 | 21.16 | 107.56 | 36.91 | 95.18 | 18.78 |
| **V** | 90.00 | 129.50 | 16.50 | 16.50 | 190.00 | 176.50 | 20.50 | 82.50 | 34.25 | 92.92 | 23.50 |
| **VI** | 86.50 | 121.00 | 17.00 | 16.00 | 177.50 | 166.00 | 21.09 | 86.50 | 48.75 | 93.52 | 24.25 |
| **VII** | 81.00 | 113.50 | 12.00 | 11.50 | 245.00 | 225.00 | 24.00 | 100.50 | 40.53 | 91.92 | 25.75 |
| **VIII** | 120.00 | 146.00 | 20.00 | 20.00 | 89.00 | 84.00 | 20.13 | 120.44 | 47.50 | 94.21 | 25.00 |

Where,

$X_1$ - Days to 50 per cent flowering
$X_2$ –Days to maturity
$X_3$ – No. of total tillers per plant
$X_4$ – No. of productive tillers per plant
$X_5$ – No. of spikelets per panicle
$X_6$ –No. filled grains per panicle
$X_7$ – Panicle length (cm)
$X_8$ – Plant height (cm)
$X_9$ – Yield per plant (g)
$X_{10}$ – Seed filling per cent
$X_{11}$ – Test weight (g)

Under drought condition the highest mean value for number of productive tillers per plant was recorded in the cluster VI (16.50) and lowest in the cluster VII (7). Whereas in control condition highest mean was recorded in the cluster VIII (20) and lowest in the cluster III (10).

Highest mean for number of spikelets per panicle under drought condition was recorded in the cluster VIII (210) and lowest in the cluster IV (73.63). Whereas in the control condition highest mean in cluster VII (245) and lowest in the cluster VIII (89).

Cluster VIII (195) exhibited highest mean value for number of filled grains per panicle and cluster IV (19.8) showed lowest mean under drought condition. Whereas under control condition cluster VII (225) showed highest mean value and cluster VIII (84) exhibited lowest mean value under control condition.

Highest mean value for panicle length under drought condition was recorded in cluster VI (21.53) and lowest mean value in the cluster VII (17.13). Whereas under control condition highest mean value was recorded in cluster VII (24) and lowest in cluster VIII (20.13).

Cluster VI (108.95) had exhibited highest and cluster VII (70.50) had exhibited lowest mean value for plant height under drought condition. Whereas under control condition cluster VIII (120.44) showed highest and cluster V (82.50) showed lowest mean value for plant height.

Highest mean value for yield per plant was observed in cluster VIII (24.25), and lowest mean value in cluster IV (3.09) under drought condition. Whereas in control condition cluster VI (48.75) showed highest and cluster V (34.25) lowest mean value for yield per plant.

Under drought condition cluster VIII (92.95) exhibited highest and cluster I (27.34) exhibited lowest mean value for seed filling per cent. Whereas in control condition cluster IV (95.18) showed highest and cluster I (91.80) showed lowest mean value.

Highest mean value for test weight under drought condition was exhibited by cluster VIII (25.80) and cluster IV (13.62) showed lowest mean value. Whereas under control condition cluster VII (25.75) showed highest and cluster II (18.66) showed lowest mean value for test weight.

### *4.3.4 Contribution of different characters towards divergence*

Contribution of all eleven characters to divergence under drought condition are presented in the Table 16.

**Table 16: Per cent contribution and their cumulative values of eleven characters towards divergence in 49 rice genotypes evaluated in field under drought condition**

| Sl. No. | Characters | % contribution | |
|---|---|---|---|
| | | Drought | Cumulative |
| 1 | No. of filled grains per panicle | 35.80 | 35.80 |
| 2 | No. of productive tillers per hill | 25.34 | 61.14 |
| 3 | No. of spikelets per panicle | 11.39 | 72.53 |
| 4 | Days to maturity | 8.94 | 81.47 |
| 5 | Days to 50% flowering | 5.78 | 87.25 |
| 6 | Yield per plant | 5.19 | 92.44 |
| 7 | Test weight | 3.74 | 96.18 |
| 8 | Seed filling per cent | 2.21 | 98.39 |
| 9 | Panicle length | 0.77 | 99.16 |
| 10 | Plant height | 0.75 | 99.91 |
| 11 | No. of total tillers per hill | 0.09 | 100.00 |

Number of filled grains per panicle (35.80 %) contributed highest to the divergence of genotypes followed by productive tillers per plant (25.34), number of spikelets per panicle (11.39), days to maturity (8.93), days to 50 per cent flowering (5.78), yield per plant (5.19) and least from test weight (3.74), seed filling per cent (2.21), panicle length and plant height (0.77) and lowest contribution to divergence by number of total tillers per plant (0.09) under drought condition.

Days to 50 per cent flowering (44.64) contributed highest to the divergence of genotypes followed by test weight (18.37), number of spikelets per panicle (10.54), yield per plant (9.95), days to maturity (7.91) and least from panicle length (3.56), plant height (2.72), number of total tillers per plant (1.87), seed filling per cent (0.34), number of productive tillers per plant (0.09) and number of filled grains per panicle (0.01) under control condition.

### 4.4 Per cent difference in physiological parameters contributing to drought tolerance between stress and control condition

Per cent difference for physiological parameters between drought and control condition is presented in table 17.

Highest per cent difference in chlorophyll content between control and stress was rerecorded in Ambimohari (97.33%), followed by Hasudi (95.65), Gandhasale (92.68)and shashti (85.88) whereas, lowest per cent difference was recorded in Tonnur (1.52), Akkalu (3.23), Madras sanna (4.17), Sannavalya (5.26), Manjakaime (5.71), JGL 1798 (7.69), Najarbad (8.25), Anagha (8.32)andGangadace (9.15). Remaining genotypes exhibited 10 per cent to 90 per cent difference in chlorophyll content.

Highest per cent difference for proline content between stress and control was recorded inBettadeyan (99.95), Honasu (97.37), Rajamani (94.17), Kallurandikar (92.85), Kaduvalai (94.61), Tonnur (92), Lalkade rice (97.52) and lowest per cent difference was recorded in Doddiga (17.44), Madras sanna (34.70), JGL-1798 (36.75), Sannavalya (31.17), Manjakaime(37.34), Gangadace (39.08), Najarbad (36.75) and Anagha (39.54). However other genotypes showed 40 per cent to 90 per cent difference.

### 4.5 Identification of Drought tolerant genotypes

From the present investigation six genotypes *viz*., Sannavaalya, Manjakaime, JGL-1798, Gangadace, Madras sanna and Najarbad were identified as drought tolerant lines which performed better than other genotypes under drought condition. Drought tolerant genotypes and their respective contributing traits viz., number of productive tillers per plant, number of spikelets per panicle, number of grains per panicle, seed filling per cent, test weight, chlorophyll content, relative water content, proline content, leaf rolling, root length, root to shoot ratio, root volume, yield per plant and days to maturity are presented in the table 18.

**Table 17: Per cent difference for physiological parameters contributing to drought tolerance between stress and control condition in 49 rice genotypes**

| Line no. | **Chlorophyll** (spad readings) | | | **Proline content**(µmole/g FW) | | |
|---|---|---|---|---|---|---|
| | **Drought** | **Control** | **% difference** | **Drought** | **control** | **% difference** |
| **1** | 14.40 | 15.00 | 4.17 | 17.04 | 12.65 | 34.70 |
| **2** | 10.00 | 14.40 | 44.00 | 18.66 | 13.15 | 41.90 |
| **3** | 9.00 | 14.00 | 55.56 | 24.50 | 14.65 | 67.24 |
| **4** | 12.00 | 14.80 | 23.33 | 16.16 | 11.25 | 43.64 |
| **5** | 13.00 | 14.00 | 7.69 | 19.35 | 14.15 | 36.75 |
| **6** | 10.00 | 15.50 | 55.00 | 21.56 | 14.25 | 51.30 |
| **7** | 8.00 | 10.70 | 33.75 | 39.80 | 20.15 | 97.52 |
| **8** | 13.20 | 13.40 | 1.52 | 34.56 | 18.00 | 92.00 |
| **9** | 8.10 | 9.80 | 20.99 | 33.96 | 17.45 | 94.61 |
| **10** | 11.90 | 17.70 | 48.74 | 21.25 | 12.50 | 70.00 |
| **11** | 9.30 | 9.60 | 3.23 | 23.15 | 12.56 | 84.32 |
| **12** | 11.80 | 15.30 | 29.66 | 26.58 | 14.25 | 86.53 |
| **13** | 11.10 | 18.20 | 63.96 | 25.54 | 14.56 | 75.41 |
| **14** | 11.80 | 15.30 | 29.66 | 22.54 | 13.00 | 73.38 |
| **15** | 8.20 | 12.80 | 56.10 | 38.57 | 10.00 | 92.85 |
| **16** | 11.80 | 14.50 | 22.88 | 24.07 | 13.15 | 83.04 |
| **17** | 11.70 | 18.00 | 53.85 | 21.56 | 15.15 | 42.31 |
| **18** | 8.60 | 15.20 | 76.74 | 25.93 | 14.52 | 78.58 |
| **19** | 8.00 | 12.40 | 55.00 | 24.13 | 13.56 | 77.95 |
| **20** | 9.10 | 14.80 | 62.64 | 36.00 | 18.54 | 94.17 |
| **21** | 10.00 | 16.50 | 65.00 | 21.15 | 13.52 | 56.43 |
| **22** | 8.50 | 15.80 | 85.88 | 24.33 | 14.54 | 67.33 |
| **23** | 11.00 | 18.00 | 63.64 | 19.56 | 12.34 | 58.51 |
| **24** | 15.20 | 16.00 | 5.26 | 18.56 | 14.15 | 31.17 |
| **25** | 6.90 | 13.50 | 95.65 | 21.92 | 12.14 | 80.56 |
| **26** | 12.00 | 15.80 | 31.67 | 21.04 | 12.34 | 70.50 |
| **27** | 14.00 | 14.80 | 5.71 | 17.25 | 12.56 | 37.34 |
| **28** | 9.15 | 16.50 | 80.33 | 34.56 | 17.51 | 97.37 |
| **29** | 7.10 | 12.50 | 76.06 | 17.04 | 14.51 | 17.44 |
| **30** | 11.00 | 18.00 | 63.64 | 18.95 | 11.15 | 69.96 |
| **31** | 10.00 | 16.80 | 68.00 | 19.56 | 12.25 | 59.67 |
| **32** | 11.15 | 18.20 | 63.23 | 20.15 | 12.56 | 60.43 |
| **33** | 9.10 | 16.50 | 81.32 | 21.93 | 12.15 | 80.49 |
| **34** | 8.20 | 15.80 | 92.68 | 19.58 | 13.12 | 49.24 |
| **35** | 9.20 | 15.70 | 70.65 | 18.65 | 14.13 | 31.99 |

**Contd..**

| Line no. | Chlorophyll (spad readings) | | | Proline content(µmole/g FW) | | |
|---|---|---|---|---|---|---|
| | Drought | Control | % difference | Drought | Control | % difference |
| **36** | 7.50 | 14.80 | 97.33 | 21.25 | 15.15 | 40.26 |
| **37** | 10.00 | 16.50 | 65.00 | 22.13 | 14.56 | 51.99 |
| **38** | 14.20 | 15.50 | 9.15 | 20.25 | 14.56 | 39.08 |
| **39** | 12.10 | 15.70 | 29.75 | 22.54 | 13.54 | 66.47 |
| **40** | 9.70 | 14.20 | 46.39 | 24.56 | 14.56 | 68.68 |
| **41** | 8.50 | 15.70 | 84.71 | 26.54 | 14.50 | 83.03 |
| **42** | 8.20 | 13.00 | 58.54 | 26.52 | 16.16 | 64.11 |
| **43** | 13.20 | 18.00 | 36.36 | 24.13 | 14.54 | 65.96 |
| **44** | 16.12 | 17.45 | 8.25 | 19.35 | 14.15 | 36.75 |
| **45** | 8.00 | 14.40 | 80.00 | 37.15 | 15.58 | 99.95 |
| **46** | 11.90 | 15.50 | 30.25 | 19.54 | 12.13 | 61.09 |
| **47** | 17.54 | 19.00 | 8.32 | 18.35 | 13.15 | 39.54 |
| **48** | 6.90 | 11.00 | 59.42 | 21.25 | 12.15 | 74.90 |
| **49** | 11.60 | 15.80 | 36.21 | 20.56 | 13.25 | 55.17 |
| **CD (5%)** | **3.26** | **3.15** | | **3.11** | **2.07** | |
| **CV (%)** | **15.37** | **10.36** | | **6.57** | **7.23** | |

**Table 18: Drought tolerant genotypes identified and their respective traits**

| Genotype | $X_1$ | $X_2$ | $X_3$ | $X_4$ | $X_5$ | $X_6$ | $X_7$ | $X_8$ | $X_9$ | $X_{10}$ | $X_{11}$ | $X_{12}$ | $X_{13}$ | $X_{14}$ |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Sannavaalya** | 14.50 | 107.50 | 97.00 | 90.25 | 26.25 | 15.20 | 78.28 | 18.56 | 4.00 | 36.00 | 0.65 | 17.00 | 24.75 | 114 |
| **Manjakaime** | 16.00 | 97.50 | 87.00 | 89.23 | 25.71 | 14.00 | 72.30 | 17.25 | 3.00 | 35.00 | 0.64 | 16.00 | 22.85 | 103 |
| **Gangadace** | 16.50 | 134.00 | 108.00 | 80.60 | 21.25 | 14.20 | 73.06 | 20.25 | 5.00 | 30.20 | 0.58 | 19.00 | 21.25 | 95 |
| **Madras sanna** | 17.00 | 77.50 | 70.00 | 90.33 | 21.50 | 14.40 | 78.50 | 17.04 | 4.00 | 27.00 | 0.60 | 15.00 | 20.85 | 129 |
| **Najarbad** | 14.50 | 111.00 | 89.50 | 80.62 | 24.25 | 16.12 | 76.21 | 19.35 | 5.00 | 28.00 | 0.48 | 16.50 | 20.25 | 117 |
| **JGL-1798** | 7.00 | 103.00 | 91.50 | 89.01 | 24.83 | 13.00 | 68.45 | 19.35 | 4.00 | 30.00 | 0.60 | 16.00 | 21.75 | 129 |
| **Anagha** | 11.50 | 210.00 | 195.00 | 92.95 | 25.80 | 17.54 | 74.23 | 18.35 | 4.00 | 40.50 | 0.93 | 18.00 | 24.25 | 106 |
| **Jyoti** | 16.50 | 82.50 | 38.50 | 46.45 | 21.00 | 6.90 | 52.15 | 21.25 | 8.00 | 18.20 | 0.44 | 7.00 | 8.75 | 110 |
| **Poustic 9** | 15.00 | 116.00 | 67.50 | 58.03 | 12.25 | 11.60 | 51.88 | 20.56 | 8.00 | 21.20 | 0.48 | 8.50 | 12.15 | 114 |
| **CD (5%)** | 2.51 | 11.68 | 8.35 | 9.64 | 1.83 | 3.26 | 7.38 | 3.11 | - | 3.71 | 0.07 | 3.28 | 2.58 | 4.19 |
| **CV (%)** | 10.84 | 7.18 | 11.41 | 11.73 | 5.65 | 15.37 | 10.12 | 6.57 | - | 8.89 | 9.26 | 16.13 | 18.28 | 1.88 |

Where,

$X_1$–No. of productive tillers per plant
$X_2$ – No. of spikelets per panicle
$X_3$ – No. of grains per panicle
$X_4$ – Seed filling percentage
$X_5$ – Test weight (g)
$X_6$ –Chlorophyll content (spad)
$X_7$ – Relative water content (%)
$X_8$ – Proline content (µmole/g FW)
$X_9$ – Leaf rolling
$X_{10}$ – Root length (cm)
$X_{11}$ – Root to shoot ratio
$X_{12}$ – Root volume (ml)
$X_{13}$ – Yield per plant (g)
$X_{14}$ – Days to maturity

# Discussion

# V DISCUSSION

Rice is the major food crop of the world. Production is drastically affected by drought in lowland rice ecosystem. In the recent years due to climate change drought has become the major limiting factor causing suboptimal yields to total crop failure. So, there is a need to adopt climate resilient agricultural practices which mainly include altered agronomic practices like irrigation schedule, micro irrigation techniques, crop spacing *etc*., and cultivation of drought tolerant varieties. Local landraces of rice being one of the major components of the germplasm serve as a source of drought tolerance which can be used as donors in the drought tolerance breeding program. Hence dissecting out the traits of importance which influencing the response of drought tolerance and yield traits of grain yield will help the breeder to know the mechanism of drought tolerance of rice leading to the development of drought tolerant varieties (Manickavelu *et al.*2006).

Improvement of any crop through breeding program depends on the presence of variability among the genotypes. The utility of such genotypes can be known based on the knowledge of extent of variability, character association and direct and indirect effects influencing different character and genetic divergence in the material. In the present investigation 49 rice land races including checks which were evaluated under field as well as under PVC pipes to assess the variability parameter, character association, direct and indirect effect of character and genetic divergence for 11 quantitative characters under drought and controlled conditions. The information obtained on the variability parameters, correlation analysis, path co-efficient analysis and genetic divergence are discussed under the following sub-headings.

5.1 Genetic variability parameters for grain yield and yield attributing traits

5.2 Correlation coefficients and path coefficient analysis among yield and yield attributing characters also with physiological and root traits.

5.3 Genetic divergence among grain yield and yield attributing characters

5.4Per cent difference for physiological parameters contributing to drought tolerance between stress and control condition

## 5.1 Genetic variability parameters for grain yield and yield attributing traits

The analysis of variance revealed highly significant difference among the rice genotypes for all the traits. All the genotypes displayed considerable amount of differences in their mean performance with respect to all the characters studied under control and drought stress condition. As indicated by highly significant mean sum of squares for these traits, and showed that, the genotypes studied were genetically diverse. Earlier workers, Alok *et al.*(2013) and Santhosh *et al.* (2014) also reported the significant differences among the genotypes in their studies for days to 50 per cent flowering, grain yield, number of effective tillers, test weight, sterility per cent, harvest index, proline content, leaf area index and total soluble sugars.

### *5.1.1 Genetic variability, heritability and genetic advance per cent mean for yield and yield attributing characters of rice genotypes*

The genetic variation present in the genotypes is the fundamental principle followed in plant breeding in order to develop improved varieties having higher yield potential than the present ruling varieties. Genetic variability is the raw material on which selection acts to bring improvement in genetic architecture of plants. The proportion of genetic variability which is transmitted from parents to off springs is reflected by heritability Lush (1949). Heritability in broad sense and genetic advance in per cent mean as direct selection parameters provide index of transmissibility of traits which gives indication about the effectiveness of selection in improving the character (Johnson *et al.* 1955).

The genotypes under study showed a wide range of variation both under control and drought stress condition, which provide an opportunity for selection of desired genotypes by the plant breeder for further breeding program.

In the present study, the high magnitude of phenotypic and genotypic coefficient of variability was recorded for number of tillers per plant, number of productive tillers per plant, number of spikelets per panicle, number of filled grains per panicle under drought stress and control condition, while yield per plant, grain filling per cent and test weight showed high value of PCV and GCV under drought stress condition but, under control condition these traits showed low to moderate PCV and GCV. This shows greater variability expressed by genotypes under stress condition than in the normal condition. These results are in conformity with the findings of earlier workers Uday (2013) and Alok *et al.* (2013).

The moderate estimates of phenotypic and genotypic coefficient of variability was recorded for days to 50 per cent flowering, plant height under drought stress and control condition, however panicle length, yield per plant, test weight under control condition. Chanbeni *et al.* (2012) observed moderate PCV and GCV estimates for panicle length, plant height and test weight. However Alok *et al.* (2013) reported low estimate of coefficient of variability for panicle length.

The low estimates of PCV and GCV was recorded for days to maturity under both drought stress and in control condition, whereas seed filling per centage in control condition. Chanbeni *et al.* (2012), Alok *et al.* (2013) and Islam *et al.* (2016) also reported low PCV and GCV estimates for days to maturity. The occurrence of low estimates of PCV and GCV indicated that selection directly based on these characters would not yield better results as selection is ineffective for this traits under both the conditions.

The estimates of PCV were slightly higher than corresponding GCV for all the characters under study. Uday (2013), Aishwarya *et al.* (2014) and Chanbeni *et al.* (2012) also reported higher phenotypic coefficient of variation than their respective genotypic coefficient of variation for all the characters they studied. This indicated that the presence of non-genetic factors in control of this traits *i.e* environmental influence in expression of traits under study

The high magnitude of heritability in broad sense with high genetic advance mean were observed for days to 50 percent flowering, number of productive tillers per plant, number of spikelets per panicle, number of filled grains per panicle, yield per plant, seed filling per cent and test weight under control as well as drought stress. While, plant height and number of tillers per plant under control condition. Similar results were obtained for plant height, test weight, number of spikelets per panicle, per cent spikelet fertility and grain yield in both control and low moisture stress situation, while for number of tillers per plant in moisture stress and for number of productive tillers per plant in control condition by Uday (2013). Chanbeni *et al.* (2012) reported high heritability coupled with high genetic advance for plant height and number of spikelets per panicle. Islam *et al.* (2016) reported high heritability with genetic advance mean for filled grains per panicle and thousand grain weight.

The above said nine traits under drought and control conditions reported high heritability coupled with high genetic advance are ideal traits for selection. These traits exhibited moderate to high PCV and GCV values which shows that the lines evaluated may provide high response to selection as these traits exhibited high heritability coupled with high genetic advance owing to their high transmissibility to next generation. They are likely to be under the influence of additive genetic variance.

Days to maturity showed high heritability in broad sense with moderate genetic advance mean with low PCV and GCV values under both drought stress and control condition. This shows that, the possibility of obtaining better response to selection for days to maturity because of high heritability since it had narrow difference between PCV and GCV values. Chanbeni *et al.* (2012) reported high heritability coupled with moderate genetic advance for days to 50 per cent flowering and days to maturity. High heritability with moderate GA was reported byUday (2013) for days to 50 % flowering, days to maturity and panicle length.Alok *et al.* (2013) for days to maturity and panicle length and Aishwarya *et al.* (2014) for plant height, panicle length and test weight.

Number of tillers per plant, panicle length and plant height under drought stress condition exhibited moderate heritability with moderate genetic advance mean coupled with moderate to high PCV and GCV values. This shows that selection for these traits are not much useful even though they have higher variability under drought because of moderate heritability and may prove of environmental interactions. Islam *et al.* (2016) had reported similar results for effective tillers per plant, number of unfilled grains per panicle and yield per plant.

The phenotypic and genotypic coefficients of variability for number of productive tillers per plant, number of spikelets per panicle, number of filled grains per panicle, yield per plant, seed filling per cent and test weight observed was high along with high heritability coupled with high genetic advance mean in drought stress condition as compared with control condition. This shows that the drought stress created more variability than control condition for these traits, therefore direct selection for these characters under drought stress condition may give better results in controlled conditions.

## 5.2 Correlation coefficients and path coefficient analysis among yield and yield attributing characters also with physiological and root traits

### *5.2.1 Correlation and path coefficient analysis among yield and yield attributing characters.*

Primary aim of any breeding program is to increase yield. The yield of the crop depends on the performance of its matrix trait known as yield attributing traits. Thus genetic architecture of grain yield is based on the balance or overall net effect produced by various yield components directly or indirectly by interacting with each other. Inter-relationship between grain yield and yield attributes were determined by correlation matrix studied.

In the present study the yield per plant was significantly and positively associated with productive tillers per plant, number of spikelets per panicle, number of filled grains per panicle, seed filling per cent and test weight under drought stress condition whereas, under control condition yield was positive association with days to 50 per cent flowering and seed filling per cent. Santosh *et al.* (2014) reported positive and significant correlation for yield with harvest index and tiller number under both drought stress and non-stress irrigated condition. Manickavelu *et al.* (2006) reported significant and positive correlation of yield with tillers per plant, grains per panicle, test weight under both stress and control conditionwhereas, days to flowering, plant height, panicle length under stress condition showed positive significant correlation with yield.

These results shows that indirect selection for grain yield could be effectively done through direct selection of yield component characters like, productive tillers per plant, number of spikelets per panicle, number of filled grains per panicle, seed filling per cent and test weight selection become effective under drought condition.

*5.2.1.1 Path coefficient analysis for yield attributing traits*

Correlation coefficient gives an idea of association between characters. But a dependant character is an interaction product of many mutually associated component characters and change system. The path coefficient analysis is a statistical device developed by Wright (1921). It takes into account cause and effect relationship between the characters by partitioning the association into direct and indirect effect of independent traits on dependent trait.

In the present study days to 50 per cent flowering, number of tillers per plant, number of spikelets per panicle, seed filling per cent under both drought stress and control condition, days to maturity, number of productive tillers per plant, number of filled grains per panicle, and test weight under drought, whereas plant height under control condition exhibited positive direct effect on yield per plantat phenotypic level. The results were in accordance with Manickavelu *et al.* (2006) reported that, tillers per plant, panicle length, grains per panicle, 100 grain weight, and harvest index showed positive direct effect on yield under both control and stress condition. Uday (2013) reported similar results that plant height, test weight, number of tillers per plant, number of productive tillers per plant, per cent spikelet fertility showed positive direct effect on yield under both control and moisture stress condition and in control condition days to 50 per cent flowering, days to maturity, panicle length exhibited positive direct effect on yield.

Among all these traits the test weight in drought and number of spikelets per panicle under control showed highest direct effect on yield per plant followed by seed filling per cent, and days to 50 per cent flowering. This indicates that, if other factors are held constant, an increase in test weight in drought stress and number of spikelets per panicle in control condition will reflect in an increased yield. The indirect effect of all these characters on grain yield was also high. These characters also exhibited highest positive correlation with yield per plant. The direct and indirect effects of these traits on yield leading to selection for enhancing yield under drought stress situation. Manickavelu *et al.* (2006) reported tillers per plant had highest direct effect on yield under drought condition and grains per panicle under control condition.

The residual effect (0.27 in drought and 0.68 in control) was less than 1, indicating that major variation in yield has been accounted by the characters studied that is the characters under study were appropriate. Similar results of low residual effect by Uday (2013).

*5.2.2 Correlation coefficients and path coefficient analysis among yield and physiological characters.*

Even though the selection for yield is the main criteria under drought other secondary traits play an important role in drought tolerance selection for these traits indirectly contribute to yield under drought stress situations. Physiological parameters play an important role in drought tolerance under stress condition. Hence knowledge of association between these drought tolerant traits and yield provide a powerful tool for selection under drought condition.

In the present study chlorophyll content, relative water content, proline content, root length, root to shoot ratio and root volume showed significant positive correlation with yield per plant under drought condition. Whereas leaf rolling under drought stress situation showed significant negative correlation. Manickavelu *et al.* (2006) also reported significant and positive correlation of yield with relative water content, root length and root to shoot ratio, but leaf rolling reported significant negative correlation with yield. Santosh *et al.* (2014) reported significant positive correlations with proline content and relative water content under drought stress environment. Beena *et al.* (2012) also found significant and positive correlations between yield and physiological traits like, proline content, chlorophyll stability index, biomass and relative water content under drought stress.

Based on the above discussion, it may be suggested that selection for productive tillers per plant, number of spikelets per panicle, number of filled grains per panicle, seed filling per cent, test weight, chlorophyll content, relative water content, proline content, root length, root to shoot ratio and root volume traits were to be given priority under drought stress condition as they exhibited positive and significant correlation with grain yield per plant.

*5.2.2.1 Path coefficient analysis for physiological parameters with yield*

Path analysis of physiological characters contributing to drought tolerance on yield under stress situation helps know the effect of these parameters on dependent character yield. In the present study chlorophyll content, root length and root volume exhibited positive direct effect on yield under both drought stress and control condition. Under drought conditionrelative water content, proline content showed positive direct effect. Similar results were reported by Manickavelu *et al.* (2006) they showed relative water content and root to shoot ratio showed positive direct effect on yield. Uday (2013) reported that root length and root number had positive direct effect on yield.

Under drought condition path coefficient analysis of leaf rolling, shoot length and root to shoot ratio exhibited direct negative effect on yield. Manickavelu *et al.* (2006) also reported that leaf rolling showed negative direct effect on yield under drought.

Among all these characters root length under drought and control condition exhibited highest direct effect on yield followed by proline content, relative water content, and root volume under drought. This indicates selection for these traits under drought condition will give fruitful outcome.

## 5.3 Genetic divergence among rice genotypes for grain yield and yield attributing characters

In order to study the diversity in 49 rice genotypes, 11 quantitative characters were considered and assessed using Mahalanobis' $D^2$analysis under drought and control condition.

### *5.3.1 Genetic diversity in different groups*

Based on $D^2$ analysis 49 genotypes were grouped into 8 clusters under both drought and control condition. Under drought condition in cluster I had 3 genotypes, 9 genotypes in cluster II, 5 genotypes in cluster III, one genotype in cluster IV, 13 in cluster V, 13 in cluster VI, 2 and 4 genotypes in cluster VII and VIII respectively. However in control condition 3 genotypes in cluster I and V, 8 genotypes in cluster II, 1 in cluster III, 6 in cluster IV, 14 genotypes in cluster VI, 10 and 4 genotypes in cluster VII and VIII respectively. Uday (2013) reported 8 clusters under control and 10 clusters in low moisture stress condition. Chanbeni *et al.* (2012) reported 9 clusters. This clustering pattern indicates the presence of wide range of diversity among genotypes.

The intra cluster distance varied from 54.19 in cluster I to a maximum distance of 107.67 in cluster V under drought stress. Under control condition intra cluster distance varied from 51.60 in cluster II to a maximum distance of 70.41 in cluster IV. This shows the presence of diverse genotypes in different clusters.

The inter cluster distance $D^2$values also ranged widely with a minimum value of 85.38 between cluster I and III to a maximum value of 1466.23 between cluster IV and cluster VIII under drought stress. Under control condition minimum value of 51.95 between cluster VI and V and maximum value of 1104 between cluster VII and VIII. Indicating high diversity among the studied genotypes. Cluster IV with 1 genotype and cluster VIII with 4 genotypes were the most divergent groups with a maximum inter cluster distance (1466.23) under drought stress condition and cluster VII with 10 genotypes and cluster VIII with 4 genotypes were the most divergent groups with a maximum inter cluster distance (1104). It is desirable to select genotypes from these clusters showing high inter cluster distance for desirable traits and they can be used as parents in recombination breeding program to obtain wide variability and desirable segregants for drought stress as well as exploit hybrid vigour in hybrids..

*5.3.2 Cluster mean values*

Indirect selection for yield improvement in any crop depends upon the selection of yield attributing traits which have direct positive effect on yield. Selection for these traits should done in the clusters which show highest cluster mean values for that characters. Under drought stress condition selection for days to 50 per cent flowering and days to maturity can be done from cluster VII, for number or total tillers and productive tillers selection from cluster VI, highest mean value for number for spikelets per panicle, number of filled grains per panicle, yield per plant, seed filling per cent and test weight was observed in the cluster VIII. Chanbeni *et al.* (2012) reported highest mean for days to 50 per cent flowering in cluster IV, plant height in cluster VI, tillers per hill and panicles per hill in cluster III, panicle length, spikelets per panicle and test weight in cluster IX.

Under control condition selection for days to 50 per cent flowering, number of tillers per plant, plant height from cluster VIII, number of spikelets per panicle from cluster VII and highest seed filling per cent mean was recorded in cluster IV. So to improve particular trait and yield selection from these clusters is recommended.

*5.3.3Per cent contribution of characters towards divergence*

Among eleven characters studied filled grains per panicle (35.8%) contributed maximum towards divergence under drought followed by productive tillers per plant (25.34) and number of spikelets per panicle (11.39). under control condition days to 50 per cent flowering (44.64%) contributed maximum followed by test weight (18.37) and number of spikelets per panicle (10.54) under control condition. Chanbeni *et al.* (2012) and Aishwarya *et al.* (2014) have observed highest contribution by spikelets per panicle (40.95% and 64.04). Uday (2013) observed highest contribution by grain yield followed by number of spikelets per panicle and per cent spikelet fertility under both control and water stress condition.

## 5.4 Per cent difference in physiological parameters contributing to drought tolerance between stress and control condition

Lowest per cent difference for chlorophyll content and relative water content was recorded in genotypes Tonnur, Akkalu, Madras sanna, Sannavalya, Manjakaime, JGL 1798, Najarbad, Anagha, Gangadace. These lines can be selected for drought stress condition. Santhosh *et al.* (2015) observed that rice genotypes IR88964-24-2-1-4, IR88964-43-1-1-4, IR88964-11-2-2-3 and IR88964-B-127-CRA-5-1-1 had higher chlorophyll content in comparison to other genotypes and check varieties under drought stress condition. Mohan *et al.* (2000) stated that the chlorophyll content was an indication of stress tolerance capacity of plants, its high value under drought condition shows that the stress did not have much effect on chlorophyll content they were selected as tolerant plants.

The lowest per cent difference for proline content between control and drought stress was recorded in Doddiga, Madras sanna, JGL-1798, Sannavalya, Manjakaime, Gangadace, Najarbad and Anagha. Jabasingh and Saravanababu (2013) reported that accumulation of more proline during water stress adversely affect the growth and development and the biochemical contents of rice because of reduced photosynthesis in the leaves by the water stressed plants.

Sannavalya, Manjakaime, Gangadace, Najarbad,Madrassanna, JGL-1798 and Anagha are the common genotypes which possessed less difference with respect to both the traits chlorophyll content and proline content, these genotypes can be recommended under drought condition in order to obtain stable yields.

### *5.4.1 Drought tolerant genotypes*

Drought tolerant genotypes identified in the present study are Sannavaalya, Manjakaime, JGL-1796, Gangadace, Madras sanna and Najarbad. These lines possessed highest yield, number of productive tillers per plant, number of filled grains per panicle, seed filling per cent, test weight, chlorophyll content, root length, root volume, root to shoot ratio, relative water content and lowest leaf rolling under drought condition. They also exhibited less percent difference between drought and control condition for all the physiological and root traits. Hence, these lines are considered as drought tolerant genotypes. Abd Allaha *et al.* (2010) reported that, they identified 13 best entries under drought condition because, as these lines possessed useful traits associated with drought tolerance such as early maturity (drought escape mechanism), medium tillering ability, medium plant height, root depth, root thickness, root volume, root to shoot ratio, plasticity in leaf rolling and unrolling (drought avoidance mechanism), in addition to crop water use efficiency and water application efficiency.

## Conclusion

The present study was conducted to tackle the problem of climate change by identifying and providing diverse parents for drought tolerance breeding. The genotypes Sannavalya, Manjakaime, Gangadace, Najarbad, Madras sanna and JGL-1796 were genetically diverse and exhibit drought tolerance. These lines performed better under drought condition in terms of yield attributing traits like productive tillers per plant, number of spikelets per panicle, number of seeds per panicle, yield per plant and test weight.  Highest inter cluster distance was observed between cluster VIII and cluster IV parents for hybridization can be selected from these clusters.Highest chlorophyll content, root length, root volume, relative water content and lowest leaf rolling score was recorded in genotypes Sannavalya, Manjakaime, Gangadace, Najarbad, Madras sanna and JGL-1798. Hence, these lines showed better tolerance to drought.

## Future line of work

Based on the results obtained from the present investigation following future line of work can be suggested.

- The identified genotypes Sannavalya, Manjakaime, Gangadace, Najarbad, Madrassanna, JGL-1798 were genetically diverse and exhibit drought tolerance. These genotypescan further be subjected to molecular analysis to obtain the information of genetic distance among genotypes and analysis for the QTL's for drought and its related traits.
- Identified genotypes can be subjected to stability analysis in different locations in order to check their performance under drought conditions.
- The drought tolerant genotypes identified from the present study can be subjected to biochemical analysis in order to confirm their tolerance level.
- Diverse genotypes which grouped under different clusters can be used in recombination breeding to exploit hybrid vigour and selection of superior segregants for high yielding and drought tolerance.

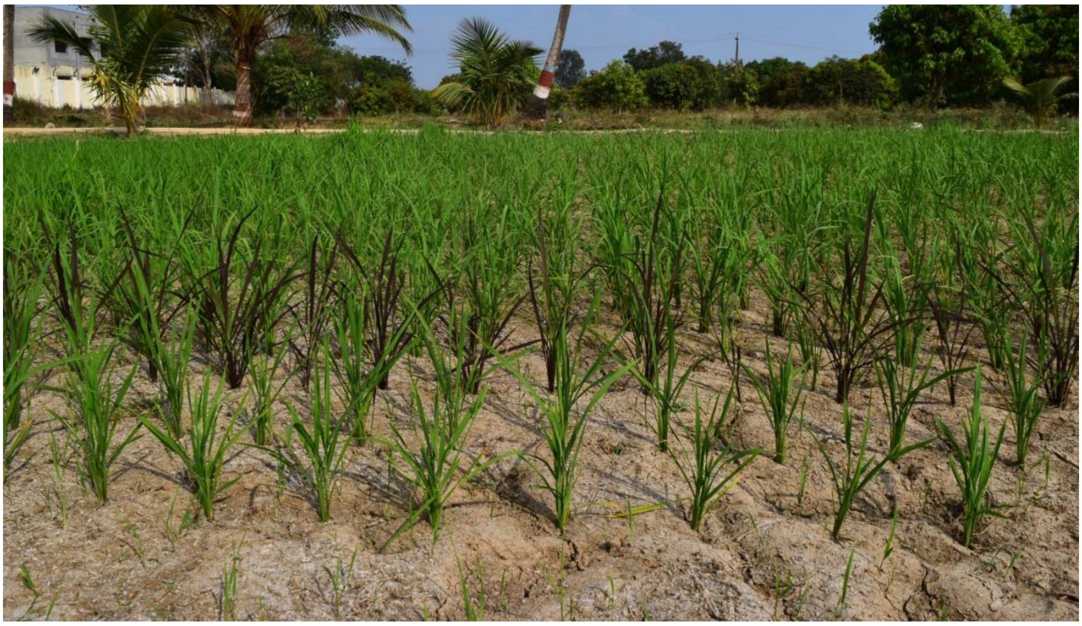

**Plate 1a: An overview of experimental plot at vegetative stage**

**Plate 1b: An overview of experimental plot at reproductive stage under drought condition**

**Plate 2: Root studies under PVC pipes of 49 genotypes of rice**

*Summary*

## VI SUMMARY

The present study aimed to assess the genetic diversity in local land races of rice with 49 genotypes including checks, available at Department of Genetics and Plant Breeding, UAHS, Shivamogga. The field experiment was conducted in the experimental plots of Department of Genetics and Plant Breeding, UAHS, Shivamogga. Root study was carried out in PVC pipes. The objectives was to assess genetic variability, heritability and genetic advance, association among yield and yield attributing characters, association between yield and physiological parameters and genetic divergence among the genotypes under drought stress and control condition.

The observations were recorded on days to 50 per cent flowering, days to maturity, number of total tillers per plant, number of productive tillers per plant, number of spikelets per panicle, number of filled grains per panicle, panicle length (cm), plant height (cm), seed filling per cent, test weight (gm), chlorophyll content (spad readings), leaf rolling, proline content, relative water content (%), root length (cm), shoot length (cm), root to shoot ratio, root volume and yield per plant (gm).

Analysis of variance exhibited significant difference among the genotypes to all the characters studied under both drought stress and control condition. Environmental influence was less on expression of characters as evidenced by narrow gap between PCV and GCV for majority of characters. A high range of variation, high GCV, PCV, with high heritability at broad sense coupled with high genetic advance average mean was recorded for days to 50 per cent flowering, number of productive tillers per plant, number of spikelets per panicle, number of filled grains per panicle, yield per plant, seed filling per cent and test weight under both drought stress and control condition.

The yield per plant was significantly and positively correlated with productive tillers per plant, number of spikelets per panicle, number of filled grains per panicle, seed filling per cent, test weight, chlorophyll content, relative water content, proline content, root length, root to shoot ratio and root volume under drought stress condition. Whereas under control condition days to 50 per cent flowering and seed filling per cent showed positive significant correlation with yield at phenotypic level. The traits; test weight, root length in drought and number of spikelets per panicle under control showed highest direct effect on yield per plant followed by seed filling per cent and days to 50 per cent flowering, proline content, relative water content and root volume.

The 49 rice genotypes in field experiment were grouped into eight clusters under both drought stress and control condition based on Mahalanobis' $D^2$statistics and Tocher method. The maximum number of genotypes were found in cluster V (13) followed by cluster VI (12) in drought stress and cluster VI (14) followed by cluster VII (10) under control condition. The intra cluster distance varied from 54.19 in cluster I to a maximum distance of 107.67 in cluster V under drought stress. Under control condition intra cluster distance varied from 51.60 in cluster II to a maximum distance of 70.41 in cluster IV. This shows the presence of diverse genotypes in different clusters. The maximum inter cluster distance was observed between cluster VIII and cluster IV in drought and between cluster VIII and cluster VII under control condition indicating high diversity among genotypes.

The selection and choice of parents mainly depends upon contribution of characters towards divergence. Among 11 characters studied number of filled grains per panicle under drought and days to 50 per cent flowering under control condition contributed maximum to diversity.

The genotypes Madras sanna, JGL-1798, Sannavaalya, Manjakaime, Gangadace, Najarbad can be utilized for further breeding program to obtain suitable varities for drought as these genotypes showed more number of productive tillers per plant, more number of filled grains per panicle, seed filling per cent, test weight, root length, root volume, less leaf rolling under drought condition than checks. They also exhibited less per cent difference between drought and control condition for physiological parameters chlorophyll content, proline content and relative water content. Higher yield per plant was also observed in these lines and their performance under drought stress was almost on par with the drought tolerant check Anagha.

# *References*

## VII REFERENCES

ABD ALLAH, A. A., AMMAR, M. H. AND BADAWI, A.T., 2010, Screening rice genotypes for drought resistance in Egypt. *J. Plant Breed. Crop Sci.,* **2**(7): 205-215.

AISHWARYA, S. R., SURESH, B, G. AND MAHENDRA, B., 2014, Genetic diversity of irrigated medium duration of rice genotypes suited for eastern plain zone of U.P. *IOSR J. Agric. Vet. Sci*., **7**(7): 42-45.

ANONYMOUS, 2016, Rice statistics.*http:www.indiastat.com* (verified 03 January, 2017)

AKRAM, H. M., ALI, A., SATTAR, A., REHMAN, H. S. U.AND BIBI, A., 2013,Impact of water deficit stress on various physiological and agronomic traits of three basmati rice (*Oryza sativa L.*) cultivars. *The J. Animal and Plant Sci.,* **23**(5):1415-1423.

ALEXANDER SARRIS., 2004, Rice in global markets. *Proceedings of the FAO rice conference.* 12-13 February, 2004, FAO, Rome (United Nations).

ALOK, K., RANGARE, N. R. AND VIDYAPATI, V., 2013, Study of genetic variability of Indian and Exotic rice germplasm in Allahabad agroclimate.*The Bioscan.,* **8**(4): 1445-1451.

AMELIA, H., ANDREW, J. C., TRISTRAM, C. B., ROLANDO, O. T. AND RACHID, S., 2012, Root attributes affecting water uptake of rice (*Oryzasativa*) under drought. *J. Exp. Bot.,* **63**(13): 4751-4763.

BATES, L. S., WALDREN, R. P. AND TEARE, I. D., 1973, Rapid determination of free proline for water- stress studies. *Plant and Soil*. **39**: 205-207.

BEENA, R., THANDAPANI, V. AND CHANDRABABU, R., 2012, Physio-morphological and biochemical characterization of selected recombinant inbred lines of rice for drought resistance. *Indian J. Plant Physiol.,* **17**(2): 189-193.

BHADRA, S.AND ROY, B., 2014, Genetic diversity analysis of rice (*Oryza sativa* L.) genotypes under aluminium toxic hydroponic culture.*J. Agric. Technol.,* **1**(2): 25-32.

BURTON, G. W. AND DEVANE, E. W., 1953, Estimating heritability in tall fescue (*Festuca arundiraceae*) from replicated clonal material. *Agron. J.,* **45**: 478-481.

CHANBENI, Y. O., LAL, G. M. AND PRASHANT, K. R., 2012, Studies on genetic diversity in Rice (*Oryza sativa*L.) .*J. Agric. Sci*., **8**(3):1059-1065.

CHANG, T. T., SOMRITH, B. AND O'TOOLE, J. C., 1979,Potential for improving drought resistance in rainfed lowland rice: Selected papers from the *1978Inter. Rice Res. Con.* IRRI. Philippines. Pp.149-164.

DWIVEDI, J. L., 2007, Role of roots in conferring drought tolerance in rice. Paper presented in: *Int. Symp. Root Bio. And MAS Strategies for Drought Resistance Improvement in Rice, Univ. Agric.Sci., Bangalore*. September 26-29, pp.14-15.

FANGJUN, F., XIAOYAN, X., XINBING, D., HANHUA, T., LIJUN LUO.AND HANWEI, M., 2012, Assessment of drought resistance among wild rice accessions using a protocol based on single-tiller propagation and PVC-tube cultivation. *Aust. J. Crop Sci.,* **6** (7):1204-1211.

FISHER, R. A. AND YATES, F., 1936, Statistical tables for biological, agricultural and medical research.*Oliver and Boyd*, London, pp.46-63.

GANA, A. S., 2011, Screening and resistance of traditional and improved cultivars of rice to drought stress at Badeggi, Niger State, Nigeria.*Agric. Biol. J. N. America.,* **2** (6): 1027-1031.

GANAPATHY, S., GANESH, S. K., SHANMUGASUNDARAM, P. AND CHANDRA, B, R., 2010,Studies on root traits for drought tolerance in rice (*Oryza sativa* L.) under controlled (PVC pipes) condition. *Electron. J. Plant Breed.,* **1**(4): 1016-1020.

GUIMARAES, C. M., ANDRIANO, P. D. C., LUIS, F. S., JAISON, P. AND DE. O., 2016, Drought tolerance in upland rice: Identification of genotypes and agronomic charectristics. *Acta Scientiarum*, **38** (2): 201-206**.**

HA, T. T. P., KHANG, T. D., MINHNGOC, T., XUAN, D. T., LANG, T. N. AND BUU, C. B., 2016, Path analysis for yield traits in $F_2$ generation and molecular approaches for breeding rice tolerant to drought and submergence. *Afr. J. Agric. Res*., **11**(26): 2329-2336.

ISLAM, M. R., FARUQUEI, M. A. B., BHUIYAN, M. A. R., BISWAS, P. S. AND SALAM, M. A., 2004, Genetic diversity in irrigated rice.*Pak. J. Biol. Sci.,* **7**(2): 226-229.

ISLAM, M. Z., KHALEQUZZAMAN, M., BASHAR, M. K., IVY, N. A., HAQUE, M. M. AND MIAN, A. K., 2016, Variability assessment of aromatic and fine rice germplasm in Bangladesh based on quantitative traits. *Bio. Med. Res. Int.,* pp.14.

JABASINGH, C. AND SARAVANA BABU.S., 2013, Proline content of *Oryza sativa* L. under water stress. *J. Academia and Industrial Res*., **2**(7): 442-445.

JIBOURI., 1958, Genetic variability and correlation studies in chillies. *Prog. Hort.,* **36**: 113-117.

JOHNSON, H. W., ROBINSON, H. F. AND COMSTOCK, R. E., 1955, Estimates of genetic and environmental variability in soybean, *Agron. J.,* **7**(7): 314-318.

KANBAR, A.,SHASHIDHAR, H. E.AND HITTALMANI, S., 2002, Mapping of QTL associated with root and related traits in DH population of rice (*Oryza sativa L*.). *Indian J. Genet.*, **62**(4): 287-290.

KANBAR, A., TOORCHI, M. AND SHASHIDHAR, H. E., 2009, Relationship between yield and root morphological characters in rainfed low land rice (*Oryza sativa L*.). *Cereal Res. Communication,* **37**(2): 261-268.

KUIXIAN, J., YANGYANG, W., WEINING, S., QIAOJUN, L.,HANWEI, M., SHIHUA, S. AND HUI CHEN., 2012, Drought-responsive mechanisms in rice genotypes with contrasting drought tolerance during reproductive stage. *J. Plant phyol*., **169**: 336-344.

KUMAR, S., DWIVEDI, S. K., SINGH, S. S., JHA, S. K., LEKSHMY, S., ELANCHEZHIAN, R., SINGH, O. N. AND BHATT, B.P., 2014, Identification of drought tolerant rice genotypes by analyzing drought tolerance indices and morpho -physiological traits. *SABRAO J. Breed. Gen.,* **46**(2): 217-230.

LENKA, D. AND MISHRA, B., 1973, Path coefficient analysis of yield in rice varieties.*Indian J. Agric. Sci.,* **43:** 376-379.

LUIS, B., GOMEZ-LUCIANO., CHING, H. H. AND CHIH, W. W., 2012, Proline accumulation role on drought-induced rice genotypes. *Conference paper*, National Pingtung Univ. Sci and Tech., Taiwan.

LUM, M. S., HANAFI, M. M., RAFFII, Y. M. AND AKMAR, A. S. N., 2014, Effect of drought stress on growth, proline and antioxidant enzyme activities of upland rice. *The J. Anim. plant Sci*., **24**(5): 1487-1493.

LUSH, J. L., 1945, Intra- sire correlation on regression of off- spring on dams as a method of estimating heritability of characters. *Proc. Am. Soc. Animal Prod.,* **33**: 292-301.

LUSH, J. L., 1949, Heritability of quantitative characters in farm animals.*Proc. 8$^{th}$ Congr. Genet. Heriditas,* pp : 35.

MAISURA. MUHAMAD, A. C., ISKANDAR, L., AHMAD, J. AND HIROSHI, E., 2014, Some physiological character responses of rice under drought conditions in a paddy system. *J. ISSAAS*., **20**(1):104-114.

MAHALANOBIS, P.C., 1936, A study on the generalized distance in statistics. *Proceedings of Nat. Inst. Sci. (Indian).*, **2**: 49-55.

MAHENDER. A., DASH, G. K., SWAIN. P. AND RAO, G. J. N., 2014, Physiological and molecular profiling of rice genotypes under drought stress. *Oryza*, **51**(1):12-24.

MANA KANO-NAKATA., YOSHIAKI INUKAI., LEN, J. W., JOEL, D. L. C., SIOPONGCO. AND AKIRA YAMAUCHI., 2011, Root development, water uptake, and shoot dry matter production under water deficit conditions in two CSSLs of rice: functional roles of root plasticity. *Plant Prod. Sci*., **14**(4): 307-317.

MANICKAVELU, A., NADARAJAN, N., GANESH. S, K., GANAMALAR, R. P. AND CHANDRA BABU, R., 2006, Drought tolerance in rice: Morphological and molecular genetic consideration. *Plant Growth Regul*., **50**: 121-138.

MANJAPPA., UDAY, G. AND SHAILAJA, H., 2014, Identification of drought tolerant and high yielding $F_2$ genotypes of rice under aerobic condition. *Oryza.,* **51**(4): 273-278.

MINA ABARSHAHR., BABAK RABIEI. AND HABIBOLLAH SAMIZADEH LAHIGI., 2011, Assessing genetic diversity of rice varieties under drought stress conditions. *Notulae Scientia Biologicae.,* **3**(1): 114-123.

MOHAN, M. M., LAXMI, N.S. AND IBRAHIM, S. M., 2000, Chlorophyll stability index (CSI): its impact on salt tolerance in rice. *Int. Rice Res. Notes,* **25**: 38-39.

MOSTAJERAN. A. AND RAHIMI-EICHI. V., 2009, Effects of drought stress on growth and yield of rice (*Oryza sativa*L.) cultivars and accumulation of proline and soluble sugars in sheath and blades of their different ages leaves. *American-Eurasian J. Agric. Environ. Sci.,* **5**(2): 264-272.

MUHAMMAD, A., MUHAMMAD, S. H., AMNA, A., MUHAMMAD, A., SANA, H.AND UROOJ.M., 2014,Screening of diverse germplasms for genetic studies of drought tolerance in rice (Oryza sativa L.). *Int. J. Cytology, Cytosystematics and Cytogenetics.,* **67**(4): 296-304.

NAVEEN, P. S., BANTILAN, M. C. S., KUMAR, A. A., JANILA, P. AND ABU WALI, R. H., 2011, Climate change impact in agriculture: vulnerability and adaptation concerns of semiarid tropics in Asia. *John Wiley and Sons Inc*., New York, pp: 107-130.

PANDEY, S., BHANDARI, H., SHARAN, R.., NAIK, D., TAUNK, N. K. AND SASTRI ASRAS., 2005, Economic costs of drought and rainfed rice farmers coping mechanisms in eastern India. Final project report. IRRI, Los Banos, Philippines.

PHAM, T. T. H., DO, T. K., PHUNG, T. T., LUONG, T. M., TRUONG, N. M ., NGUYEN, T. L., BUI, C. B. AND TRAN, D. X., 2015, Correlation among agro-morphological variation and genetic diversityof rice (*Oryza sativa* L.) under drought stress. *Int. Letters of Natural Sci.,* **58**: 42-53.

PHUNG, T. T. H., 2014, Physiological responses of rice seedlings under drought stress. *J. Sci. Devel*., **12**(5): 635-640.

PRICE, A. H., STEELE, K. A., GORHAM, J., BRIDGES,J. M., MOORE, B. J., EVANS, J. L., RICHARDSON, P. AND JONES, R. G. W., 2002,Upland rice grown in soil-filled chambers and exposed to contrasting water-deficit regimes I. root distribution, water use and plant water status. *Field Crop Res.*, **76**:11-24.

RAMANJANEYULU, A. V., GOURI SHANKAR, V., NEELIMA, T. L. AND SHASHIBHUSAHN, D., 2014, Genetic analysis of rice (*Oryza sativa*L.) genotypes under aerobic conditions on alfisols. *SABRAO J. Breed. Gen.,* **46**(1): 99-111.

RANAWAKE, A.L. AND HEWAGE, M. J., 2014, Correlation analysis of drought, Salinity and submergence tolerance in some traditional rice cultivars of Sri Lanka. *Int. J. Scientific and Res. Publications*., **4**(7): 2250-3153.

RAO, C. R., 1952, Advanced statistical methods in biometrical research. John Wiley and Sons Inc., New York, 236-272.

ROBINSON, H. E. AND COMSTOCK, R. S., 1949, Biometrical studies of yield in segregating population of Korean lespedeza.*Agron. J.,* **48**: 268-272.

ROEL, R. S., NONAWIN, B. L. AND LOIDA, M. P., 2012, Shoot and root development in rice (*Oryza sativa* L.) genotypes during progressive drying in soils with varying moisture regimes. *Philippine J. Crop Sci.,* **37**(2): 1-12.

ROEL, R. S., YOSHIAKI, I. AND AKIRA, Y., 2009, Dry matter production in relation to root plastic development, oxygen transport, and water uptake of rice under transient soil moisture stresses. *Plant Soil,* **9**: 8-25.

SANTOSH, K., DWIVEDI. S, K., HARIS. A. A., VED, P., MONDAL. S. AND SHISHIR, K. S., 2015, Screening and identification of rice genotypes for drought tolerance at reproductive stage under rainfed lowland condition. *J. Agri Search,* **2**(2): 105-111.

SANTOSH, K., DWIVEDI, S. K., SINGH, S. S., BHATT, B. P., PREMALATA MEHTA., ELANCHEZHIAN, R., SINGH, V. P. AND SINGH, O. N., 2014, Morpho-physiological traits associated with reproductive stage drought tolerance of rice (*Oryza sativa* L.) genotypes under rain-fed condition of eastern Indo-Gangetic plain. *Indian J. Plant Physiol*., **19**(2): 87-93.

SEDEEK, S. E. M., METWALLY, T. F., KAZUTOSHI, O.AND ABDELKHALIK, A. F., 2010, Genotypic variation of some Egyptian and upland rice genotypes in some physio-morphological traits and microsatellite DNA under drought condition.*J. Agric. Chem. and Biotech.,* **1**(3): 141-155.

SHIVASUBRAMANIAN, S. AND MENON, N., 1973, Heterosis and inbreeding depression in rice. *Madras Agric. J.,* **60**: 1134-1144.

SINGH, A.K. AND SINGH L., 2007, Role of thermal time in rice phenology. *Envi.Ecol.*, **25**(1): 46-49.

SINGH, R. K. AND CHAUDHARY, B. D., 1977, Biometrical Methods in Quantitative Genetic Analysis. *Kalyani Publishers*, New Delhi. Pp.215-218.

SRIDHAR, T. C., DUSHYANTHA, K. B.M., MANI, B. R. AND NISHANTH, G. K., 2016, Genetic diversity, variability and association analysis for yield traits in traditional rice (*Oryza sativa*L.) cultivars of southern Karnataka. *Green Farming.,* pp. 20-24.

SUMONTIP, B. AND PRAPAPORN, P., 2013, Selection of rice (*Oryza sativa*L.) cultivars tolerant to drought stress at the vegetative stage under field conditions. *Am. J. Plant Sci***., 4**: 1701-1708.

SURIYAN CHA-UM., SURAVOOT, Y. AND KANYARATT, S., 2010, Water deficit stress in the reproductive stage of four indica rice (*Oryza sativa*L.) genotypes. *Pak. J. Bot.,* **42**(5): 3387-3398.

THIPPESWAMY, S., CHANDRAMOHAN, Y., SRINIVAS, B. ANDPADMAJA, D., 2016, Selection of diverse parental lines for heterotic hybrid development in rice (*Oryza sativa*L.). *SABRAO J. Breed. Gen.,* **48**(3): 284-295.

TUHINA-KHATUN., MOHAMED, M. H., MOHD RAFII, Y., WONG, M. Y., FAEZAH, M. S. AND JANNATUL, F, 2015, Genetic variation, heritability, and diversity analysis of upland rice (*Oryza sativa* L.) genotypes based on quantitative traits. *BioMed.Res.Int.,* pp.7.

UDAY, K, H. R., 2013, Assessment of genetic diversity of traditional rice (*Oryza sativa* L.) genotypes for grain yield and its components under moisture stress. *M.Sc.(Agri) Thesis*, Univ. Agric. Sci., Bangalore.

WEATHERLEY, P.E., 1950, Studies in water relation of cotton plants. The field measurement of water deficit in leaves. *New Phytol.,* **49**: 81-87.

WRIGHT, S., 1921, Correlation and causation.*J. Agric. Res.*, **20**: 557-585.

ZAHARIEVA, M., GAULIN, E., HAVAUX, M., ACEVEDO, E. AND MONNEVEUX, P., 2001, Drought and heat responses in the wild wheat relative *Aegilops geniculate* Roth.*Crop Sci.,* **41**:1321-1329.

ZULQAMAIN, H., ABDUL, R., ASRAR, M., SALEEMUR, R., AFTAB, I., AAMIR, H., USMAN, S., MUHAMMAD, Y. N., SAMTA, Z., ZAHID, MA.AND KHALID, M., 2013, Comparison of associations among yield and yield components in rice (*Oryza sativa* L.) under simulated drought stress condition using multivariate statistics.*Int. J. Sci. and Engg. Res.,***4**(8): 2229-5518.

# *Appendices*

# VIII APPENDIX

## Appendix I: List of 49 local land races of rice taken for study

| Line No. | GENOTYPES | Line No. | GENOTYPES |
|---|---|---|---|
| 1 | MADRAS SANNA | 26 | BAIGAN MANJU |
| 2 | SELUM SANNA | 27 | MANJA KAIME |
| 3 | DELHI BOG BATTA | 28 | HONASU |
| 4 | NAVARA | 29 | DODDIGA |
| 5 | JGL 1798* | 30 | GILISALLE |
| 6 | RASAKADARI | 31 | RAJAKAIME |
| 7 | LAL KADE RICE | 32 | MALGUDISANNA |
| 8 | TONNUR | 33 | MOTTAIKAR |
| 9 | KADU VALAI | 34 | GANDHASALE |
| 10 | MORADHI | 35 | VELAIPONNI |
| 11 | AKKALU | 36 | AMBIMOHARI |
| 12 | DOPPA VAALYA | 37 | VIJAYNANDED |
| 13 | KANGALLI | 38 | GANGADACE |
| 14 | KARANGARAV | 39 | KATARU |
| 15 | KALLURANDIKAR | 40 | SHARAVATI KEMPAKKI |
| 16 | SANDUKAAR | 41 | KEMPUTADI |
| 17 | CHAMPAKALI | 42 | SANNABATHA |
| 18 | NAARIKELA | 43 | THOGARSI |
| 19 | KARURAI KALANJI | 44 | NAJARBAD |
| 20 | RAJAMANI | 45 | BETTADEYAN |
| 21 | SAMBAMA SANNA | 46 | KAGGA |
| 22 | SHASHTI | 47 | ANAGHA* |
| 23 | BANGLA RICE | 48 | JYOTI* |
| 24 | SANNAVALYA | 49 | POUSTIC 9* |
| 25 | HASUDI | | |

*** Improved lines / checks**

**Appendix II: Mean values of 49 land races of rice for yield and yield attributing traits under drought stress and control condition**

**Appendix IIa: Mean values for 11 traits of 49 rice genotypes under drought stress condition**

| Line No. | DFF | DM | TT | PT | SPP | FGPP | PL | PH | YPP | SFP | TW |
|---|---|---|---|---|---|---|---|---|---|---|---|
| **1** | 95.00 | 129.00 | 18.00 | 17.00 | 77.50 | 70.00 | 16.27 | 67.57 | 20.85 | 90.33 | 21.50 |
| **2** | 104.00 | 129.00 | 19.00 | 14.50 | 74.00 | 35.00 | 21.10 | 75.95 | 3.75 | 47.47 | 13.04 |
| **3** | 95.50 | 129.50 | 17.00 | 8.00 | 72.50 | 31.00 | 18.25 | 85.45 | 4.75 | 42.93 | 14.50 |
| **4** | 95.50 | 130.00 | 13.50 | 9.50 | 45.00 | 25.50 | 16.32 | 84.70 | 6.10 | 57.28 | 15.50 |
| **5** | 98.00 | 129.00 | 11.00 | 7.00 | 103.00 | 91.50 | 17.12 | 70.50 | 21.75 | 89.01 | 24.83 |
| **6** | 84.00 | 122.00 | 17.00 | 11.00 | 126.00 | 72.50 | 18.15 | 66.77 | 6.50 | 57.51 | 14.09 |
| **7** | 65.50 | 102.50 | 21.50 | 15.00 | 57.50 | 20.50 | 14.80 | 78.50 | 5.92 | 35.83 | 17.11 |
| **8** | 50.50 | 90.00 | 17.50 | 12.50 | 66.00 | 29.50 | 20.35 | 74.36 | 4.73 | 44.80 | 13.50 |
| **9** | 75.50 | 109.00 | 12.50 | 7.00 | 66.50 | 20.00 | 22.05 | 76.40 | 5.26 | 30.31 | 16.00 |
| **10** | 81.50 | 112.50 | 13.50 | 11.00 | 52.50 | 6.00 | 13.77 | 90.60 | 3.50 | 11.94 | 14.32 |
| **11** | 79.00 | 110.00 | 16.00 | 9.00 | 81.50 | 25.00 | 20.10 | 90.20 | 4.87 | 30.68 | 14.45 |
| **12** | 70.50 | 98.00 | 19.50 | 13.00 | 71.50 | 17.50 | 20.15 | 86.70 | 4.80 | 24.35 | 16.95 |
| **13** | 79.50 | 104.00 | 15.00 | 11.00 | 77.00 | 20.50 | 19.60 | 76.85 | 5.10 | 26.89 | 14.96 |
| **14** | 75.50 | 111.00 | 17.50 | 13.00 | 97.50 | 20.00 | 21.25 | 77.55 | 5.25 | 20.63 | 13.97 |
| **15** | 74.50 | 106.50 | 21.00 | 10.50 | 100.50 | 26.50 | 20.10 | 85.70 | 5.70 | 26.40 | 14.62 |
| **16** | 84.50 | 114.50 | 12.50 | 10.00 | 64.00 | 26.00 | 17.38 | 94.60 | 5.50 | 40.60 | 14.25 |
| **17** | 81.00 | 105.00 | 18.50 | 7.00 | 76.00 | 12.50 | 18.70 | 89.87 | 1.25 | 16.80 | 13.25 |
| **18** | 77.50 | 107.50 | 13.00 | 5.50 | 47.50 | 15.00 | 18.18 | 95.80 | 1.90 | 31.33 | 15.00 |
| **19** | 73.00 | 108.00 | 15.00 | 8.00 | 65.50 | 33.00 | 18.74 | 102.40 | 5.30 | 50.35 | 15.00 |
| **20** | 86.50 | 115.50 | 10.00 | 5.50 | 87.50 | 13.50 | 18.50 | 106.05 | 2.62 | 15.88 | 13.37 |
| **21** | 105.50 | 135.50 | 11.50 | 2.50 | 58.00 | 11.00 | 17.27 | 87.04 | 0.87 | 19.17 | 13.25 |
| **22** | 83.50 | 120.00 | 13.00 | 3.50 | 52.50 | 3.00 | 17.10 | 79.65 | 0.45 | 6.25 | 12.03 |
| **23** | 82.00 | 117.00 | 15.50 | 6.00 | 47.50 | 13.00 | 18.75 | 87.20 | 1.50 | 27.44 | 15.51 |
| **24** | 79.00 | 114.00 | 24.00 | 14.50 | 107.50 | 97.00 | 22.27 | 88.16 | 24.75 | 90.25 | 26.25 |

**Contd…..**

| Line No. | DFF | DM | TT | PT | SPP | FGPP | PL | PH | YPP | SFP | TW |
|---|---|---|---|---|---|---|---|---|---|---|---|
| **25** | 72.00 | 105.00 | 23.00 | 15.00 | 70.00 | 11.00 | 21.80 | 83.50 | 2.80 | 15.66 | 15.00 |
| **26** | 67.50 | 102.50 | 21.00 | 14.50 | 42.00 | 10.50 | 17.37 | 86.20 | 2.20 | 24.77 | 13.25 |
| **27** | 72.50 | 103.00 | 25.50 | 16.00 | 97.50 | 87.00 | 18.27 | 90.95 | 22.85 | 89.23 | 25.71 |
| **28** | 80.00 | 110.00 | 15.50 | 14.00 | 66.00 | 13.50 | 21.03 | 91.15 | 3.70 | 20.41 | 14.75 |
| **29** | 74.00 | 103.50 | 27.00 | 16.00 | 98.50 | 20.00 | 21.09 | 92.13 | 6.66 | 20.14 | 15.10 |
| **30** | 74.50 | 108.00 | 19.00 | 13.50 | 82.00 | 14.50 | 18.36 | 79.35 | 5.33 | 17.67 | 15.75 |
| **31** | 83.50 | 115.50 | 25.50 | 18.00 | 91.50 | 10.00 | 20.55 | 92.27 | 1.75 | 11.07 | 12.90 |
| **32** | 65.50 | 95.50 | 21.50 | 14.00 | 74.50 | 46.50 | 19.92 | 86.82 | 8.10 | 62.41 | 18.50 |
| **33** | 81.00 | 118.00 | 19.00 | 13.50 | 56.00 | 20.50 | 19.45 | 91.00 | 0.80 | 36.85 | 13.15 |
| **34** | 77.00 | 109.00 | 19.00 | 13.50 | 95.00 | 6.50 | 20.36 | 97.95 | 1.30 | 7.27 | 12.90 |
| **35** | 67.00 | 99.00 | 19.00 | 17.50 | 89.00 | 15.00 | 15.90 | 71.86 | 2.30 | 16.81 | 12.59 |
| **36** | 84.00 | 115.00 | 22.50 | 13.50 | 95.00 | 11.50 | 20.12 | 86.60 | 1.50 | 12.05 | 13.70 |
| **37** | 75.00 | 108.00 | 21.00 | 11.50 | 60.50 | 7.50 | 20.10 | 87.58 | 1.50 | 12.37 | 13.75 |
| **38** | 68.00 | 95.00 | 20.50 | 16.50 | 134.00 | 108.00 | 21.52 | 108.95 | 21.25 | 80.60 | 21.25 |
| **39** | 81.50 | 113.50 | 13.50 | 9.00 | 60.00 | 31.50 | 18.15 | 94.70 | 2.90 | 52.37 | 13.15 |
| **40** | 70.00 | 100.00 | 15.50 | 7.00 | 61.50 | 26.00 | 19.88 | 85.15 | 5.80 | 42.57 | 17.75 |
| **41** | 83.50 | 114.50 | 16.00 | 10.50 | 75.00 | 47.50 | 20.75 | 104.30 | 7.30 | 63.39 | 14.75 |
| **42** | 65.50 | 95.50 | 15.00 | 11.00 | 65.00 | 44.00 | 14.69 | 90.27 | 9.00 | 67.69 | 18.29 |
| **43** | 74.50 | 106.50 | 18.00 | 12.50 | 97.00 | 54.00 | 18.55 | 82.95 | 4.82 | 55.66 | 15.32 |
| **44** | 83.50 | 117.50 | 13.00 | 14.50 | 111.00 | 89.50 | 19.00 | 81.13 | 20.25 | 80.62 | 24.25 |
| **45** | 76.50 | 107.50 | 12.00 | 7.00 | 96.50 | 63.00 | 19.03 | 85.85 | 11.00 | 65.06 | 18.25 |
| **46** | 80.00 | 100.50 | 16.00 | 12.50 | 62.50 | 10.50 | 18.63 | 86.52 | 3.20 | 16.62 | 14.55 |
| **47** | 77.00 | 106.00 | 12.50 | 11.50 | 210.00 | 195.00 | 20.50 | 74.17 | 24.25 | 92.95 | 25.80 |
| **48** | 80.50 | 110.00 | 19.50 | 16.50 | 82.50 | 38.50 | 19.75 | 83.95 | 8.75 | 46.45 | 21.00 |
| **49** | 83.00 | 114.00 | 15.50 | 15.00 | 116.00 | 67.50 | 19.85 | 49.34 | 12.15 | 58.03 | 12.25 |

**Appendix IIb: Mean values for 11 traits of 49 rice genotypes under control condition**

| Line No. | DFF | DM | TT | PT | SPP | FGPP | PL | PH | YPP | SFP | TW |
|---|---|---|---|---|---|---|---|---|---|---|---|
| **1** | 100.00 | 135.00 | 19.00 | 17.50 | 97.50 | 94.00 | 22.75 | 87.15 | 37.00 | 96.44 | 23.25 |
| **2** | 95.50 | 135.00 | 14.50 | 14.00 | 106.00 | 103.00 | 23.70 | 113.50 | 44.50 | 97.13 | 20.75 |
| **3** | 108.00 | 136.00 | 13.00 | 12.00 | 112.50 | 106.00 | 21.83 | 97.50 | 47.50 | 94.19 | 18.75 |
| **4** | 94.50 | 129.50 | 24.00 | 22.50 | 86.00 | 72.00 | 20.80 | 98.93 | 35.87 | 83.70 | 19.25 |
| **5** | 100.00 | 131.50 | 10.00 | 10.00 | 117.50 | 110.00 | 22.65 | 94.75 | 44.75 | 93.62 | 26.75 |
| **6** | 86.50 | 121.00 | 17.00 | 16.00 | 177.50 | 166.00 | 21.08 | 86.50 | 48.75 | 93.51 | 24.25 |
| **7** | 77.00 | 110.00 | 15.50 | 15.50 | 97.50 | 90.00 | 17.51 | 93.66 | 24.62 | 92.34 | 19.11 |
| **8** | 80.00 | 116.50 | 18.00 | 15.50 | 102.50 | 96.00 | 24.25 | 139.15 | 35.62 | 97.47 | 15.75 |
| **9** | 94.00 | 129.00 | 14.00 | 13.00 | 102.50 | 94.50 | 24.33 | 130.50 | 34.62 | 92.28 | 18.17 |
| **10** | 93.00 | 129.00 | 11.50 | 11.50 | 81.00 | 74.00 | 25.91 | 127.66 | 31.50 | 91.77 | 17.82 |
| **11** | 113.50 | 147.00 | 14.50 | 14.00 | 96.50 | 91.00 | 28.83 | 123.44 | 35.37 | 94.34 | 16.22 |
| **12** | 99.00 | 131.00 | 13.00 | 13.00 | 87.50 | 84.50 | 21.66 | 119.60 | 47.75 | 96.63 | 20.87 |
| **13** | 104.00 | 145.00 | 13.00 | 12.00 | 96.50 | 89.00 | 22.57 | 127.00 | 28.53 | 92.31 | 18.96 |
| **14** | 97.00 | 131.50 | 19.50 | 16.50 | 107.50 | 101.50 | 24.61 | 121.50 | 41.88 | 94.39 | 20.22 |
| **15** | 99.00 | 133.50 | 21.50 | 20.00 | 122.50 | 113.50 | 24.31 | 125.77 | 38.00 | 92.71 | 21.00 |
| **16** | 87.00 | 125.50 | 12.50 | 12.50 | 117.50 | 106.50 | 20.40 | 114.25 | 38.50 | 90.82 | 18.80 |
| **17** | 94.00 | 125.50 | 13.00 | 12.50 | 102.50 | 97.00 | 19.44 | 103.77 | 38.45 | 94.42 | 21.75 |
| **18** | 110.50 | 147.00 | 13.50 | 13.00 | 86.50 | 80.00 | 19.49 | 123.10 | 45.00 | 92.57 | 18.25 |
| **19** | 94.00 | 127.00 | 12.50 | 12.50 | 102.50 | 96.50 | 25.70 | 132.60 | 37.00 | 94.17 | 22.50 |
| **20** | 95.00 | 125.50 | 11.00 | 10.00 | 97.50 | 93.50 | 23.03 | 118.09 | 36.40 | 95.84 | 24.75 |
| **21** | 109.00 | 133.50 | 13.00 | 11.50 | 100.00 | 91.50 | 23.81 | 131.87 | 46.62 | 91.40 | 18.87 |
| **22** | 105.50 | 141.50 | 14.00 | 12.50 | 82.50 | 73.00 | 23.08 | 113.83 | 36.87 | 88.67 | 19.32 |
| **23** | 98.00 | 130.00 | 11.00 | 10.00 | 86.50 | 79.00 | 23.60 | 99.87 | 37.62 | 91.25 | 22.08 |
| **24** | 90.00 | 119.00 | 15.50 | 15.50 | 120.00 | 110.50 | 22.15 | 127.62 | 35.12 | 91.85 | 26.25 |
| **25** | 112.00 | 149.50 | 15.00 | 15.00 | 95.00 | 89.00 | 21.16 | 130.06 | 36.50 | 93.68 | 17.15 |
| **26** | 91.00 | 119.50 | 16.50 | 16.00 | 79.50 | 70.00 | 23.58 | 112.85 | 31.39 | 88.33 | 20.25 |
| **27** | 84.00 | 122.50 | 19.00 | 19.00 | 90.00 | 85.50 | 23.92 | 138.00 | 37.09 | 95.01 | 25.71 |

**Contd….**

| Line No. | DFF | DM | TT | PT | SPP | FGPP | PL | PH | YPP | SFP | TW |
|---|---|---|---|---|---|---|---|---|---|---|---|
| **28** | 103.00 | 139.50 | 19.50 | 16.50 | 87.00 | 82.00 | 21.77 | 124.91 | 39.00 | 94.21 | 16.97 |
| **29** | 80.00 | 113.50 | 23.50 | 22.50 | 129.00 | 123.00 | 22.13 | 119.91 | 48.00 | 95.34 | 18.52 |
| **30** | 92.00 | 125.00 | 11.00 | 11.00 | 99.00 | 94.00 | 23.89 | 102.06 | 45.05 | 94.95 | 15.75 |
| **31** | 94.00 | 128.00 | 12.50 | 12.50 | 108.00 | 95.00 | 19.35 | 98.42 | 46.22 | 87.60 | 22.78 |
| **32** | 90.00 | 120.00 | 19.00 | 18.00 | 94.00 | 86.00 | 23.70 | 102.87 | 35.37 | 91.54 | 22.70 |
| **33** | 84.00 | 122.00 | 10.50 | 9.50 | 81.50 | 73.00 | 21.31 | 120.11 | 31.15 | 89.57 | 23.15 |
| **34** | 97.00 | 134.00 | 15.00 | 15.00 | 109.00 | 100.50 | 21.10 | 107.28 | 33.43 | 91.70 | 22.90 |
| **35** | 109.00 | 140.00 | 14.00 | 13.50 | 122.50 | 109.50 | 18.50 | 106.30 | 39.98 | 88.99 | 18.92 |
| **36** | 95.50 | 130.00 | 12.50 | 10.00 | 115.00 | 104.00 | 20.12 | 113.58 | 30.62 | 89.20 | 18.20 |
| **37** | 120.00 | 146.00 | 20.00 | 20.00 | 89.00 | 84.00 | 20.12 | 120.43 | 47.50 | 94.21 | 25.00 |
| **38** | 87.50 | 130.00 | 13.50 | 12.50 | 155.00 | 139.50 | 20.52 | 119.55 | 34.50 | 89.30 | 22.00 |
| **39** | 102.00 | 142.00 | 14.00 | 12.50 | 71.50 | 64.00 | 20.02 | 120.12 | 38.95 | 88.72 | 23.15 |
| **40** | 85.00 | 120.00 | 13.00 | 12.00 | 86.50 | 78.00 | 20.68 | 107.98 | 32.95 | 89.44 | 21.75 |
| **41** | 86.00 | 123.00 | 12.50 | 11.00 | 84.00 | 75.00 | 21.22 | 103.04 | 38.10 | 88.88 | 18.75 |
| **42** | 95.00 | 125.00 | 12.50 | 12.50 | 91.00 | 81.00 | 19.52 | 100.17 | 37.87 | 88.75 | 20.50 |
| **43** | 93.00 | 129.50 | 12.50 | 11.50 | 102.50 | 93.00 | 20.03 | 106.41 | 47.12 | 90.35 | 20.50 |
| **44** | 91.50 | 122.50 | 11.50 | 11.50 | 111.00 | 100.50 | 21.52 | 99.30 | 33.85 | 90.29 | 25.75 |
| **45** | 90.00 | 125.50 | 13.50 | 13.00 | 116.50 | 107.50 | 21.36 | 108.10 | 31.55 | 93.15 | 23.50 |
| **46** | 97.00 | 133.00 | 11.00 | 11.00 | 86.50 | 79.50 | 20.90 | 122.50 | 42.31 | 92.50 | 19.05 |
| **47** | 81.00 | 113.50 | 12.00 | 11.50 | 245.00 | 225.00 | 24.00 | 100.50 | 40.53 | 91.91 | 25.75 |
| **48** | 90.00 | 129.50 | 16.50 | 16.50 | 190.00 | 176.50 | 20.50 | 82.50 | 34.25 | 92.91 | 23.50 |
| **49** | 80.00 | 115.00 | 19.00 | 18.50 | 145.00 | 138.50 | 20.75 | 77.50 | 39.37 | 95.57 | 21.75 |

Where,

DFF: days to 50 % flowering
PT: No. of productive tillers per plant
PH: Plant height (cm)
DM: Days to maturity
SPP: No. of spikelet's per panicle
YPP: Yield per plant (g)
TT: No. of tillers per plant
FGPP: Filled grains per panicle
SFP: Seed filling per cent
PT: No. of productive tillers per plant
PL: Panicle length (cm)
TW: Test weight (g)

**Appendix III: Mean values of 49 land races of rice for physiological parameters under drought stress and control condition**

**Appendix IIIa: Mean values for physiological traits of 49 rice genotypes under drought stress condition**

| Line No. | SPAD | RWC (%) | Proline | Leaf rolling | Root length (cm) | Shoot length (cm) | Root/Shoot | Root volume (ml) |
|---|---|---|---|---|---|---|---|---|
| **1** | 14.40 | 78.50 | 17.04 | 4 | 27.00 | 45.00 | 0.60 | 15.00 |
| **2** | 10.00 | 61.14 | 18.66 | 6 | 21.00 | 42.60 | 0.49 | 10.00 |
| **3** | 9.00 | 58.09 | 24.50 | 7 | 20.00 | 30.00 | 0.67 | 11.00 |
| **4** | 12.00 | 58.40 | 16.16 | 7 | 19.50 | 51.50 | 0.38 | 10.00 |
| **5** | 13.00 | 68.45 | 19.35 | 4 | 30.00 | 50.00 | 0.60 | 16.00 |
| **6** | 10.00 | 45.15 | 21.56 | 6 | 22.50 | 49.50 | 0.45 | 13.20 |
| **7** | 8.00 | 59.15 | 39.80 | 6 | 21.00 | 38.00 | 0.55 | 10.50 |
| **8** | 13.20 | 55.71 | 34.56 | 5 | 23.50 | 58.60 | 0.40 | 11.50 |
| **9** | 8.10 | 62.19 | 33.96 | 5 | 24.00 | 60.20 | 0.40 | 9.50 |
| **10** | 11.90 | 46.55 | 21.25 | 7 | 20.00 | 64.50 | 0.31 | 10.00 |
| **11** | 9.30 | 58.54 | 23.15 | 7 | 21.50 | 54.30 | 0.40 | 10.50 |
| **12** | 11.80 | 57.54 | 26.58 | 7 | 19.65 | 51.60 | 0.38 | 12.50 |
| **13** | 11.10 | 64.94 | 25.54 | 7 | 21.00 | 38.50 | 0.55 | 10.00 |
| **14** | 11.80 | 55.55 | 22.54 | 6 | 22.00 | 38.00 | 0.58 | 9.00 |
| **15** | 8.20 | 50.09 | 38.57 | 5 | 22.20 | 49.80 | 0.45 | 8.60 |
| **16** | 11.80 | 56.05 | 24.07 | 7 | 21.00 | 52.50 | 0.40 | 9.50 |
| **17** | 11.70 | 58.15 | 21.56 | 9 | 16.00 | 57.00 | 0.28 | 4.00 |
| **18** | 8.60 | 63.63 | 25.93 | 9 | 12.00 | 59.50 | 0.20 | 5.00 |
| **19** | 8.00 | 65.50 | 24.13 | 7 | 20.00 | 62.80 | 0.32 | 10.50 |
| **20** | 9.10 | 51.28 | 36.00 | 9 | 17.00 | 75.50 | 0.23 | 9.50 |
| **21** | 10.00 | 58.74 | 21.15 | 9 | 13.50 | 58.20 | 0.23 | 4.50 |
| **22** | 8.50 | 50.76 | 24.33 | 9 | 12.00 | 46.50 | 0.26 | 8.50 |
| **23** | 11.00 | 45.39 | 19.56 | 7 | 13.00 | 42.50 | 0.31 | 8.00 |
| **24** | 15.20 | 78.28 | 18.56 | 4 | 36.00 | 55.50 | 0.65 | 17.00 |
| **25** | 6.90 | 51.40 | 21.92 | 8 | 20.50 | 50.20 | 0.41 | 11.50 |

**Contd….**

| Line No. | SPAD | RWC (%) | Proline | Leaf rolling | Root length (cm) | Shoot length (cm) | Root/Shoot | Root volume (ml) |
|---|---|---|---|---|---|---|---|---|
| **26** | 12.00 | 59.55 | 21.04 | 7 | 24.80 | 41.50 | 0.60 | 11.00 |
| **27** | 14.00 | 72.30 | 17.25 | 4 | 35.00 | 54.60 | 0.64 | 16.00 |
| **28** | 9.15 | 53.69 | 34.56 | 7 | 22.30 | 51.50 | 0.43 | 10.00 |
| **29** | 7.10 | 53.79 | 17.04 | 7 | 23.80 | 40.50 | 0.59 | 12.00 |
| **30** | 11.00 | 59.76 | 18.95 | 5 | 23.20 | 61.80 | 0.38 | 9.00 |
| **31** | 10.00 | 52.60 | 19.56 | 9 | 16.00 | 58.50 | 0.27 | 6.50 |
| **32** | 11.15 | 55.20 | 20.15 | 9 | 19.00 | 45.50 | 0.42 | 8.00 |
| **33** | 9.10 | 48.35 | 21.93 | 9 | 10.00 | 52.80 | 0.19 | 7.20 |
| **34** | 8.20 | 48.35 | 19.58 | 6 | 12.00 | 60.00 | 0.20 | 5.80 |
| **35** | 9.20 | 37.16 | 18.65 | 6 | 19.00 | 44.50 | 0.43 | 7.00 |
| **36** | 7.50 | 42.50 | 21.25 | 9 | 16.00 | 63.50 | 0.25 | 8.00 |
| **37** | 10.00 | 49.86 | 22.13 | 9 | 13.00 | 53.50 | 0.24 | 7.50 |
| **38** | 14.20 | 83.06 | 20.25 | 5 | 30.20 | 52.50 | 0.58 | 19.00 |
| **39** | 12.10 | 50.60 | 22.54 | 8 | 20.00 | 53.50 | 0.37 | 9.50 |
| **40** | 9.70 | 46.65 | 24.56 | 7 | 21.20 | 45.50 | 0.47 | 10.00 |
| **41** | 8.50 | 42.05 | 26.54 | 6 | 20.00 | 40.50 | 0.49 | 9.00 |
| **42** | 8.20 | 48.15 | 26.52 | 8 | 16.80 | 41.50 | 0.40 | 8.50 |
| **43** | 13.20 | 47.00 | 24.13 | 6 | 13.00 | 50.00 | 0.26 | 8.00 |
| **44** | 16.12 | 76.21 | 19.35 | 5 | 28.00 | 58.50 | 0.48 | 16.50 |
| **45** | 8.00 | 45.35 | 37.15 | 7 | 18.50 | 61.50 | 0.30 | 10.20 |
| **46** | 11.90 | 48.51 | 19.54 | 7 | 19.20 | 44.60 | 0.43 | 9.60 |
| **47** | 17.54 | 74.23 | 18.35 | 4 | 40.50 | 43.50 | 0.93 | 18.00 |
| **48** | 6.90 | 52.15 | 21.25 | 8 | 18.20 | 41.20 | 0.44 | 7.00 |
| **49** | 11.60 | 51.88 | 20.56 | 8 | 21.20 | 44.00 | 0.48 | 8.50 |

**Appendix IIIb: Mean values for physiological traits of 49 rice genotypes under control condition**

| Line No. | SPAD | RWC (%) | Proline | Leaf rolling | Root length (cm) | Shoot length (cm) | Root/Shoot | Root volume (ml) |
|---|---|---|---|---|---|---|---|---|
| **1** | 15.00 | 82.24 | 12.65 | 0 | 18.00 | 59.00 | 0.31 | 8.00 |
| **2** | 14.40 | 85.02 | 13.15 | 1 | 16.00 | 56.00 | 0.29 | 7.25 |
| **3** | 14.00 | 86.50 | 14.65 | 1 | 16.00 | 38.00 | 0.42 | 6.00 |
| **4** | 14.80 | 80.99 | 11.25 | 1 | 14.50 | 58.00 | 0.25 | 5.50 |
| **5** | 14.00 | 72.94 | 14.15 | 0 | 19.50 | 63.00 | 0.31 | 8.50 |
| **6** | 15.50 | 80.25 | 14.25 | 0 | 16.50 | 60.00 | 0.28 | 8.00 |
| **7** | 10.70 | 80.94 | 20.15 | 1 | 17.20 | 45.00 | 0.38 | 6.00 |
| **8** | 13.40 | 90.84 | 18.00 | 0 | 15.80 | 70.00 | 0.23 | 6.80 |
| **9** | 9.80 | 87.66 | 17.45 | 0 | 16.80 | 68.00 | 0.25 | 7.00 |
| **10** | 17.70 | 80.25 | 12.50 | 0 | 18.00 | 74.00 | 0.24 | 6.50 |
| **11** | 9.60 | 86.22 | 12.56 | 1 | 19.00 | 59.00 | 0.32 | 9.00 |
| **12** | 15.30 | 80.22 | 14.25 | 0 | 18.50 | 60.00 | 0.31 | 9.00 |
| **13** | 18.20 | 87.66 | 14.56 | 0 | 17.90 | 45.00 | 0.40 | 7.00 |
| **14** | 15.30 | 85.87 | 13.00 | 0 | 16.50 | 40.50 | 0.41 | 5.00 |
| **15** | 12.80 | 78.05 | 10.00 | 1 | 15.50 | 58.50 | 0.26 | 5.00 |
| **16** | 14.50 | 81.62 | 13.15 | 1 | 20.00 | 60.00 | 0.33 | 8.00 |
| **17** | 18.00 | 82.70 | 15.15 | 1 | 19.50 | 61.50 | 0.32 | 6.00 |
| **18** | 15.20 | 87.63 | 14.52 | 1 | 18.00 | 65.54 | 0.27 | 7.00 |
| **19** | 12.40 | 82.27 | 13.56 | 0 | 17.60 | 75.00 | 0.23 | 9.00 |
| **20** | 14.80 | 82.50 | 18.54 | 0 | 16.00 | 80.00 | 0.20 | 6.00 |
| **21** | 16.50 | 88.15 | 13.52 | 1 | 16.00 | 65.00 | 0.25 | 5.80 |
| **22** | 15.80 | 78.62 | 14.54 | 0 | 14.80 | 55.50 | 0.27 | 9.60 |
| **23** | 18.00 | 80.00 | 12.34 | 0 | 17.00 | 48.50 | 0.35 | 6.50 |
| **24** | 16.00 | 83.70 | 14.15 | 0 | 23.00 | 60.20 | 0.38 | 9.20 |
| **25** | 13.50 | 79.37 | 12.14 | 1 | 20.00 | 57.30 | 0.35 | 10.00 |
| **26** | 15.80 | 88.99 | 12.34 | 1 | 19.50 | 48.90 | 0.40 | 6.00 |
| **27** | 14.80 | 76.25 | 12.56 | 0 | 21.00 | 58.60 | 0.36 | 8.60 |

**Contd…..**

| Line No. | SPAD | RWC (%) | Proline | Leaf rolling | Root length(cm) | Shoot length(cm) | Root/Shoot | Root volume (ml) |
|---|---|---|---|---|---|---|---|---|
| **28** | 16.50 | 82.80 | 17.51 | 1 | 17.00 | 60.50 | 0.28 | 6.00 |
| **29** | 12.50 | 82.50 | 14.51 | 1 | 16.80 | 45.50 | 0.37 | 9.00 |
| **30** | 18.00 | 78.42 | 11.15 | 0 | 15.90 | 70.80 | 0.22 | 5.00 |
| **31** | 16.80 | 82.54 | 12.25 | 1 | 18.00 | 65.50 | 0.27 | 7.00 |
| **32** | 18.20 | 85.32 | 12.56 | 1 | 16.00 | 58.50 | 0.27 | 5.00 |
| **33** | 16.50 | 85.79 | 12.15 | 0 | 9.00 | 65.00 | 0.14 | 8.00 |
| **34** | 15.80 | 87.67 | 13.12 | 1 | 12.50 | 59.00 | 0.21 | 4.80 |
| **35** | 15.70 | 82.52 | 14.13 | 0 | 18.50 | 52.30 | 0.35 | 5.00 |
| **36** | 14.80 | 82.96 | 15.15 | 0 | 15.00 | 74.00 | 0.20 | 5.80 |
| **37** | 16.50 | 81.80 | 14.56 | 0 | 19.00 | 62.00 | 0.31 | 6.00 |
| **38** | 15.50 | 85.15 | 14.56 | 0 | 20.00 | 59.00 | 0.34 | 10.20 |
| **39** | 15.70 | 80.37 | 13.54 | 1 | 16.00 | 62.50 | 0.26 | 5.60 |
| **40** | 14.20 | 85.51 | 14.56 | 1 | 15.50 | 58.50 | 0.26 | 8.00 |
| **41** | 15.70 | 82.15 | 14.50 | 1 | 17.20 | 49.60 | 0.35 | 5.00 |
| **42** | 13.00 | 78.80 | 16.16 | 0 | 13.00 | 52.60 | 0.25 | 5.00 |
| **43** | 18.00 | 82.50 | 14.54 | 0 | 12.00 | 55.30 | 0.22 | 10.00 |
| **44** | 17.45 | 79.52 | 14.15 | 0 | 18.60 | 70.00 | 0.27 | 9.00 |
| **45** | 14.40 | 82.00 | 15.58 | 1 | 14.20 | 69.50 | 0.20 | 6.80 |
| **46** | 15.50 | 80.00 | 12.13 | 0 | 15.00 | 54.00 | 0.28 | 5.50 |
| **47** | 19.00 | 85.00 | 13.15 | 0 | 25.00 | 50.00 | 0.50 | 10.00 |
| **48** | 11.00 | 84.56 | 12.15 | 1 | 15.50 | 53.50 | 0.29 | 5.80 |
| **49** | 15.80 | 80.50 | 13.25 | 1 | 16.50 | 45.00 | 0.37 | 5.00 |