GENETIC EVALUATION OF F_2 GENERATION FOR YIELD AND WATER STRESS TOLEANCE IN UPLAND RICE

by

IVY MARY RAJAN
(2016-11-032)

THESIS
Submitted in partial fulfilment of the requirements for the degree of

MASTER OF SCIENCE IN AGRICULTURE

Faculty of Agriculture
Kerala Agricultural University

DEPARTMENT OF PLANT BREEDING AND GENETICS
COLLEGE OF AGRICULTURE
VELLAYANI, THIRUVANANTHAPURAM -695522
KERALA, INDIA

2018

DECLARATION

I, hereby declare that this thesis entitled **"GENETIC EVALUATION OF F_2 GENERATION FOR YIELD AND WATER STRESS TOLERANCE IN UPLAND RICE"** is a bonafide record of research work done by me during the course of research and the thesis has not previously formed the basis for the award to me of any degree, diploma, associateship, fellowship or other similar title, of any other University or Society.

Ivy Mary Rajan

Vellayani,

Date: 10.08.2018

Ivy Mary Rajan

(2016 -11-032)

CERTIFICATE

Certified that this thesis entitled **"GENETIC EVALUATION OF F_2 GENERATION FOR YIELD AND WATER STRESS TOLERANCE IN UPLAND RICE"** is a record of research work done independently by Ms. Ivy Mary Rajan under my guidance and supervision and that it has not previously formed the basis for the award of any degree, diploma, fellowship or associateship to her.

Vellayani,

Date: 10-08-2018

Dr. C. Lekha Rani

(Major Advisor, Advisory Committee)

Professor

Dept. of Plant Breeding and Genetics

College of Agriculture, Vellayani

CERTIFICATE

We, the undersigned members of the advisory committee of Ms. Ivy Mary Rajan a candidate for the degree of **Master of Science in Agriculture** with major in Plant Breeding and Genetics, agree that the thesis **"GENETIC EVALUATION OF F_2 GENERATION FOR YIELD AND WATER STRESS TOLERANCE IN UPLAND RICE"** may be submitted by Ms. Ivy Mary Rajan, in partial fulfilment of the requirement for the degree.

10/8/18

Dr. C. Lekha Rani
Professor
Department of Plant Breeding and Genetics
College of Agriculture, Vellayani
Thiruvananthapuram – 695522

10/8/18

Dr. Roy Stephen
Professor
Dept. of Plant Physiology
College of Agriculture, Vellayani
Thiruvananthapuram - 695522

Aryak 10/8/18

Dr. Arya ~~K.~~
Professor and Head
Department of Plant Breeding and Genetics
College of Agriculture, Vellayani
Thiruvananthapuram – 695522

Dr. Vijayaraghava Kumar
Professor (RC) and Head
Department of Agricultural Statistics
College of Agriculture, Vellayani
Thiruvananthapuram – 695522

10/8/18

Jayalekshmy.V.G 10/8/18

Dr. V.G. Jayalekshmy
Professor
Department of Plant Breeding and Genetics
College of Agriculture, Vellayani
Thiruvananthapuram – 695522

N. 10/8/18

External Examiner

PROFESSOR AND HEAD
AGRICULTURAL RESEARCH STATION
THIRUPATHISARAM - 629 901

CONTENTS

LIST OF TABLES

6

39(b)	Mean, Standard Error (mean), Range, Skewness and Kurtosis values of frequency distribution graphs for six characters in Vaishak x Harsha	76
39(c)	Mean, Standard Error (mean), Range, Skewness and Kurtosis values of frequency distribution graphs for six characters in Thottacheera x Harsha	77

LIST OF FIGURES

LIST OF PLATES

LIST OF ABBREVIATIONS AND SYMBOLS USED

%	Per cent
^0C	Degree Celsius
BSA	Bovine Serum Albumin
cm	Centi meter
DMSO	Dimethyl sulphoxide
DRR	Directorate of Rice Research
Evapn.	Evaporation
F_1	First filial generation
F_2	Second filial generation
FAO	Food and Agricultural Organisation
Fig.	Figure
g	Gram
gca	General combining ability
IRRI	International Rice Research Institute
KAU	Kerala Agricultural University
m	Meter
M	Molar
mg g^{-1}	Milligram per gram
mm	Mllimeter
ml	Millilitre

15

No.	Number
OD	Optical density
Panicle^{-1}	Per panicle
Plant^{-1}	Per plant
RBD	Randomised Block Design
S. E	Standard Error
sca	Specific combining ability
Sl.	Serial
Tiller^{-1}	Per tiller
var.	Variety
viz.	Namely

Acknowledgement

With immense pleasure, I would like to express my sincere gratitude to my major advisor **Dr.C. Lekha Rani** *, Professor, Department of Plant Breeding and Genetics for the constructive guidance, constant inspiration, abundant encouragement, kind treatment, critical scrutiny of the manuscript and valuable suggestions which render me to accomplish the research work successfully. I extend my sincere gratitude for providing a stress free situation by the open minded approach and for the care and affection bestowed on me throughout the study period.*

I convey my heartfelt gratitude to **Dr. Arya K**, *Professor and Head, Department of Plant Breeding and Genetics, for the unceasing encouragement, valuable advices and whole hearted approach right from the beginning, which helped me in the successful completion of the thesis.*

I extend my sincere gratefulness to Dr. V. G. **Jayalekshmy**, *Professor Department of f Plant Breeding and Genetics, for the valuable suggestions, technical advices that helped me with the the research work.*

I am extremely thankful to **Dr. Roy Stephen**, *professor, Department of Plant Physiology for the unstinting support, suggestions and passionate approach rendered during the period of research work.*

I wish to extend my sincere gratitude to **Dr. Vijayaraghavakumar,** *Professor and Head, Department of Agricultural Statistics, for the timely advice and statistical interpretation of the experiment data.*

I am deeply grateful to the teachers of Plant Breeding and Genetics, **Dr. Beena Thomas** *and* **Dr. Mareen Abraham**. *for generous support, continues and timely advice, constructive criticisms and constant encouragement rendered to me during the course of my study and research work.*

*I owe my deepest gratitude to my batch mates **Nayana Jyothibas**, **Arun Chacko**, and **Shahiba A. M.**, whose cooperation, love, support and affection helped me through many hardships. Without their persistent help and care, this would not have been possible.*

*Words are inadequate to express my thanks to **Stephy M.A**, **Lekshmi S.** , **Geethu Jacob**, **Muhsina A.** , **Arya V.C** for their unbound love and bighearted support. I express my sincere thanks to my senior **Patil Kranthikumar Haunsajiraorions**, whose thesis was very helpful as a reference for the successful completion of my work.*

*My pleasure to express my special thanks to **Sini chechi**, **sheeba chechi**, **Beena chechi** and **Saji chettan** for their sincere cooperation and kindly approach offered during the field work.*

*I am beholden beyond words to express my indebtedness to my **Pappa**, **Amma** and **Abey**, for their unconditional love, sacrifices and support bestowed on me during my hard periods, without which I would not have completed this research.*

*Above all, I believe it is the unbound love and Blessings of **God**, which is the prime factor that led to the successful completion of my entire work. I humbly bow my head before that almighty for the numberless blessings that he shower upon my life.*

Ivy Mary Rajan

Introduction

1. INTRODUCTION

Rice (*Oryza sativa* L.) as a cereal grain, is the most widely consumed staple food feeding more than 3.5 billion people worldwide (Muthayya *et al.*, 2014). Rice is the world's second most important cereal crop following maize. It is grown in almost all the continents occupying 158.8 million hectare area and producing 501.2 million tonnes. More than 90 percent of rice is produced and consumed in south and south-east Asia with China and India leading the way (FAO,2017).

Rice, being semi-aquatic, is commonly grown in irrigated or lowland systems. Globally, 18.5 million hectare of rice is grown under rainfed lowlands (Haefele *et al.*, 2014). In Asia, more than 50 percent of all water used for irrigation is expended on rice. Being an extravagant consumer of water, rice uses around 5,000 l of fresh water to produce 1 kg of grain (Kahani and Hittalmani, 2015). Shrinking arable land and diminishing water resources have resulted in a switching over to upland rice cultivation. Upland rice accounts for 12 percent of global rice production area where drought at any stage of crop growth ultimately reduces the grain yield. It is generally the lowest yielding rice ecosystem.

Rice production in India holds a major share of national economy. Our country occupies first position in area and second position in production of rice. Rice occupies an area of 4.92 million hectare and has a production of 1.59 million tonnes in India (FAO, 2016). Being a tropical plant, it flourishes well in hot and humid climate. Rice is mainly grown in those areas which receive heavy annual rainfall and hence it is fundamentally a kharif crop in India. FAO's forecast for world cereal output for the year 2018 is expected to be around 2,586 million tonnes (including rice in milled terms) which is 64.5 million tonnes (2.4 percentage) less than the record output in 2017 (FAO,2018).

According to Koppen's climatic classification, Kerala's climate is tropical monsoon and tropical savannah (Koppen, 1918). The state normally experiences heavy seasonal rainfall and hot summer. More than 80 percent of Kerala's annual rainfall is contributed by south- west monsoon. Kerala receives an annual rainfall of around 3,107 mm.

There are three main rice growing seasons in the state: (a) Virippu season, which starts in April-May and extends upto September-October; (b) Mundakan season which starts in September-October and extends upto December-January; and (c) Puncha season, which starts in December-January and extends upto March-April. Generally, mundakan season is more favourable in terms of both area as well as production. The area under paddy cultivation in 2016-17 was 171.4 million hectare which was 12.94 percent less than the previous agricultural year, 2015-16. Besides, the production of rice showed a declining trend in all the three seasons during 2016-17, since drought had intensively affected cop growth all over the state (GOK,2017).

Scarcity of land and water along with the diminishing scope of expansion of irrigated area under rice cultivation in Kerala points to the need to promote upland rice cultivation. During 2011-12, the department of agriculture, government of Kerala took initiative to bring 6,539 hectare area under upland rice cultivation. Statistics shows that an area of 101,379 hectare is available as cultivable fallow land in Kerala during 2016-17. This underutilized land has great potential to be used for upland rice cultivation. Presently, dry land paddy cultivation in Kerala accounts for about 5.21 million hectare as per 2016-17 data (GOK,2017).

A serious problem faced by upland rice ecosystem is drought. Drought can be defined as "a period of no rainfall or irrigation that affects crop growth"(Fukai and Cooper, 1995). According to Indian Meteorological Department, a particular year is declared as drought year when the annual rainfall is reduced to more than 20 percent to that of the normal rainfall for that particular area.

The breeding strategies adopted for drought stress depends on the moisture stress environments. Direct selection for yield may not be sufficient as yield will be affected by water holding capacity of soil, root characteristics etc. A more reasonable strategy is to select for yield under various drought prone environments. Moreover, a number of morphological, physiological and biochemical traits are utilised for the selection process. However, simultaneous selection for yield under non stress and stress environments is advisable to identify drought resistant genotypes (Singh and Sarkar, 1985).

The present study on F_2 evaluation undertaken at College of Agriculture, Vellayani, Thiruvananthapuram is a continuation of the Ph.D research work entitled "Genetic analysis of drought tolerance in rice (*Oryza sativa* L.)" wherein the F_1 hybrids were developed.

The major objectives of the investigation are listed below:

(i) To evaluate the pattern of variability in F_2 for yield and yield contributing traits under upland and drought situations.

(ii) Selection of superior segregants combining drought tolerance and high yield.

Review of Literature

2. REVIEW OF LITERATURE

The literature related to the present study have been reviewed under the following headings.

2.1 Upland rice and drought

2.2 Morphological studies

2.3 Physiological and biochemical studies

2.3 Statistical analysis

2.1 UPLAND RICE AND DROUGHT

Upland rice produced by small and marginal farmers is probably the lowest yielding rice ecosystem. The rice productivity is affected by both biotic and abiotic stresses. Of all the abiotic stresses, the one which is a serious threat to the crop is drought. Drought has been marked as the primary cause of yield loss in rainfed rice grown over 40 million hectare in Asia (Venuprasad *et al.*, 2007). Upland rice is more prone to water stress than lowland rice because it is generally grown on unbunded fields where good drainage and uneven topography makes water accumulation impossible (Khush, 1997). They are vulnerable to drought at any growth stage and the plant response to water limited condition mainly depends on the time and duration of occurrence of drought stress (Boojung and Fukai, 1996). Further, occurrence of other abiotic stresses amplify the negative impact of drought on plant growth and metabolism (Mittler, 2006).

The global reduction in rice production due to drought accounts to 18 metric tonnes annually (Bernier *et al.*, 2008). In Asia alone, it is estimated that a total of 23 million hectare of rice fields are drought prone of which 10 million hectare comes under upland ecosystem (Pandey *et al.*, 2000). Hence, improving the rice production in upland ecosystem is essential to meet the food requirements of the growing population.

In the past decade, the progress in breeding to improve drought resistance has been slow. A major reason for this is the complexity of drought environment which makes it difficult to have a clear identification of the target environment. Other probable reasons include the quantitative genetic basis and poor understanding of the physiological responses of the plants under stress (Fukai and Cooper, 1995).

From an application point of view, it is essential to select genotypes that can optimize water harvest and have higher water use efficiency while maximizing yield in relation to the dynamics of water stress prevailing in the target environment.

Several putative traits and drought resistance mechanisms have been identified in rice; important among these being drought escape, dehydration avoidance and tolerance mechanisms and drought recovery. An appropriate phenology and root characteristic that matches the crop growth and development with the water availability must be given special reference. An ideal upland rice root system is expected to be composed of deep roots with large xylem vessels, capable of extracting water from deeper soil layers (Fukai and Cooper, 1995).

Numerous secondary characters have been suggested to help plant breeders in their efforts to improve drought tolerance. It includes number of days to flowering, spikelet sterility, carbon isotopic discrimination, leaf water potential and root characteristics. Most of these traits are not considered for selection process as they exhibit low heritability or are not highly correlated with grain yield.

The use of managed drought stress has shown to increase heritability of yield under stress to values similar to those obtained in well drained condition (Bernier *et al.*, 2008).

A collaborative approach of traditional breeding incorporating functional, comparative and structural genomics has greatly enhanced the quality of breeding programme. The major gaps that remain in applying genomics to crop improvement are: (i) understanding the desirable phenotypic traits of crops under field condition and enhancing that knowledge through genomics; (ii) mechanisms for applying genomic information (Ishitani *et al.*,2004).

The use of molecular markers in the selection process eventually improved the efficiency of selection methods. Presently, many quantitative trait loci have been identified which confer resistance to drought. These could further be used in marker assisted selection (Bernier *et al.*, 2008).

Various studies revealed that the impact of drought stress on morphological, physiological and biochemical traits varies greatly and sufficient care should be taken while generalising the crop responses in case of a particular variety within a crop species. It should also be taken into consideration that the drought impacts on these varieties greatly depend on the intensity and duration of stress and stage of crop growth.

2.2 MORPHOLOGICAL STUDIES

2.2.1 Days to 50% Flowering

Fukai *et al.* (1999) reported that the timing, intensity and occurrence of water stress have an association with delay in flowering and Panthuwan *et al.* (2002) pointed out that greater the delay in flowering, greater is the yield and harvest index reduction in rice due to drought.

Drought stress experienced at an early phase of reproductive stage resulted in a delay in flowering in rice and could be mainly due to slowed elongation of panicle and supporting tissues (Saini and Westgate, 2000)

2.2.2 Nature of Panicle Exsertion

Cruz and O'Toole (1982) found out that the exsertion of panicle was sensitive to changes in leaf water potential. They reported that poor panicle exsertion caused up to 30 percent of water stress mediated spikelet sterility and hence, concluded that degree of panicle exsertion during moisture stress at flowering stage could be a useful criterion in the selection of breeding lines with high degree of reproductive stage drought resistance.

Under drought condition panicle exsertion is a major indication for determining the yield and is positively correlated with grain yield and harvest index (Subashri *et al.*, 2008).

Pinheiro *et al.* (2006) observed that secondary traits such as leaf rolling, good panicle exsertion and reduced spikelet sterility can be used as selection criteria for drought resistance.

2.2.3 Number of Productive Tillers Plant^{-1}

Vijayalakshmi and Nagarajan (1994) reported that the reduction in tiller production of drought resistant varieties were marginal compared to those of susceptible varieties under water limited conditions.

Leaf expansion, tillering and midday photosynthesis are suppressed by moisture stress. In rice, tillering is closely associated with development of new roots. Therefore profuse tillering is associated with dense and shallow roots while sparse tillering results in deeper roots. This is why most of the cereal crops grown in dry regions shows reduced tillering (Kramer and Boyer, 1995).

2.2.4 Plant Height at Maturity

Basu and Das (1981) reported that moisture stress resulted in reduced plant height and upland rice varieties were less sensitive compared to lowland types.

Rice varieties with well developed root system had only marginal reduction in plant height (Vijayalakshmi and Nagarajan, 1994)

2.2.5 Panicle Length

Sikuku *et al.* (2010) investigated the effects of water deficit on days to maturity and yield development in three rainfed rice varieties under the scheme New Rice for Africa (NERICA coded as N_2, N_4 and N_{11}) and reported that under moisture deficit conditions N_2 was least affected and had the least reduction in panicle length, tiller number and yield components. Hence it could be confidently recommended for growing under rainfed conditions in Kenya.

2.2.6 Number of Spikelets Panicle^{-1}

Abarshahr *et al.* (2011) conducted an experiment on 30 rice varieties under two moisture conditions in order to estimate genetic variability and relationships among some agronomic traits and found out that Nemat cultivar recorded highest spikelet number of 209.33 under optimum moisture condition which was reduced to 104 under stress.

2.2.7 Number of Filled Grains Panicle^{-1}

Filled-grain percentage was more sensitive to drought stress than shading when a comparison was made at similar crop growth rate (Boonjung and Fukai, 1996)

Blum (2005) reported that as photosynthesis is inhibited by drought, the grain filling process becomes increasingly dependent on stem reserve utilization. In case of rice, this mechanism maintains grain yield under moisture stress during grain filling stage (Yang *et al.*, 2001).

2.2.8 Spikelet Sterility

Boonjung and Fukai (1996) pointed out that spikelet sterility mainly results due to poor panicle exsertion which in turn reduced the yield upto 30 percent.

Booting and flowering were the most sensitive stages to temperature stress and a stress occurring at these stages could even lead to complete sterility (Shah *et al.*, 2011).

Prasad *et al.* (2006) studied the species, ecotype and cultivar differences in spikelet fertility and harvest index of rice in response to high temperature stress. They found that high temperature significantly decreased spikelet fertility across all cultivars, but the effects varied among cultivars and there were no clear species or ecotype differences. They concluded that decreased spikelet fertility and cultivar difference at high temperature were mainly due to decreased pollen production and pollen reception. Lower spikelet fertility at elevated temperature resulted in fewer filled grains, lower grain weight per panicle, and decreased harvest index. Therefore, spikelet fertility at high temperature could be used as a screening tool for heat tolerance during the reproductive phase.

2.2.9 Grain Weight Panicle^{-1}

Abdallah *et al.* (2010) examined the magnitude of yield response of different genotypes under normal and drought conditions and identified traits that confer drought resistance. They pointed out that grain weight panicle^{-1} decreased under drought condition.

2.2.10 1000 Grain Weight

Liu *et al.* (1993) reported that moisture stress at booting, heading and flowering stages reduced the number of productive tillers, grain number panicle^{-1} and 1000 grain weight.

Selection for plant height, number of tillers plant^{-1} and 1000 grain weight could be utilized more effectively compared to other traits in boosting yield performance of upland rice genotypes (Osman *et al.* 2012).

2.2.11 Grain Yield Plant^{-1}

Fukai and Cooper (1995) investigated the development of drought-resistant cultivars using physio - morphological traits in rice. They reported that a drought-resistant genotype gave higher grain yield than others when grown under water stress. The most important was appropriate phenology which matches crop growth and development with the water environment. They also found out that under water-limited environments, genotypes with a deeper root system, with higher root length density at depth and with the highest leaf water potential grew best.

A study on the genetic variation and interrelationship of grain yield and yield contributing traits of thirty six exotic upland rice varieties pointed out that more emphasis should be placed on traits such as higher biological yield, higher harvest index and more number of spikelets panicle^{-1} for maximizing the grain yield plant^{-1} (Sravan *et al.*, 2012)

2.2.12 Straw Yield Plant^{-1}

Simane *et al.* (1993) pointed out that there existed a difference in total dry matter accumulation rate of drought resistant and susceptible cultivars. Dry matter yield of rice was reduced by 11-37 percent and 30-65 percent in mild and severe stress conditions respectively.

2.2.13 Harvest Index

Reuben and Katuli (1990) reported the constant association of grain yield and harvest index under water limited conditions. Harvest index could be used as an efficient criteria for yield improvement in rice under water stress (Rao and Saxena, 1999).

Lanceras *et al.* (2004) reported a positive value of correlation coefficient for grain yield and harvest index with increase in drought intensity and this was a confirmation of importance of harvest index as an indicator of grain yield.

2.2.14 Leaf Rolling Score

O'Toole and Moya (1978) suggested that visual scoring based on leaf rolling or leaf tip drying could be an indication of maintenance of leaf water potential and were highly correlated.

Rolling of leaves with a reversible decrease in area could be a major drought adaptation mechanism and an effective way to reduce radiation. It not only reduces the water loss but also reduces the area of leaf exposed to light and heat radiation (Turner, 1986).

2.2.15 Incidence of Pests and Diseases

Koh *et al.* (1987) investigated the incidence of pests and diseases under water limited conditions and found out that the infestation was high during maximum tillering stage and declined thereafter. They arrived at a conclusion that the probable reason could be adult plant resistance.

The most destructive symptom of leaf infection was neck blast, occurring at the reproductive stage and was characterised by the infection at panicle base (Bonman *et al.*, 1991).

2.3 PHYSIOLOGICAL AND BIOCHEMICAL STUDIES

2.3.1 Proline Content

Sikuku *et al.* (2010) reported that there was no significant damage to the photosynthetic apparatus under moisture deficit conditions by investigating the impact of water stress on chlorophyll fluorescence, protein and chlorophyll content.

The physiological characters that played an important role in drought tolerance in rice were reduction in grain yield under drought stress, accumulation of proline in long term drought and an increased total sugar accumulation at anthesis phase during drought (Chozin *et al.*, 2014)

Lum *et al.* (2014) studied the effect of moisture stress on growth, proline accumulation and antioxidant enzyme activities of upland rice and concluded that the above mechanisms were associated with dry matter production and hence, confers drought tolerance to upland rice varieties.

2.3.2 Chlorophyll Content

Mohan *et al.* (2002) reported that high value of chlorophyll content in stress tolerant plants was an indication that stress did not have much impact on them.

There was a decrease in chlorophyll content under moisture stress as compared to irrigated environment (Gowri, 2005).

Maisura *et al.* (2014) reported that water stress reduced chlorophyll a, chlorophyll a/b ratio and grain yield but increased chlorophyll b content.

2.3.3 Leaf soluble protein content

Beena *et al.* (2012) studied the impact of drought stress on protein content of several rice genotypes and reported that stress tolerant genotypes recorded higher protein content than susceptible ones.

2.3.4 Leaf Area Index

Gloria *et al.* (2002) reported that leaf area was highly sensitive to moisture stress than dry matter accumulation as they observed more reduction in leaf area than shoot dry matter in their study.

Reproductive stage moisture stress in rice genotypes significantly reduced the physiological characters such as leaf area index when grown under stress compared to non-stress condition. The leaf area was found to be highest for IR84895-B-127-CA-5-1-1 and lowest for IR64 (Kumar *et al.*,2014).

2.4 STATISTICAL ANALYSIS

Even though direct selection for yield under stress is generally practiced for drought breeding programme, knowledge of genetic variability and association of yield and its component traits provides a more useful tool in the selection process (Babu *et al.,* 2003).

2.4.1 Variability

A high phenotypic variability in grain yield, weight of panicle, number of total tillers and productive tillers in an F_2 population in rice was observed by Venkataravana (1991).

Chauhan *et al.* (1996) found out substantial variability in grain yield, spikelets panicle^{-1}, grain weight, biological yield and harvest index and recommended that improvement in grain yield plant^{-1} could be achieved by performing simultaneous selection for spikelet number, panicle weight and biological yield which recorded significant and positive correlation with grain yield.

There was significant variation in days to flowering in rice genotypes under stressed condition compared to normal condition where they showed similarity in flowering period (Panthuwan *et al.*, 2002).

Vaithiyalingan and Nandarajan (2006) studied an F_2 population in rice and reported that there was significant variation in all the characters considered. The highest variation was observed for grain yield, followed by spikelet fertility percentage, productive tillers plant^{-1} and number of grains panicle^{-1}. They suggested that these characters were highly useful while selecting for crop improvement in rice.

Selection based on plant height, days to 50% flowering, 1000 grain weight and number of productive tillers could be more effective for yield improvement and drought tolerance in upland rice (Jambhulkar and Bose, 2014)

2.4.2 Correlation

A positive correlation of days to flowering, fertile spikelets panicle^{-1} and harvest index with grain yield was reported by Rao and Srivastava (1999).

Raju *et al.* (2004) evaluated F_2 generations of twenty one crosses and studied the genetic parameters and character association of certain yield components. They observed significant correlation of yield components such as productive tillers plant^{-1} and 100 grain weight with grain yield plant^{-1}.

Yogameenakshi *et al.* (2004) observed positive correlation of grain yield plant^{-1} with all the characters studied excepting days to 50% flowering. A high positive correlation for number of grains panicle^{-1}, chlorophyll stability index and harvest index to grain yield were also recorded.

Plant height, number of productive tillers, dry matter plant^{-1}, leaf weight and harvest index were significantly positively correlated with grain yield Shashidhar *et al.*, 2005).

Girish *et al.* (2006) conducted an experiment on correlation studies in rice and found that grain yield was significantly and positively correlated with plant height, number of tillers, panicle length, number of panicles plant^{-1}, panicle weight,1000 grain weight, straw weight, biomass plant^{-1} and harvest index.

Kahani and Hittalmani (2015) studied F_2 population under aerobic condition during dry season and found out that grain yield plant^{-1} was significantly and positively correlated with number of tillers, number of panicles, grain length and straw yield. It was also reported that days to flowering, days to maturity, plant height, 100 grain weight, grain width and leaf width were negatively correlated with grain yield plant^{-1}.

2.4.3 Analysis of Transgressive Segregants

Xu *et al.*, (1998) investigated the transgressive segregation of tiller angle in rice caused by complementary gene action in which divergent selection for tiller angle was practiced in each F_2 population from the crosses 5002/Zhu-Fei 10 and HA79317-7/Zhen-Long13. They observed two types of true-breeding transgressive segregants, one with larger tiller angle and the other with smaller tiller angle. They concluded that, the alleles of similar effect were dispersed in the original parents and were associated in the extreme selections and the intervarietal transgression could be explained by complementary action of additive genes that had been dispersed among the original parents.

Combining ability of parents and crosses when compared with observed and predicted frequencies of transgressive segregants indicated that the potential crosses for transgressive segregants were those that had high sca effects and involved high and low general combiners. Poor performance with respect to transgressive segregation was shown by crosses involving low general combiners irrespective of their sca effects (Yadav *et al.*, 1998).

Rieseberg *et al.*(1999) investigated the production of transgressive phenotypes in segregating hybrid populations and pointed out the action of complementary genes as the primary cause of transgression, although overdominance and epistasis also contribute. They suggested that hybridization may provide the raw material for rapid adaptation and provide a simple explanation for niche divergence and phenotypic novelty often associated with hybrid lineages.

A comparison made between the F_2 progenies of indica- japonica Hybrids, 02428/pei'ai 64 and Thichung 65/ Teiqing revealed a similarity in seed setting in F_1 and F_2 of the first cross where there was excellent cross compatibility. The second cross reported a remarkable increase in seed setting in F_2 compared to its F_1. Thus it was concluded that gametic selection takes place only in indica-japonica crosses with low compatibility while null or little selection takes place in crosses with high compatibility (Zhang *et al.*,2003).

Estimating the frequency distribution and variability produced in two F_2 populations of rice *viz.*, IR 64 × BPHR-1 and Jaya × BPHR-1 for grain yield and its seven component characters revealed that yield can be improved indirectly by selecting F_2 plants with traits showing high heritability coupled with high genetic advance as per cent of mean (Kiran *et al.*, 2013).

Materials and Methods

3. MATERIALS AND METHODS

The study entitled " Genetic evaluation of F_2 generation for yield and water stress tolerance in upland rice" was conducted in the Department of Plant Breeding and Genetics, College of Agriculture, Vellayani during the period from June, 2017 to May, 2018.

The study comprised of two experiments.

Experiment I : Field evaluation of F_2 in target environment

Experiment II : Drought screening of F_2 in controlled condition

3.1 EXPERIMENT I : FIELD EVALUATION OF F_2 IN TARGET ENVIRONMENT

The study material included four parents and three F_2populations selected from the Ph.D project entitled "Genetic analysis of drought tolerance in rice (*Oryza sativa* L.)". The crop was raised in the field under rainfed upland condition exposed to natural stress. Morphological, physiological and biochemical observations were taken at appropriate stages and recorded.

3.2 EXPERIMENT II : DROUGHT SCREENING OF F_2 IN CONTROLLED CONDITION

Another set of the same study material was raised in rainshelter, imposing reproductive stage moisture stress. Irrigation was given at 20mm depth once in seven days.

3.3 SELECTION OF SUPERIOR GENOTYPES

Inexperiments I and II, genotypes with desirable agronomic traits and superior yield attributes were selected from the segregating F_2 populations. Selfed seeds were collected from the selected plants for carrying forward to the next generation.

3.4 ANALYSIS OF TRANSGRESSIVE SEGREGANTS

Analysis of distribution of yield and related traits in the F_2 segregants and identification of transgressive segregants were performed in both the experiments.

3.5 GENOTYPES SELECTED FOR THE STUDY

The genotypes selected for the study were Vaishak (PTB 60), Thottacheera, Vyttila 6 and Harsha (PTB 55) among parents and Vaishak x Vyttila 6, Vaishak x Harsha and Thottacheera xHarsha among hybrids.

3.6 DESIGN OF EXPERIMENT I AND II

Design : RBD

Treatments : 7

Parents : T_1 – Vaishak

T_2 – Thottacheera

T_3 – Vyttila 6

T_4 – Harsha

F_2populations: T_5 – Vaishak x Vyttila 6

T_6 – Vaishak x Harsha

T_7 – Thottacheera x Harsha

Replications : 3

Spacing : 30cm x 30cm

A population size of 300 plants for each parent and 600 plants for each F_2 population was maintained.

3.7 BIOMETRIC OBSERVATIONS: EXPERIMENTS I AND II

The following observations were recorded in this experiment. Five plants from each replication of parents and fifteen plants from each F_2 were taken as observation plants to calculate the mean value.

3.7.1 Days to 50% Flowering

Number of days from sowing to 50 percent flowering of the parents and F_2 population was recorded.

3.7.2 Nature of Panicle Exsertion

Based on the standards set by DRR(2004), the nature of panicle exsertion from the flag leaf was recorded.

Table 1. Nature of panicle exsertion (DRR,2004)

Sl. No	Type of panicle exsertion	Percentage panicle exsertion from flag leaf
1	Partly exserted	Less than 80%
2	Mostly exserted	81-99%
3	Well exserted	100%

3.7.3 Number of Productive Tillers Plant^{-1}

Numbers of productive tillers were recorded prior to harvest.

3.7.4 Plant Height at Maturity (cm)

Plant height from ground level to tip of the tallest leaf was measured in centimetres about one week prior to harvest.

3.7.5 Panicle Length(cm)

Length of the panicle was measured from base to tip and expressed in centimetres.

3.7.6 Number of Spikelets Panicle^{-1}

The number of spikelets panicle^{-1} was counted and the mean value was recorded.

3.7.7 Number of Filled Grains Panicle^{-1}

The number of filled grains panicle^{-1}was counted and the mean value was recorded.

3.7.8 Spikelet Sterility (%)

The number of sterile spikelets in the primary panicle were counted and recorded as percentage.

3.7.9 Grain WeightPanicle^{-1} (g)

The weight of panicles were taken and the average weight was calculated for single panicle and recorded in grams.

3.7.10 1000 Grain Weight (g)

The weight of 1000 grains selected at random from each treatment was recorded in grams.

3.7.11 Grain Yield Plant^{-1} (g)

The total weight of grains separated from all the panicles plant^{-1} was recorded as grain yield plant^{-1} in grams.

3.7.12 Straw Yield Plant^{-1} (g)

The weight of straw after removing all the panicles was recorded as straw yield plant^{-1} in grams.

3.7.13 Harvest Index(%)

Harvest index is calculated as the ratio of economic yield (grain yield) to biological yield (grain + straw yield) and is expressed in percentage.

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

3.7.14 Leaf Rolling Score

Leaf rolling score was recorded one week after the start of drought. Scoring was done based on the scoring scale standardized for rice by IRRI (1996). The scores ranged from 1(no leaf rolling) to 9(leaves completely rolled).

Table 2. Leaf rolling score (IRRI,1996)

Decimal score	**Leaf rolling description**
0	Leaves normal (no rolling)
1	Leaves start to fold(shallow V shape)
3	Leaves folding(deep V shape)
5	Leaves fully cupped(U shape)
7	Leaf margins touching(O shape)
9	Leaves tightly rolled

3.7.15 Incidence of Pests and Diseases

Pest and disease incidence were recorded based on the procedure given by standard evaluation system for rice(IRRI, 1996).

$$Disease\ incidence(\%) = \frac{Total\ number\ of\ infected\ plants}{Total\ number\ of\ plants\ observed} \times 100$$

$$Pest\ incidence(\%) = \frac{Total\ number\ of\ infected\ plants}{Total\ number\ of\ plants\ observed} \times 100$$

3.8 PHYSIOLOGICAL AND BIOCHEMICAL STUDIES : EXPERIMENTS I AND II

The following were the various observations done

3.8.1 Proline Content(mg g^{-1})

Proline content was estimated based on the standard procedure explained by Bates *et al.* (1973). 0.5g of plant material was extracted by homogenizing in 10ml of 3% aqueous sulphosalicylic acid. The homogenate was then filtered through Whatman No. 2 filter paper. 2ml of the filtrate was taken in a test tube and 2 ml of glacial acetic acid and 2ml acid ninhydrin were added. The mixture was then heated using a boiling water bath for 1h. After the required time the reaction was terminated by placing the tube in ice bath. 4ml toluene was added to the reaction mixture and stirred for 20-30sec. The toluene layer was separated and warmed to room temperature. The intensity of red colour formedwas measured at 520nm. A series of standards with pure proline in a similar way was also run simultaneously to prepare a standard curve. The amount of proline in the test sample was found out from the standard curve.The results were then expressed in mg g^{-1} of fresh weight of leaf.

3.8.2 Chlorophyll Content(mg g^{-1})

The method described by Arnon(1949) was followed. 0.5 g of the sample (small pieces of fully expanded third leaf) were introduced into test tube containing 10 ml dimethyl sulfoxide (DMSO) and 80% acetone (1:1 v/v) and incubated overnight at room temperature to extract chlorophyll. The extract was then filtered and transferred to a measuring cylinder and made up to 25 ml volume with DMSO – acetone mixture. For determining chlorophyll the optical density (OD) was measured by spectrophotometer at 663 and 645 nm. The chlorophyll A content (CA), chlorophyll B (CB) and the total chlorophyll (CAB) were calculated according to the following equations and results were expressed in mg g^{-1}.

$$C\,A = 12.7 \times (OD663) - 2.69 \times (OD645) \times V/1000 \times 1/f_{wt}$$

$$C\,B = 22.9 \times (OD645) - 2.69 \times (OD663) \times V/1000 \times 1/f_{wt}$$

$$C\,AB = 20.2 \times (OD645) + 8.02 \times (OD663) \times V/1000 \times 1/f_{wt}$$

Where, V= Volume made up

f_{wt} = Fresh weight of sample

3.8.3 Leaf Soluble Protein Content (mg g^{-1})

Simple protein dye binding assay (Marion and Bradford, 1976) was used to estimate the leaf soluble protein content. Bovine serum albumin (BSA) was used as the standard. One hundred milligram of CBB 250 was dissolved in 50ml of 95% ethanol and 100ml of 85% (w/v) orthophosphoric acid was added to it. Distilled water was then added to dilute the solution to a final volume of 200ml. 0.1g of leaf samples were taken from third fully opened leaves The sample was ground to a thin paste and leaf soluble protein was extracted with 10ml of phosphate buffer (pH 7.8). The extract was centrifuged for 10 minutes at 5000 rpm. 20µl of the supernatant was collected and a known volume (5ml) of diluted dye binding solution was added. The properly mixed solution was then left undisturbed for at least five minutes to develop a blue colour and the absorbance was measured at 596nm. Using the BSA standard in the range of 10-100µg, the protein content was calculated and expressed in mg g^{-1} of fresh weight.

3.8.4 Leaf Area Index

Leaf area index is calculated as the ratio of leaf area to the ground area. It has no unit.

$$Leaf\ area\ index = \frac{Leaf\ area\ plant^{-1}}{Spacing\ of\ plant}$$

3.9 SOIL MOISTURE STUDIES IN THE FIELD : EXPERIMENTS I ANDII

Percentage soil moisture changes at periodic intervals were estimated.

Gravimetric method was used for estimating the soil moisture content at various levels of depth. Screw auger was used for taking samples from different replications and in different depths such as 10 cm, 15cm, 20 cm and 30 cm. A minimum of five samples were taken and were weighed to find the initial weight,W_i. The samples were then kept in hot air oven at 105^{0}C until it lost no more weight. After drying, the samples were again weighed to find the final weight ,W_f. Soil moisture content was then calculated on dry weight basis using the following formula. The results were expressed in percentage.

$$Moisture\ content\ (\%) = \frac{W_i - W_f}{W_f} \times 100$$

3.10 STATISTICAL ANALYSIS : EXPERIMENTS I AND II

Analysis of variance was not carried out since there was high variability within the segregating populations. However, the mean value of parents and segregants were presented.

3.10.1 Correlation analysis

Simple correlation of all the characters observed with grain yield were worked out for parents and F_2 population.

$$r_{xy} = \frac{COV_{xy}}{\sqrt{Var_x \times Var_y}}$$

Where,

r_{xy} = Correlation coefficients between characters x and y

COV $_{xy}$= Covariance between x and y

Var_x = Variance of x

Var_y = Variance of y

3.10.2 Estimation of similarity between the genotypes

Squared Euclidean distances based on standardised values ofcharacters under consideration were estimated for the material under study. It uses the same equation as the Euclidean distance metric, except for the square root. Therefore, clustering with the Euclidean Squared distance metric is faster than clustering with the regular Euclidean distance.

The following equation was used to form the distance matrix,

$$\text{Squared Euclidean distance}, E_{ij} = \sum(X_{ik} - X_{jk})^2$$

Where,

X_{ik} = Standardised mean of k^{th}character of i^{th}parent

X_{jk}= Standardised mean of k^{th}character of j^{th}parent

The matrix formed was then used to drawdendrogram of the same. Dendrogram shows the similarity and dissimilarity of various genotypes by clustering them.

3.10.3 Analysis of F_2 Segregants (%)

The percentage of both positive and negative segregants among the F_2 populations were calculated using the formula:

$$Positive\ segregants\ (\%) = \frac{Number\ of\ plants\ with\ values\ above\ superior\ parent}{Total\ number\ of\ F_2\ plants\ observed} \times 100$$

$$Negative\ segregants\ (\%) = \frac{Number\ of\ plants\ with\ values\ below\ inferior\ parent}{Total\ number\ of\ F_2\ plants\ observed} \times 100$$

Result

4. RESULT

The present study entitled "Genetic evaluation of F_2 generation for yield and water stress tolerance in upland rice" was aimed to estimate the performance of three F_2 populations, along with four parents under two growth conditions – target environment *i.e* upland Virippu and protected condition imposing reproductive stage moisture stress. The first crop was raised under rainfed upland condition at College of Agriculture, Vellayani during June – November, 2017 exposed to natural stress. Another set of the same material was raised under rain shelter imposing reproductive stage moisture stress during the period from February to June, 2018. Morpho – physiological and biochemical traits of the genotypes were studied and recorded in both the experiments. The results obtained are reported hereunder.

4.1 EXPERIMENT I

Field preparation and general view of the field is shown in Plate 1 and 2 respectively. The parents and F_2 populations at vegetative and reproductive stages are depicted in Plates 3 and 4.

4.1.1 Genetic Variability

The mean values of the seven genotypes (four parents and three F_2 populations) for 16 characters under rainfed upland condition were tabulated and are presented in Table 3 and Table 7. The graphical representation of the same is given in Fig 1 and Fig 2.

Morphological Traits

4.1.1.1 Days to 50% Flowering

Among the parents, Thottacheera (75.76 days) was the earliest flowering type and Vyttila 6 (99.44 days) was late in flowering. In the F_2 population Thottacheera x Harsha (77.43 days) flowered early whereas Vaishak x Vyttila 6 (97.82 days) flowered later in the season .

Plate 1. Land preparation under rainfed upland condition

Plate 2. General field view of parents and F_2 three weeks after sowing under rainfed upland condition

Plate 3. Seedling stage of parents and F_2 populations under upland condition

Vaishak

Thottacheera

Vyttila 6

Harsha

Vaishak x Vyttila 6

Vaishak x Harsha

Thottacheera x Harsha

Plate 4. Reproductive stage of parents and F_2populations under rainfed upland condition

Vaishak

Thottacheera

Vyttila 6

Harsha

Vaishak x Vyttila 6

Vaishak x Harsha

Thottacheera x Harsha

Plate 5. Estimation of soil moisture content: Soil samples in hot air oven

4.1.1.2 Number of Productive Tillers Plant^{-1}

All the three hybrids recorded higher number of productive tillers compared to the better parent *i.e* Vyttila 6 (10.13). The lowest value among the parents was for Thottacheera (9.00). The mean of F_2 segregants of Vaishak x Harsha recorded the highest number of productive tillers with the value of 14.13. The F_2 population of the other two *viz;* Vaishak x Vyttila 6 (12.06) and Thottacheera x Harsha (11.13) were superior to the better parent. The mean of F_2 segregants mean (12.44) for this character exceeded the parental mean (9.44) considerably.

4.1.1.3 Plant Height at Maturity (cm)

The plant height among parents ranged from 88.20 cm in Harsha to 126.40 cm in Vaishak. All the F_2 populations, Thottacheera x Harsha (129.27 cm), Vaishak x Harsha (128.13 cm) and Vaishak x Vyttila 6 (127.40) were comparatively taller than the parents.

4.1.1.4 Panicle Length (cm)

Panicle length among the parents was highest for Thottacheera (24.53 cm) and lowest for Vyttila 6 (20.91 cm). Among the F_2 segregants, Vaishak x Vyttila 6 (24.68 cm) recorded the highest mean value whereas Thottacheera x Harsha (21.87 cm) recorded the lowest. The mean of segregants of Vaishak x Harsha (23.78 cm) recorded an intermediate value.

4.1.1.5 Number of Spikelets Panicle^{-1}

Vaishak (171.00) scored the highest mean value among the parents for number of spikelets panicle^{-1} and Vyttila 6 (148.66) scored the lowest. Among the F_2 segregants, Vaishak x Vyttila 6 (169.05) recorded the highest mean value and Thottacheera x Harsha (163.33) was intermediate. The lowest mean among the F_2 population was reported by Vaishak x Harsha (155.22).

4.1.1.6 Number of Filled Grains Panicle^{-1}

Among the parents, the highest mean value for number of filled grains panicle^{-1} was recorded by Vaishak (158.22) and the lowest mean value was marked by Vyttila 6 (128.56). Vaishak x Harsha (137.11) was found to be the highest among the F_2 segregants whereas the segregants of Thottacheera x Harsha (122.00) recorded the lowest value.

4.1.1.7 Spikelet Sterility (%)

Spikelet sterility ranged from 7.44 percent in Vaishak to 13.56 percent in Vyttila 6 among the parents whereas in F_2 population, Thottacheera x Harsha (41.33%) recorded the highest mean spikelet sterility percentage. Spikelet sterility was comparatively high among the F_2 populations. It was also observed that the segregants of Vaishak x Vyttila 6 recorded a mean spikelet sterility of 20.35 percent whereas that of Vaishak x Harsha was 18.11 percent.

4.1.1.8 Grain Weight Panicle^{-1} (g)

Grain weight was the lowest for Vyttila 6 (2.49g) and the highest for Harsha (4.26g). Among the F_2 segregants the highest mean value was recorded by Vaishak x Harsha (3.43g) and Vaishak x Vyttila 6 (3.10g) followed close behind. The lowest mean value among the F_2 segregants was recorded by Thottacheera x Harsha (2.95g).

4.1.1.9 1000 Grain Weight (g)

1000 grain weight was the lowest for Thottacheera (23.27g) and the highest for Vaishak (28.53g).Vyttila 6 (26.77g) and Harsha (26.77g) recorded intermediate values. All the F_2 populations, Vaishak x Harsha (28.47g), Vaishak x Vyttila 6 (27.57g) and Thottacheera x Harsha (26.47g) recorded relatively high values.

4.1.1.10 Grain Yield Plant^{-1} (g)

The mean grain yield among parents was highest for Vaishak (40.13g) and lowest for Vyttila 6 (27.41g). Among F_2 segregants, Vaishak x Harsha (47.99g) recorded the highest mean grain yield which was higher than Vaishak. The lowest mean among F_2 population was recorded by Thottacheera x Harsha (28.95g). Vaishak x Vyttila 6 (41.25g) was found to be intermediate.

4.1.1.11 Straw Yield Plant^{-1}

Straw yield plant^{-1} among the parents varied from 30.98g in Vyttila 6 to 58.29g in Harsha. when the mean of F_2 population was recorded, the segregants of Vaishak x Harsha (57.14g) recorded the highest value whereas Thottacheera x Harsha (33.03g) recorded the lowest.

4.1.1.12 Harvest Index (%)

Harvest index was the highest for Vyttila 6 (46.84%) and the lowest for Harsha (39.63%). Among F_2 population, the segregants of Vaishak x Vyttila 6 (47.33%) represented the highest mean value which was higher than the better parent. The F_2 segregants of Thottacheera x Harsha (46.68%) and Vaishak x Harsha (45.56%) also recorded high values.

4.1.1.13 Nature of Panicle Exsertion

The nature of panicle exsertion is presented in Table 4. Vyttila 6 had its panicles partially exserted from the flag leaf. The varieties Vaishak and Harsha and the F_2 populations of Vaishak x Vyttila 6 and Vaishak x Harsha had their panicles mostly exserted. The variety, Thottacheera and the F_2 population of Thottacheera x Harsha expressed well exserted panicles.

4.1.1.14 Leaf Rolling Score

Leaf rolling score was noted after seven days of dry spell and the mean values are presented in Table 5. The varieties Vyttila 6 and Harsha expressed less prominent leaf rolling. All other genotypes expressed more prominent leaf rolling marked by deep V shaped folding especially in the late morning hours.

4.1.1.15 Incidence of Pests and Diseases

The incidence of pests and diseases are furnished in Table 6. The major pest found in the field was rice bug and the major disease noted was sheath blight. It was observed that among the parents, heavy infestation of rice bug was observed in Thottacheera (4.31%) and among F_2 populations it was for Thottacheera x Harsha (3.15%). The infestation in varieties Harsha (1.55%), Vaishak (1.72%) and F_2 segregants of Vaishak x Vyttila 6 (1.50%) and Vaishak x Harsha (1.98%) was comparatively low.

In case of disease infestation, the varieties Vaishak (1.32%) and Harsha (1.44%) were less susceptible compared to Vyttila 6 (4.66%) and Thottacheera (3.91%). Among the F_2 population, Vaishak x Harsha (1.13%) was resistant compared to segregants of Vaishak x Vyttila 6 (3.15%) and Thottacheera x Harsha (2.50%).

Physiological and Biochemical Traits

4.1.1.16 Proline Content (mg g^{-1})

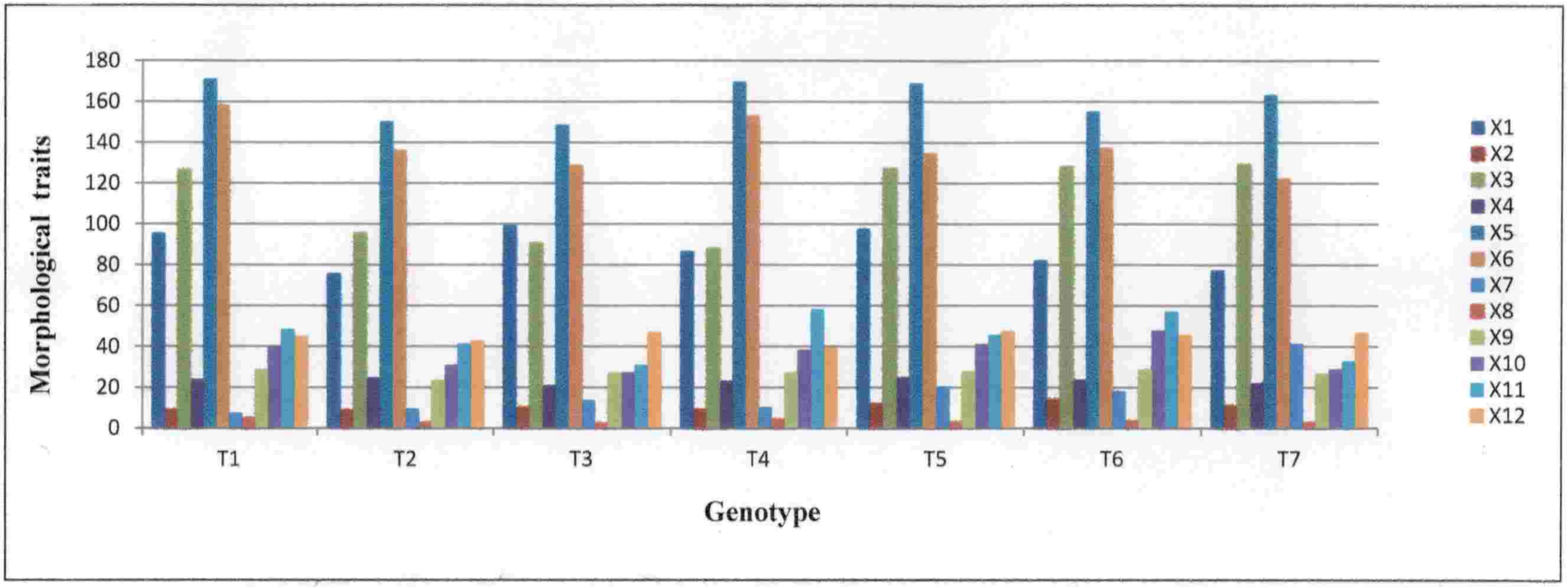
Proline content was found to be generally low when grown under normal upland condition. Among parents, it was found to be the highest in Vyttila 6 (0.35 mg g^{-1}) and the lowest in Thottacheera (0.22 mg g^{-1}). The highest mean value among F_2 segregants was 0.29 mg g^{-1} recorded in Vaishak x Vyttila 6 followed by Thottacheera x Harsha (0.28 mg g^{-1}). The lowest mean was recorded in segregants of Vaishak x Harsha (0.22 mg g^{-1}) which was similar to that of Thottacheera.

4.1.1.17 Chlorophyll Content (mg g^{-1})

The parent Harsha (2.31 mg g^{-1}) recorded the highest chlorophyll content whereas Thottacheera (1.17 mg g^{-1}) recorded the lowest. In the F_2 population the

Table 3. Mean performance for 12 morphological characters of parents and F_2 segregants under rainfed upland condition

Sl. No	Parents and F_2Segregants	Days to 50% flowering	No. of productive tillers plant^{-1}	Plant height at maturity (cm)	Panicle length (cm)	No. of spikelets panicle^{-1}	No. of filled grains panicle^{-1}	Spikelet sterility (%)	Grain weight panicle^{-1} (g)	1000 grain weight (g)	Grain yield plant^{-1} (g)	Straw yield plant^{-1} (g)	Harvest index (%)
		X_1	X_2	X_3	X_4	X_5	X_6	X_7	X_8	X_9	X_{10}	X_{11}	X_{12}
1	Vaishak (T_1)	95.34	9.23	126.40	23.89	171.00	158.22	7.44	4.19	28.53	40.13	48.56	44.80
2	Thottacheera (T2)	75.76	9.00	95.60	24.53	150.22	135.87	9.51	2.91	23.27	30.98	41.31	42.73
3	Vyttila 6 (T_3)	99.44	10.13	90.60	20.91	148.66	128.56	13.56	2.49	26.77	27.41	30.98	46.84
4	Harsha (T_4)	86.69	9.40	88.20	23.00	169.78	152.99	10.24	4.26	26.77	38.37	58.29	39.63
5	Vaishak x Vyttila6 (T_5)	97.82	12.06	127.40	24.68	169.05	134.67	20.35	3.10	27.57	41.25	45.65	47.33
6	Vaishak x Harsha (T_6)	82.25	14.13	128.13	23.78	155.22	137.11	18.11	3.43	28.47	47.99	57.14	45.56
7	Thottacheera x Harsha (T_7)	77.43	11.13	129.27	21.87	163.33	122.00	41.33	2.95	26.47	28.95	33.03	46.68
Parents mean		89.31	9.44	101.03	23.08	159.92	144.33	10.21	3.89	26.33	34.23	44.79	43.50
F_2Segregantsmean		85.83	12.44	127.49	23.44	162.54	131.26	26.59	3.62	27.38	39.39	45.27	46.52



X1: Days to 50% flowering
X2: Number of productive tillers plant^{-1}
X3: Plant height at maturity(cm)
X4: Panicle length(cm)
X5: Number of spikelets panicle^{-1}
X6: Number of filled grains pancle^{-1}
X7: Spikelet sterility(%)
X8: Grain weight panicle^{-1}(g)
X9 : 1000 grain weight(g)
X10: Grain yield plant^{-1}(g)
X11: Straw yield plant^{-1}(g)
X12 : Harvest index(%)

Fig. 1. Mean performance for 12 morphological traits of parents and F_2 Segregants under rainfed upland condition

Table 4. Nature of panicle exsertion in four parents and three F_2 segregants under rainfed upland rice

Sl. no	Parents and F_2 segregants	Nature of panicle exsertion
1	Vaishak (T_1)	Mostly exserted
2	Thottacheera (T_2)	Well exserted
3	Vyttila 6(T_3)	Partially exserted
4	Harsha(T_4)	Mostly exserted
5	Vaishak x Vyttila 6 (T_5)	Mostly exserted
6	Vaishak x Harsha (T_6)	Mostly exserted
7	Thottacheera x Harsha (T_7)	Well exserted

Table 5. Leaf rolling score for parents and F_2 segregants under rainfed upland condition

Sl. no	Parents and F_2 segregants	Score	Description
1	Vaishak (T_1)	3	Leaves folding (deep V shape)
2	Thottacheera(T_2)	3	Leaves folding (deep V shape)
3	Vyttila 6(T_3)	1	Leaves start to fold (shallow V shape)
4	Harsha (T_4)	1	Leaves start to fold (shallow V shape)
5	Vaishak x Vyttila 6(T_5)	3	Leaves folding (deep V shape)
6	Vaishak x Harsha(T_6)	3	Leaves folding (deep V shape)
7	Thottacheera x Harsha(T_7)	3	Leaves folding (deep V shape)

Table 6: Incidence of pests and diseases in parents and F_2 segregants under rainfed upland condition

Sl. No	Parents and F_2 segregants	Incidence (%)	
		Pest (Rice bug)	Disease (Sheath rot)
1	Vaishak (T_1)	1.72	1.32
2	Thottacheera (T_2)	4.31	3.91
3	Vyttila 6 (T_3)	2.45	4.66
4	Harsha (T_4)	1.52	1.44
5	Vaishak x Vyttila 6 (T_5)	1.50	3.15
6	Vaishak x Harsha (T_6)	1.98	1.13
7	Thottacheera x Harsha (T_7)	3.15	2.50

highest mean chlorophyll content was recorded by segregants of Thottacheera x Harsha (1.78 mg g^{-1}). The segregants of Vaishak x Vyttila 6 recorded 1.56 mg g^{-1} and it was 1.54 mg g^{-1} for Vaishak x Harsha F_2 population.

4.1.1.18 Leaf Soluble Protein Content (mg g^{-1})

Leaf soluble protein was noted to be high in Thottacheera (8.85 mg g^{-1}) and low in Harsha (6.90 m g^{-1}). Among the F_2 population, Thottacheera x Harsha segregants (9.36 mg g^{-1}) recorded the highest mean value which was higher than the better parent. The lowest mean among F_2 population was for Vaishak x Harsha (5.75 mg g^{-1}). The segregants of Vaishak x Vyttila 6 recorded 7.61 mg g^{-1}.

4.1.1.19 Leaf Area Index

Mean leaf area index was found to be the highest in Vyttila 6 (2.86) and the lowest in Thottacheera (1.21) in case of parents and in F_2 segregants, Vaishak x Harsha (1.67) recorded the highest mean value whereas segregants of Thottacheera x Harsha (0.97) recorded the lowest.

4.1.2 Dry Spell During Crop Growth Season

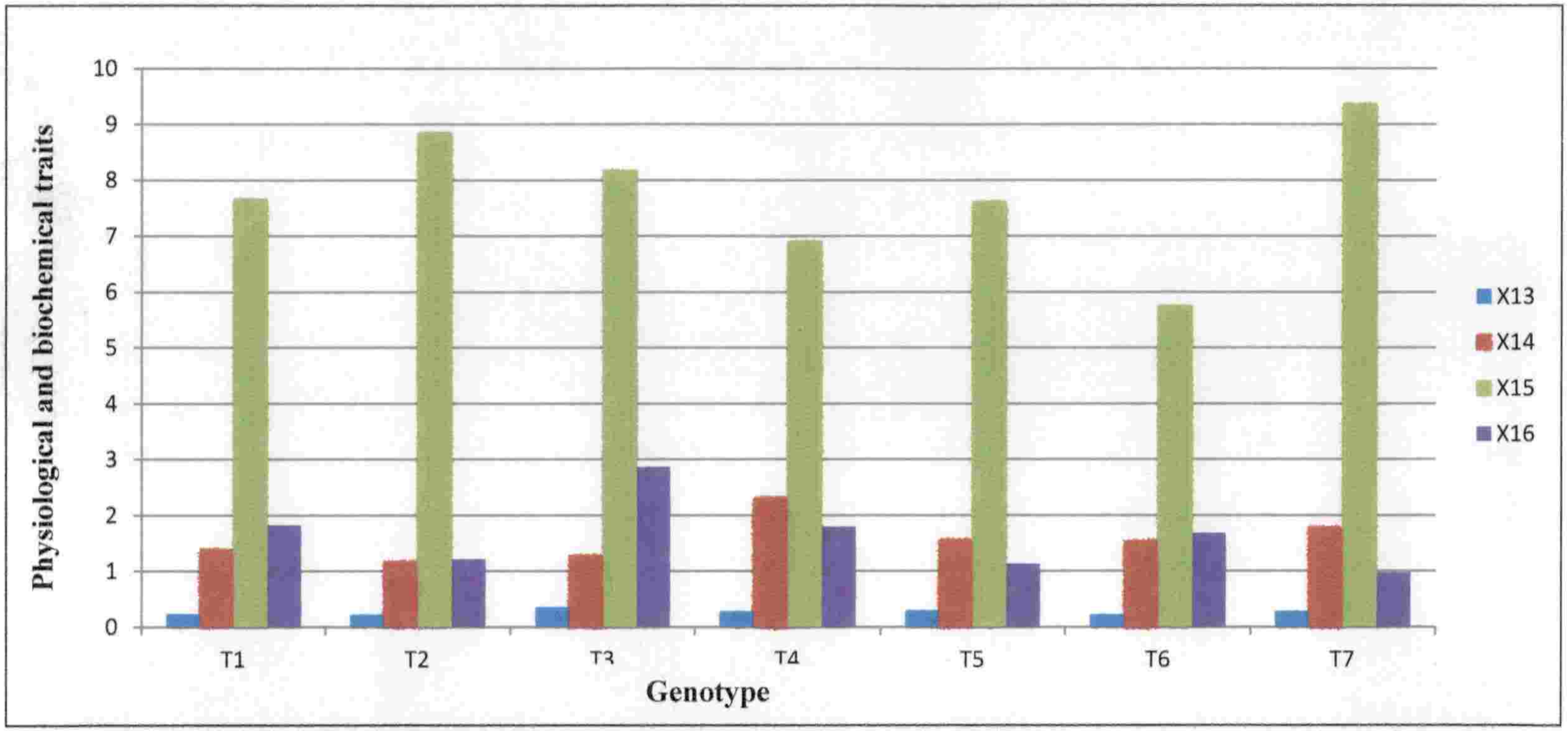
The weather data from 28th May 2017 to 2nd December 2017 is presented in table 8. and dry spell during the crop growth season (21-06-2017 to 04-11-2017) is furnished in table 9. Four dry spells occurred during the panicle initiation stage. The first dry spell was from July 30th to August 4th. The second was from August 10th to August 15th while the third was from August 22nd to August 27th and the fourth from September 23rd to September 26th.

4.1.3 Percentage of Soil Moisture Content

Percentage soil moisture content is presented in Table 10. The moisture content varied from 12.50 percent at seedling stage, 10.11 percent at maturity and 7.88 percent before harvest. Estimation of moisture content using gravimetric method is shown in plate 5.

Table 7. Mean performance for physiological and biochemical characters of parents and F_2segregantsunder rainfed upland condition

Sl . No	Parents and F_2Segregants	Proline content (mg g^{-1})	Chlorophyll content (mg g^{-1})	Leaf soluble protein content (mg g^{-1})	Leaf area index (at maturity)
		X_{13}	X_{14}	X_{15}	X_{16}
1	Vaishak (T1)	0.23	1.39	7.66	1.82
2	Thottacheera (T2)	0.22	1.17	8.85	1.21
3	Vyttila 6 (T_3)	0.35	1.28	8.17	2.86
4	Harsha (T_4)	0.27	2.31	6.90	1.79
5	Vaishak x Vyttila 6 (T_5)	0.29	1.56	7.61	1.12
6	Vaishak x Harsha (T_6)	0.22	1.54	5.75	1.67
7	Thottacheera x Harsha (T_7)	0.28	1.78	9.36	0.97
Parents mean		0.27	1.54	7.90	1.92
F_2Segregantsmean		0.26	1.62	7.75	1.26



X13: Proline content (mg g^{-1})
X14: Chlorophyll content (mg g^{-1})
X15: Leaf soluble protein content (mg g^{-1})
X16: Leaf area index (at maturity)

Fig. 2. Mean performance for physiological and biochemical traits of parents and F_2 segregants under rainfed upland condition

Table 8 . Weather data during the cropping period of field evaluation of parents and F_2 segregants under rainfed upland condition from 28th May 2017 to 2nd December 2017

Week No.	Date	Temperature(0C)						RH (%)		Sunshine	Rain	Evapn.
		Dry	Wet	Dry	Wet	Max.	Min.	I	II	Hours	(mm)	(mm)
1	28-05-17 to 03-06-17	25.4	25.1	24.8	28.4	26.4	31.5	97.3	84.7		23.1	-
2	04-06-17 to 10-06-17	27.1	26.2	29.5	27.7	30.8	24.6	92.9	86.7	7.5	5.2	3.4
3	11-06-17 to 17-06-17	27.0	25.9	31.3	27.9	31.7	25.2	91.0	76.3	8.3	3.8	4.5
4	18-06-17 to 24-06-17	24.8	26.3	30.7	27.7	32.2	24.4	89.9	78.6	8.8	9.5	4.3
5	25-06-17 to 01-07-17	25.5	25.1	29.1	27.1	31.1	23.7	95.9	85.4		20.5	-
6	02-07-17 to 08-07-17	26.6	25.5	30.5	27.1	31.7	24.6	-	-	-	-	-
7	09-07-17 to 15-07-17	26.6	25.5	30.6	27.3	31.2	24.5	91.7	76.4	7.9	2.54	3.8
8	16-07-17 to 22-07-17	26.7	25.5	-	27.7	31.2	24.6	89.9	79.6		5.5	3.9
9	23-07-17 to 29-07-17	-	26.1	31.5	27.9	32.2	25.0	89	74.9	9.3	-	4.4
10	30-07-17 to 05-08-17	-	26.1	30.8	27.8	32.3	25.0	90.9	79	8.75	7.2	-
11	06-08-17 to 12-08-17	26.2	25.3	30.6	27.2	31.3	24.5	92.3	76.1	9.7	9.3	3.5
12	13-08-17 to 19-08-17	26.4	25.6	30.1	27.3	31.1	24.7	92.9	79.7	-	7.1	3.7
13	20-08-17 to 26-08-17	26.5	25.5	30.1	27.4	-	24.6	91.7	80.7	6.7	15.3	3.3
14	27-08-17 to 02-09-17	26.5	25.5	31.3	27.5	31.5	24.4	91.6	73.9	7.9	4.7	4.0
15	03-09-17 to 09-09-17	26.9	25.8	30.5	27.4	32.3	24.6	91.4	78	7.9	28.7	3.4
16	10-09-17 to 16-09-17	26.3	25.4	30.6	27.5	31.5	24.2	92.1	78.1	-	5.1	3.4
17	17-09-17 to 23-09-17	25.7	25.0	29.7	27.3	30.4	24.4	94	82	-	15.6	3.5
18	24-09-17 to 30-09-17	26.5	25.6	30.5	27.6	31.6	24.9	93.3	79.4	-	14.0	3.9
19	01-10-17 to 07-09-17	26.8	25.7	30.9	27.9	31.7	25.1	91.9	78.6	-	15.8	4.0
20	08-10-17 to14-09-17	26.5	25.8	29.6	27.6	31.4	24.8	93.7	85.1	-	17.15	3.6
21	15-10-17 to 21-10-17	25.9	25.3	29.3	27.9	30.7	24.6	95.6	89.1	5.6	8.0	3.4
22	22-10-17 to 28-10-17	26.1	25.6	30.3	28.3	31.0	24.9	95.9	85.1	8.0	21.7	3.5
23	29-10-17 to 04-11-17	25.9	25.3	29.7	27.9	30.6	24.8	94.6	86.9	5.2	5.25	3.1
24	05-11-17 to 11-11-17	25.5	25	29.1	27.1	30.6	24.4	96.4	85.3	5.3	14.9	2.6
25	12-11-17 to 18-11-17	25.3	24.7	31.7	28.0	31.6	24.1	94.3	74.1	8.2		4.0
26	19-11-17 to 25-11-17	25.1	24.5	30.3	27.6	31.1	23.9	94	80.7	4.8	22.65	2.9
27	26-11-17 to 02-12-17	23.8	23.5	26.1	25.2	29.5	22.5	97.1	92	1.1	41.18	1.5

Table 9. Dry spell during crop growth season (21-06-2017 to 04-11-2017)

Sl. No.	Duration of dry spell	Number of days
1	July 30 to August 04	6 days
2	August 10 to August 15	6 days
3	August 22 to August 27	6 days
4	September 23 to September 26	4 days

(Data from Department of Agricultural Meteorology, College of Agriculture, Vellayani)

Table 10. Percentage soil moisture content under rainfed upland condition

Sl.no	Stage of crop	Moisture content (%)
1	Seedling stage	12.50
2	At maturity	10.11
3	Before harvest	7.88

4.1.4 Correlation Studies

Simple correlation for all the characters with grain yield plant^{-1} was worked out and is presented in Table 11.

The parental genotypes marked significant correlation for characters such as number of spikelets panicle^{-1} (0.768), number of filled grains panicle^{-1} (0.773), spikelet sterility (0.628), grain weight panicle^{-1} (0.736) and straw yield plant^{-1} (0.885). Except spikelet sterility all other characters showed significant positive correlation with grain yield plant^{-1}.

In the F_2 population, significant correlation was observed for number of productive tillers plant^{-1} (0.801), number of filled grains panicle^{-1} (0.792), spikelet sterility (0.823), straw yield plant^{-1} (0.984) and leaf soluble protein content (-0.679). Except spikelet sterility and leaf soluble protein content all other characters recorded significant positive correlation with grain yield plant^{-1}.

4.1.5 Estimation of Similarity between the Genotypes

Proximity matrix based on squared Euclidean distances was worked out for the parents and F_2 populations and is furnished in Table 12. From the table it was observed that the F_2 populations of Vaishak x Vyttila 6 (14.219) and Vaishak x Harsha (20.794) were closely related to the parental variety Vaishak whereas the F_2 populations of Thottacheera x Harsha (28.771) was more similar to the parent Thottacheera.

Dendrogram using complete linkage for the dissimilarity matrix was also prepared using SPSS software and is presented in Fig 3. The dendrogram reveals that at a distance of 11 units , the genotypes were grouped into 4 clusters. The parent Vaishak and the F_2 population of Vaishak x Vyttila 6 and Vaishak x Harsha fall in the first cluster. The second and fourth clusters were solitary clusters that included Harsha and Vyttila 6 alone. Thottacheera and Thottacheera x Harsha formed the third cluster.

Table 11. Simple correlation of 15 characters with grain yield plant^{-1} in parents and F_2 segregants under upland condition

Sl.No	Characters	Parents	F_2 segregants
1	Days to 50% flowering	-0.003	0.159
2	No. of productive tillers plant^{-1}	0.154	0.801**
3	Plant height at maturity(cm)	0.388	0.076
4	Panicle length (cm)	0.424	0.601
5	No. of spikelets panicle^{-1}	0.768**	-0.173
6	No. of filled grains panicle^{-1}	0.773**	0.792*
7	Spikelet sterility(%)	-0.628*	-0.823**
8	Grain weight panicle^{-1}(g)	0.736**	0.454
9	1000 grain weight(g)	0.465	0.355
10	Straw yield plant^{-1}	0.885**	0.984**
11	Harvest index(%)	-0.250	0.098
12	Proline content (mg g^{-1})	-0.455	-0.641
13	Chlorophyll content (mg g^{-1})	0.404	-0.099
14	Leaf soluble protein content (mg g^{-1})	-0.466	-0.679*
15	Leaf area index (at maturity)	-0.318	0.644

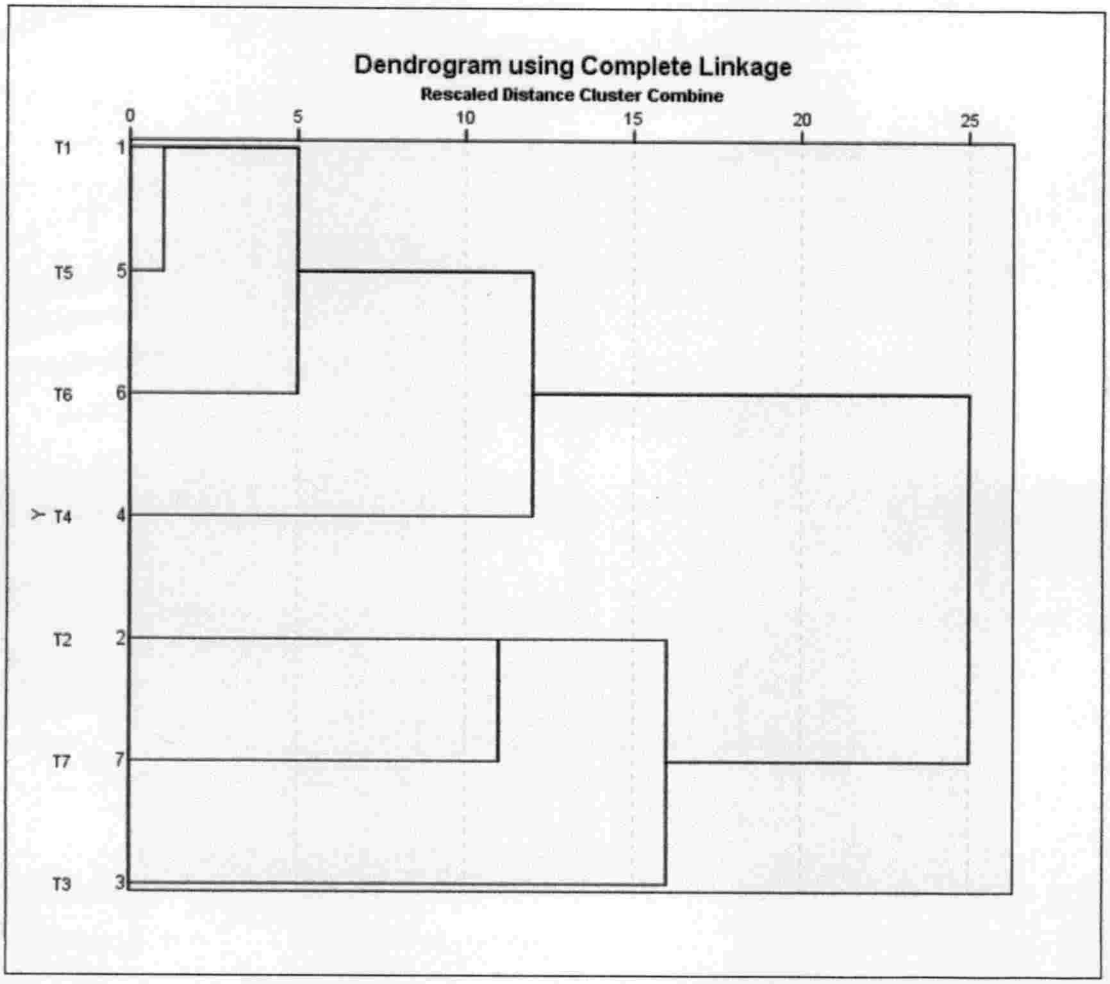
*significant at 5% level

**significant at 1% level

Table 12 . Proximity matrix based on squared Euclidean distances calculated from standardised mean values for all the characters under study (under rainfed upland condition)

Genotype	Squared Euclidean Distance						
	T1	T2	T3	T4	T5	T6	T7
T1	0.000	31.898	41.842	17.921	14.219	20.794	39.043
T2	31.898	0.000	35.664	34.730	30.375	37.762	28.771
T3	41.842	35.664	0.000	49.120	32.667	48.232	31.557
T4	17.921	34.730	49.120	0.000	30.057	30.744	45.361
T5	14.219	30.375	32.667	30.057	0.000	14.721	20.095
T6	20.794	37.762	48.232	30.744	14.721	0.000	36.430
T7	39.043	28.771	31.557	45.361	20.095	36.430	0.000

T1: Vaishak
T2: Thottacheera
T3: Vyttila 6
T4: Harsha
T5: Vaishak x Vyttila 6
T6: Vaishak x Harsha
T7: Thottacheera x Harsha



T1: Vaishak
T2: Thottacheera
T3: Vyttila 6
T4: Harsha
T5 : Vaishak x Vyttila 6
T6 : Vaishak x Harsha
T7 : Thottacheera x Harsha

Fig. 3. Dendrogram using complete linkage for the proximity matrix presented in Table 12 (under rainfed upland condition)

4.1.6 Percentage of F_2 segregants

Transgressive segregants are those plants in the segregating populations that transgress the limits prescribed by the parents. They can be either positive or negative segregants. Positive segregants are those which have phenotypic values greater than the maximum value among parents and negative segregants are those which have phenotypic values less than the minimum value among the parents. Transgressive segregants can be utilised for the development of new hybrid derivatives that are more fit than their ancestors. In this experiment, percentage of those segregants which showed positive deviation and negative deviation from their parents for each morphological character under study is estimated separately. The data is presented in Table 13.

The F_2 segregants of Vaishak x Vyttila 6 gave high percentage of positive segregants for spikelet sterility (88%), number of productive tillers plant^{-1} (85%), number of spikelets panicle^{-1} (78%), plant height at maturity (76%) and panicle length (66%). Negative segregants were the highest for number of filled grains panicle^{-1} (30%) and 1000 grain weight (28%).

The F_2 population of Vaishak x Harsha, recorded the highest percentage of positive transgressive segregants for number of productive tillers plant^{-1} (91%), grain yield plant^{-1} (85%), plant height at maturity (84%) and spikelet sterility (80%). Negative segregants were more for days to 50% flowering (88%) and grain weight panicle^{-1} (76%).

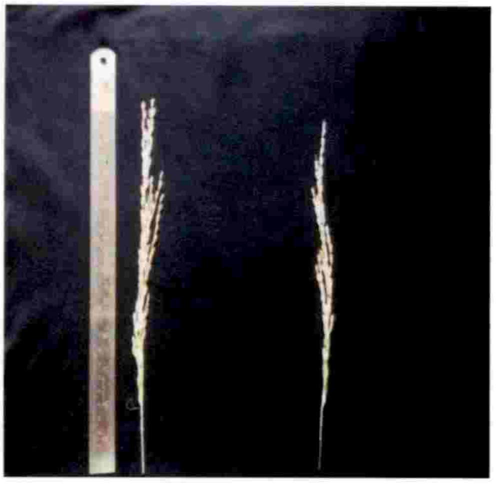
The percentage of positive segregants were the highest for spikelet sterility (95%) and number of productive tillers plant^{-1} (82%) in the F_2 population of Thottacheera x Harsha. Plant height at maturity (70%) and number of filled grains panicle^{-1} (68%) recorded the highest percentage for negative segregants. Plate 6 shows the variation in panicle length among the F_2 segregants.

Table 13. Percentage estimates of positive and negative segregants in the three F_2 populations under rainfed upland condition

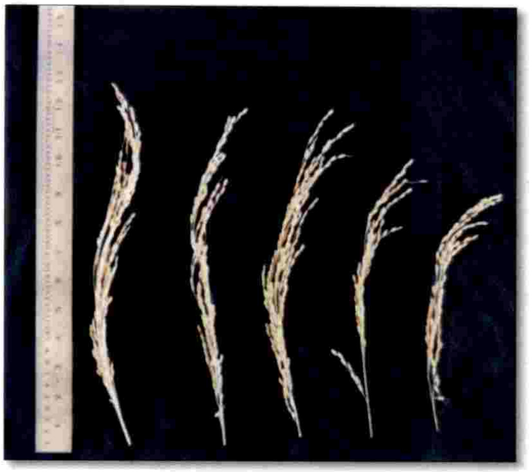
Sl. no	Characters	F_2 segregants (%)					
		Vaishak x Vyttila 6 (T_5)		Vaishak x Harsha (T_6)		Thottacheera x Harsha (T_7)	
		Positive	Negative	Positive	Negative	Positive	Negative
1	Days to 50% flowering	32	26	Nil	88	Nil	39
2	No. of productive tillers plant^{-1}	85	Nil	91	Nil	32	Nil
3	Plant height at maturity(cm)	76	Nil	84	Nil	Nil	70
4	Panicle length (cm)	66	Nil	25	Nil	Nil	24
5	No. of spikelets panicle^{-1}	78	Nil	Nil	38	39	28
6	No. of filled grains panicle^{-1}	Nil	30	Nil	33	Nil	68
7	Spikelet sterility(%)	88	Nil	80	Nil	95	Nil
8	Grain weight panicle^{-1}(g)	15	10	Nil	76	Nil	36
9	1000 grain weight(g)	13	28	33	18	20	Nil
10	Grain yield plant^{-1}	36	Nil	85	Nil	Nil	18
11	Straw yield plant^{-1}	20	Nil	35	Nil	Nil	38
12	Harvest index(%)	22	Nil	28	15	36	Nil

Plate 6.Variation in panicle length of F_2 populations under rainfed upland condition

Parents **F_2 populations**



Vaishak Vyttila 6

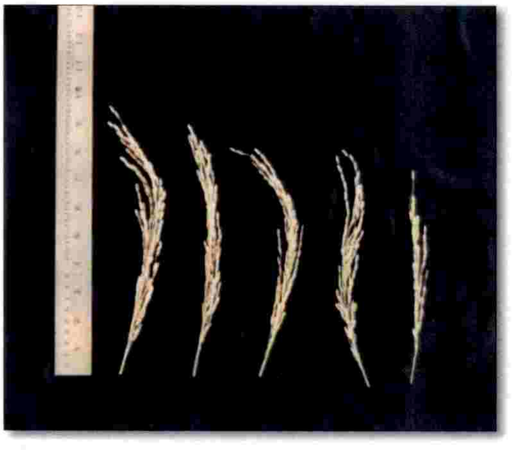


Vaishak x Vyttila

Vaishak Harsha

Vaishak x Harsha

Thottacheera Harsha



Thottacheera x Harsha

4.2 EXPERIMENT II

Plate 7 shows the general field view at vegetative and reproductive stages respectively. The parents and F_2 population at vegetative stage (Plate 8) and reproductive stage (Plate 9) are also shown.

4.2.1 Genetic Variability

The mean values of the seven genotypes (four parents and three F_2 population) for 16 characters were tabulated and presented in Table 14 and Table 18. The graphical representation of the same is given in Fig. 4 and Fig.5.

Morphological Traits

4.2.1.1 Days to 50% Flowering

Among the parents, Thottacheera (76.22 days) flowered early in the season. Varieties Harsha (79.71 days) and Vaishak (80.87 days) closely followed Thottacheera. In the F_2 populations, Thottacheera x Harsha (89.35 days) flowered early followed by segregants of Vaishak x Harsha (93.92 days). The longest duration for 50% flowering was observed in the F_2 population of Vaishak x Vyttila 6 (104.85 days).

4.2.1.2 Number of Productive Tillers Plant^{-1}

Among the parents, Vaishak (6.63) recorded the highest number of productive tillers followed by Thottacheera (5.90) whereas Vyttila 6 (5.17) and Harsha (5.13) recorded lower values. In the F_2 population Thottacheera x Harsha (4.83) recorded the highest mean whereas Vaishak x Harsha (2.23) was the lowest. The number of productive tillers in segregants of Vaishak x Vyttila 6 (3.67) was intermediate to that of the other two F_2 populations.

Plate 7. General view of field at vegetative and reproductive stages under protected condition

Vegetative stage

Reproductive stage

Plate 8. Vegetative stage of parents and F_2 populations under protected condition

Vaishak

Thottacheera

Vyttila 6

Harsha

Vaishak x Vyttila 6

Vaishak x Harsha

Thottacheera x Harsha

Plate 9. Reproductive stage of parents and F_2 population (after moisture stress was given) of parents and F_2 populations under protected condition

Vaishak

Thottacheera

Vyttila 6

Harsha

Vaishak x Vyttila 6

Vaishak x Harsha

Thottacheera x Harsha

4.2.1.3 Plant Height at Maturity (cm)

The parent Vaishak (118.05 cm) was found to be the tallest and Thottacheera (113.77 cm) was found to be following closely behind. The shortest among the parents was Harsha (78.52 cm). Among the F_2 segregants, the tallest was Vaishak x Vyttila 6 (109.15cm). The shortest among F_2 population was Thottacheera x Harsha which recorded 95.09 cm plant height.

4.2.1.4 Panicle Length (cm)

Panicle length among the parents was the highest for Vaishak (28.52 cm) followed by Vyttila 6 (25.88 cm). Thottacheera (22.23 cm) and Harsha (21.52 cm) recorded similar panicle length. Among the F_2 segregants, Vaishak x Vyttila 6 (21.29 cm) and Vaishak x Harsha (22.68 cm) were comparatively taller. The F_2 population of Thottacheera x Harsha (19.54 cm) recorded the lowest value

4.2.1.5 Number of Spikelets Panicle^{-1}

Vyttila 6 (131.20) scored the highest among the parents and Thottacheera (75.51) scored the lowest. Among the F_2 populations, Vaishak x Vyttila 6 (162.40) was found to have the highest mean value whereas segregants of Vaishak x Harsha (96.38) and Thottacheera x Harsha (86.16) marked lower values for number of spikelets panicle^{-1}.

4.2.1.6 Number of Filled Grains Panicle^{-1}

. The highest among the parents was recorded by Vaishak (119.63) and the lowest by Thottacheera (58.66). Among the F_2 segregants, Vaishak x Vyttila 6 (150.53) recorded the highest and was higher than the better parent whereas segregants of Thottacheera x Harsha (79.29) recorded the lowest.

4.2.1.7 Spikelet Sterility (%)

The mean spikelet sterility percentage among the parents ranged from 7.17 percent in Vaishak to 22.38 percent in Vyttila 6 under controlled condition. The

F_2 population recorded lower sterility percentage compared to parents where segregants in F_2 population of Vaishak x Vyttila 6 (5.70 %) marked the lowest followed by segregants of Vaishak x Harsha (7.58%) and Thottacheera x Harsha (7.84%) recorded lower values.

4.2.1.8 Grain Weight Panicle^{-1} (g)

Mean grain weight was the lowest for Thottacheera (0.99g) and the highest for Vaishak(2.72g). Vyttila 6(2.59g) was on par with Vaishak. Among the F_2 segregants, the highest mean value was recorded by Vaishak x Vyttila 6(3.82g) which was higher than the better parent. The F_2 population of Vaishak x Harsha (1.96g) and Thottacheera x Harsha(1.66g) were found to be better than Thottacheera (0.99g).

4.2.1.9 1000 Grain Weight (g)

Mean 1000 grain weight was the lowest for Thottacheera (16.68g) and the highest for Vyttila 6 (25.81g).Vaishak (23.76g) recorded a value closer to Vyttila 6. All the F_2 segregant means were closer to the better parent. Among the F_2 population the segregants of Vaishak x Vyttila 6(25.91g) recorded the highest mean value. The mean of segregants Vaishak x Harsha was 21.40g and that of Thottacheera x Harsha was 20.25g.

4.2.1.10 Grain Yield Plant^{-1} (g)

The mean grain yield among parents was the highest for Vaishak (18.04g) and the lowest for Thottacheera (5.89g). Among F_2 population the segregants of Vaishak x Vyttila 6 (14.02g) reported the highest grain yield. The lowest among F_2 population was for segregants of Vaishak x Harsha (4.32g).

4.2.1.11 Straw Yield Plant^{-1}

Straw yield varied among the parents from 19.31g in Vyttila 6 to 8.04g in Harsha. All the F_2 segregants recorded comparatively higher mean straw yield than parents. Among the F_2 population Thottacheera x Harsha (13.93g) and

Vaishak x Vyttila 6 (13.54g) segregants recorded high values. The lowest mean straw yield was marked in Vaishak x Harsha (10.72g).

4.2.1.12 Harvest Index (%)

Harvest index among parents was the highest for Vaishak (67.44%) and the lowest for Thottacheera (35.25%). Among F_2 population segregants of Vaishak x Vyttila 6 (50.57%) represented the highest mean value whereas the segregants of Vaishak x Harsha (29.56%) recorded the lowest. Harvest index of F_2 population of Thottacheera x Harsha (37.14%) was slightly greater than that of Thottacheera (35.25%).

4.2.1.13 Nature of Panicle Exsertion

The nature of panicle exsertion is presented in Table 15 . Vyttila 6 and Vaishak x Vyttila 6 had their panicles partially exserted from the flag leaf. The varieties, Vaishak and Harsha and the F_2 population, Thottacheera x Harsha had their panicles mostly exserted. The variety, Thottacheera and the F_2 population of Vaishak x Harsha expressed well exserted panicles.

4.2.1.14 Leaf Rolling Score

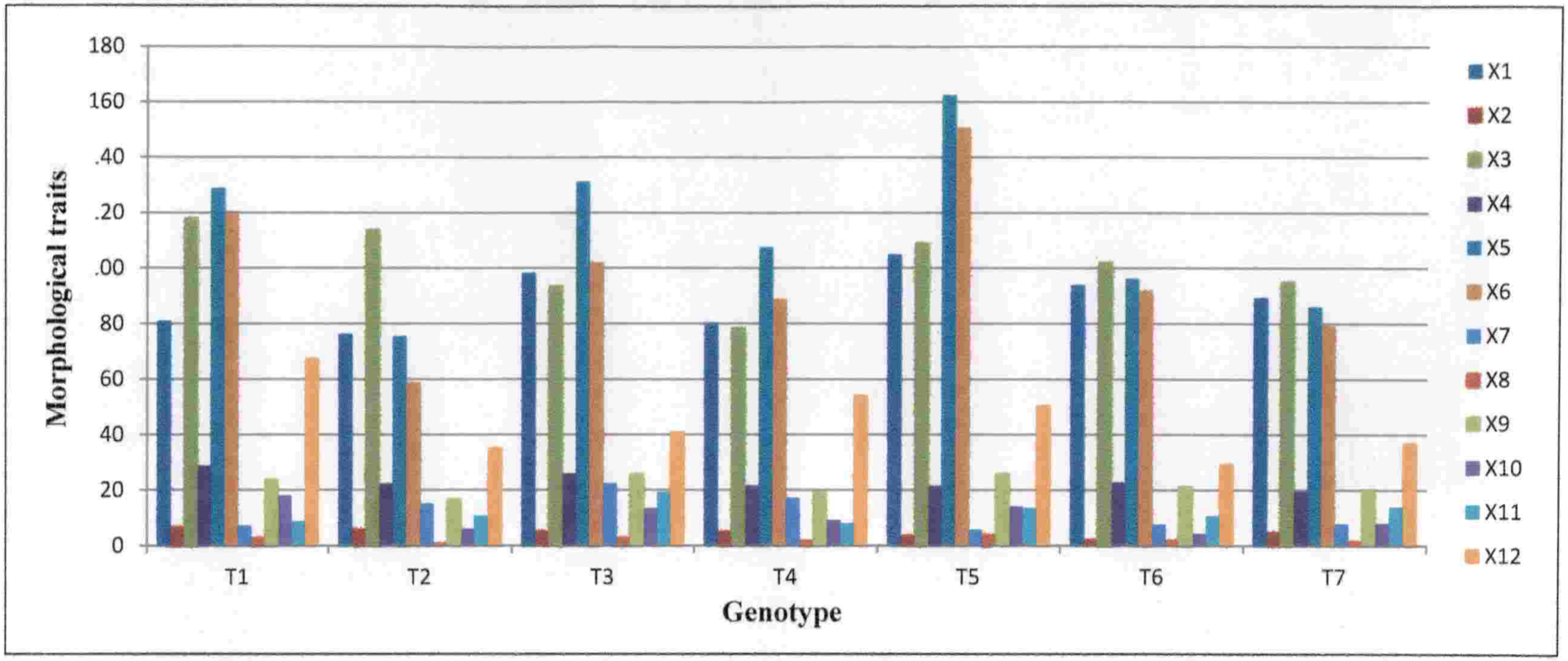
Leaf rolling score was noted after panicle initiation which was accompanied by controlled irrigation and the mean values are presented in Table 16. Leaf rolling in Vaishak (score 1) was not significant. The varieties Thottacheera, Vyttila 6 and Harsha expressed less prominent leaf rolling (score 3). All the F_2 segregants expressed more prominent leaf rolling (score 7) marked by touching of leaf margins especially in the late morning hours (Plate 10) .

4.2.1.15 Incidence of Pests and Diseases

The incidence of pests and diseases is furnished in Table 17. The major pest found in the field was rice bug and the major disease noted was sheath blight. Among the parents, heavy infestation of rice bug was observed in Thottacheera (4.40%) followed by Harsha (3.89%). Among F_2 population pest infestation was

Table 14 .Mean performance for 12 morphological characters of parents and F_2 segregants under protected condition

Sl . No	Parents and F_2 Segregants	Days to 50% flowering	No. of productive tillers plant⁻¹	Plant height at maturity (cm)	Panicle length (cm)	No. of spikelets panicle⁻¹	No. of filled grains panicle⁻¹	Spikelet sterility (%)	Grain weight panicle⁻¹ (g)	1000 grain weight (g)	Grain yield plant⁻¹ (g)	Straw yield plant⁻¹ (g)	Harvest index (%)
		X_1	X_2	X_3	X_4	X_5	X_6	X_7	X_8	X_9	X_{10}	X_{11}	X_{12}
1	Vaishak (T1)	80.87	6.63	118.05	28.52	128.83	119.63	7.17	2.72	23.76	18.04	8.72	67.44
2	Thottacheera (T2)	76.22	5.90	113.77	22.23	75.51	58.66	15.09	0.99	16.68	5.89	10.74	35.25
3	Vyttila 6 (T_3)	98.26	5.17	93.63	25.88	131.20	101.84	22.38	2.59	25.81	13.36	19.31	41.00
4	Harsha (T_4)	79.71	5.13	78.52	21.52	107.57	88.60	17.12	1.76	19.36	9.07	8.04	54.17
5	Vaishak x Vyttila 6 (T_5)	104.85	3.67	109.15	21.29	162.40	150.53	5.70	3.82	25.91	14.02	13.54	50.57
6	Vaishak x Harsha (T_6)	93.92	2.23	102.13	22.68	96.38	91.85	7.58	1.96	21.40	4.32	10.72	29.56
7	Thottacheera x Harsha (T_7)	89.35	4.83	95.09	19.54	86.16	79.29	7.84	1.66	20.25	8.00	13.93	37.14
Parents mean		83.77	5.71	100.99	24.53	110.77	92.18	15.43	2.02	21.40	11.59	11.70	49.47
F_2Segregantsmean		96.04	3.58	102.12	21.17	114.98	107.22	7.04	2.48	22.52	8.78	12.73	39.09



X1: Days to 50% flowering
X2: Number of productive tillers plant^{-1}
X3: Plant height at maturity(cm)
X4: Panicle length(cm)
X5: Number of spikelets panicle^{-1}
X6: Number of filled grains pancle^{-1}
X7: Spikelet sterility(%)
X8: Grain weight panicle^{-1}(g)
X9 : 1000 grain weight(g)
X10: Grain yield plant^{-1}(g)
X11: Straw yield plant^{-1}(g)
X12 : Harvest index(%)

Fig. 4. Mean performance for 12 morphological traits of parents and F_2 segregants under protected condition

Table 15. Nature of panicle exsertion in parents and F_2 segregants under protected condition

Sl. No	Parents and F_2 segregants	Nature of panicle exsertion
1	Vaishak (T_1)	Mostly exserted
2	Thottacheera (T_2)	Well exserted
3	Vyttila 6(T_3)	Partially exserted
4	Harsha(T_4)	Mostly exserted
5	Vaishak x Vyttila 6 (T_5)	Partially exserted
6	Vaishak x Harsha (T_6)	Well exserted
7	Thottacheera x Harsha (T_7)	Mostly exserted

Table 16. Leaf rolling score for parents and F_2 segregants under protected condition

Sl. No	Parents and F_2 segregants	Score	Description
1	Vaishak (T_1)	1	Leaves start to fold (shallow V shape)
2	Thottacheera(T_2)	3	Leaves folding (deep V shape)
3	Vyttila 6(T_3)	3	Leaves folding (deep V shape)
4	Harsha (T_4)	3	Leaves folding (deep V shape
5	Vaishak x Vyttila 6(T_5)	7	Leaf margin touching(O shape)
6	Vaishak x Harsha(T_6)	7	Leaf margin touching(O shape)
7	Thottacheera x Harsha(T_7)	7	Leaf margin touching(O shape)

Table 17. Incidence of pest and diseases in parents and F_2 segregants under protected condition

Sl. No	Parents and F_2 segregants	Incidence (%)	
		Pest (Rice bug)	Disease (Sheath rot)
1	Vaishak (T_1)	1.25	1.13
2	Thottacheera (T_2)	4.40	2.32
3	Vyttila 6 (T_3)	1.32	1.09
4	Harsha (T_4)	3.89	2.45
5	Vaishak x Vyttila 6 (T_5)	1.15	1.17
6	Vaishak x Harsha (T_6)	2.05	1.50
7	Thottacheera x Harsha (T_7)	2.67	1.77

Plate 10. Leaf rolling in F_2 populations (after moisture stress given) under protected condition

Vaishak x Vyttila 6

Vaishak x Harsha

Thottacheera x Harsha

the highest in segregants of Thottacheera x Harsha (2.67%). The F_2 population Vaishak x Harsha recorded 2.05% whereas the infestation in Vaishak (1.25%), Vyttila 6 (1.32%) and Vaishak x Vyttila 6 (1.15%) was comparatively low.

In case of disease incidence, the varieties Vaishak (1.13%) and Vyttila 6 (1.09%) were less susceptible compared to Thottacheera (2.32%) and Harsha (2.45%). The infestation in F_2 populations of Vaishak x Vyttila 6 (1.17%) , Vaishak x Harsha (1.50%) and Thottacheera x Harsha (1.77%) was of lower magnitude.

Physiological and Biochemical Traits

4.2.1.16 Proline Content

Proline content among parents, varied from 0.30 mg g^{-1} in Harsha to 0.55 mg g^{-1} in Vyttila 6. Among the F_2 population highest mean value was observed in segregant ts of Vaishak x Vyttila 6 (0.57 mg g^{-1}) followed by Thottacheera x Harsha (0.51 mg g^{-1}). The lowest mean among F_2 population was for Vaishak x Harsha (0.40 mg g^{-1}).

4.2.1.17 Chlorophyll Content (mg g^{-1})

The parent, Harsha (1.34mg g^{-1}) recorded the highest chlorophyll content whereas Thottacheera (0.68 mg g^{-1}) recorded the lowest mean value. Among the F_2 segregants Thottacheera x Harsha (1.28 mg g^{-1}) marked the highest mean value. Both the F_2 populations Vaishak x Harsha (1.18 mg g^{-1}) and Vaishak x Vyttila 6 (1.14mg g^{-1}) recorded mean values closer to each other.

4.2.1.18 Leaf Soluble Protein Content (mg g^{-1})

Leaf soluble protein content among parents ranged from 4.56 mg g^{-1} in Harsha to 7.38 mg g^{-1} in Vyttila 6. Among the F_2 segregants the highest mean value was recorded by the population of Thottacheera x Harsha (8.28 mg g^{-1})

which was higher than the better parent. The lowest mean value was recorded by the F_2 population of Vaishak x Harsha (4.57mg g^{-1}).

4.2.1.19 Leaf Area Index

Mean leaf area index at maturity was found to be the highest in Thottacheera (0.64) and the lowest in Harsha (0.34) in case of parents. In the F_2 population Thottacheera x Harsha (0.71) recorded the highest mean value whereas segregants of Vaishak x Vyttila 6 (0.36) and Vaishak x Harsha (0.36) recorded the lowest value.

4.2.2 Percentage of Soil Moisture Content

Percentage soil moisture content is presented in Table 19. The moisture content varied from 4.07 percent at seedling stage, 7.87 percent at maturity and 3.27 percent before harvest.

4.2.3 Correlation Studies

Simple correlation for all the characters with grain yield plant^{-1} was worked out and is presented in Table 20.

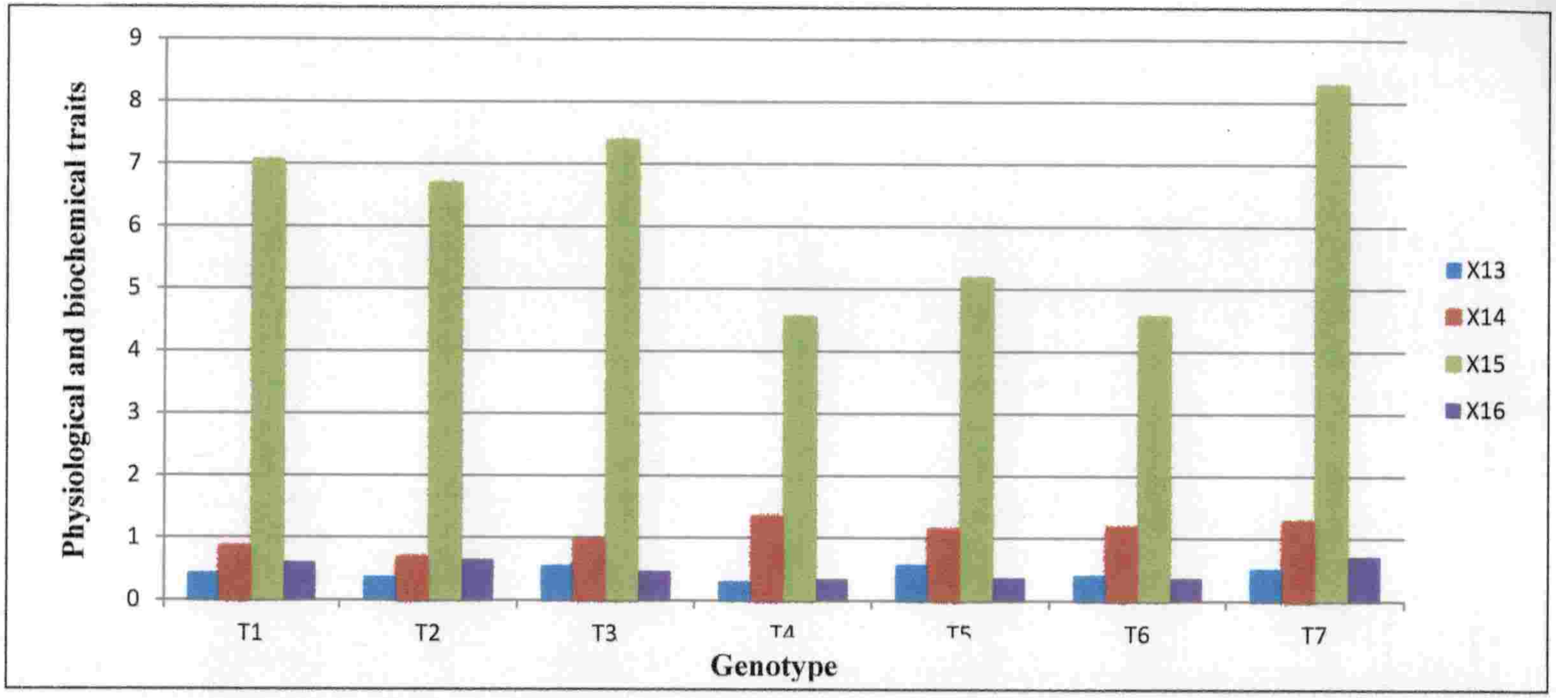
The parental genotypes marked significant positive correlation for characters such as panicle length (0.788), number of spikelets panicle^{-1} (0.844), number of filled grains panicle^{-1} (0.902), grain weight panicle^{-1} (0.944) and 1000 grain weight (0.800). In the F_2 population, significant positive correlation was observed for number of spikelets panicle^{-1} (0.699), number of filled grains panicle^{-1} (0.671), grain weight panicle^{-1}(0.882) , 1000 grain weight (0.692) harvest index (0.901) and proline content (0.922).

4.2.4 Estimation of Similarity between the Genotypes

Proximity matrix based on squared Euclidean distances was worked out for the parents and F_2 populations and is furnished in Table 21. From the table it can be observed that the F_2 population Vaishak x Vyttila 6 (22.885) was more

Table 18. Mean performance of physiological and biochemical characters of parents and F_2segregantsunder protected condition

Sl . No	Parents and F_2 Segregants	Proline content (mg g^{-1})	Chlorophyll content (mg g^{-1})	Leaf soluble protein content (mg g^{-1})	Leaf area index (at maturity)
		X_{13}	X_{14}	X_{15}	X_{16}
1	Vaishak (T1)	0.43	0.85	7.06	0.60
2	Thottacheera (T2)	0.37	0.68	6.69	0.64
3	Vyttila 6 (T_3)	0.55	0.97	7.38	0.46
4	Harsha (T_4)	0.30	1.34	4.56	0.34
5	Vaishak x Vyttila 6 (T_5)	0.57	1.14	5.18	0.36
6	Vaishak x Harsha (T_6)	0.40	1.18	4.57	0.36
7	Thottacheera x Harsha (T_7)	0.51	1.28	8.28	0.71
Parents mean		0.41	0.96	6.42	0.51
F_2Segregantsmean		0.32	1.19	6.01	0.47



X13: Proline content (mg g^{-1})
X14: Chlorophyll content (mg g^{-1})
X15: Leaf soluble protein content (mg g^{-1})
X16: Leaf area index (at maturity)

Fig. 5. Mean performance for physiological and biochemical traits of parents and F_2 segregants under protected condition

Table 19. Percentage soil moisture content under protected condition

Sl.no	Stage of crop	Moisture content (%)
1	Seedling stage	4.07
2	At maturity	7.87
3	Before harvest	3.27

Table 20. Simple correlation of 15 characters with grain yield plant^{-1} in parents and F_2 segregants under protected condition

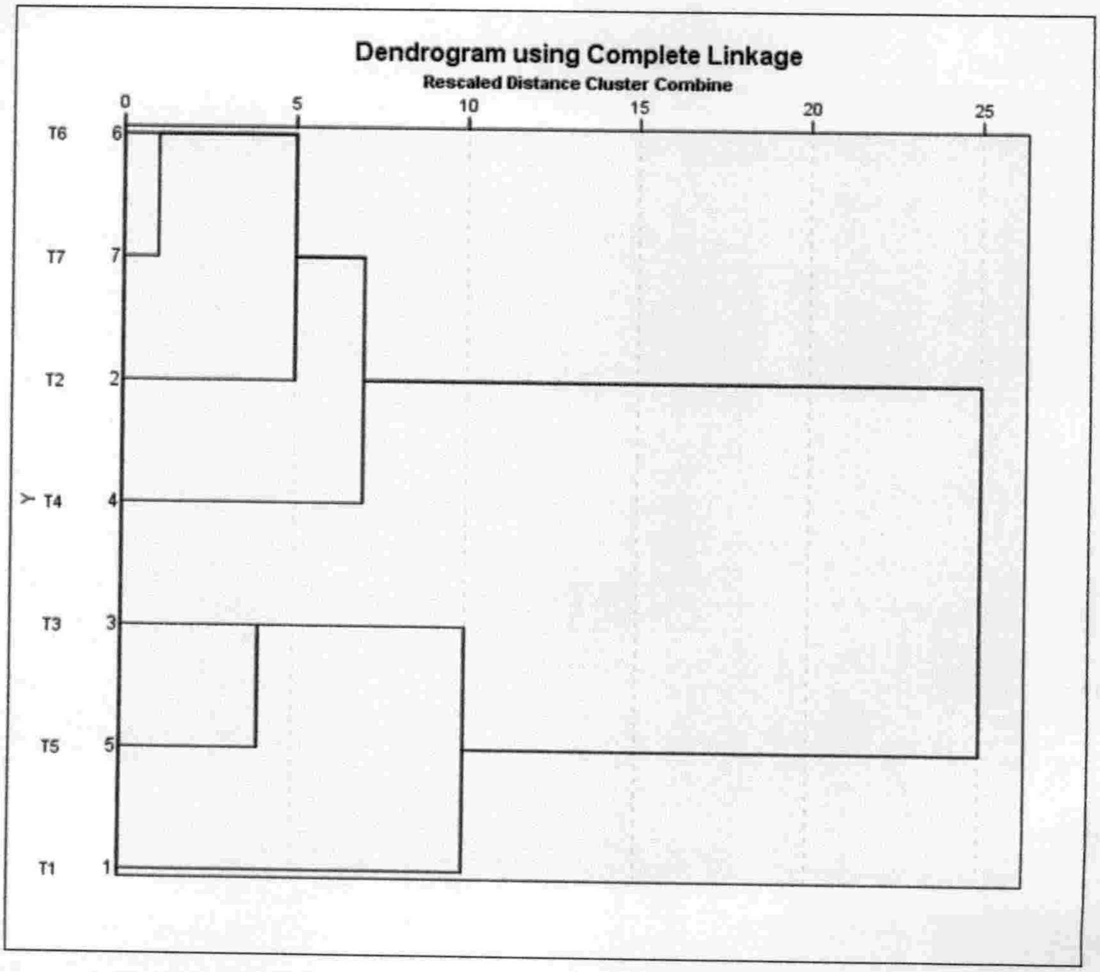
Sl.No	Characters	Parents	F_2 segregants
1	Days to 50% flowering	0.371	0.547
2	No. of productive tillers plant^{-1}	0.472	0.381
3	Plant height at maturity(cm)	0.207	0.554
4	Panicle length (cm)	0.788**	-0.301
5	No. of spikelets panicle^{-1}	0.844**	0.699*
6	No. of filled grains panicle^{-1}	0.902**	0.671*
7	Spikelet sterility(%)	-0.280	-0.280
8	Grain weight panicle^{-1}(g)	0.944**	0.882**
9	1000 grain weight(g)	0.800**	0.692*
10	Straw yield plant^{-1}	0.159	0.212
11	Harvest index(%)	0.688*	0.901**
12	Proline content (mg g^{-1})	0.495	0.922**
13	Chlorophyll content (mg g^{-1})	-0.089	-0.007
14	Leaf soluble protein content (mg g^{-1})	0.423	0.0003
15	Leaf area index	0.096	-0.126

* Significant at 5% level
** significant at 1% level

Table 21 : Proximity matrix based on squared Euclidean distances calculated from standardised mean values for all the characters under study (under protected condition)

Genotype	Squared Euclidean Distance						
	T1	T2	T3	T4	T5	T6	T7
T1	0.000	34.887	29.074	37.458	33.348	39.781	37.707
T2	34.887	0.000	38.988	28.352	65.193	24.257	20.037
T3	29.074	38.988	0.000	35.942	22.885	27.262	24.810
T4	37.458	28.352	35.942	0.000	39.430	21.271	27.969
T5	33.348	65.193	22.885	39.430	0.000	28.808	38.433
T6	39.781	24.257	27.262	21.271	28.808	0.000	15.028
T7	37.707	20.037	24.810	27.969	38.433	15.028	0.000

T1: Vaishak
T2: Thottacheera
T3: Vyttila 6
T4: Harsha
T5: Vaishak x Vyttila 6
T6: Vaishak x Harsha
T7: Thottacheera x Harsha



T1: Vaishak
T2: Thottacheera
T3: Vyttila 6
T4: Harsha

T5 : Vaishak x Vyttila 6
T6 : Vaishak x Harsha
T7 : Thottacheera x Harsha

Fig. 6. Dendrogram using complete linkage for the proximity matrix presented in table 21 (under protected condition)

close to the parent Vyttila 6. The segregants of Vaishak x Harsha (21.271) was similar to Harsha and the segregants in F_2 populations of Thottacheera x Harsha (20.037) was closer to the variety Thottacheera.

Dendrogram using complete linkage for the dissimilarity matrix was also prepared using SPSS software and is presented in Fig. 6. The dendrogram revealed that at a distance of 5 units , the genotypes were grouped into four clusters. Harsha and segregants of Vaishak x Harsha formed the first cluster. Thottacheera and F_2 population of Thottacheera x Harsha were grouped into the second cluster. The third cluster included Vyttila 6 and the segregants of Vaishak x Vyttila 6. The fourth cluster had Vaishak alone.

4.2.5 Percentage of F_2 segregants

Percentage estimates of positive and negative segregants in all the three F_2 populations were worked out and are presented in Table 22.

The highest percentage of positive segregants in the F_2 population of Vaishak x Vyttila 6 was observed for grain weight panicle^{-1} (88%), number of filled grains panicle^{-1} (85%) and number of spikelets panicle^{-1} (70%) whereas a higher percentage of negative segregants were observed for panicle length (75%) and number of productive tillers plant^{-1} (55%).

The segregants in F_2 population of Vaishak x Harsha gave high percentage of positive segregants in days to 50% flowering (78%) and straw yield plant^{-1} (76%). Negative segregants were more for harvest index (90%), grain yield plant^{-1} (88%), number of productive tillers^{-1} (80%) and number of spikelets panicle^{-1} (75%).

The third F_2 population, Thottacheera x Harsha recorded the highest percentage of positive segregants for 1000 grain weight (80%). Negative segregants were greater in spikelet sterility (90%) and number of productive tillers plant^{-1} (75%). Plate 11 shows the variation in panicle length in the F_2 population.

Table 22. Percent estimates of positive and negative segregants in the three F_2 segregants under protected condition

Sl. No	Characters	F_2 segregants (%)					
		Vaishak x Vyttila 6 (T_5)		Vaishak x Harsha (T_6)		Thottacheera x Harsha (T_7)	
		Positive	Negative	Positive	Negative	Positive	Negative
1	Days to 50% flowering	38	Nil	78	Nil	45	Nil
2	No. of productive tillers plant^{-1}	Nil	55	Nil	80	15	75
3	Plant height at maturity(cm)	28	38	35	Nil	28	Nil
4	Panicle length (cm)	Nil	75	Nil	36	21	30
5	No. of spikelets panicle^{-1}	70	Nil	Nil	75	Nil	18
6	No. of filled grains panicle^{-1}	85	Nil	21	38	Nil	20
7	Spikelet sterility(%)	Nil	47	Nil	15	Nil	90
8	Grain weight panicle^{-1}(g)	88	Nil	38	10	19	Nil
9	1000 grain weight(g)	20	Nil	Nil	18	80	Nil
10	Grain yield plant^{-1}	Nil	28	Nil	88	22	Nil
11	Straw yield plant^{-1}	15	Nil	76	Nil	44	Nil
12	Harvest index(%)	36	25	Nil	90	Nil	28

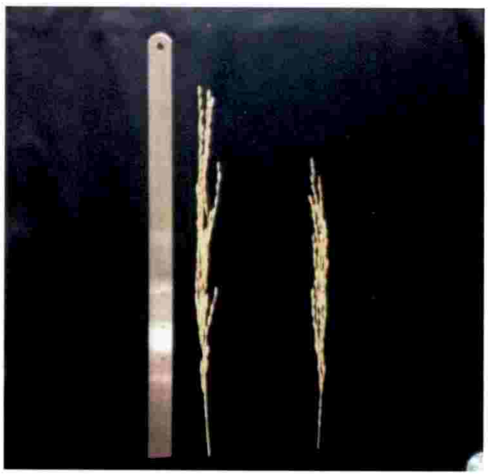
Plate 11. Variation in panicle length of F_2 populations under protected condition

Parents

F_2 populations

Vaishak   Vyttila 6

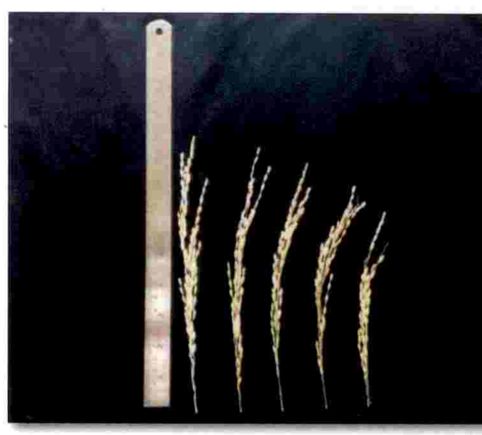
Vaishak x Vyttila 6



Vaishak   Harsha

Vaishak x Harsha

Thottacheera   Harsha



Thottacheera x Harsha

4.3 COMPARISON OF EXPERIMENTS I AND II

4.3.1 Mean performance of the characters under study

The mean performance of the genotypes for the 16 characters studied under upland and protected condition and the percentage change in characters due to imposed moisture stress are presented in Tables 23 to 38 and Figures 7 to 24.

Morphological traits

4.3.1.1 Days to 50% Flowering

An increase was observed for days to 50% flowering in case of F_2 segregants as compared to the parents under stress condition (Table 23 and Fig. 7). Among the parents, Thottacheera (75.76 days) was the earliest in flowering under normal condition whereas Harsha (79.71 days) flowered early under controlled condition. The parental variety, Vyttila 6 flowered late in the season both under normal and stress conditions taking 99.44 days and 98.26 days respectively to reach 50% flowering. Among the F_2 populations, segregants of Thottacheera x Harsha was the earliest in flowering both under normal (77.43 days) and stress (89.35 days) condition. The late flowering type under both conditions was segregants of Vaishak x Vyttila 6, taking 97.82 days and 104.85 days under normal and drought condition respectively.

Number of days to 50% flowering decreased in all the parents except Thottacheera and increased in all the F_2 populations when grown under stress condition. The decrease was more prominent in Vaishak (15.18%) whereas Vyttila 6 (1.19%) marked the least increase. Among the F_2 populations, the increase in days to 50% flowering was more in segregants of Thottacheera x Harsha (15.39%) and the least in segregants of Vaishak x Vyttila 6(7.19%).

4.3.1.2 Number of Productive Tillers Plant^{-1}

A decrease in number of productive tillers plant^{-1} was observed under stress condition (Table 24 and Fig. 8). Among the parents, number of productive

Table 23. Mean performance for days to 50% flowering of parents and F_2 segregants under upland and protected condition

Sl. No	Parents and F_2 segregants	Days to 50% flowering		Percentage change(%)
		Upland	Protected	
1	Vaishak (T_1)	95.34	80.87	-15.18
2	Thottacheera (T_2)	75.76	96.22	27.01
3	Vyttila 6(T_3)	99.44	98.26	-1.19
4	Harsha (T_4)	86.69	79.71	-8.05
5	Vaishak x Vyttila 6(T_5)	97.82	104.85	7.19
6	Vaishak x Harsha(T_6)	82.25	93.92	14.19
7	Thottacheera x Harsha(T_7)	77.43	89.35	15.39

Table 24. Mean performance for number of productive tillers plant^{-1} of parents and F_2 segregants under upland and protected condition

Sl. No	Parents and F_2 segregants	Number of productive tillers plant^{-1}		Percentage change(%)
		Upland	Protected	
1	Vaishak (T_1)	9.23	6.63	-28.17
2	Thottacheera (T_2)	9.00	5.90	-34.44
3	Vyttila 6(T_3)	10.13	5.17	-48.96
4	Harsha (T_4)	9.40	5.13	-45.42
5	Vaishak x Vyttila 6(T_5)	12.07	3.67	-69.59
6	Vaishak x Harsha(T_6)	14.13	2.23	-84.22
7	Thottacheera x Harsha(T_7)	11.13	4.83	-56.60

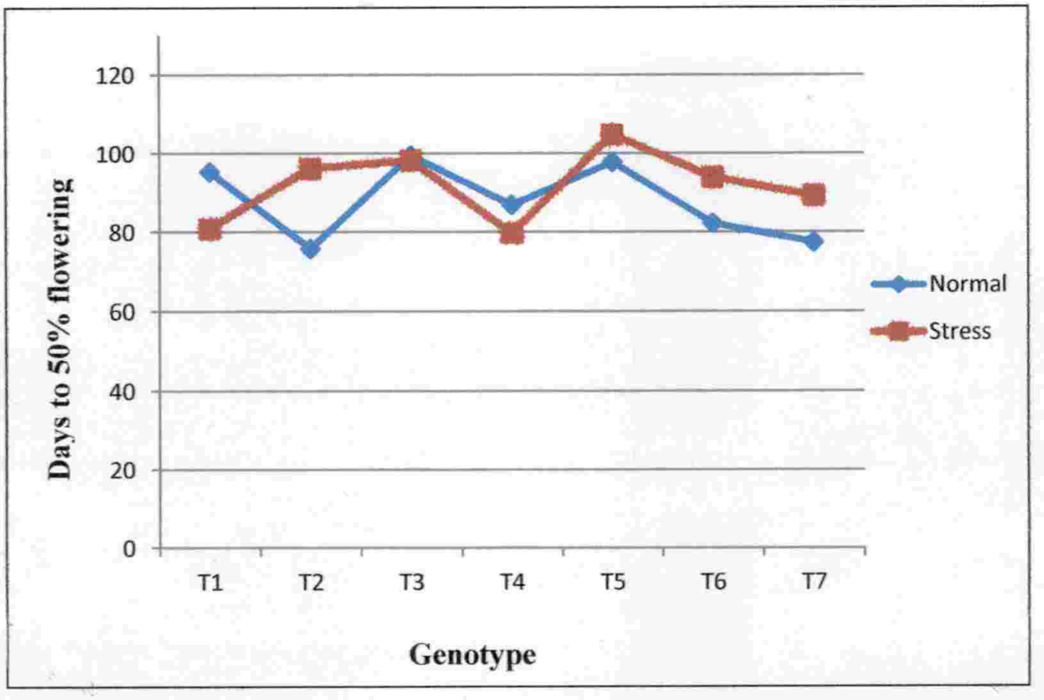


Fig. 7. Variation in mean days to 50% flowering under normal and stress condition

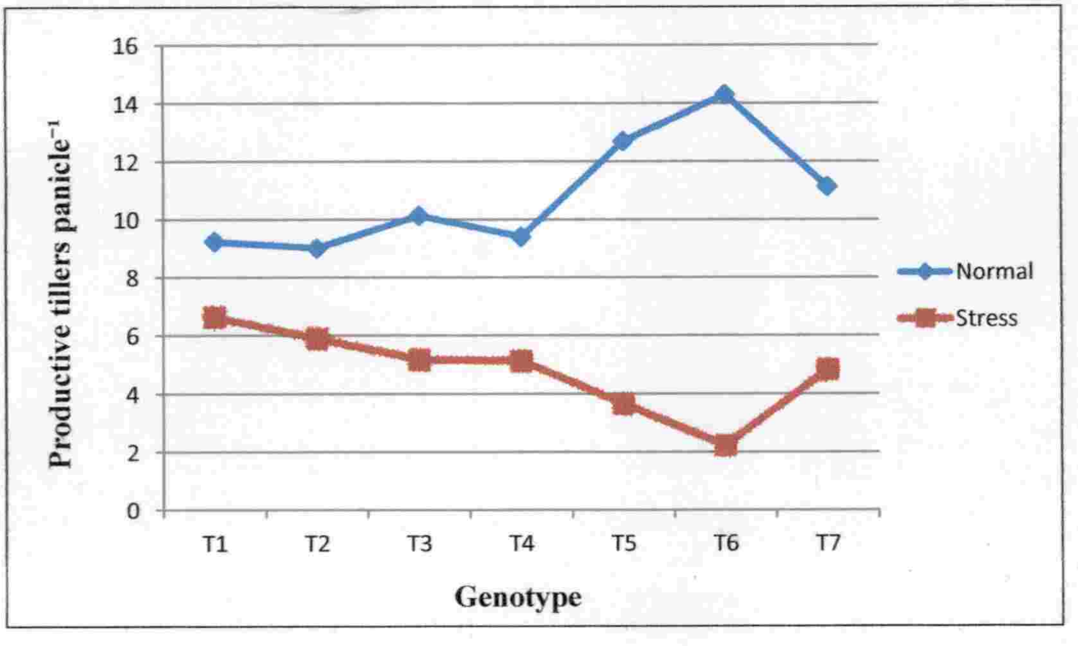


Fig. 8. Variation in mean number of productive tillers plant^{-1} under normal and stress condition

tillers was the highest in Vyttila 6(10.13) and the lowest in Thottacheera (9.00) under upland condition. Under stress condition it ranged from Vaishak (6.63) to Harsha (5.13). In the F_2 population, number of productive tillers was the highest in Vaishak x Harsha (14.13) and the lowest in segregants of Thottacheera x Harsha (11.13) under normal condition. When grown under protected condition, Thottacheera x Harsha (4.83) recorded the highest and Vaishak x Harsha (2.23) marked the lowest mean value.

In case of parents, the percentage decrease in number of productive tillers plant^{-1} was more prominent in Vyttila 6 (48.96%) and less in Vaishak (28.17%). In the F_2 populations, the decrease was more in Vaishak x Harsha (84.22) and less in Thottacheera x Harsha (56.60).

4.3.1.3 Plant Height at Maturity (cm)

A decrease in mean plant height was observed under stress condition (Table 25 and Fig. 9). Plant height was the highest in Vaishak both under upland (126.4cm) and stress condition(118.05cm). Harsha (88.2 days) marked the lowest value under normal condition whereas under stress Vyttila 6 (60.29cm) was the shortest. Among the F_2 populations, Vaishak x Harsha (128.13cm) recorded the highest value under normal condition whereas segregants of Vaishak x Vyttila 6(109.15cm) recorded the highest value under protected condition. The F_2 population of Thottacheera x Harsha recorded the lowest value both under upland (126.93) and controlled (95.09cm) condition.

The percentage decrease in height among the parents was more for Vyttila 6(35.81%) and less for Vaishak (6.61%) whereas an increase in plant height was observed for Thottacheera (19.01%) Among the F_2 populations, the decrease was more prominent in Thottacheera x Harsha (25.08%) and less in Vaishak x Vyttila 6 (14.33%).

4.3.1.4 Panicle Length (cm)

The variation in panicle length under stress condition compared to normal is presented in Table 26 and Figure 10. The variety Thottacheera (24.53cm) recorded the highest mean value and Vyttila 6 (20.91cm) recorded the lowest mean value under normal condition. When grown under stress condition, Vaishak (28.52cm) marked the longest panicle length whereas Harsha (21.52cm) was the shortest. Among the F_2 segregants, Vaishak x Vyttila 6 (24.68cm) recorded the highest mean value under upland condition whereas segregants of Vaishak x Vyttila 6(22.68cm) was found to have the longest panicles under stress. The F_2 population of Thottacheera x Harsha recorded the lowest value both under upland (21.87cm) and stress (19.54cm) conditions.

Both increase and decease in panicle length was noted among the parents when grown under protected condition. The percentage increase was more prominent in Vyttila 6(23.77%) and the decrease was more in Thottacheera (9.38%). All the F_2 populations showed a decrease in panicle length among which Vaishak x Vyttila 6 segregants (13.74%) recorded the highest value whereas Vaishak X Harsha segregants (4.63%) recorded the lowest.

4.3.1.5 Number of Spikelets Panicle^{-1}

Number of spikelets panicle^{-1} showed a decrease when grown under stress condition (Table 27 and Fig. 11). Vaishak (171.00) produced more number of spikelets when grown under normal condition. Vyttila 6 marked the lowest value (148.67) for number of spikelets under upland condition whereas it recorded the highest value (131.20) when grown under stress. Thottacheera (75.51) was found to produce more number of spikelets panicle^{-1} when grown under stress. Among the F_2 populations, Vaishak x Vyttila 6 recorded the highest mean value both under normal (169.05) and stress condition (162.40). Segregants of the F_2 population Vaishak x Harsha (155.22) recorded the lowest mean value under normal condition whereas segregants of Thottacheera x Harsha (86.16) recorded the lowest mean value under stress condition.

Table 25. Mean performance for plant height at maturity(cm) of parents and F_2 segregants under upland and protected condition

Sl. No	Parents and F_2 segregants	Plant height at maturity(cm)		Percentage change(%)
		Upland	Protected	
1	Vaishak (T_1)	126.40	118.05	-6.61
2	Thottacheera (T_2)	95.60	113.77	19.01
3	Vyttila 6(T_3)	93.93	60.29	-35.81
4	Harsha (T_4)	88.20	78.52	-10.98
5	Vaishak x Vyttila 6(T_5)	127.4	109.15	-14.33
6	Vaishak x Harsha(T_6)	128.13	102.13	-20.29
7	Thottacheera x Harsha(T_7)	126.93	95.09	-25.08

Table 26. Mean performance for panicle length (cm) of parents and F_2 segregants under upland and protected condition

Sl. No	Parents and F_2 segregants	Panicle length(cm)		Percentage change(%)
		Upland	Protected	
1	Vaishak (T_1)	23.89	28.52	19.38
2	Thottacheera (T_2)	24.53	22.23	-9.38
3	Vyttila 6(T_3)	20.91	25.88	23.77
4	Harsha (T_4)	23.00	21.52	-6.43
5	Vaishak x Vyttila 6(T_5)	24.68	21.29	-13.74
6	Vaishak x Harsha(T_6)	23.78	22.68	-4.63
7	Thottacheera x Harsha(T_7)	21.87	19.54	-10.65

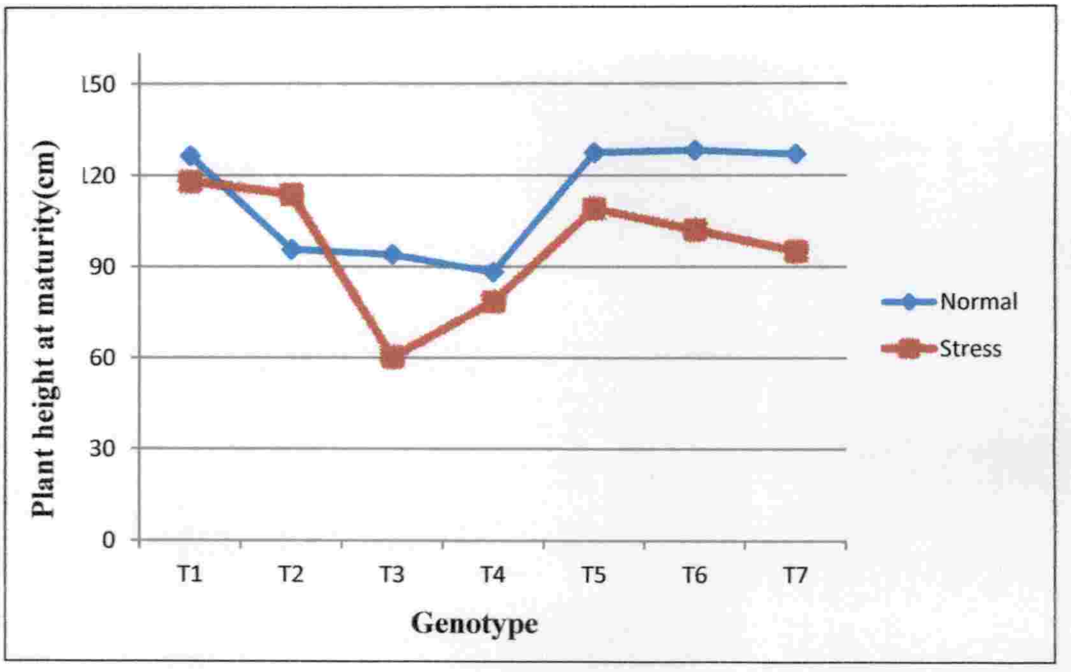


Fig.9. Variation in mean plant height at maturity under normal and stress condition

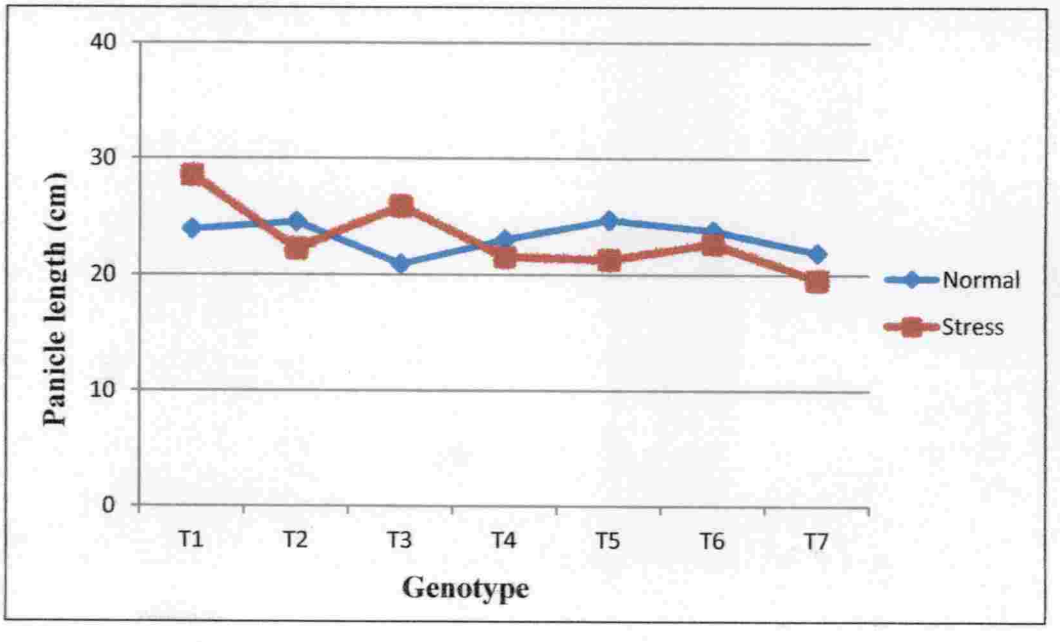


Fig. 10. Variation in mean panicle length under normal and stress condition

Among the parents, the percentage decrease in number of spikelets was more prominent in Thottacheera (49.73%) and less in Vyttila 6 (11.75%). Among the F_2, the percentage decrease was the highest in Thottacheera x Harsha (47.25%) whereas it was the lowest in Vaishak x Vyttila 6 (3.93%).

4.3.2.6 Number of Filled Grains Panicle^{-1}

Number of filled grains panicle generally decreased under stress condition (Table 28 and Fig. 12). Among the parents, Vaishak was found to have the highest number of filled grains panicle^{-1} both under upland (159.88) and stress conditions (119.63). Vyttila 6 (128.56) recorded the lowest value under normal condition whereas Thottacheera (58.66) recorded the lowest value under stress. Among the F_2 population, the segregants of Vaishak x Harsha (137.11) marked the highest mean value under normal condition whereas segregants of Vaishak x Vyttila 6 (150.53) recorded more number of filled grains under stress. The F_2 population, Thottacheera x Harsha recorded the lowest mean value both under upland (121.99) and stress (79.29) condition.

The percentage decrease in the character was the highest in Thottacheera (56.83%) and the lowest in Vyttila 6 (20.78%) among the parents. In case of F_2 populations, the decrease was more prominent in Thottacheera x Harsha segregants (35%) and less in Vaishak x Harsha segregants (33.01%) whereas a slight increase was observed in case of Vaishak x Vyttila 6 (11.78%) population.

4.3.1.7 Spikelet Sterility (%)

The variation in mean spikelet sterility is presented in Table 29 and Figure 13. Among the parents, mean spikelet sterility was the highest in Vyttila 6 both under upland (13.56%) and stress (22.38%) conditions. Vaishak recorded the lowest mean value when gown under both normal (7.44%) and controlled (7.17%) conditions. Among the F_2 populations, segregants of Thottacheera x Harsha (41.33%) recorded the highest mean value and Vaishak x Harsha (18.11%) recorded the lowest when grown under normal condition. Under stress, F_2

Table 27. Mean performance for number of spikelets panicle^{-1} of parents and F_2 segregants under upland and protected condition

Sl. No	Parents and F_2 segregants	Number of spikelets panicle^{-1}		Percentage change(%)
		Upland	Protected	
1	Vaishak (T_1)	171.00	128.83	-24.66
2	Thottacheera (T_2)	150.22	75.51	-49.73
3	Vyttila 6(T_3)	148.67	131.20	-11.75
4	Harsha (T_4)	169.78	107.57	-36.64
5	Vaishak x Vyttila 6(T_5)	169.05	162.40	-3.93
6	Vaishak x Harsha(T_6)	155.22	96.38	-37.91
7	Thottacheera x Harsha(T_7)	163.33	86.16	-47.25

Table 28. Mean performance for number of filled grains panicle^{-1} of parents and F_2 segregants under upland and protected condition

Sl. No	Parents and F_2 segregants	Number of filled grains panicle^{-1}		Percentage change(%)
		Upland	Protected	
1	Vaishak (T_1)	159.88	119.63	-25.18
2	Thottacheera (T_2)	135.87	58.66	-56.83
3	Vyttila 6(T_3)	128.56	101.84	-20.78
4	Harsha (T_4)	152.99	88.6	-42.08
5	Vaishak x Vyttila 6(T_5)	134.67	150.53	11.78
6	Vaishak x Harsha(T_6)	137.11	91.85	-33.01
7	Thottacheera x Harsha(T_7)	121.99	79.29	-35.00

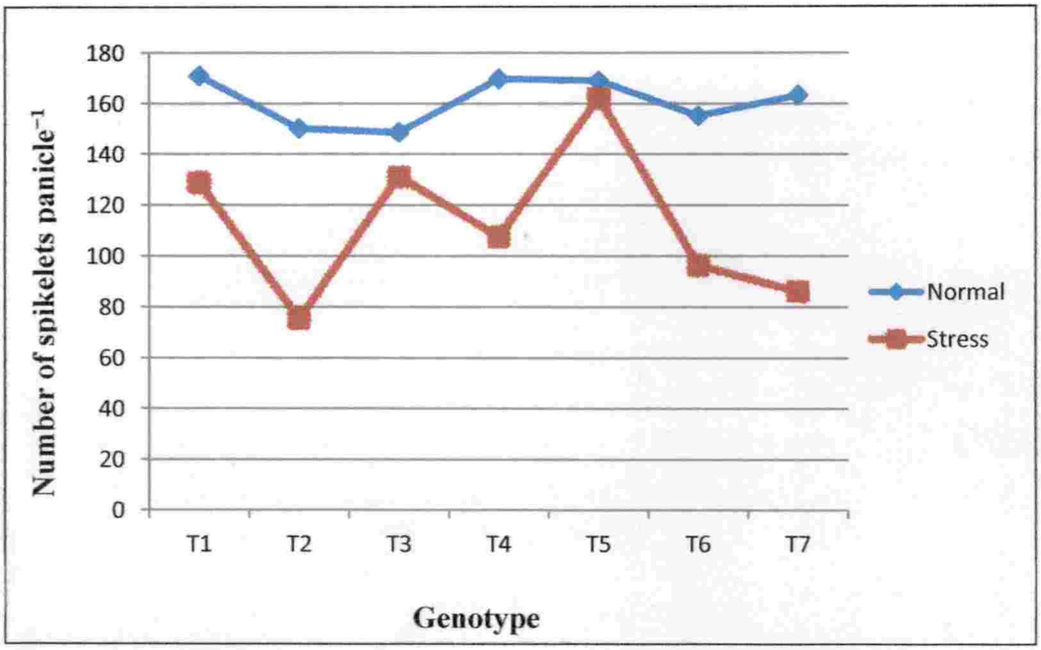


Fig. 11. Variation in mean number of spikelets panicle^{-1} under normal and stress condition

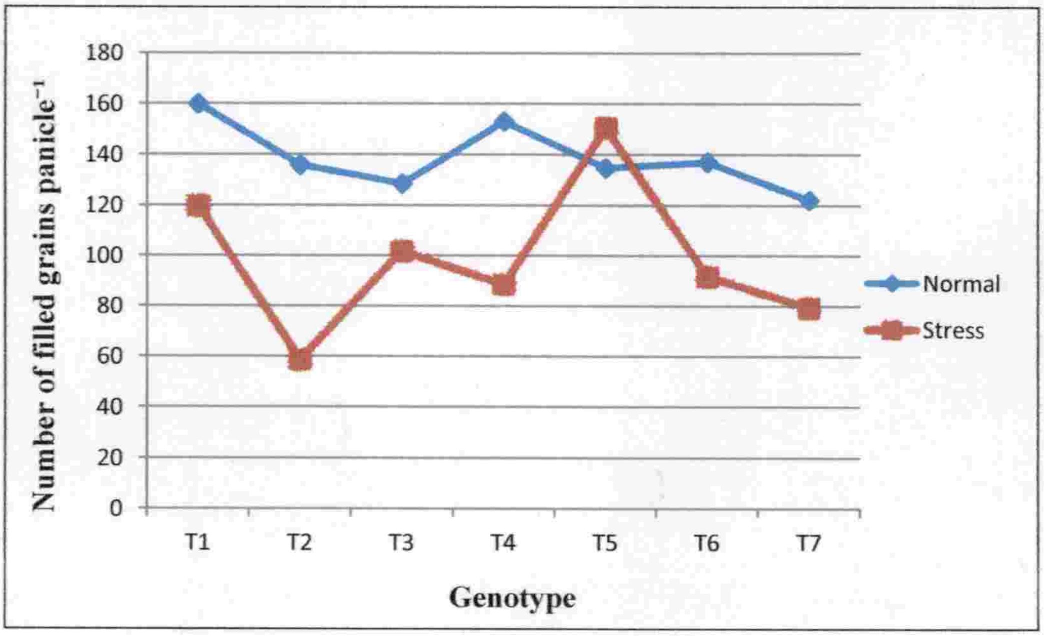


Fig. 12. Variation in number of filled grains panicle^{-1} under normal and stress condition

population of Thottacheera x Harsha (7.84%) recorded the highest mean value and Vaishak x Vyttila 6 segregants (5.70%) recorded the lowest value.

Mean spikelet sterility generally increased when grown under stress in case of parents whereas it decreased in case of F_2 population. The percentage increase in parents was the highest for Harsha (67.09%) and lowest for Thottacheera (57.35%). A slight decrease was noted in Vaishak (3.63%). In case of F_2 segregants the decrease was more prominent for segregants of Thottacheera x Harsha (81.03%) and less for Vaishak x Harsha (58.14%).

4.3.1.8 Grain Weight Panicle^{-1} (g)

Variation in grain weight panicle is presented in Table 30 and Figure 14. Under upland condition, the parent, Harsha (4.26g) recorded the highest value and Vyttila 6 (2.49g) recorded the lowest value. When gown under rain shelter, Vaishak (2.72g) recorded the highest value and Thottacheera (0.99g) recorded the lowest value. Among the F_2 population, Vaishak x Harsha (3.43g) recorded the highest mean value under normal condition whereas segregants of Vaishak x Vyttila 6 (3.82g) recorded the highest mean under stress condition. The lowest mean value was recorded for segregants of Thottacheera x Harsha both under upland (2.95g) and stress (1.66g) conditions.

Among the parents, a slight increase in grain weight panicle^{-1} was observed in Vyttila 6 (4.02%) under stress whereas it decreased in case of other varieties. The percentage decrease was more for Thottacheera (65.98%). In case of F_2 population mean grain weight increased in case of Vaishak x Vyttila 6 (23.23%). The percentage decrease was more for Thottacheera x Harsha (43.73%) population respectively.

4.3.1.9 1000 Grain Weight (g)

1000 grain weight decreased under stress condition (Table 31 and Fig. 15). When grown under upland condition, the variety Vaishak (28.53g) recorded the highest 1000 grain weight whereas the lowest value was recorded by Thottacheera

Table 29. Mean performance for spikelet sterility (%) of parents and F_2 segregants under upland and protected condition

Sl. No	Parents and F_2 segregants	Spikelet sterility (%)		Percentage change(%)
		Upland	Protected	
1	Vaishak (T_1)	7.44	7.17	-3.63
2	Thottacheera (T_2)	9.59	15.09	57.35
3	Vyttila 6(T_3)	13.56	22.38	65.04
4	Harsha (T_4)	10.24	17.11	67.09
5	Vaishak x Vyttila 6(T_5)	20.34	5.70	-72.03
6	Vaishak x Harsha(T_6)	18.11	7.58	-58.14
7	Thottacheera x Harsha(T_7)	41.33	7.84	-81.03

Table 30. Mean performance for grain weight panicle^{-1} of parents and F_2 segregants under upland and protected condition

Sl. No	Parents and F_2 segregants	Grain weight panicle^{-1} (g)		Percentage change(%)
		Upland	Protected	
1	Vaishak (T_1)	4.19	2.72	-35.08
2	Thottacheera (T_2)	2.91	0.99	-65.98
3	Vyttila 6(T_3)	2.49	2.59	4.02
4	Harsha (T_4)	4.26	1.76	-58.69
5	Vaishak x Vyttila 6(T_5)	3.10	3.82	23.23
6	Vaishak x Harsha(T_6)	3.43	1.96	-42.86
7	Thottacheera x Harsha(T_7)	2.95	1.66	-43.73

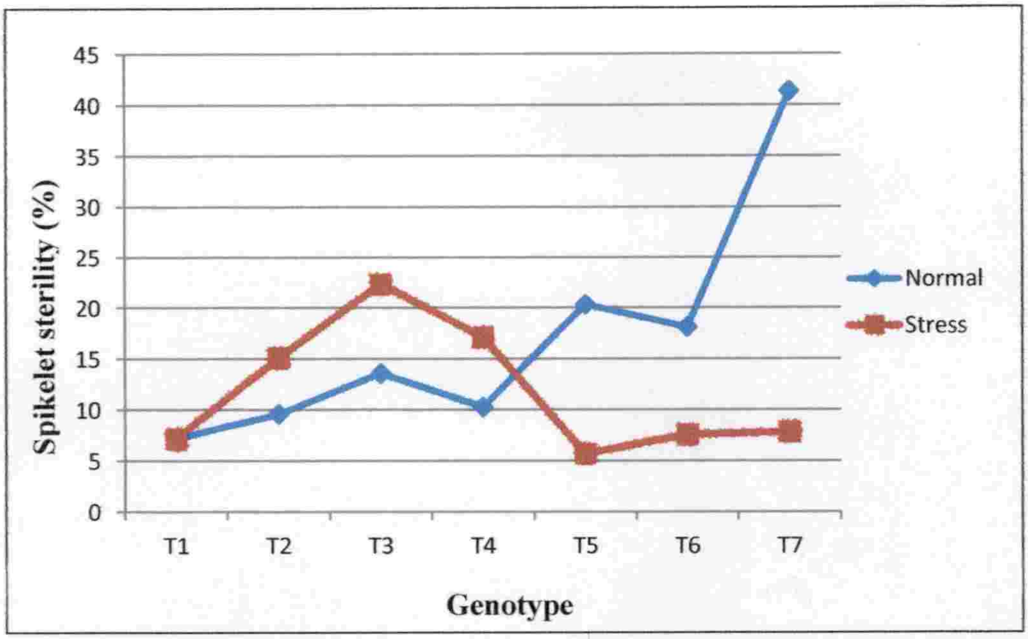


Fig. 13. Variation in mean spikelet sterility (%) under normal and stress condition

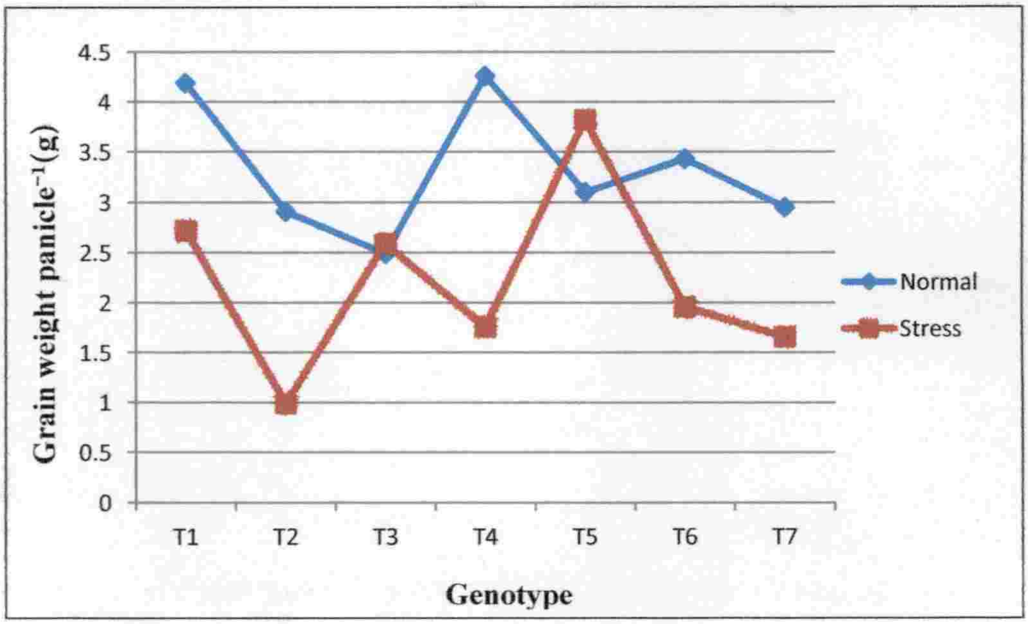


Fig. 14. Variation in mean grain weight panicle^{-1}(g) under normal and stress condition

(23.27g). Under stress, Vyttila 6 (25.81g) marked the highest value and Thottacheera (16.68g) again recorded the lowest. Among the F_2 population, Vaishak x Harsha (28.47g) recorded the highest value under normal condition whereas the segregants of Vaishak x Vyttila 6 (25.91g) recorded the highest mean value under stress. The F_2 population Thottacheera x Harsha recorded the lowest value both under upland (26.47g) and protected (20.25g) condition.

The percentage decrease in 1000 grain weight was more for the variety Thottacheera (28.32%) and less for Vyttila 6(3.59%). The F_2, Vaishak x Harsha (24.83%) recorded the highest percentage decrease in 1000 grain weight whereas Vaishak x Vyttila 6 (6.02%) recorded the lowest.

4.3.1.10 Grain Yield Plant^{-1} (g)

Grain yield plant^{-1} was found to decrease when grown under stress (Table 32 and Fig. 16). The variety Vaishak recorded the highest grain yield both under upland (40.13g) and drought (17.84g) condition. Vyttila 6 (27.42g) recorded the lowest value under normal condition and Thottacheera (5.89g) recorded the lowest under stress condition. Among the F_2 population, Vaishak x Harsha (47.99g) recorded the highest mean whereas the segregants of Thottacheera x Harsha (28.95%) recorded the lowest mean grain yield plant^{-1} under upland condition. When grown under stress, Vaishak x Vyttila 6 segregants (14.02g) recorded the highest mean value whereas the segregants of Vaishak x Harsha (4.32g) recorded the lowest value.

Among the parents, the percentage decrease in grain yield plant^{1} was more for Thottacheera (80.99%) and less for Vyttila 6 (51.28%). Among the F_2 populations the decrease was highest for Vaishak x Harsha (90.99%) and lowest for Vaishak x Vyttila 6 (66.01%).

4.3.1.11 Straw Yield Plant^{-1}

A decrease in straw yield plant^{-1} was observed under stress condition (Table 33 and Fig. 17). Among the parents Harsha (58.29g) recorded the highest

Table 31. Mean performance for 1000 grain weight of parents and F_2 segregants under upland and protected condition

Sl. No	Parents and F_2 segregants	1000 grain weight(g)		Percentage change(%)
		Upland	Protected	
1	Vaishak (T_1)	28.53	23.76	-16.72
2	Thottacheera (T_2)	23.27	16.68	-28.32
3	Vyttila 6(T_3)	26.77	25.81	-3.59
4	Harsha (T_4)	26.77	19.36	-27.68
5	Vaishak x Vyttila 6(T_5)	27.57	25.91	-6.02
6	Vaishak x Harsha(T_6)	28.47	21.40	-24.83
7	Thottacheera x Harsha(T_7)	26.47	20.25	-23.50

Table 32. Mean performance for grain yield plant^{-1} of parents and F_2 segregants under upland and protected condition

Sl. No	Parents and F_2 segregants	Grain yield plant^{-1}(g)		Percentage change(%)
		Upland	Protected	
1	Vaishak (T_1)	40.13	17.84	-55.54
2	Thottacheera (T_2)	30.98	5.89	-80.99
3	Vyttila 6(T_3)	27.42	13.36	-51.28
4	Harsha (T_4)	38.37	9.08	-76.34
5	Vaishak x Vyttila 6(T_5)	41.25	14.02	-66.01
6	Vaishak x Harsha(T_6)	47.99	4.32	-90.99
7	Thottacheera x Harsha(T_7)	28.95	8.00	-72.37

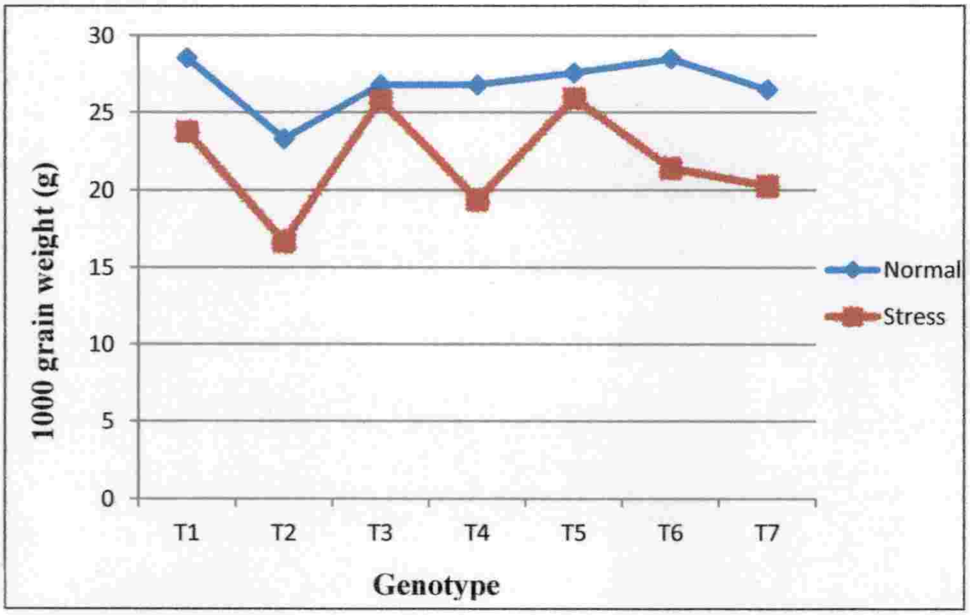


Fig. 15. Variation in mean 1000 grain weight (g) under normal and stress condition

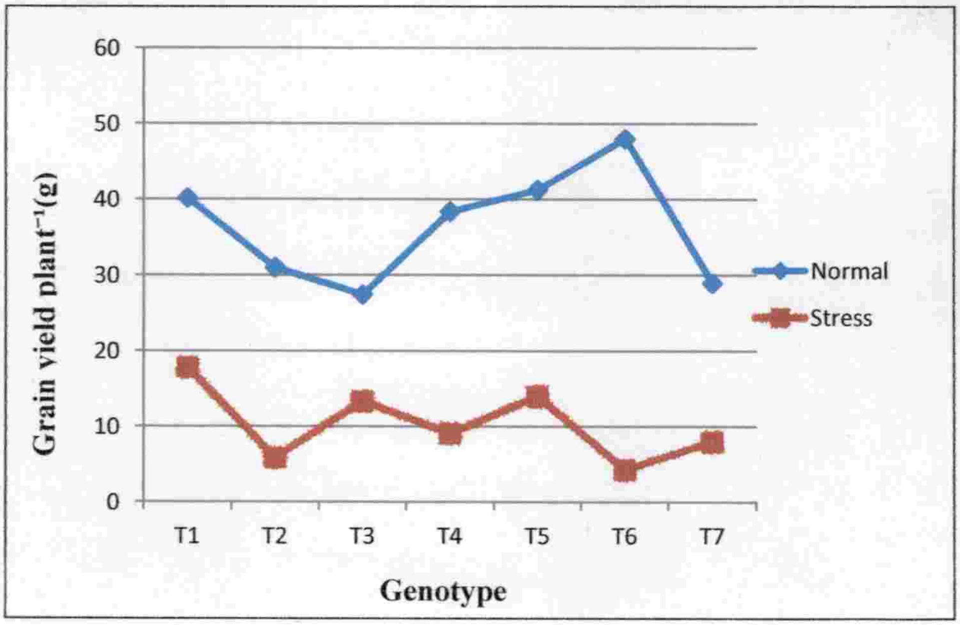


Fig. 16. Variation in mean grain yield plant^{-1} (g) under normal and stress condition

value whereas Vyttila 6 (30.98) recorded the lowest value under upland condition. Under stress condition, Vyttila 6 (19.31g) recorded the highest value whereas Harsha recorded the lowest value (8.04g). Among the F_2 population Vaishak x Harsha (57.14g) recorded the highest value and Thottacheera x Harsha (33.03g) recorded the lowest value under upland condition. When grown under stress, Thottacheera x Harsha (13.93g) recorded the highest value whereas Vaishak x Harsha (10.72g) recorded the lowest value.

The percentage decrease in straw yield plant^{-1} was highest for the variety Harsha (86.21%) and lowest for Vyttila 6 (37.67%). Among the F_2, Vaishak x Harsha (81.24%) recorded the highest percentage decrease whereas Thottacheera x Harsha (57.83%) recorded the lowest.

4.3.1.12 Harvest Index (%)

Variation in harvest index is presented in Table 34 and Fig 18. Among the parents, Vyttila 6 (46.84%) recorded the highest value whereas Harsha (39.63%) recorded the lowest value when grown under upland condition. Under protected condition, Vaishak (67.44%) recorded the highest value and Thottacheera (35.25%) recorded the lowest value. Among the F_2, Vaishak x Vyttila 6 recorded the highest value both under upland (47.33%) and stress (50.57%) conditions. The F_2, Vaishak x Harsha marked the lowest value under both conditions (45.56% under normal and 29.56% under stress condition).

Percentage decrease in harvest index under stress was more for Vaishak (50.54%) and less for Vyttila 6 (12.47%). Harsha (36.69%) recorded a percentage increase in harvest index under stress. Among the F_2 population the decrease was more prominent in Vaishak x Harsha segregants (35.12%) and less in Thottacheera x Harsha segregants whereas Vaishak x Vyttila 6 segregants (20.44%) recorded a slight increase in harvest index under stress (6.85%).

Table 33. Mean performance for straw yield plant^{-1} of parents and F_2 segregants under upland and protected condition

Sl. No	Parents and F_2 segregants	Straw yield plant^{-1} (g)		Percentage change(%)
		Upland	Protected	
1	Vaishak (T_1)	48.56	8.72	-82.04
2	Thottacheera (T_2)	41.31	10.74	-74.00
3	Vyttila 6(T_3)	30.98	19.31	-37.67
4	Harsha (T_4)	58.29	8.04	-86.21
5	Vaishak x Vyttila 6(T_5)	45.65	13.54	-70.34
6	Vaishak x Harsha(T_6)	57.14	10.72	-81.24
7	Thottacheera x Harsha(T_7)	33.03	13.93	-57.83

Table 34. Mean performance for harvest index (%) of parents and F_2 segregants under upland and protected condition

Sl. No	Parents and F_2 segregants	Harvest index (%)		Percentage change(%)
		Upland	Protected	
1	Vaishak (T_1)	44.80	67.44	-50.54
2	Thottacheera (T_2)	42.73	35.25	-17.51
3	Vyttila 6(T_3)	46.84	41.00	-12.47
4	Harsha (T_4)	39.63	54.17	36.69
5	Vaishak x Vyttila 6(T_5)	47.33	50.57	6.85
6	Vaishak x Harsha(T_6)	45.56	29.56	-35.12
7	Thottacheera x Harsha(T_7)	46.68	37.14	-20.44

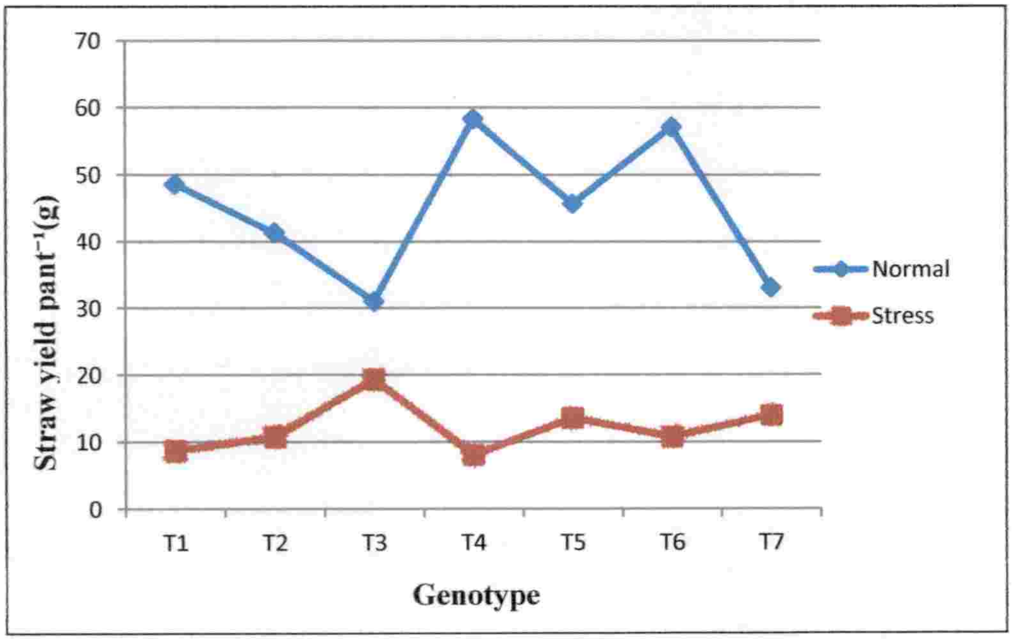


Fig. 17. Variation in mean straw yield pant^{-1} (g) under normal and stress condition

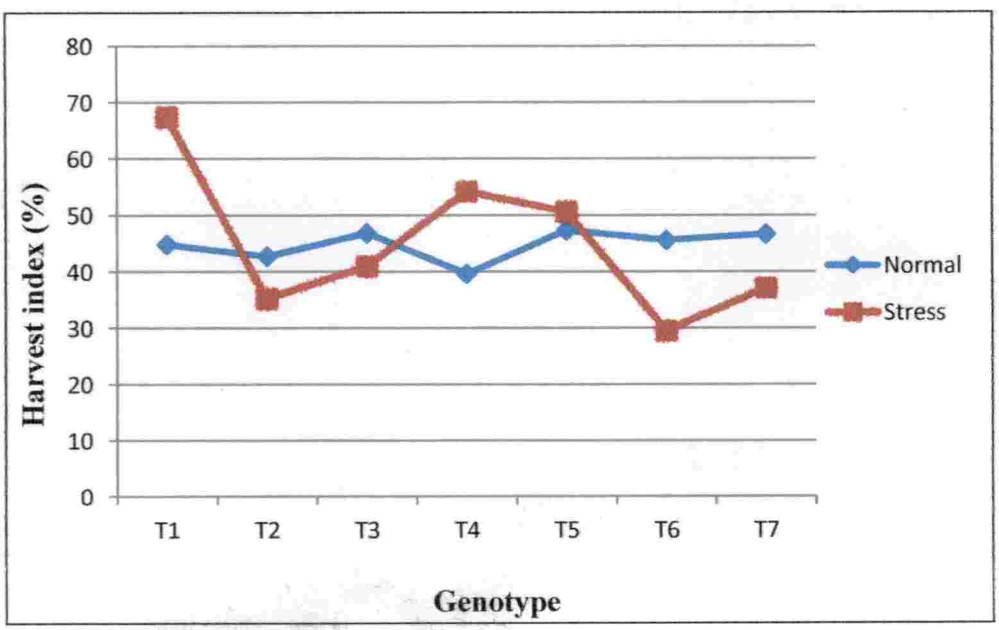


Fig. 18. Variation in mean harvest index (%) under normal and stress condition

4.3.1.13 Nature of Panicle Exsertion

On comparing the mean values in experiment I (Table 4) and experiment II (Table 15), it can be observed that the nature of panicle exsertion was the same in case of the varieties under both conditions whereas there was a change in case of the F_2 populations. In the first experiment which was conducted under upland condition, panicles of Vaishak x Vyttila 6 and Vaishak x Harsha segregants were mostly exserted whereas segregants of Thottacheera x Harsha recorded well exserted panicles. In the second experiment conducted inside rain shelter, it was noted that the segregants of Vaishak x Vyttila 6 had their panicles partially exserted, Vaishak x Harsha segregants showed well exserted panicles and Thottacheera x Harsha segregants had their panicles mostly exserted.

4.3.1.14 Leaf Rolling Score

Comparing Table 5 (normal condition) and Table 16 (stress condition), it can be observed that when grown under upland condition the varieties Vaishak and Thottacheera and all the three F_2 populations exhibited deep V shaped rolling (score 3) whereas Vyttila 6 and Harsha recorded only shallow V shaped folding of leaves (score 1). Under protected condition, the leaf rolling was more prominent in the F_2 populations compared to the parents which was marked by touching of leaf margins (score 7). The parental varieties, Thottacheera, Vyttila 6 and Harsha showed deep V shaped folding of leaves (score 3) whereas Vaishak exhibited only shallow V shaped folding (score 1). The variation in leaf rolling score is presented in Figure 19.

4.3.1.15 Pests and Disease Incidence (%)

Comparing Table 6 (upland condition) and Table 17 (stress condition) it can be observed that the variety Thottacheera has the highest percentage of rice bug infestation in upland (4.31%) as well as in controlled (4.40%) condition. The lowest percentage was recorded by Harsha (1.52%) under upland condition and by Vaishak (1.25%) under stress condition. In case of F_2 population Thottacheera x Harsha recorded the highest percentage of pest infestation under upland (3.15%)

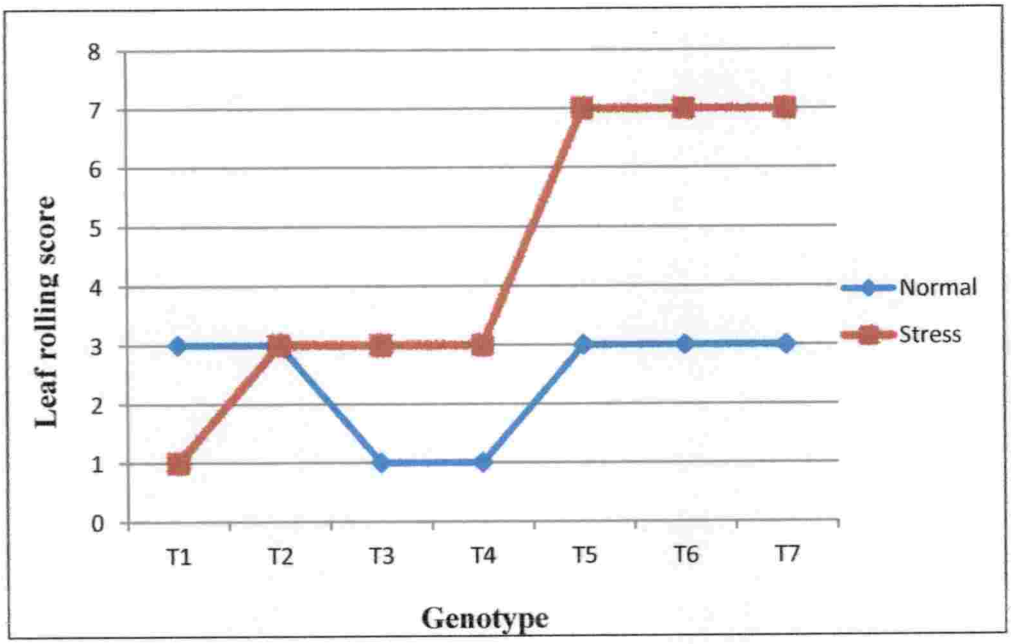


Fig. 19.Variation in Leaf rolling score under normal and stress condition

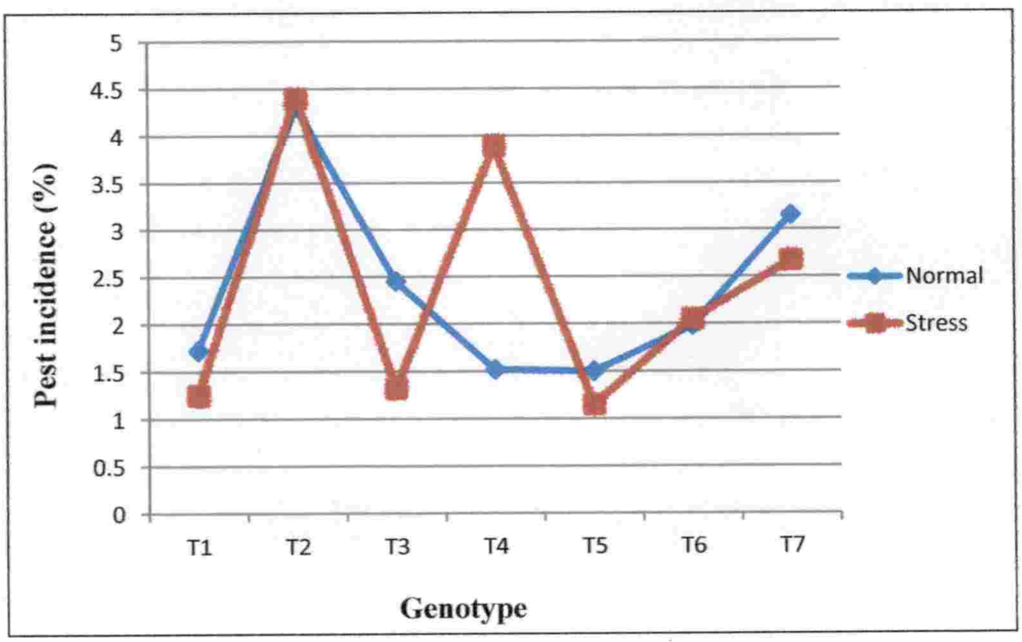


Fig. 20 (a). Variation in mean percentage of pest (rice bug) incidence (%) under normal and stress condition

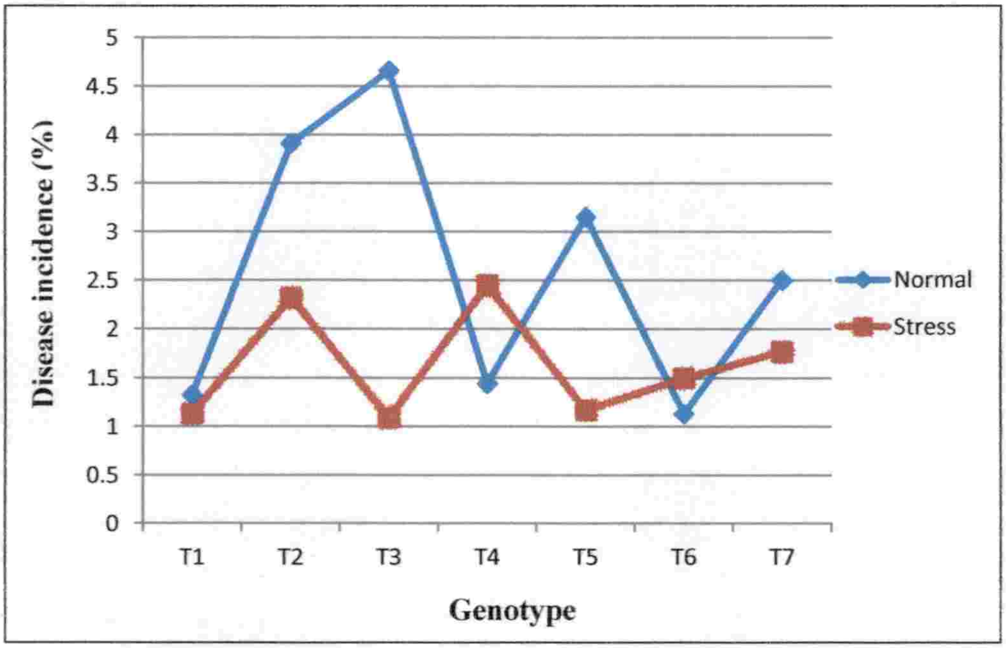


Fig. 20(b). Variation in mean percentage of disease (sheath rot) incidence (%) under normal and stress condition

and controlled (2.67%) conditions. The lowest percentage of pest infestation was observed in Vaishak x Vyttila 6 segregants under both conditions (1.50% under normal and 1.15% under stress condition).

Under upland condition, the variety Vyttila 6 (4.66%) was the most susceptible to sheath blight disease whereas Vaishak (1.32%) was more tolerant. The disease percentage was the highest in Harsha (2.45%) and the lowest in Vyttila 6 (1.09%) under stress condition. In case of F_2 populations, the highest percentage of disease infestation was observed in segregants of Vaishak x Vyttila 6 (3.15%) and the lowest in Vaishak x Harsha segregants (1.13%) under upland condition. When grown under protected condition, Thottacheera x Harsha segregants (1.77%) recorded the highest value whereas F_2 population of Vaishak x Vyttila 6 (1.17%) recorded the lowest value. The variation in pest and disease infestation is presented in Figure 20(a) and 20(b).

Physiological and Biochemical Traits

4.3.1.16 Proline Content (mg g^{-1})

There was a notable increase in proline content under stress condition and the data is presented in Table 35 and Fig. 21. The variety Vyttila 6 recorded the highest proline content under upland (0.35mg g^{-1}) and stress (0.55 mg g^{-1}) conditions. The lowest value was recorded by Thottacheera (0.22mg g^{-1}) under upland condition and by Harsha (0.30mg g^{-1}) under stress condition. Among the F_2 population, Vaishak x Vyttila 6 segregants recorded the highest value both under upland (0.29mg g^{-1}) and stress (0.57mg g^{-1}) conditions whereas segregants of Vaishak x Harsha recorded the lowest value under both conditions (0.22mg g^{-1} under normal condition and 0.4mg g^{-1} under stress).

Among parents the percentage increase in proline content was the highest in Vaishak (86.96%) and the lowest in Harsha (11.11%). Among F_2 segregants the percentage increase was highest for Vaishak x Vyttila 6 (96.55%) and lowest for Vaishak x Harsha (81.14%).

4.3.1.17 Chlorophyll Content (mg g^{-1})

Chlorophyll content was found to decrease under stress condition (Table 36 and Fig. 22). Among the parents, Harsha recorded the highest chlorophyll content under upland (2.31mg g^{-1}) and stress (1.34mg g^{-1}) conditions. The variety Thottacheera recorded the lowest chlorophyll content under both conditions (1.17mg g^{-1} under normal and 0.68mg g^{-1} under stress). Among the F_2 segregants, Thottacheera x Harsha recorded the highest value both under upland (1.78mg g^{-1}) and controlled (1.28mg g^{-1}) condition. The lowest value was recorded by Vaishak x Harsha segregants (1.54mg g^{-1}) under upland condition and by Vaishak x Vyttila 6 segregants (1.14mg g^{-1}) under stress condition.

Among the parents, the percentage decrease in chlorophyll content was more for Harsha (41.99%) and Thottacheera (41.88%) and less for Vyttila 6 (24.22%). Among the F_2 populations, the percentage decrease was more prominent in Thottacheera x Harsha segregants and less in Vaishak x Harsha segregants (23.38%).

4.3.1.18 Leaf Soluble Protein Content (mg g^{-1})

Leaf soluble protein content decreased in all the genotypes when grown under stress condition (Table 37 and Fig. 23). When grown under normal condition, the highest value for leaf soluble protein content was recorded by Thottacheera (8.85mg g^{-1}). Under protected condition, Vyttila 6 (7.38mg g^{-1}) recorded the highest value. The variety Harsha recorded the lowest value both under upland (6.90mg g^{-1}) and stress (4.56mg g^{-1}) condition. Among the F_2, the highest value was recorded by Thottacheera x Harsha both under upland (9.36mg g^{-1}) and controlled (8.28mg g^{-1}) conditions. The lowest value for leaf soluble protein was recorded by Vaishak x Harsha both under upland (5.75 mg g^{-1}) and stress (4.57mg g^{-1}) conditions.

The percentage decrease in leaf soluble protein content under stress condition was the highest for the variety Harsha (33.91%) and the lowest for

Table 35. Mean performance for proline content (mg g^{-1}) of parents and F_2 segregants under upland and protected condition

Sl. No	Parents and F_2 segregants	Proline content(mg g^{-1})		Percentage change
		Upland	Protected	
1	Vaishak (T_1)	0.23	0.43	86.96
2	Thottacheera (T_2)	0.22	0.37	68.18
3	Vyttila 6(T_3)	0.35	0.55	57.14
4	Harsha (T_4)	0.27	0.30	11.11
5	Vaishak x Vyttila 6(T_5)	0.29	0.57	96.55
6	Vaishak x Harsha(T_6)	0.22	0.40	81.82
7	Thottacheera x Harsha(T_7)	0.28	0.51	82.14

Table 36. Mean performance for chlorophyll content (mg g^{-1}) of parents and F_2 segregants under upland and protected condition

Sl No	Parents and F_2 segregants	Chlorophyll content (mg g^{-1})		Percentage change
		Upland	Protected	
1	Vaishak (T_1)	1.39	0.85	-38.85
2	Thottacheera (T_2)	1.17	0.68	-41.88
3	Vyttila 6(T_3)	1.28	0.97	-24.22
4	Harsha (T_4)	2.31	1.34	-41.99
5	Vaishak x Vyttila 6(T_5)	1.56	1.14	-26.92
6	Vaishak x Harsha(T_6)	1.54	1.18	-23.38
7	Thottacheera x Harsha(T_7)	1.78	1.28	-28.09

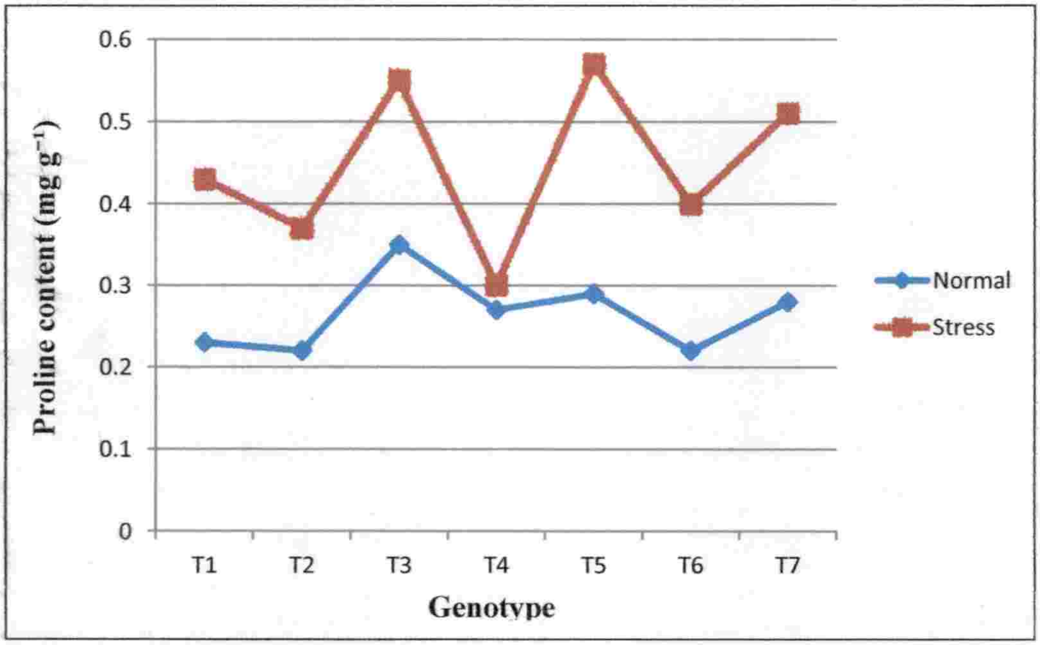


Fig. 21.Variation in mean proline content (mg g^{-1}) under normal and stress condition

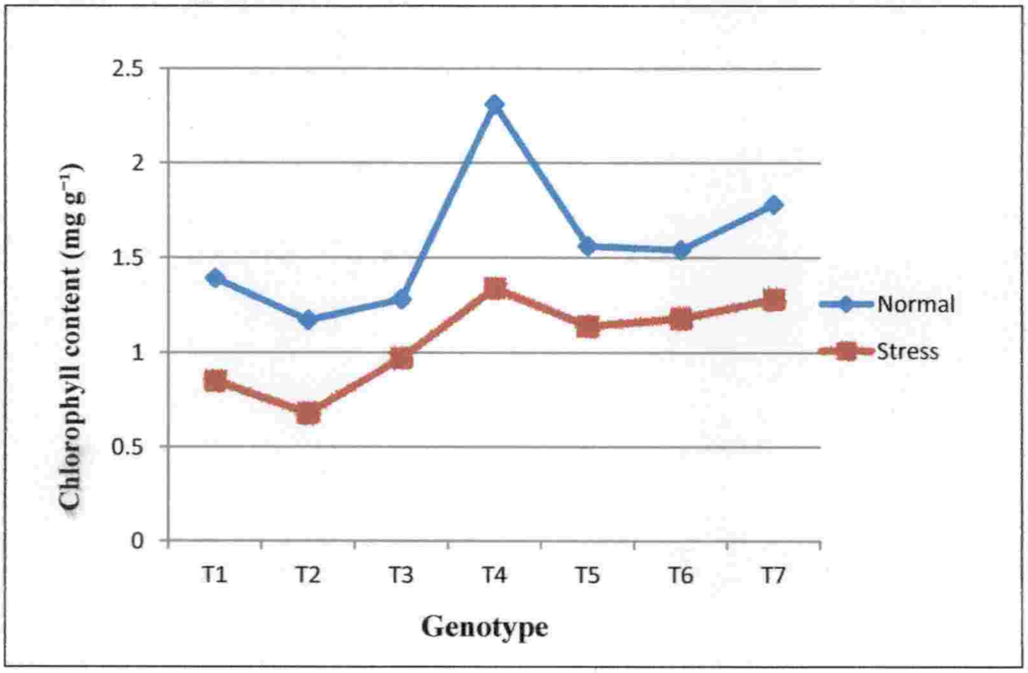


Fig. 22.Variation in mean chlorophyll content (mg g^{-1}) under normal and stress condition

Vaishak (7.83%). Among the F_2, the highest percentage decrease was marked by Vaishak x Vyttila 6 (31.93%) and the lowest by Thottacheera x Harsha (11.54%).

4.3.1.19 Leaf area index

Leaf area index was found to decrease when grown under stress and the data is furnished in Table 38 and Figure 24. Among the parents, the highest leaf area was recorded by Vyttila 6 (2.86) and the lowest by Thottacheera (1.21) when grown under upland condition. Under stress condition, Thottacheera (0.64) recorded the highest leaf area index whereas Harsha (0.34) recorded the lowest value. Among the F_2 populations, Vaishak x Harsha (1.67) recorded the highest whereas Thottacheera x Harsha (0.97) recorded the lowest mean leaf area index under normal condition. When grown under stress, Thottacheera x Harsha segregants recorded the highest mean value whereas Vaishak x Vyttila 6 and Thottacheera x Harsha segregants recorded the lowest mean value (0.36 each) for leaf area index.

The percentage decrease in leaf area index was the highest for the variety Vyttila 6 (83.92%) and the lowest for Thottacheera (47.11). Among the F_2 segregants, the decrease was the highest in Vaishak x Harsha (78.44%) and the lowest in Thottacheera x Harsha (26.80%).

4.3.2 Pattern of Variability in F_2 segregants for Yield and Yield Contributing Traits

The pattern of variability in F_2 segregants for various characters can be represented using frequency distribution graphs. Such graphs clearly show the pattern of distribution of the population for a character. Few terms associated with the frequency distribution graphs are range, standard error of mean (SE(m)), skewness and kurtosis. Range is calculated as the difference between the highest and lowest value recorded for a character. Standard error (mean) is the deviation of the values from the mean value. Skewness reflects the asymmetry of a distribution. A graph is said to be positively skewed when most of the values are falling on the left side and the tail is longer towards the right side. Similarly, a

Table 37. **Mean performance for leaf soluble protein content (mg g^{-1}) of parents and F_2 segregants under upland and protected condition**

Sl. No	Parents and F_2 segregants	Leaf soluble protein content(mg g^{-1})		Percentage change(%)
		Upland	Protected	
1	Vaishak (T_1	7.66	7.06	-7.83
2	Thottacheera (T_2)	8.85	6.69	-24.41
3	Vyttila 6(T_3)	8.17	7.38	-9.67
4	Harsha (T_4)	6.90	4.56	-33.91
5	Vaishak x Vyttila 6(T_5)	7.61	5.18	-31.93
6	Vaishak x Harsha(T_6)	5.75	4.57	-20.52
7	Thottacheera x Harsha(T_7)	9.36	8.28	-11.54

Table 38. Mean performance for leaf area index (at maturity) of parents and F_2 segregants under upland and protected condition

Sl. No	Parents and F_2 segregants	Leaf area index (at maturity)		Percentage change(%)
		Upland	Protected	
1	Vaishak (T_1)	1.82	0.60	-67.03
2	Thottacheera (T_2)	1.21	0.64	-47.11
3	Vyttila 6(T_3)	2.86	0.46	-83.92
4	Harsha (T_4)	1.79	0.34	-81.01
5	Vaishak x Vyttila 6(T_5)	1.12	0.36	-67.86
6	Vaishak x Harsha(T_6)	1.67	0.36	-78.44
7	Thottacheera x Harsha(T_7)	0.97	0.71	-26.80

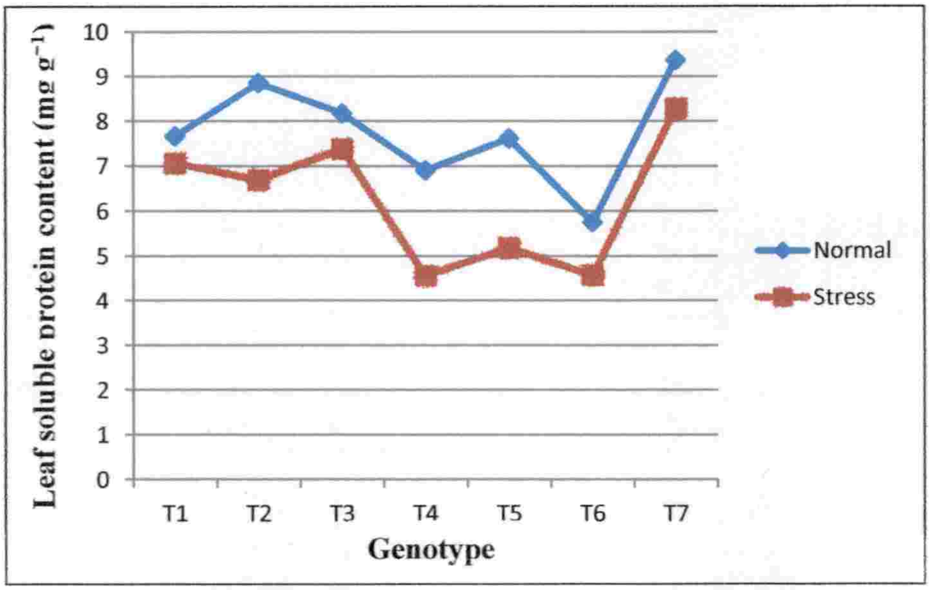


Fig. 23.Variation in mean leaf soluble protein content (mg g^{-1}) under normal and stress condition

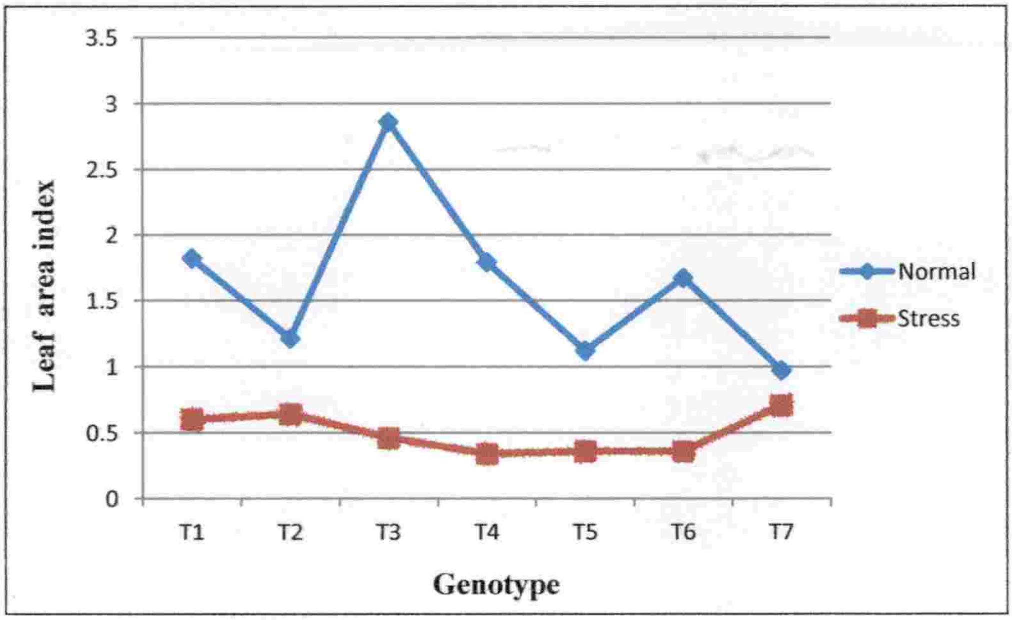


Fig. 24. Variation in mean leaf area index (at maturity) under normal and stress condition

graph is said to be negatively skewed when most of the values are falling on the right side and the tail is longer towards the left. Blumer (1979), reported a thumb rule to interpret the skewness of a frequency distribution graph. According to the rule if the value for skewness is less than -1 or more than +1, the graph is highly skewed. If the value is between -0.5 and -1 or, +0.5 and +1, the graph is moderately skewed. If the value falls between -0.5 and +0.5, the graph is approximately symmetrical. The kurtosis reflects the characteristics of the tails of a distribution. Balanda and McGillivray (1988) suggested that if the value for kurtosis is zero, the graph is a normal distribution (Mesokurtic). If kurtosis is negative, the central peak is lower or broader and the population is more distributed (Platykurtic). A positive kurtosis denotes a higher or sharper central peak and in such cases majority of the individuals will be concentrated at or near the mean value (Leptokurtic). The range, SE(m), skewness and kurtosis for various F_2 distributions are presented in Table 39 (a),(b) and (c).

4.3.2.1 Frequency Distribution of F_2 segregants for Number of Productive Tillers Plant^{-1}

The number of productive tillers plant^{-1} in Vaishak x Vyttila 6 segregants ranged from 9 to 15 under normal condition whereas it ranged from 3 to 6 under the stress condition. The graphs under both conditions were approximately symmetrical (-0.36 and 0.22 under normal and stress condition respectively) and with negative kurtosis (-0.63 under normal and -1.25 under stress condition). Figure 25(a) shows the graph under normal condition and Figure 25(b) shows the graph under stress condition.

In the F_2 segregants Vaishak x Harsha, the number of productive tillers plant^{-1} ranged from 9 to 16 under normal condition whereas under stress the range was from 2 to 6.The graph under normal condition (Fig. 26(a)) was approximately symmetrical (0.31) with a negative kurtosis (-1.10) whereas under stress condition the graph was moderately positively skewed (0.53) with a negative kurtosis(-0.59) (Fig. 26(b)).

Table 39(a). Mean, Standard Error (mean), Range, Skewness and Kurtosis values of frequency distribution graphs for six characters in Vaishak x Vyttila 6

Sl. No.	Character		Mean	Standard Error (mean)	Range	Skewness	Kurtosis
1	Number of productive tillers plant^{-1}	Normal	12.47	0.34	9-15	-0.36	-0.63
		Stress	4.23	0.20	3-6	0.22	-1.25
2	Number of spikelets panicle^{-1}	Normal	169.73	1.51	149 – 178	-1.69	2.20
		Stress	147.23	3.34	128 - 174	0.37	-1.80
3	Number of filled grains panicle^{-1}	Normal	136.80	2.29	120 – 157	0.48	-1.20
		Stress	133.70	2.82	102 – 155	-0.53	-0.74
4	1000 grain weight(g)	Normal	27.80	0.22	24.88 – 28.67	-0.58	-0.65
		Stress	25.01	0.15	23.78 – 26.15	-0.36	-1.10
5	Grain yield plant^{-1} (g)	Normal	37.89	0.76	28.36 – 43.13	-0.86	0.08
		stress	14.64	0.40	11.80 – 18.88	0.47	-0.88
6	Straw yield plant^{-1}(g)	Normal	43.27	0.96	31.88 – 48.74	-1.34	0.46
		stress	14.23	0.74	8.73 – 22.45	0.55	-0.53

Table 39(b). Mean, Standard Error (mean), Range, Skewness and Kurtosis values of frequency distribution graphs for six characters in Vaishak x Harsha

Sl. No.	Character		Mean	Standard Error (mean)	Range	Skewness	Kurtosis
1	Number of productive tillers $plant^{-1}$	Normal	12.23	0.42	9 – 16	0.31	-1.10
		Stress	3.50	0.23	2 – 6	0.53	-0.59
2	Number of spikelets $panicle^{-1}$	Normal	159.83	1.62	148 – 171	0.15	-1.70
		stress	102.77	1.94	90 – 127	0.86	0.06
3	Number of filled grains $panicle^{-1}$	Normal	150.37	1.43	133 – 157	-1.27	0.18
		stress	95.67	2.36	80 - 118	0.59	-1.15
4	1000 grain weight(g)	Normal	27.48	0.21	25.45 – 28.78	-0.55	-0.99
		stress	20.86	0.35	17.50 – 23.75	-0.15	-0.10
5	Grain yield $plant^{-1}$(g)	Normal	43.65	0.56	38.45 – 48.15	0.07	-1.23
		stress	8.05	0.63	4.25 – 17.15	1.38	2.05
6	Straw yield $plant^{-1}$(g)	Normal	54.36	0.73	49.38 – 59.20	-0.26	-1.92
		stress	10.97	0.34	8.10 – 14.15	-0.05	-1.01

Table 39(c). Mean, Standard Error (mean), Range, Skewness and Kurtosis values of frequency distribution graphs for six characters in Thottacheera x Harsha

Sl. No.	Character		Mean	Standard Error (mean)	Range	Skewness	Kurtosis
1	Number of productive tillers plant^{-1}	Normal	12.27	0.47	7 – 9	0.08	-1.58
		stress	4.13	0.23	3 – 7	1.21	0.56
2	Number of spikelets panicle^{-1}	Normal	161.43	1.97	143 – 174	-0.46	-1.37
		stress	83.27	1.60	70 – 100	0.41	-0.79
3	Number of filled grains panicle^{-1}	Normal	133.07	1.85	120 – 151	0.64	-0.94
		stress	68.77	1.91	52 – 88	-0.02	-1.13
4	1000 grain weight(g)	Normal	25.54	0.27	23.28 – 28.12	0.16	-0.99
		stress	20.32	0.22	17.00 – 22.16	-1.36	2.23
5	Grain yield plant^{-1} (g)	Normal	33.41	0.72	25.88 – 38.30	-0.50	-0.92
		stress	10.15	0.32	8.10 – 14.19	0.86	0.22
6	Straw yield plant^{-1}(g)	Normal	43.15	1.72	29.95 – 58.19	0.16	-1.21
		stress	11.03	0.42	8.20 – 16.15	0.81	-0.12

The number of productive tillers plant^{-1} in Thottacheera x Harsha segregants ranged from 7 to 9 under normal condition whereas it ranged from 3 to 7 under stress. The graph under normal condition was approximately symmetrical (0.08) with kurtosis value -1.58 ((Fig. 27(a)) whereas the graph was highly positively skewed (1.22) with a positive kurtosis (0.56) under stress condition. (Fig. 27(b)).

4.3.2.2 Frequency Distribution of F_2 segregants for Number of Spikelets Panicle^{-1}

In F_2 population of Vaishak x Vyttila 6, the number of spikelets panicle^{-1} ranged from 149 to 178 under normal condition whereas the number varied from 128 to 174 under the stress condition. The frequency distribution graph under normal condition (Fig. 28(a)) was highly negatively skewed (-1.69) with a positive kurtosis (2.02) and under the stress condition (Fig. 28(b)) the graph was approximately symmetrical (0.37) with a negative kurtosis (-1.80).

Number of spikelets panicle^{-1} in Vaishak x Harsha segregants ranged from 148 to 171 under normal condition. Under stress condition the range was from 90 to 127. The graph under normal condition (Fig. 29(a)) was approximately symmetrical (0.15) with a negative kurtosis (-1.70) whereas the graph was moderately positively skewed (0.86) and mesokurtic (0.06) under stress condition (Fig. 29(b)).

In the F_2 population of Thottacheera x Harsha number of spikelets was ranging from 143 to 174 under the normal condition. It ranged from 70 to 100 under stress. The graphs were approximately symmetrical (-0.46 under normal and 0.41 under stress condition) with negative kurtosis (-1.37 under normal and -0.79 under stress condition). Figure 30(a) and Figure 30(b) represents graphs under normal and stress conditions respectively.

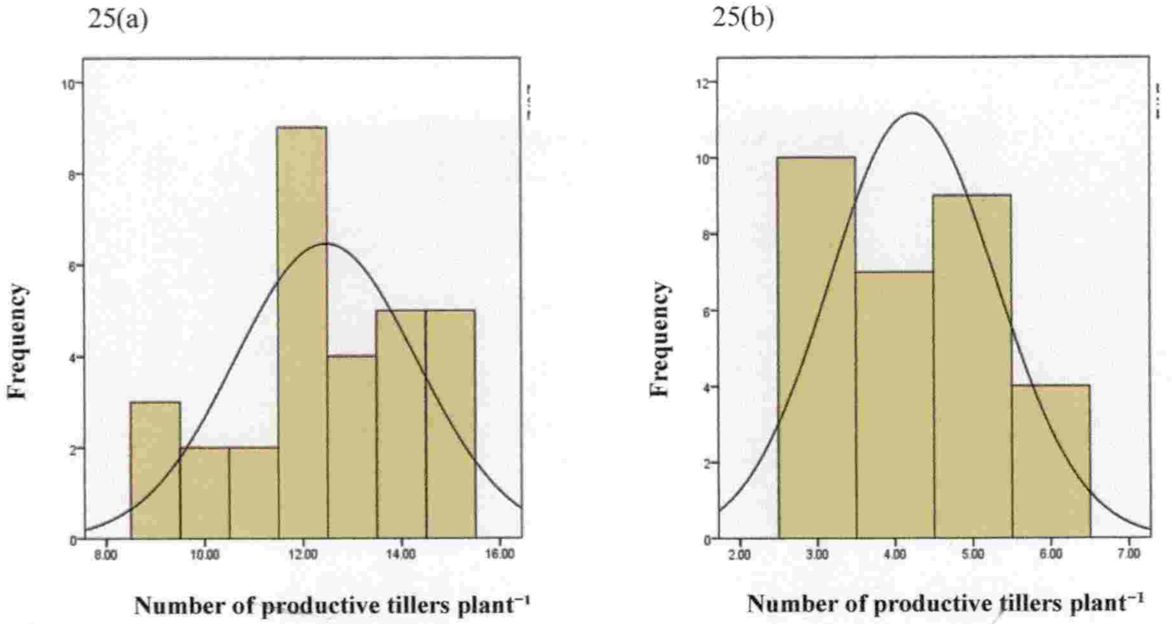


Fig 25. F_2 distribution for number of productive tillers plant in Vaishak x Vyttila 6

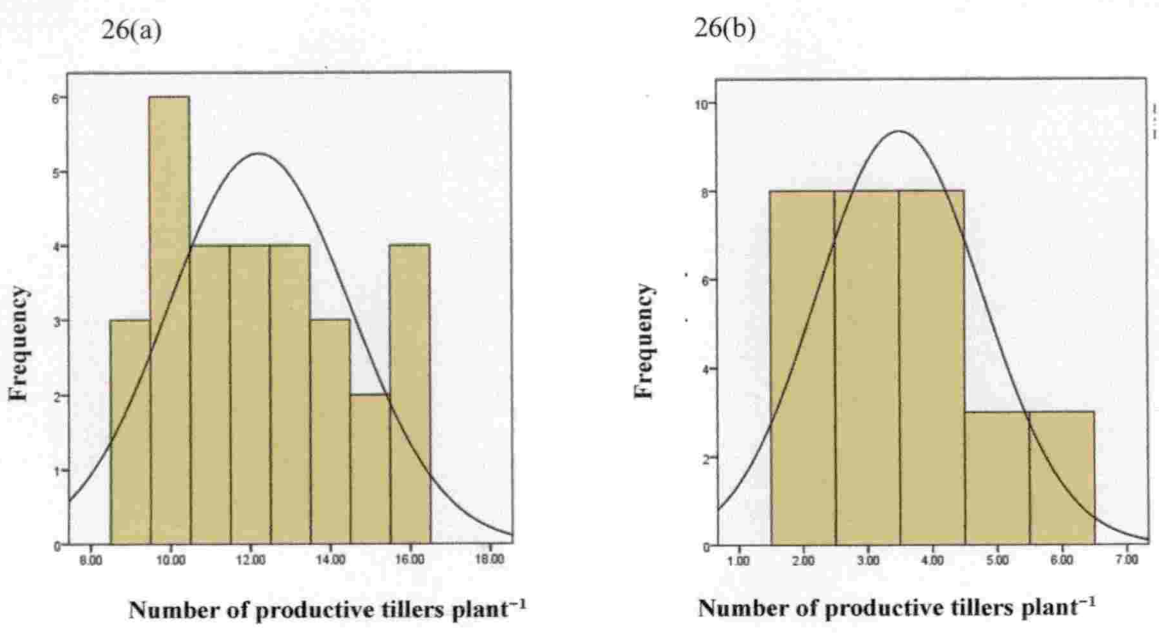


Fig 26. F_2 distribution for number of productive tillers plant in Vaishak x Harsha

27(a) 27(b)

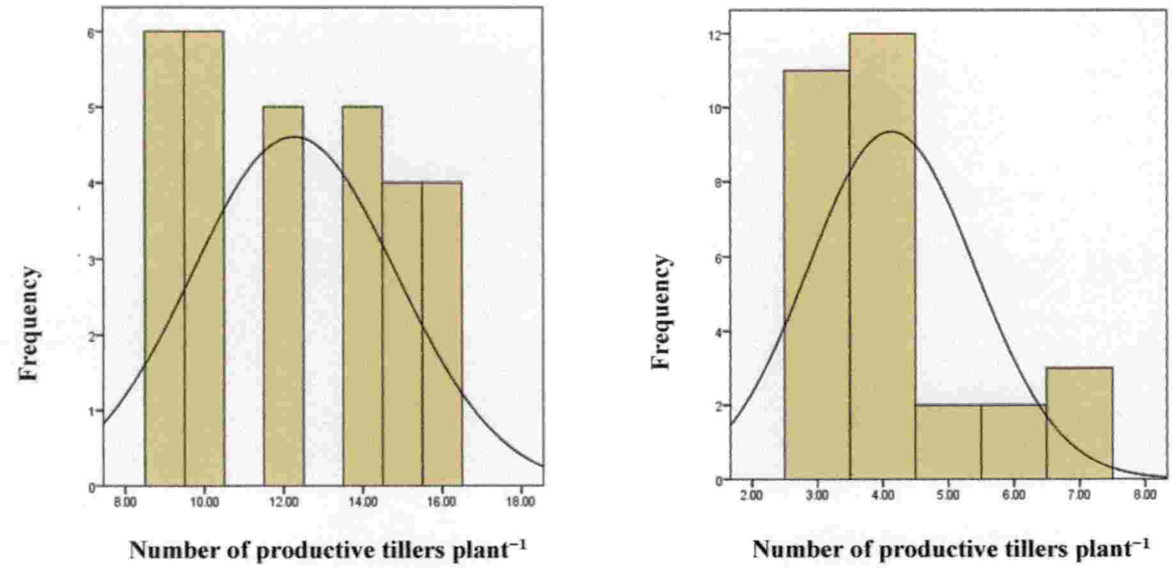


Fig.27. F_2 distribution for number of productive tillers plant in Thottacheera x Harsha

28(a) 28(b)

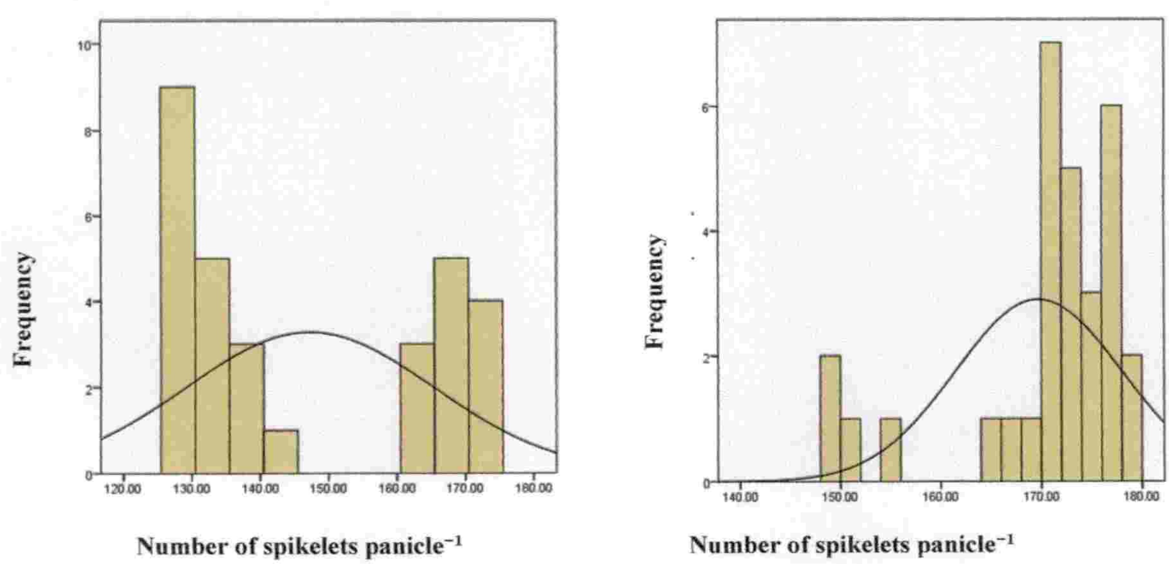
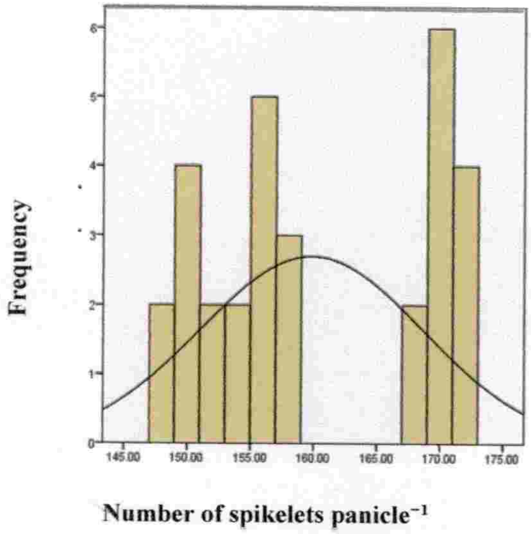


Fig. 28.F_2 distribution for number of spikelets panicle^{-1}in Vaishak x Vyttila 6

29(a)



29(b)

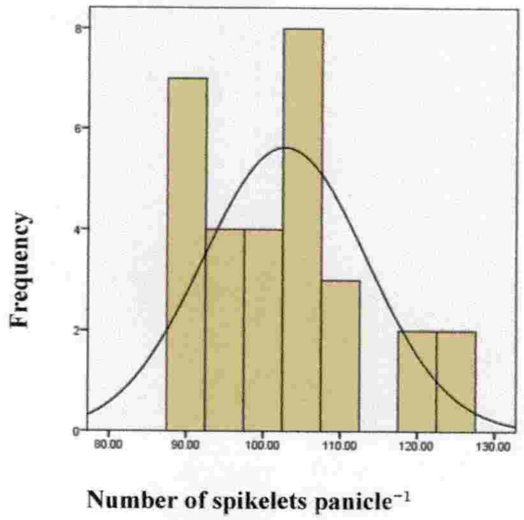
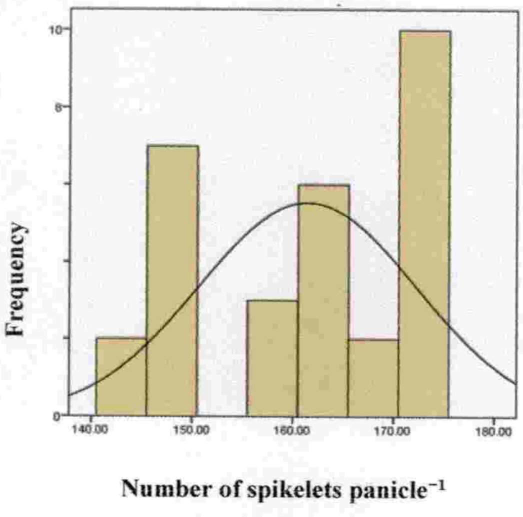


Fig.29. F_2 distribution for number of spikelets panicle^{-1}in Vaishak x Harsha

30(a)



30(b)

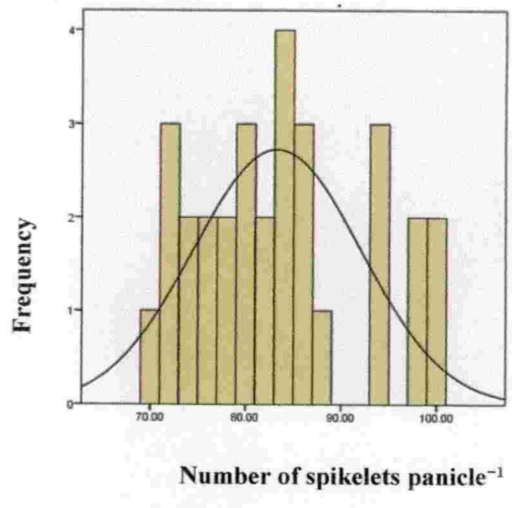


Fig. 30.F_2 distribution for number of spikelets panicle^{-1}in Thottacheera x Harsha

4.3.2.3 Frequency Distribution of F_2 segregants for Filled Grains Panicle^{-1}

The F_2 segregants of Vaishak x Vyttila 6 recorded values ranging from 120 to 157 under normal condition which was slightly reduced to a range of 102 to 155 under stress. The graph was approximately symmetrical under normal condition (0.48) whereas it was moderately negatively skewed (-0.53) under stress. The kurtosis values were negative in both the cases (-1.20 and -0.74 under normal and stress condition respectively). The graphs are presented in Figures 31(a) and (b).

Number of filled grains panicle^{-1} in Vaishak x Harsha segregants ranged from 133 to 157 under normal condition and its graph was highly negatively skewed (-1.27) with a positive kurtosis(0.18) (Fig 32(a)). Under stress condition, the number of filled grains reduced considerably ranging from 80 to 118. The graph under stress was moderately positively skewed (0.59) with a negative kurtosis(-1.15) (Fig. 32(b)).

In F_2 segregants of Thottacheera x Harsha, the number of filled grains panicle^{-1} ranged from 120 to 151 under normal condition whereas under the stress condition it ranged from 52 to 88 filled grains. The graph under normal condition was moderately positively skewed (0.64) with a negative kurtosis (-0.94) (Fig. 33(a)). Under the stress condition, the graph was approximately symmetrical (-0.02) with a negative kurtosis (-1.13) (Fig 33(b)).

4.3.2.4 Frequency Distribution of F_2 segregants for 1000 Grain Weight (g)

For 1000 grain weight, in the F_2 population of Vaishak x Vyttila 6 values ranged from 24.88g to 28.67g under normal condition whereas it was slightly reduced under stress condition, ranging from 23.78g to 26.15g. The graph under normal condition was moderately negatively skewed (-0.58) with a negative kurtosis (-0.65) (Fig. 34(a)). Under the stress condition(Fig. 34(b)), the graph was approximately symmetrical (-0.36) and platykurtic (-1.10).

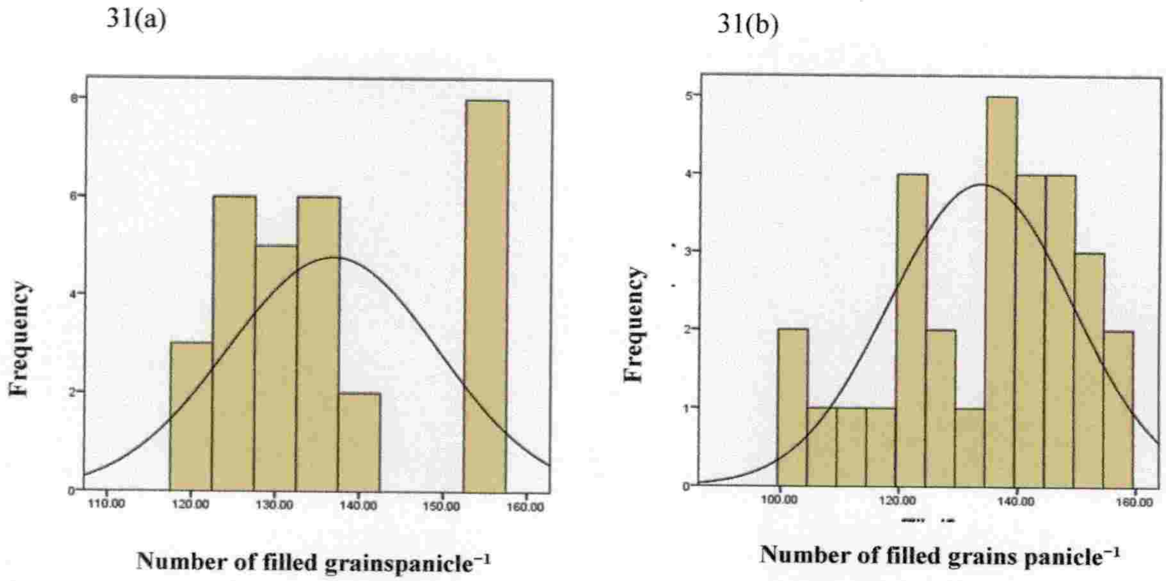


Fig. 31. F_2 distribution for number of filled grains panicle^{-1}in Vaishak x Vyttila 6

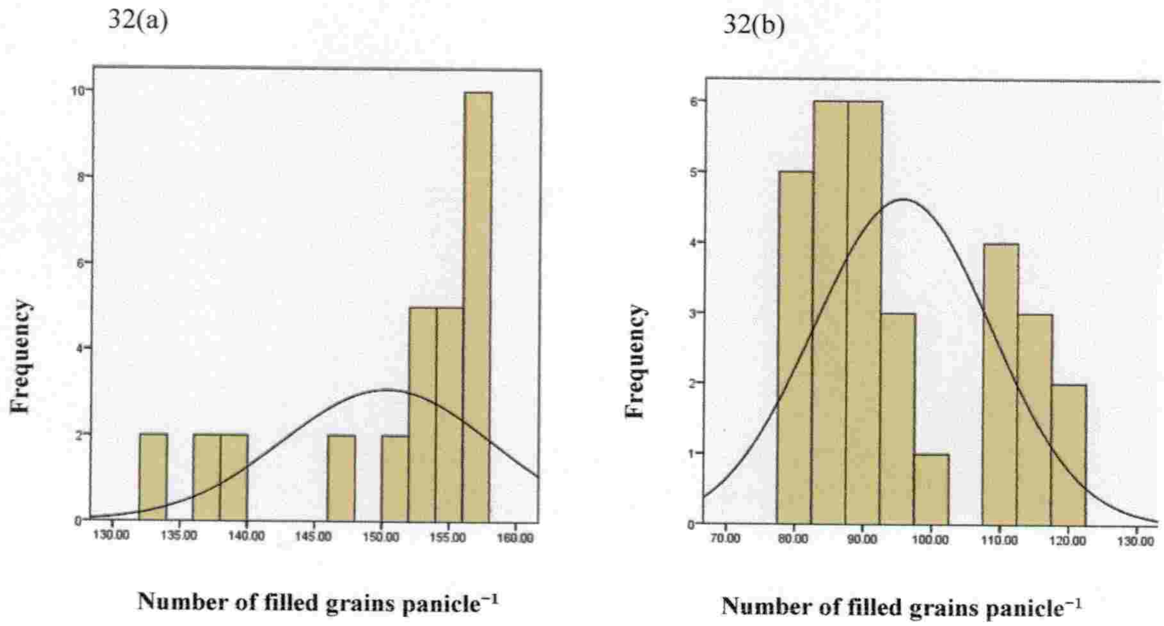


Fig.32. F_2 distribution for number of filled grains panicle^{-1}in Vaishak x Harsha

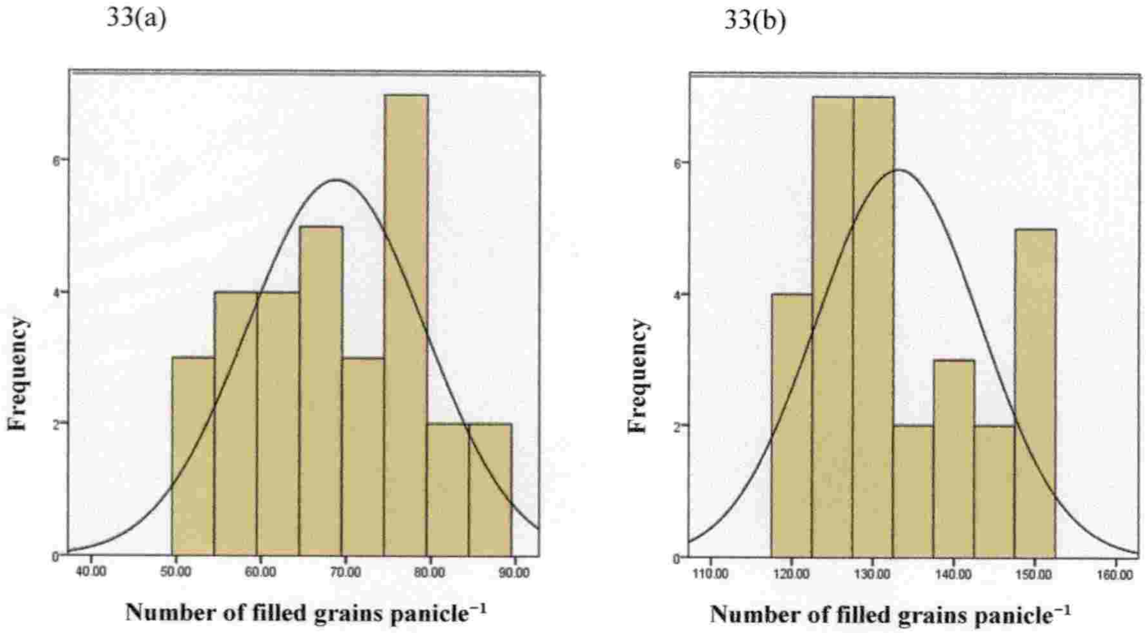


Fig.33.F_2 distribution for number of filled grains panicle^{-1}in Thottacheera x Harsha

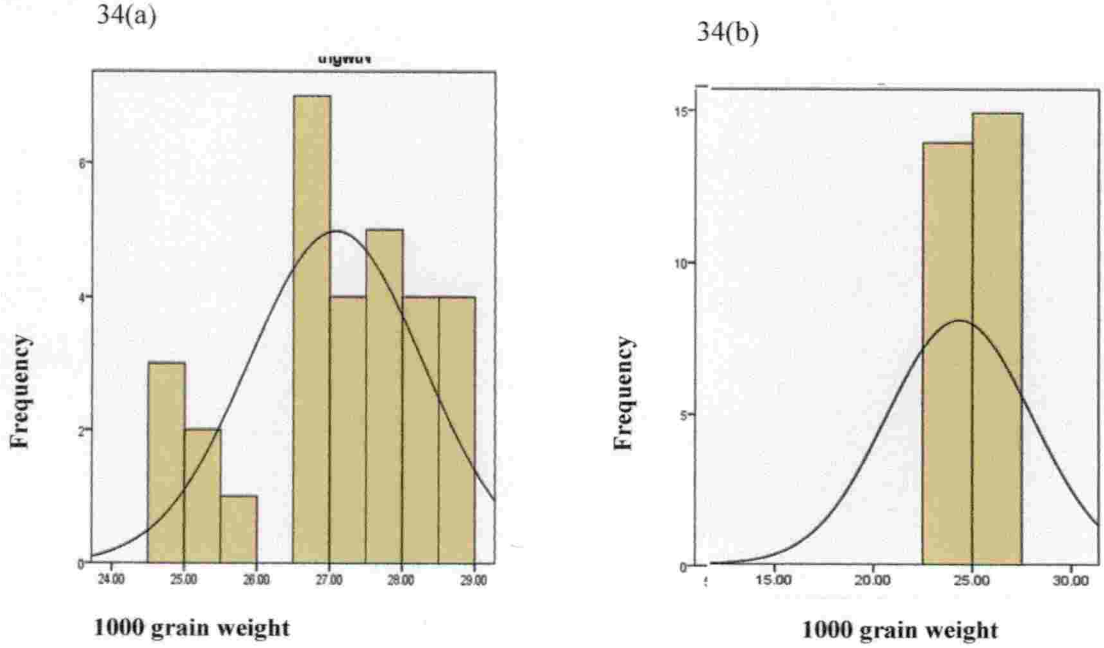


Fig.34.F_2 distribution for 1000 grain weight in Vaishak x Vyttila 6

For Vaishak x Harsha segregants the value of 1000 grain weight ranged from 25.45g to 28.78g under normal condition whereas under stress it was highly reduced and ranged from 17.50g to 23.75g. The graph under normal condition was moderately negatively skewed (-0.55) with negative kurtosis (-0.99) (Fig. 35(a)). Under stress condition the graph was approximately symmetrical (-0.15) with negative kurtosis (-0.10) (Fig. 35(b)).

In F_2 population of Thottacheera x Harsha, the value of this character ranged from 23.28g to 28.12g under normal condition and the range was from 17g to 22.16g under stress condition. The graph under normal condition (Fig. 36(a)) was approximately symmetrical (0.16) with negative kurtosis (-0.99) whereas it was highly negatively skewed (-1.36) and leptokurtic (2.23) under stress condition Fig. 36(b)).

4.3.2.5 Frequency Distribution of F_2 segregants for Grain Yield Plant^{-1}(g)

Grain yield plant^{-1} in Vaishak x Vyttila 6 segregants ranged from 28.36g to 43.13g whereas under stress condition it ranged from 11.80g to 18.88g. The frequency distribution graph under normal condition was moderately negatively skewed (-0.86) with approximately zero kurtosis (Fig. 37(a)). Under stress condition the graph was approximately symmetrical (0.47) with a negative kurtosis (-0.88) (Fig. 37(b)).

The F_2 population of Vaishak x Harsha recorded values ranging from 38.45g to 48.15g under normal condition whereas under stress the values were very low ranging from 4.25g to 17.15g. The graph under normal condition was approximately symmetrical (0.07) with negative kurtosis (-1.23) (Fig. 38(a)) whereas under the stress condition it was highly positively skewed (1.38) and leptokurtic (2.05) (Fig. 38(b)).

The F_2 population of Thottacheera x Harsha when grown under normal condition recorded values ranging from 25.88g to 38.30g. Under stress condition, grain yield plant^{-1} ranged from 8.10g to 14.19g. The graph under normal

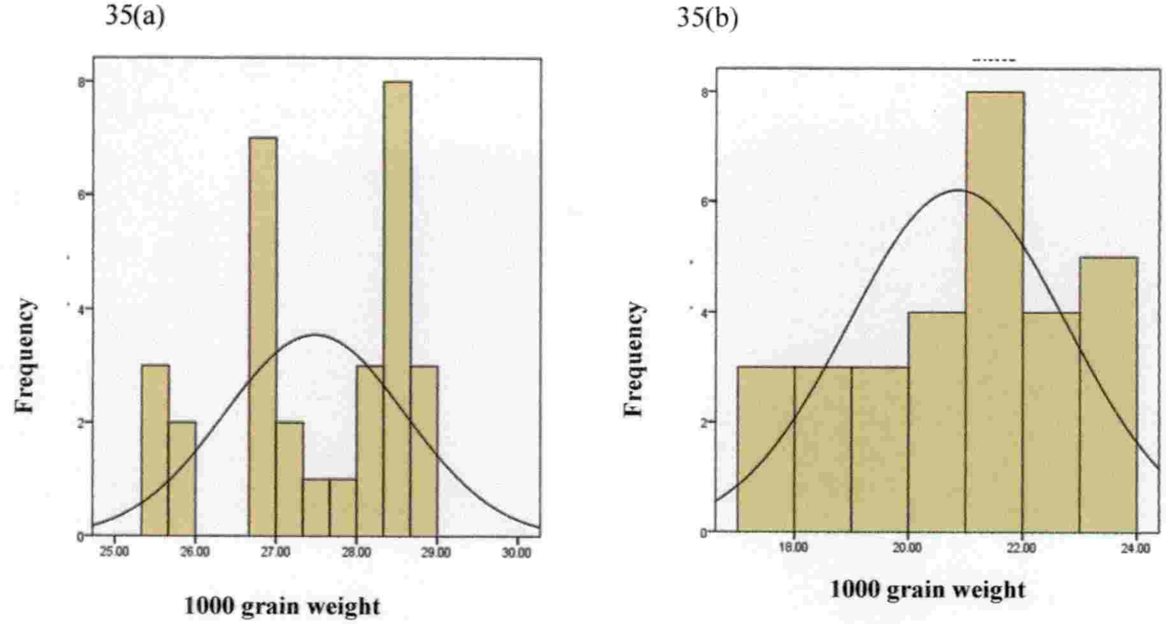


Fig.35. F_2 distribution for 1000 grain weight in Vaishak x Harsha

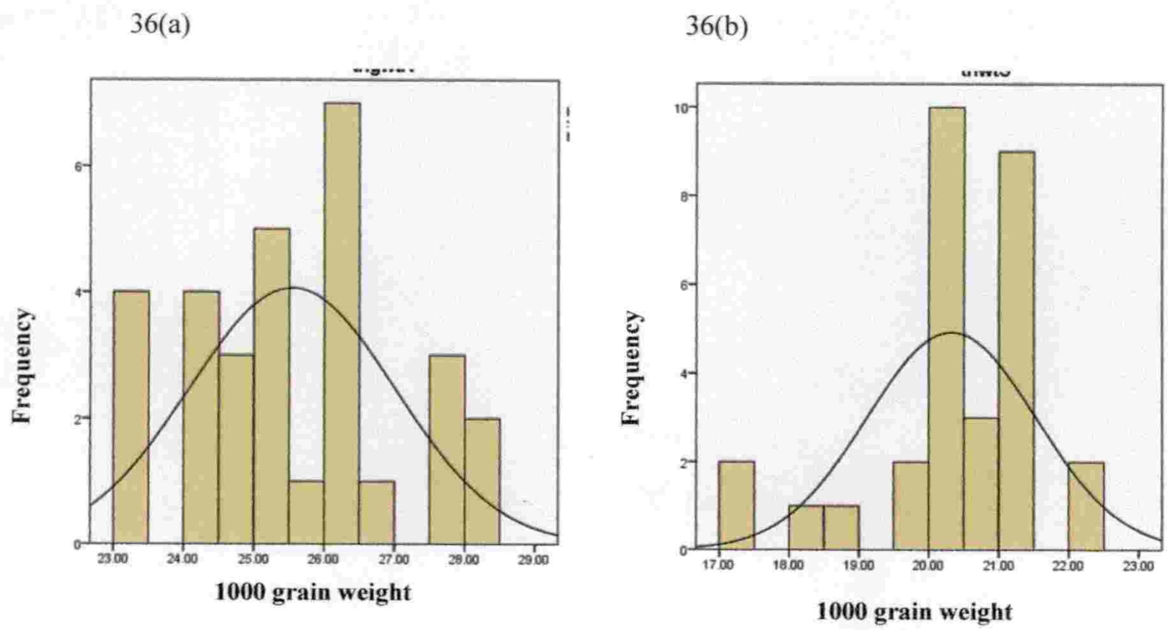


Fig. 36. F_2 distribution for 1000 grain weight in Thottacheera x Harsha

37(a) 37(b)

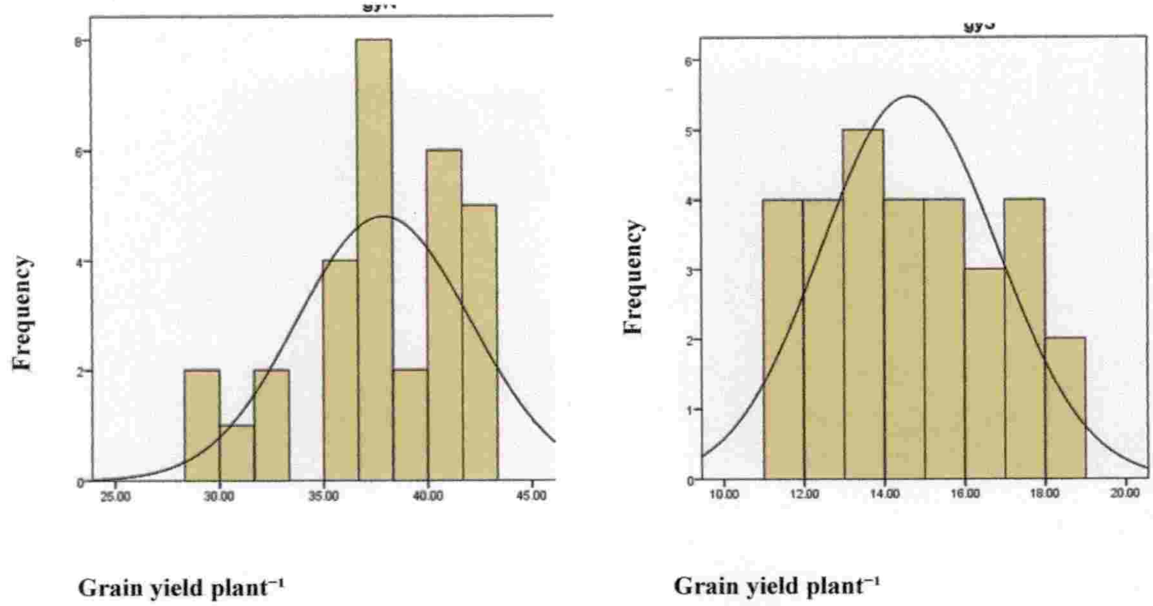


Fig. 37. F_2 distribution for grain yield plant^{-1} in Vaishak x Vyttila 6

38(a) 38(b)

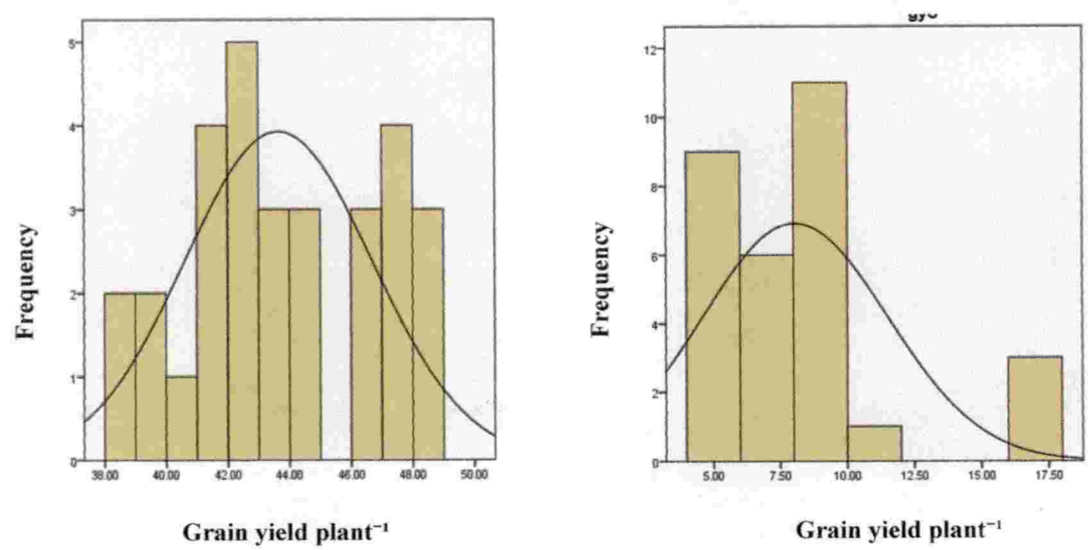


Fig.38. F_2 distribution for grain yield plant^{-1} in Vaishak x Harsha

condition (Fig. 39(a)) was moderately negatively skewed (-0.50) with a negative kurtosis (-0.92) whereas the graph under stress condition (Fig. 39(b)) was moderately positively skewed (0.86) with a positive kurtosis (0.22).

4.3.2.6 Frequency Distribution of F_2 segregants for Straw Yield Plant^{-1}(g)

Straw yield plant^{-1} in Vaishak x Vyttila 6 segregants ranged from 31.88g to 48.74g under normal condition whereas a notable decease in the values were observed under stress condition. When grown under stress the straw yield plant^{-1} ranged from 8.73g to 22.45g. The frequency distribution graph under normal condition was highly negatively skewed to the right side (-1.34) with a positive kurtosis (0.46) (Fig. 40(a)). The graph under stress condition was moderately positively skewed (0.55) and platykurtic (-0.53) (Fig. 40(b)).

The values for Vaishak x Harsha segregants ranged from 49.38g to 59.20g under normal condition whereas under stress the values ranged from 8.10g to 14.15g. The frequency distribution graph under both conditions was approximately symmetrical (-0.26 and -0.05 under normal and stress conditions respectively) with a negative kurtosis (-1.92 and -1.01 under normal and stress conditions respectively). Figure 41(a) and Figure 41(b) represent graphs under normal and stress conditions respectively.

Straw yield plant^{-1} in F_2 population of Thottacheera x Harsha ranged from 29.95g to 58.19g whereas under stress condition the values ranged from 8.20g to 16.15g. The graph under normal condition was approximately symmetrical (0.16) (Fig. 42(a)) whereas under stress it was moderately positively skewed (0.81) (Fig. 42(b)). The kurtosis was negative under normal (-1.21) and stress (-0.12) conditions.

39(a) 39(b)

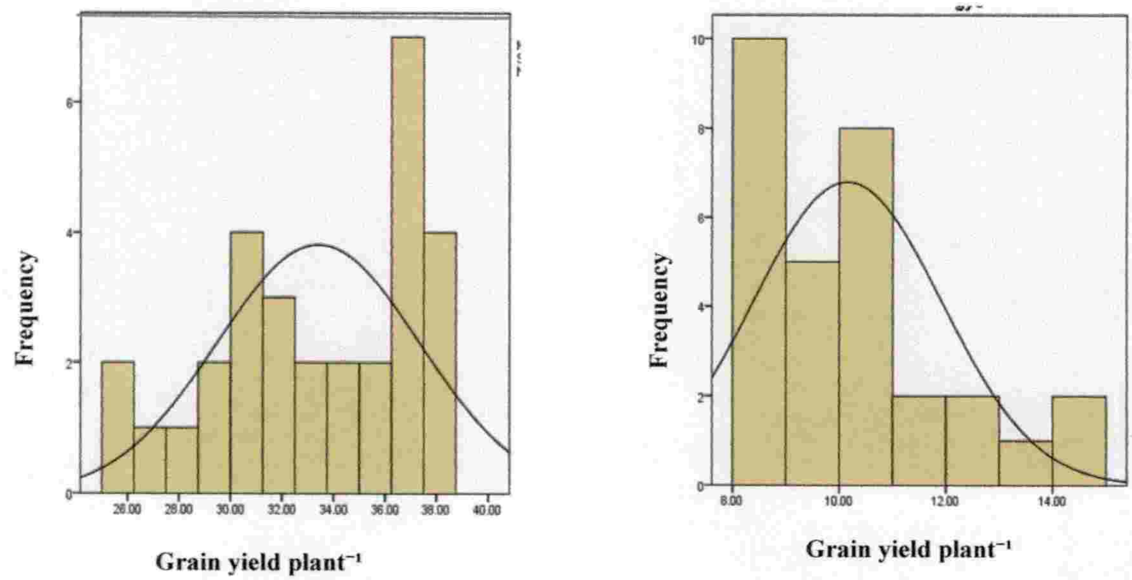


Fig. 39. F_2 distribution for grain yield plant^{-1}in Thottacheera x Harsha

40(a) 40(b)

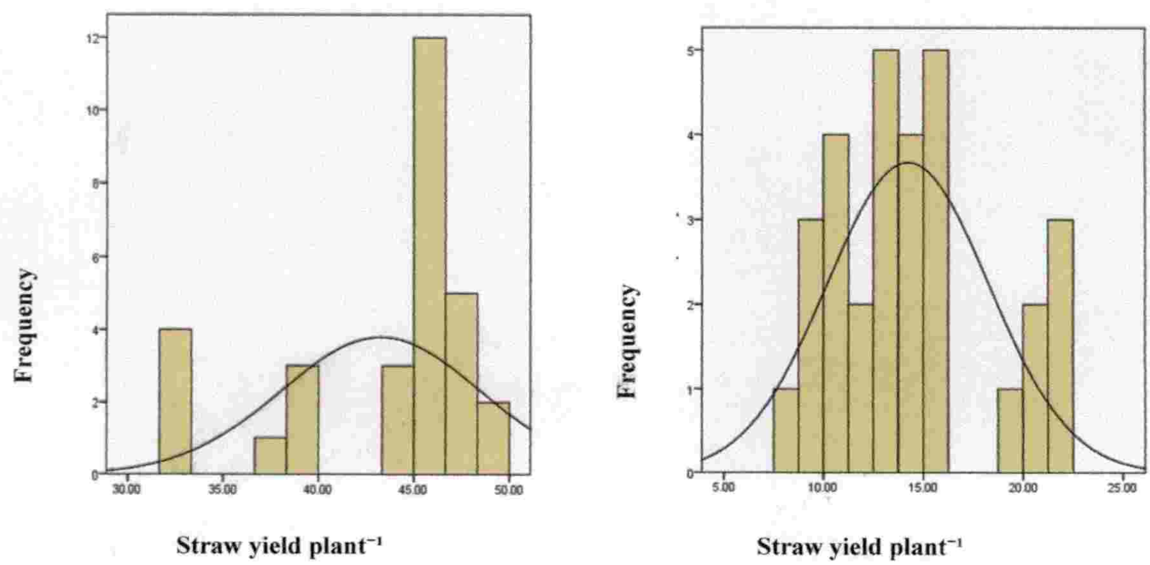


Fig.40. F_2 distribution for straw yield plant^{-1}in Vaishak x Vyttila 6

41(a) 41(b)

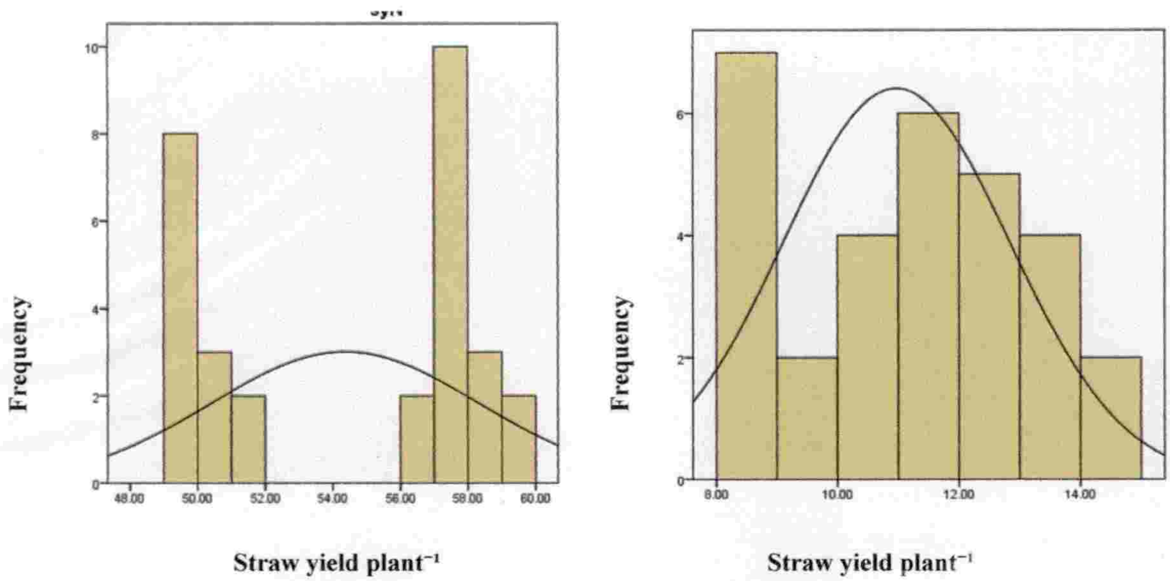


Fig.41. F_2 distribution for straw yield plant^{-1}in Vaishak x Harsha

42(a) 42(a)

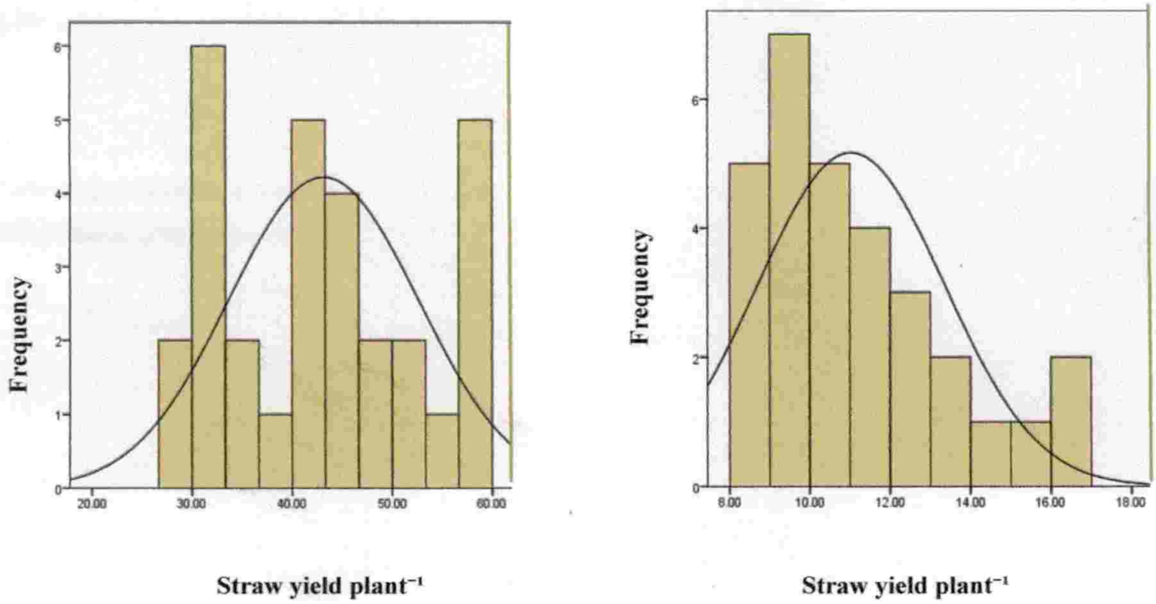


Fig.42. F_2 distribution for straw yield plant^{-1}in Thottacheera x Harsha

Discussion

5. DISCUSSION

Rice (*Oryza sativa* L.) is one of the most important food crop that feed more than half of the world population Worldwide production of husked rice was approximately 482 million metric tonnes in 2016. Asian countries account for about 90 percent of the world's production and consumption (FAO, 2017). With the ever increasing population, the demand for rice is expected to continue to increase atleastupto 2035. Based on the condition of crops already in the field and assuming normal weather for the rest of 2018 cropping seasons, FAO's forecast for world cereal output this year is 2,586 million tonnes which is 2.4 percentless than the record output in 2017 (FAO,2018).

Population explosion creates an urgent need to develop high yielding rice cultivars. The global rice research and development effectors are focusing on lowland rice. Thus, together with fertilisers and proper irrigation, high yielding varieties have contributed in considerable yield increase in lowland rice (Saito *et al.*, 2015). Upland rice is probably the lowest yielding rice ecosystem and the low yields are often attributed to improper crop management practices, limited availability of high yielding varieties coupled with biotic and abiotic stresses (Tanaka *et al.*,2017). The vulnerability of upland rice production is accelerated by global climatic change which in turn prevents the farmers from investing more on the inputs and thus results in larger yield gaps (van Oort*et al.*, 2017).

Genetic improvement addresses the major research topics for overcoming these constraints and improving yield. Genetic diversity among the parents plays a key role in selection of parents with wider adaptability (Nayak*et al.*, 2004). Superior hybrids and durable transgressive segregants are a result of hybridisation programme using such diverse parents (Rathi*et al.*, 2011). Thus, to increase the productivity, the breeder needs to maintain a pool of highly diverse donor parents (Joshi *et al.*, 2013).

Conventional breeding strategies for drought resistance have been slow because of the complexity of drought responses, environmental factors and their interactions. Recent advances in genome mapping and functional genomics are powerful tools that support researches in crop improvement. Genetic engineering techniques provide a better understanding of the molecular basis of genes underlying drought resistance.

Recent breeding progress, to some extend has succeeded in replacing the tall, sparsely tillered and low yielding traditional upland varieties with improved varieties (Lafittet *al*., 2002). In IRRI an improved upland rice variety IR 55423 – 01 (Apo) has been developed which could maintain an intermediate plant height, more number of panicles, strong weed suppressing ability and high harvest index even under water deficit conditions (Atlin*et al*., 2006; Lafitte *et al*.,2002).

The present investigation entitled "Genetic evaluation of F_2 generation for yield and water stress tolerance in upland rice" was carried out with an objective to evaluate the pattern of variability in F_2 for yield and yield contributing traits under upland and drought situations and to select superior segregants combining drought tolerance and high yield. The results obtained from the study are discussed here under the following headings.

5.1 Comparison of performance of genotypes under upland and drought conditions

5.2 Pattern of F_2 segregation for yield and yield contributing traits under upland and drought condition

5.1 COMPARISON OF GENOTYPES UNDER UPLAND AND DROUGHT CONDITIONS

5.1.1 Mean Performance

Genetic variability is a key factor in determining the extent of success in a breeding programme. Selection will be more effective if the genotypes are more diverse. Experiment I and II of the present study deals with the evaluation of seven genotypes (four parents and three F_2 populations) under rainfed upland and controlled condition respectively. The characters analysed were days to 50%

flowering, number of productive tillers plant^{-1}, plant height at maturity, panicle length, number of spikelets panicle^{-1}, number of filled grains panicle^{-1}, spikelet sterility, grain weight panicle^{-1}, 1000 grain weight, grain yield plant^{-1}, straw yield plant^{-1}, harvest index, proline content, chlorophyll content, leaf soluble protein content and leaf area index. The mean value for each character in parents and F_2 segregants, correlation with grain yield plant^{-1}, clustering and analysis of percentageof positive and negative segregants in F_2 point out that there is further scope for genetic improvement through conventional breeding.

Under upland condition, the early flowering and maturing genotypes among parents and F_2populations were Thottacheera and Thottacheera x Harsha respectively wherein the mean values were lower than the parental mean (89.33 days) and F_2 segregants mean(85.83days). The late flowering and maturing genotypes were Vyttila 6 and Vaishak x Vyttila 6 segregants. The mean value for parents and F_2 segregants were comparable for this character. Under controlled condition the parental mean(83.77days) and F_2 segregants mean (96.04 days) differed considerably. The same treatments *viz.*Thottacheera among parents and Thottacheera x Harsha among F_2 populations flowered early. Under controlled condition, parental mean decreased whereas F_2 segregants mean increased notably. This greater delay in flowering eventually led to yield and harvest index reduction.In general, apart from varietal character, the lower the time taken to flowering and maturation, the higher the chances of escaping drought. A close association between time taken to flowering and drought tolerance was observed in upland rice varieties by Laffitte and Curtosis(2002). Panthuwan*et al.*(2002) have reported similar results that the greater the delay in flowering the greater is the yield and harvest index reduction

For the character number of productive tillers plant^{-1} the F_2 segregant population mean (12.14) far exceeded the parental mean (9.44) when grown under upland condition. All the three F_2 segregant populations had mean values greater than the best parent and this character had a major role in increasing grain yield and harvest index among F_2.These findings support the report that under upland conditions F_2 performed much better than parents for number of productive tillers plant^{-1}. The result is in agreement with the findings of Valarmathi and Leenakumary (1998) that grain yield increased when the number of productive tillers increased. Conversely, under stress condition, the mean number of productive tillers plant^{-1} decreased for both parents and F_2populations compared to the normal condition. The F_2 segregant mean (3.58) was observed to be lower than the parental mean(5.71) and this has reflected on mean grain yield of F_2 population also.

For plant height at maturity, under upland condition the F_2 segregants mean (127.49cm) was higher than the parental mean (101.03cm). Vaishak (126.40cm) was the tallest parent which effectively transferred its height to both the F_2 segregant populations (Vaishak x Vyttila 6 and Vaishak x Harsha) wherein it featured as the female parent. When grown under the stress condition, there was an overall reduction in plant height for both parents and F_2population. But the parental mean (100.99cm) and F_2 segregants mean (102.12cm) were comparable indicating that the reduction was prominent for the highly variable F_2 than the uniform parent varieties. This is in line with the report by Basu and Das (1981) pointed out that moisture stress had resulted in a reduction in plant height and upland rice varieties were less sensitive compared to lowland rice varieties.

Mean panicle length did not vary much under both upland and drought conditions. When grown under normal condition, the mean panicle length for parents (23.08cm) and F_2segregant populations (23.44cm) werecomparable. The character was not much affected even under stress where the parental mean was 24.53cm and F_2 segregants mean was 21.17cm. In both conditions, this character was not found to be correlated with yield among parents or the F_2populations.This is in agreement with the report of Sikuku*et al.*(2010) that the drought tolerant genotypes had the least reduction in panicle length, tiller number and other yield components under moisture stress.

Under upland condition, the parent Vaishak marked the highest mean values for number of spikelets panicle^{-1}, number of filled grains panicle^{-1}, 1000 grain weight and grain yield plant^{-1} Among the F_2 populations, Vaishak x Harsha segregants recorded the highest mean values for number of filled grains panicle^{-1}, grain weight panicle^{-1}, 1000 grain weight and grain yield plant^{-1}. Under stress, the variety Vaishak recorded the highest mean values for number of filled grains panicle^{-1}, grain weight panicle^{-1}, grain yield plant^{-1} and harvest index whereas among the F_2 populations, Vaishak x Vyttila 6 segregants marked the highest mean values for number of spikelets panicle^{-1}, grain weight panicle^{-1}, 1000 grain weight, grain yield plant^{-1}, harvest index and proline content.Vaishak which featured as the female parent was observed to be the best general combiner for number of spikelets panicle^{-1} and grain yield plant^{-1} under upland rainfed situation by Haunsajirao (2017). Vaishak might have successfully transferred its superior grain characters to its hybrid which has become evident in the F_2 segregating generation under both conditions. This is in conformity with the report that more fertile grains panicle^{-1} and heavy grains are important traits to be considered while selecting for high yield (Prasa*et al.*,2001; Surek and Beser, 2003).Guimaraes*et al.* (2016) have reported similar findings that precocity, less dense panicles, low sterility and greater 100-grain weight under water stress should be prioritised while selecting genotypes for drought tolerance.

When grown Spikelet sterility was found to be much higher in the F_2 population (26.59%) compared to parental varieties(10.21%) under rainfed upland condition whereas such a distinction was not observed under imposed moisture stress. The reason is the high range of variability in the days to onset of different growth phases expressed in the heterozygous segregating populations as against the strict, narrow range of the homozygous parental varieties. Each parental variety was subjected to a single major dry spell (five days or more without rain) during its early reproductive phase from panicle initiation to booting when it is most susceptible to moisture stress. The much variable segregating populations on the other hand had to tide over three major dry spells each during the prolonged early reproductive phase (Table 9). This is supported by the finding of Liu *et al.* (1993) and Wopereis*et al.* (1996) that moisture stress at an early reproductive stage reduces the number of filled grains panicle^{-1}, 1000 grain weight and grain yield plant^{-1} and increases spikelet sterility. Haunsajirao (2017) had in his study reported such a situation in a long duration variety Uma. This finding further stresses the significance in recommending short duration types for drought situations. Under artificial stress, the range in duration of panicle initiation stage was not considered, but a mean date was taken to initiate stress imposition.

The mean value for straw yield plant^{-1} did not vary much for parents and F_2 segregants both under normal and controlled conditions. Under normal condition, straw yield was the highest for Harsha(58.29g) and segregants of Vaishak x Harsha (57.14g) whereas it was the lowest for Vyttila 6(30.98g) and Thottacheera x Harshasegregants (33.03g). Under stress condition, Vyttila 6 (19.31g) and F_2 population of Thottacheera x Harsha(13.93g) recorded the highest mean value whereas Harsha(8.04g) and Vaishak x Harsha segregants (10.72g) recorded the lowest mean.For harvest index, the F_2 segregant mean was greater than the parental mean under both normal and stress conditions. Vyttila 6 and Vaishak x Vyttila 6 segregants recorded the highest mean value for harvest index whereas Harsha and segregants of Vaishak x Harsha recorded the lowest mean value for this character when grown under upland condition. Under stress,Vaishak and Vaishak x Vyttila6 segregants recorded the highest mean values whereas Thottacheera and Vaishak x Harshasegregants marked the lowest mean values. Straw yield plant^{-1} was significantly and positively correlated with yield in both the groups analysed. This correlation is in accordance with the reportsof Shanmugasundaram*et al.* (2002) that straw yield and harvest index forms an important selection criterion for superior genotypes under rainfed condition.

Rice is highly sensitive to reproductive stage moisture stress. The beginning of reproductive stage is marked by panicle initiation followed by exsertion. Cruz and O'Toole(1982) reported that panicle exsertion is sensitive to changes in leaf water potential and upto 30 percent of water stress mediated spikelet sterility was associated with poor panicle exsertion. Thus, degree of panicle exsertion during flowering stage water stress could be used as an important visual criterion in selection of genotypes with high degree of reproductive stage drought tolerance.Under upland condition, Thottacheera and F_2 population of Thottacheera x Harsha recorded well exserted panicles whereas the panicles were only partially exserted in Vyttila 6. When grown under stress, Thottacheera and Vaishak x Harsha segregants recorded well exserted panicles whereas Vyttila 6 and Vaishak x Vyttila 6 segregantsrecorded partially exserted panicles.

Leaf rolling is a reversible phenomenon which reduces the leaf area exposed to stress reducing transpiration and thus has an adaptive role in tissue water conservation. Leaf rolling is determined based on scores. The scores are based on the degree of rolling observed (Table 2). When grown under upland condition exposed to natural stressthe varieties Vaishak, Thottacheera and F_2 populationof Vaishak x Vyttila 6, Vaishak x Harsha and Thottacheera x Harsha recorded a leaf rolling score of 3 which was marked by the folding of leaves with a deep 'V' shape. Leaf rolling in Vyttila 6 and Harsha were not significant (score 1). Under artificial stress condition, all the F_2 populations recorded a score of 7 which was characterised by the touching of leaf margins forming an 'O' shape whereas the parents Thottacheera, Vyttila 6 and Harsha recorded a score of 3. The leaf rolling in Vaishak recorded a score of 1. Similar findings were reported by Singh and Singh (2000) that leaf rolling is an adaptive response to water deficit which helps in maintaining favourable water balance within plant tissues thus resulting in relatively better plant performance. Hence, the high score for reversible leaf rolling observed in the present F_2 population can be considered as a positive character.

The parents and F_2 segregants did not vary considerably for mean proline content under rainfed upland condition. Vyttila 6 recorded the highest value among the parents and its progeny, Vaishak x Vyttila 6 segregants recorded the highest mean value among the F_2 segregants. Proline content increased considerably under stress in both parents and F_2 segregants wherein Vyttila 6 and Vaishak x Vyttila 6 segregants recorded the highest mean value. Proline content was comparatively low for Harsha and Vaishak x Harsha. The proline accumulation during moisture stress is associated with dry matter production and hence confers drought tolerance (Lum*et al*., 2014). The increased proline content under stressin the current study is thus an indication of drought tolerance.

For chlorophyll content, the F_2 segregants recorded higher mean as compared to the parents under both upland and drought conditions. Among the parents, Harsha recorded the highest mean chlorophyll content and among the F_2 segregants, Thottacheera x Harsha ranked first.Water stress limits chlorophyll contents in leaves of rice plants and the loss of chlorophyll is a fundamental basis of disrupting of the photosynthetic rate in plants affecting production (Sheela and Alexander, 1996)The higher mean content of chlorophyll observed among F_2 segregants is thus a desirable character. For the character, leaf soluble protein content, the parental mean and F_2 segregant means were comparable under both conditions. Under upland condition parents recorded a mean value of 7.90mg g^{-1} and the F_2 segregants marked a mean of 7.75mg g^{-1}. When grown under stress, the parental mean was 6.42mg g^{-1} and the F_2 segregants mean was 6.01mg g^{-1}.This is in line with the report that the high value of chlorophyll content and leaf soluble protein content are indications of drought tolerance(Mohan*et al*., 2002; Beena*et al*., 2012).

For leaf area index at maturity, the parental mean was greater than the F_2 segregants mean under both conditions. When grown under upland condition, Vyttila 6 recorded the highest mean leaf area index of 2.86 among the parents whereas Vaishak x Harsha segregants (1.67) topped among the F_2 populations. Under stress condition, the variety Thottacheera (0.64) recorded the highest mean value whereas F_2 population of Thottacheera x Harsha(0.71) recorded the highest among the F_2 populations. Thus, leaf area index was highly reduced under stress in both the parents and the F_2 populations. This indicates that physiological characters such as leaf area index are highly sensitive to reproductive stage moisture stress as reported by Kumar *et al.* (2014) that a reduction in leaf area index was observed under moisture stress.

5.1.2 Simple Correlation

Simple correlation for various yield contributing traits with grain yield was worked out under both upland and imposed moisture stress conditions. Under rainfed upland condition, the number of spikelets panicle^{-1}, number of filled grains panicle^{-1}, grain weight panicle^{-1}andstraw yield plant^{-1}were significantly and positively correlated with grain yield plant^{-1} in case of parents. Among the F_2 population number of productive tillers panicle^{-1}, number of filled grains panicle^{-1} and straw yield plant^{-1} recordedsignificant positive correlation with grain yield plant^{-1} whereas leaf soluble protein content recorded significant negative correlation. Spikelet sterility had significant negative correlation with grain yield for both parents and F_2population. When grown under stress condition, the characters such as panicle length, number of spikelets panicle^{-1}, number of filled grains panicle^{-1}, grain weight and 1000 grain weight recorded a significant positive correlation with grain yield in case of parents whereas for the F_2 populations traits such as number of spikelets panicle^{-1}, number of filled grains panicle^{-1}, grain weight and 1000 grain weight, harvest index and proline content were significantly and positively correlated with grain yield plant^{-1}.Various studies have revealed similar results that days to 50% flowering, fertile spikelets panicle^{-1}, harvest index, productive tillers panicle^{-1} and 100 grain weight are positively correlated with grain yield (Rao and Srivastava, 1999; Raju*et al.*,2004).Kahani and Hittalmani (2015) reported that grain yield plant^{-1} was significantly and positively correlated with number of tillers, number of panicles, grain length and straw yield whereas days to flowering, days to maturity, plant height, 100 grain weight, grain width and leaf width were negatively correlated with grain yield plant^{-1}.

5.1.3 Similarity between the genotypes

In the present investigation, Vaishak featured as the female parent in two F_2 populations and Thottacheera featured as the female parent in one F_2 population. Vyttila 6 and Harsha were the male parents. The dendrogram prepared based on the similarity matrix (Table 10) grouped the genotypes into four clusters. Vaishak and the two F_2 populations involving Vaishak as female parent (Vaishak x Vyttila 6 and Vaishak x Harsha) were included in the same cluster (cluster I) whereas Thottacheera and the F_2 involving Thottacheera as female parent (Thottacheera x Harsha) formed another cluster (cluster III). The male parents, Harsha and Vyttila 6 stood alone in clusters II and IV respectively. Hence, a female parent based clustering was observed for the experiment conducted under rainfed upland condition.

Under protected condition, the genotypes were grouped into four clusters wherein the male parent Harsha and the F_2 population involving Harsha as male parent were grouped together to form cluster I. Similarly, the male parent Vyttila 6 and the F_2population Vaishak x Vyttila 6 formed cluster III. Similar to clustering observed under upland condition, the female parent Thottacheera and the F_2population Thottacheera x Harsha were included in the same cluster (cluster II). Vaishak stood alone in cluster IV. Hence, a male parent based clustering was observed for the experiment conducted under protected condition.

5.1.4 Percentage of F_2 Segregants

All the three F_2 populations investigated showed much variability and had positive or negative segregants or both, for each character studied. The percentage of positive and negative segregants varied in each F_2population depending on their adaptability.

For the character days to 50% flowering under upland condition, Vaishak x Vyttila 6 segregants recorded the highest percentage of positive segregants

(32%) wherein the duration of flowering was increased.There were no positive segregants for this character in the other two F_2 populations. The percentage of negative segregants were the highest in Vaishak x Harsha segregants (88%) whereas population of Vaishak x Vyttila 6 and Thottacheera x Harsha recorded 26 percent and 39 percent of negative segregants respectively. This increase in frequency of genotypes showing early flowering is highly advantageous in breeding for drought tolerance. Precocious flowering has been pointed out as an effective drought avoidance mechanism (Laffitte*et al.*, 2002). With the highest percentage of early flowering genotypes, the F_2 Vaishak x Harsha has the potential to develop drought tolerant, early maturing hybrid derivatives through selection. Under protected condition, there were only positive segregants for days to 50% flowering wherein Vaishak x Harsha (78%) recorded the highestpercentage. The percentage of positive segregants were comparable in other two F_2 populations.

Under rainfed upland condition, the number of productive tillers plant^{-1} were high for all the F_2 populations compared to their parents and there were no negative segregants for this character. Among the F_2 populations, Vaishak x Harsha recorded the highest percentage of positive segregants (91%) with segregants of Vaishak x Vyttila 6 (85%) and Thottacheera x Harsha (82%) following closely behind. An overall decrease in number of productive tillers was observed under protected condition in F_2 populations. A small percentage of positive segregants for this character was observed in Thottacheera x Harsha (15%) segregants only. As yield increases with increase in number of productive tillers (Valarmathi and Leenakumay, 1998; Haunsajirao, 2017) the F_2 segregants with a positive shift for this character can be tapped favourably while selecting for drought tolerant high yielding types.

For the character plant height at maturity, under upland condition there were only positive segregants in populations of Vaishak x Vyttila 6 (76%) and Vaishak x Harshasegregants (84%) whereas only negative segregants were observed in Thottacheera x Harsha. Moisture stress adversely affects plant height.

Even though amarginal reduction in plant height was observed in all the three F_2 populations under stress compared to normal condition, a small percentage of positive segregants were observed in all the three F_2 populations. Negative segregants for this character was observed in case of segregants of Vaishak x Vyttila 6 (38%) only. Vjayalakshmi and Nagarajan (1994) reported that a marginal reduction in plant height is observed in drought resistant rice varieties with a well developed root system as has been observed in the present study.

When grown under upland condition, positive segregants for panicle length was observed in segregants of Vaishak x Vyttila 6 (66%) and Vaishak x Harsha (25%). Only negative segregants were noted in populations of Thottacheera x Harsha population(24%). Under stress, Thottacheera x Harsha population (21%) alone recorded positive segregants. But there was no notable reduction in mean panicle length of the three F_2 populations under both conditions. Similar result was reported by Sikuku*et al.* (2010) that drought tolerant genotypes had the least reduction in panicle length under moisture stress.

For the character, number of spikelets panicle^{-1} a higher percentage of positive segregants were observed in Vaishak x Vyttila 6 segregants(78%) followed by segregants of Thottacheera x Harsha (49%) whereas only negative segregants were observed in Vaishak x Harsha (38%) under upland condition. There was considerable reduction in number of spikelets in all the three F_2 populations under stress compared to the normal condition. Among the F_2 populations,segregants of Vaishak x Vyttila 6 maintained comparatively higher mean value for this character with a higher percentage of positive segregants which was recorded to be 70 percent. Other two F_2 populations were having only negative segregants. Abashahr*et al.* (2011) who observed high spikelet number of 209.33 in Nemat cultivar under optimum moisture regimes which was reduced to 104 under stress condition have reported results in the same direction.

Under upland condition, there were only negative segregants for filled grains panicle^{-1} and only positive segregants for spikelet sterility. Under stress condition there was an overall reduction in number of filled grains panicle^{-1}. The F_2 populations of Vaishak x Vyttila 6 and Vaishak x Harsha recorded positive segregants among which the population of Vaishak x Vyttila 6 had only positive segregants and was the highest (85%). This higher percentage of positive segregants helped the F_2 population (Vaishak x Vyttila 6) in recording comparatively higher grain yield under stress. Negative segregants were reported in F_2 populations of Vaishak x Harsha (38%) and Thottacheera x Harsha (20%). For spikelet sterility under stress condition, all the three F_2populations recorded negative segregants only and spikelet sterility was comparatively low. Similar findings were reported by Sarvasthani*et al.* (2008) that moisture stress at reproductive stage caused poor grain filling which ultimately led to 50 percent reduction in grain yield. Jongdee*et al.* (2002) reported a 40 percent yield reduction due to increase in spikelet sterility when drought occurred during grain filling period.Haunsajirao (2017) reported drastic yield reduction in Uma due to reproductive stage moisture stress under rainfed upland condition.

For grain weight panicle^{-1} under upland condition, positive segregants were observed in case of Vaishak x Vyttila 6 segregants alone (15%). When grown under stress, all the three F_2 populations recorded positive segregants for grain weight with the highest being 88 percent recorded by Vaishak x Vyttila 6. Both positive and negative segregants could be observed in the F_2segregants Vaishak x Harsha under protected condition. The F_1 cross showed a highsca effect (0.269**) for this character whereas Vaishak had low gca (0.022) and Harsha had high gca (0.076*) as reported by Haunsajirao (2017). This is in conformation with the findings of Yadav*et al.* (1998) that the potential crosses for transgressive segregants were those that had high sca effects and involved high and low general combiners.

In case of 1000 grain weight all the three F_2 populations recorded positive segregants wherein Vaishak x Harsha segregants (33%) recorded the highest percentage under upland condition.Under stress, positive segregants were recorded by the F_2 populations of Thottacheera x Harsha (80%) and Vaishak x

Vyttila 6 (20%) whereas Vaishak x Harsha segregants was having only negative segregants (18%). This is in accordance with the report by Boonjung and Fukai(1996) that the percentage of filled grains decreased to 40 percent and individual grain mass decreased by 20 percent when drought occurred during grain filling stage. Water stress at booting and flowering stage has resulted in a decrease in 1000 grain weight in rice.

For grain yield plant^{-1},the F_2 populations of Vaishak x Harsha (85%) and Vaishak x Vyttila 6 (36%) recorded positive segregants whereas population of Thottacheera x Harsha recorded negative segregants only under upland condition. When grown under stress, only Thottacheera x Harsha segregants (22%) alone recorded positive segregants. Due to the presence of positive segregants Thottacheera x Harsha was able to record comparatively higher yield among the F_2 populations.Overall a decrease in grain yield was observed for the genotypes when grown under stress. This is in line with the report by Boonjung and Fukai (1996) that stress experienced at the panicle initiation stage caused an yield reduction of 30 percent. For the trait straw yield plant^{-1}, the F_2 population ofVaishak x Vyttila 6 and Vaishak x Harsha segregants recorded only positive segregants whereas Thottacheera x Harsha recorded negative segregants only when grown under normal condition. Under stress, all the three F_2 population recorded only positive segregants. Inspite of the positive segregants, the biomass production reduced under stress compared to the normal condition. Similar results were reported by Lilley and Fukai (1994) that the biomass production in rice reduced under moisture stress and the reduction depends on the severity of moisture stress.

Under upland condition, the F_2 population of Vaishak x Harsha recorded both positive (28%) and negative(15%) segregants for harvest index whereas populations of Thottacheera x Harsha (36%) and Vaishak x Vyttila 6 (22%)recorded only positive segregants. There were both positive (36%) and negative(25%) segregants for harvest index in case of Vaishak x Vyttila 6 segregants when grown under protected condition whereas F_2 populations

Vaishak x Harsha and Thottacheera x Harsha recorded only negative segregants. This shows that harvest index had a positive association with grain yield plant^{-1} as reported by Yamaguchi *et al.* (1994).

5.2 PATTERN OF F_2 SEGREGATION FOR YIELD AND YIELD CONTRIBUTING TRAITS UNDER UPLAND AND DROUGHT CONDITION

In F_2 distribution for number of productive tillers plant^{-1} under upland condition, the population of Vaishak x Vyttila 6 recorded the highest mean (12.47) and the range was from 9 to 15 tillers. The same F_2 population was found to have high mean value (4.23) for productive tillers compared to other F_2 means when grown under stress. The graphs under both conditions were approximately symmetrical with negative kurtosis. This indicates a normal distribution for the population. The ability to maintain a higher number of productive tillers under stress resulted in a notably high grain yield in Vaishak x Vyttila 6 segregants even under adverse condition. This is in line with the reports of Valarmathi and Leenakumary(1998) and Haunsajirao(2017) that grain yield increased with increase in number of productive tillers.

For number of spikelets panicle^{-1},in Vaishak x Vyttila 6segregants the number ranged from 149 to 178 under normal condition with a mean of 169.73. The frequency distribution graph under normal condition was highly negatively skewed suggesting the presence of more individuals with number of spikelets higher than the mean value. Under stress condition, the same F_2 recorded the highest mean number of spikelets panicle^{-1}which was 147.23. The graph was approximately symmetrical signifying a normal distribution and the number of spikelets ranged from 128 to 174.

In the F_2 distribution for number of filled grains panicle^{-1}under normal condition, Vaishak x Harsha segregants recorded the highest mean value (150.37) and it ranged from 133 to 157. The graph was highly negatively skewed with a positive kurtosis stating that a higher frequency of individuals had values at or near to the mean value. Under stress condition, the number of filled grains reduced considerably ranging from 80 to 118 with a mean of 95.67. The graph under stress was moderately positively skewed with a negative kurtosis. The decrease in mean number of filled grains under stress for this population was the lowest compared to others which shows that stress has not affected Vaishak x Harsha segregants much.

1000 grain weight of all the three F_2 populations was comparable when grown under upland condition and it did not show a notable decrease in weight when grown under stress. The decrease in 1000 grain weight was the least for Vaishak x Vyttila 6 segregants where it ranged from 23.78g to 26.15g with a mean of 25.01g which was comparable to the mean under normal condition (27.80g). The graph under normal condition was moderately negatively skewed with a negative kurtosis. Under stress condition the population was more distributed.

In the F_2 distribution for grain yield plant^{-1},Vaishak x Harsha segregants recorded the highest mean (43.65g) under normal condition with individual values ranging from 38.45g to 48.15g. The frequency distribution graph under normal condition was moderately negatively skewed and mesokurtic. A considerable decrease in grain yield was observed under stress condition wherein the least decrease was noted in segregants of Vaishak x Vyttila 6. Grain yield ranged from 11.80g to 18.88g with a mean of 14.64g and the graph was approximately symmetrical with a negative kurtosis.Fukai and Cooper (1995) reported a relative yield advantage in stress tolerant genotypes compared to susceptible ones when grown under moisture stress, suggesting that Vaishak x Vyttila 6 segregants are the most stress tolerant F_2 population.

The highest mean straw yield plant^{-1} under upland condition was recorded by Vaishak x Harsha segregants where it ranged from 49.38g to 59.20g with a mean of 54.36g. The frequency distribution graph was approximately symmetrical with a negative kurtosis. A notable decease in biomass production was observed in all the F_2 populations when grown under stress and the decrease was comparatively less in Vaishak x Vyttila 6 segregants (8.73g - 22.45g) with a mean of 14.23 which was the highest mean value recorded under stress condition. The graph was moderately positively skewed and platykurtic.

Under stress condition, the distribution of F_2 populations foryield related attributes such as number of productive tillers plant^{-1}, number of spikelet panicle^{-1}, number of filled grains panicle^{-1}, 1000 grain weight and straw yield plant^{-1} were not much affected in F_2 segregants of Vaishak x Vyttila 6 and Vaishak x Harsha. There can be a probability that their female parent Vaishak might have transferred its superior yield and drought tolerance traits to the progeny. The above results are in agreement with the findings of Jambhulkar and Bose (2014) and Haunsajirao (2017) that a selection based on days to 50% flowering, 1000 grain weight and number of productive tillers is more advantageous for yield improvement and drought tolerance in upland rice. Similar results were reported by Kahani and Hittalmani (2015) that grain yield plant^{-1} has a positive association with number of tillers, number of panicles, grain length and straw yield and these characters should be given more importance while selecting for yield advantage under moisture stress condition.

Among the F_2 populations, the segregants of Vaishak x Harsha performed well under upland condition whereas Vaishak x Vyttila 6 segregants performed well under stress. In both these F_2 populations Vaishak featured as the female parent. The high yielding variety Vaishak released for uplands might have transferred its superior yield characters to the progeny. There were more positive segregants for yield and yield contributing traits in the F_2 populations of Vaishak x Vyttila 6 and Vaishak x Harsha. This points to the possibility of appearance of desirable transgressive segregants in later segregating generations which can be effectively utilised for selecting superior genotypes combining drought tolerance and high yield.

Summary

6. SUMMARY

Rice (*Oryza sativa* L.) is one of the world's most important staple food crops, feeding a large part of the human population, especially in Asia. In the present scenario the world population is growing at an alarming rate and is expected to reach 9 billion by 2050 (FAO, 2010). In order to meet the food requirements of the ever increasing population, there must be a several-fold increase in food grain production compared to the present level. The major constraints faced by famers are changing climate and shrinking arable land. According to FAO (2016), out of a total of 4,924 million hectare area of potentially cultivable land, the actual arable land is only 1,407 million hectare. In addition to reduced land availability, erratic rainfall, temperature fluctuations and emergence of new pests and diseases also contribute to a major portion of yield loss.

Rice is semi-aquatic and is cultivated either as irrigated (lowland) or rainfed (upland). Most of the researches till date are concentrating on improving lowland rice productivity. Since the availability of good quality water is diminishing, upland rice which depends entirely on rainfall needs special attention. Keeping this in view, the present investigation entitled "Genetic evaluation of F_2 generation for yield and water stress tolerance in upland rice" was carried out at College of Agriculture, Vellayani during the period from June, 2017 to May, 2018 to evaluate the pattern of variability in F_2 generation for yield and yield contributing traits under upland and drought situations and to select superior segregants combining drought tolerance and high yield.

The genetic material for the study comprised of four parents (Vaishak, Thottacheera, Vyttila 6 and Harsha) and three F_2 populations (Vaishak x Vyttila 6, Vaishak x Harsha and Thottacheera x Harsha) selected from the Ph. D project entitled "Genetic analysis of drought tolerance in rice (*Oryza sativa* L.)". The study was carried out in two separate experiments. In experiment I, the parents and F_2 segregants were raised in the field under rainfed upland condition exposed

to natural stress. Experiment II was drought screening of F_2 populations in controlled condition where another set of parents and F_2 segregants raised in rainshelter was subjected to reproductive stage moisture stress. Irrigation was given at 20mm depth once in seven days from panicle initiation stage onwards.

Morphological, physiological and biochemical observations were taken at appropriate stages and recorded in both the experiments. The characters studied were days to 50% flowering, nature of panicle exsertion, number of productive tillers plant^{-1}, plant height at maturity(cm), panicle length(cm), number of spikelets panicle^{-1}, number of filled grains panicle^{-1}, spikelet sterility(%), grain weight panicle^{-1} (g), 1000 grain weight(g), grain yield plant^{-1}(g), straw yield plant^{-1}(g), harvest index(%), leaf rolling score and incidence of pests and diseases, proline content, chlorophyll content(mg g^{-1}), leaf soluble protein content(mg g^{-1}) and leaf area index.

On analysing the mean performance of the genotypes for all the above characters under rainfed upland condition, it was found that among the parents the variety Vaishak recorded the highest mean grain yield plant^{-1}. It also recorded the highest mean value for plant height at maturity, number of spikelets panicle^{-1}, number of filled grains panicle^{-1}, 1000 grain weight and the lowest value for spikelet sterility. The variety Thottacheera was the earliest in flowering and recorded the highest mean value for panicle length and leaf soluble protein content. Vyttila 6 was late in flowering with the lowest mean straw yield plant^{-1} but the number of productive tillers plant^{-1}, harvest index, proline content and leaf area index were found to be the highest. Harsha recorded the lowest mean value for plant height at maturity but its grain weight panicle^{-1}, straw yield plant^{-1} and chlorophyll content were the highest. Among the F_2 populations, segregants of Vaishak x Harsha recorded the highest mean value for grain yield plant^{-1}, number of productive tillers plant^{-1}, number of filled grains panicle^{-1}, grain weight panicle^{-1}, 1000 grain weight, straw yield plant^{-1} and leaf area index and the lowest mean value for spikelet sterility. The F_2 population of Vaishak x Vyttila 6 was late in flowering with the lowest value for plant height at maturity but recorded the highest mean values for panicle length, number of spikelets panicle^{-1}, harvest index and proline content. The F_2 segregants of Thottacheera x Harsha flowered early and was having the highest mean value for plant height and the lowest value for straw yield plant^{-1}. It recorded the highest mean value for chlorophyll and leaf soluble protein content.

There was significant positive correlation of grain yield plant^{-1} with number of spikelets panicle^{-1}, number of filled grains panicle^{-1} and grain weight panicle^{-1} and straw yield plant^{-1} whereas spikelet sterility recorded a significant negative correlation in case of parents. Significant positive correlation was noted for number of productive tillers plant^{-1} and straw yield plant^{-1} whereas spikelet sterility and leaf soluble protein content recorded a significant negative correlation in F_2.

The data obtained was subjected to transgressive segregation analysis and in F_2 population of Vaishak x Vyttila 6 segregants more than 50 percent positive segregants were observed for number of productive tillers plant^{-1}, spikelet sterility, number of spikelets panicle^{-1} and panicle length. A higher percent of negative segregants were noted for number of filled grains panicle^{-1} and 1000 grain weight. The F_2 population of Vaishak x Harsha recorded high percent of positive segregants for number of productive tillers^{-1}, grain yield plant^{-1}, plant height and spikelet sterility whereas a higher percent of negative segregants were noted in days to 50% flowering and grain weight panicle^{-1}. In Thottacheera x Harsha segregants, spikelet sterility and number of productive tillers plant^{-1} recorded a higher percent of positive segregants whereas plant height at maturity and number of filled grains panicle^{-1} recorded a higher percent of negative segregants.

Dendrogram drawn on the basis of squared Euclidean distances classified the genotypes into four clusters. Cluster I included Vaishak, F_2 segregants of Vaishak x Vyttila 6 and Vaishak x Harsha. Cluster II and IV were solitary clusters that included Harsha and Vyttila 6 respectively. Cluster III included parent Thottacheera and segregants of Thottacheera x Harsha.

Based on the mean performance of the genotypes under protected condition, the variety Vaishak recorded the highest grain yield plant^{-1} among the parents. It recorded the highest mean value for plant height at maturity, number of productive tillers plant^{-1}, panicle length, number of filled grains panicle^{-1}, grain weight panicle^{-1} and harvest index whereas it recorded the lowest mean value for spikelet sterility. Thottacheera was the earliest in flowering and recorded the highest mean value for leaf area index. Vyttila 6 was late in flowering and recorded the highest mean value for number of spikelets panicle^{-1},1000 grain weight, straw yield plant, proline and leaf soluble protein content. Harsha recorded the lowest mean value for plant height and straw yield plant^{-1} but it marked the highest mean value for chlorophyll content. Among the F_2 populations, Vaishak x Vyttila 6 segregants recorded the highest grain yield plant^{-1}. It recorded the highest mean value for plant height at maturity, days to 50% flowering, number of spikelets panicle^{-1}, number of filled grains panicle^{-1}, grain weight panicle^{-1}, 1000 grain weight, harvest index and proline content. The segregants of Vaishak x Harsha recorded the lowest mean value for spikelet sterility and straw yield plant^{-1} whereas it recorded the highest mean value for panicle length. The F_2 population of Thottacheera x Harsha was the earliest in flowering and marked the highest mean value for number of productive tillers plant^{-1}, straw yield plant^{-1}, chlorophyll content, leaf soluble protein content and leaf area index.

Among parents, there was significant positive correlation for panicle length, number of spikelets panicle^{-1}, number of filled grains panilce^{-1}, grain weight panicle^{-1} and 1000 grain weight with grain yield plant^{-1} . In F_2 populations, grain yield plant^{-1} was positively correlated with number of spikelets panicle^{-1}, number of filled grains panicle^{-1}, grain weight panicle^{-1}, 1000 grain weight, harvest index and proline content.

In Vaishak x Vyttila 6 segregants , more than 50 percent of positive segregants were recorded for grain weight panicle^{-1}, number of filled grains panicle^{-1} and number of spikelets panicle^{-1} whereas number of productive tillers

$plant^{-1}$ and panicle length recorded a higher percent of negative segregants. The F_2 population of Vaishak x Harsha recorded higher percent of positive segregants for days to 50% flowering and straw yield $plant^{-1}$. It recorded a higher percent of negative segregants for number of productive tillers $plant^{-1}$, number of spikelets $panicle^{-1}$, grain yield $plant^{-1}$ and harvest index. In Thottacheera x Harsha segregants 1000 grain weight recorded the highest percent of positive segregants whereas number of productive tillers $plant^{-1}$ and spikelet sterility marked a higher percent of negative segregants.

On the basis of dendrogram drawn, the genotypes were grouped into four clusters. Cluster I included Harsha and segregants of Vaishak x Harsha. Thottacheera and F_2 population of Thottacheera x Harsha were grouped into cluster II. Cluster III included Vyttila 6 and segregants of Vaishak x Vyttila 6 and cluster IV included Vaishak only.

Comparison of frequency distribution graphs for the F_2 populations under upland and controlled condition for yield related characters such as number of productive tillers $plant^{-1}$, panicle length, number of spikelets $panicle^{-1}$, number of filled grains $panicle^{-1}$, 1000 grain weight, grain yield $plant^{-1}$ and straw yield $plant^{-1}$ was done. The results revealed that in majority of the characters considered the frequency distribution graph under stress condition showed moderate to high positive skewness. It points out that the performance of all the three F_2 populations under artificial stress were lower than the respective performance noted under upland field condition.

Among the F_2 population, segregants of Vaishak x Harsha performed well under upland condition whereas segregants of Vaishak x Vyttila 6 performed well under stress condition. The high yielding variety Vaishak released for uplands might have transferred its superior yield characters to the progeny. The transgressive segregants with favourable traits thus obtained can be effectively utilised for selecting superior genotypes combining drought tolerance and high yield.

Future line of work

The appearance of positive and negative segregants in the study is an indication that desirable transgressive segregants may appear in later segregating generations which can be isolated out to develop high yielding, drought tolerant upland rice varieties.

References

7. REFERENCES

Abarshahr, M., Babak, R., and Lahigi, H. S. 2011. Genetic variability correlation and path analysis in rice under optimum and stress irrigation regimes. *Nat. Sci. Biol.* 3(4): 134-142.

Abdallah, A. A., Ammar, M. H., and Badwai, A. T. 2010. Screening rice genotypes for drought resistance in Egypt. *J. Plant Breed. Crop Sci.* 2(7): 205-215.

Arnon, D. 1949. Copper enzymes isolated chloroplast, polyphenoloxidase in *Beta vulgaris*. *Plant Physiol.* 24:1-15.

Atlin, G. N., Lafitte, H. R., Tao, D., Laza, M., Amante, M., and Courtois, B. 2006. Developing rice cultivars for high-fertility upland systems in the Asian tropics. *Field Crops Res. 97*: 43–52.

Babu, C. R., Nguyen, B. D., Chamarerk, V., Shanmughasundaram, P., Chezhian, P., Jayaprakash, P., Ganesh, S. K, Palchamy, A., Sadasivam, S. and Sarkarung, S. 2003. Genetic analysis of dought resistance in rice bymolecular markes:association between secondary traits and field performance. *Crop Sci.* 43: 41:1457-1469.

Balanda, K. P. and MacGillivray, H. L. 1988. Kurtosis: A Critical Review. *The American Statistician.* 42(2), 111–119.

Basu, R. N. C. and Das, G. D. K. 1981. Morphological characters of rice associated with drought tolerance in uplands. *Oryza.* 18:150-152.

Bates, L. S., Waldren, R. P., and Teare, I. D. 1973. Rapid determination of free proline for water stress studies. *Plant and Soil* . 39(1): 205-207

Beena, R., Thandapani, and Chandrababu, R. 2012. Physio-morphological and biochemical characterization of selected recombinant inbred lines of rice for drought resistance. *Indian J. Plant Physiology*. 17(2):189-193.

Bernier, J., Atlin, G. N., Seraj, R., Kumar, A., and Spaner, D. 2008. Breeding upland rice for drought resistance. *J. Sci. Agric*. 88: 927-939.

Blum, A. 2005. Drought resistance, water- use efficiency and yield potential: are they capable, dissonant or mutually exclusive?. *Aust. J. Agric. Res*. 56:1159-1168.

Bulmer, M. G. 1979. Principles of Statistics. Dover edition, New York. 256p

Bonman, J. M., Estrada, B. A., Kim, C. K., Ra, D. S., and Lee, E. J. 1991. Assessment of blast disease and yield loss in susceptible and partially resistant rice cultivars in two irrigated lowland environments. *Plant Dis*. 75:462-466.

Boonjung, H. And Fukai, S. 1996. Effects of soil water deficit at different growth stages on rice growth and yield under upland conditions. 1. Growth during drought. *Field Crops Res. 84: 37-45*

Chauhan, J. S., Moya, T. B., Singh, R. K., Singh, R. K., and Singh. C.N. 1996. Influence of Soil moisture stress during reproductive stage on physiology parameters and grain yield in upland rice. Oryza. 36(2): 130-135.

Chozin, M. M. A., Lubis, I., Junaedi, A., and Ehara, H. 2014. Some physiological character responses of rice under drought conditions in a paddy system. *J. ISSAAS*. 20(1): 104-114

Cruz, R. T. and O'Toole, J. C. 1982 Dryland rice response to an irrigation gradient at flowering stage. *Agron. J.* 76 (2): 178-183.

DRR [Directorate of Rice Research]. 2012. Rice Knowledge Management Portal [on-line]. Available: http://www.rkmp.co.in. [11 May 2018].

FAO [Food and Agiculture Organization of the United Nations]. 2010. FAOSTAT. [on line]. Available: http://www.faostat.fao.org [11 May 2018].

FAO [Food and Agiculture Organization of the United Nations]. 2016. FAOSTAT. [on line]. Available: http://www.faostat.fao.org [11 May 2018].

FAO [Food and Agiculture Organization of the United Nations]. 2017. FAOSTAT. [on line]. Available: http://www.faostat.fao.org [11 May 2018].

FAO [Food and Agiculture Organization of the United Nations]. 2018. FAOSTAT. [on line]. Available: http://www.faostat.fao.org [02 july 2018].

Fukai, S. and Cooper, M. 1995. Development of drought-resistant cultivars using physio morphological traits in rice. *Field Crops Res.* 40:67–86.

Fukai, S., Pantuwan, G., Jongdee, B., and Cooper, M. 1999. Screening for drought resistance in rainfed lowland ice. *Field Corps Res.* 64:.. 61-74

Girsh, T., Gireehma, T., Vaishali, M., Hanamareddy, B., and Hittalmani, S. 2006. Response of new IR50/Moroberekan recombinant inbred population of rice (*Oryza sativa* L.) form an indica x japonica cross for growth and yield traits under aerobic conditions. *Euphytica.* 152:149-161.

Gloria, S. C., Osamu, I., and Arcela, A. a. 2002. Physiological evaluation of responses of rice (*Oryza sativa* L.) to water deficit. *Plant Sci*. 163:815-827.

GOK [Government of Kerala]. 2017. *Economic Review 2017*[on line]. Available: http://www.ecostat.kerala.gov.in/images/pdf/er2017/pdf/ Chapter06.pdf [02 July 2018].

Gowri, S. 2005. Physiological studies on aerobic rice (Oryza sativa L.)M.Sc. (Ag) Thesis, Tamil Nadu Agricultural University, Coimbatore

Guimarães, C. M., de Castro, A. P., Stone, L. F., and de Oliveira, J. P. 2016. Drought tolerance in upland rice: identification of genotypes and agronomic characteristics. *Acta Sci., Agron*. 38(2): ISSN 1679-9275

Haefele, S. M., Nelson, A., and Hijmans, R. 2014. Soil quality and constraints in global rice production. *Geoderma*. 236:250–259.

Haunsajirao, P. K. 2017. Genetic analysis of drought tolerance in rice (*Oryza sativa* L.). Ph. D (Ag) Thesis, Kerala Agricultural University, Thrissur.

IRRI [International Rice Research Institute].1996. *Standard Evaluation System for Rice (4th Ed.)*. International Rice Testing Programme, Los Banos, Philippines, 52p.

Ishitani, M., Rao, I., Wenzl, P., Beebe, S., and Tohme, J. 2004. Integration of genomics approach with traditional breeding towards improving abiotic stress adaptation: Drought and aluminum toxicity as case studies. *Field Crops Res*. 90(1): 35-45.

Jambhulkar, N. N. and Bose, L. K. 2014. Genetic variability and association of yield attributing traits with grain yield in upland rice. *Genetika* 46(3): 831-838.

Jongdee, B., Fukai. S., and Cooper, M. 2002. Leaf water potential and osmotic adjustment as physiological traits to improve drought tolerance in rice. *Field Crops Res*. 76:153-163.

Joshi, M., Verma, S. K., Singh, J. P., and Barh, A. 2013. Genetic diversity assessment in lentil (lens culinaris Medikus) genotypes through ISSR marker. *Bioscan*. 8(4): 1529-15.

Kahani, F. and Hittalmani, S. 2015. Genetic Analysis and Traits Association in F_2 Intervarietal Populations in Rice Under Aerobic Condition. *J. Rice Res.* 3: 152.

Khush, G. S. 1997. Origin, dispersal, cultivation and Variation of rice. *Plant Mol. Biol.* 35: 25-34

Kiran, K. K., Rao, M. R. Gururaja, and Suresh, K. 2013. Variability and frequency distribution studies in F_2 population of two crosses of rice(*Oryza sativa* L.). *Asian J. Bio. Sci.* 8 (2) : 153-159.

Koh, Y, J., Hwang, B. K and Chung, H. S. 1987. Adult plant resistance to rice blast. *Phtopath.* 77:232-236.

Köppen, W. 1918. Classification of climates according to temperature, precipitation and seasonal cycle. *Petermanns Geogr. Mitt.* 64: 193-203.

Kramer, P. J. and Boyer, J. S. 1995. Water Relations to Plant and Soil. Academic press, San Dego CA. U.S.A. 495p.

Kumar, A., Dixit, S., Ram, T., Yadaw, R. B., Mishra, K. K., and Mandal, N. P. 2014. Breeding high-yielding drought- tolerant rice:genetic variations and conventional and molecular approaches. *J. Exp. Bot.* 65(21):6265-6278.

Laffitte, H. R., Courtosis, B. 2002. Interpreting cultivar x environment interactions for yield in upland rice: assigning values to drought adaptive traits. *Crop Sci.* 42: 1409 – 1420.

Laffitte, H. R., Courtosis, B., and Arraudeau, M. 2002. Genetic improvement of rice in aerobic systems: Progress from yield to genes. *Field Crops Res. 75*: 171–190.

Lanceras , J., Pantuwan, G., Jongdee, B., and Toojinda, T. 2004. Quantitative trait loci associated with drought tolerance at reproductive stage in rice. *Plant Physiol.* 135: 384-399.

Lilly, J. M. and Fukai, S. 1994. Effect of timing and severity of water deficit on four diverse rice cultivars.I. Rooting pattern and soil water extraction. *Field Crops Res.* 37:205-213.

Liu, B. G., Li, C. M., Ren, C. F., Yang, Q. L., and Chen, X. W. 1993. A study of the physiological basis for upland cultivation of paddy rice. *J Southwest Agric Univ.*15:477-482.

Lum, M.S, Hanafi, M. M. , Rafii, Y. M., and Akmar, A. S. N. 2014. Effect of drought stress on growth, proline and antioxidant enzyme activities of upland rice. *J. Anim. Plant Sci.* 24(5): 1487-1493.

Maisura, M.A.C., Lubis, I., Junaedi, A., and Ehara, H.2014. Some physiological character responses of rice under drought conditions in a paddy system. *J. ISSAAS.* 20(1):104-114.

Marion, M. And Bradford. 1976. A rapid and sensitive method for the quantitation of microgram quantities of protein utilising the principle of protein-dye binding. *Analytical bioche.* 72:248-254.

Mittler, R. 2006. Abiotic stress, the field environment and stress combination. *Trend Plant Sci*. 11: 15-19.

Mohan, M. M., Laxmi, N. S., Ibrahim, S. M. 2002. Chlorophyll stability index(CSI): its impact on salt tolerance in rice. *Int. Rice Res. Notes*.25:38-39.

Muthayya, S., Sugimoto J. D., Montgomery, S., and Maberly, G. F. 2014. An overview of global rice production, supply, trade, and consumption. *Ann. N.Y. Acad. Sci*. 1324:7-14.

Nayak, A. R., Chaudhury, D. and Reddy, J.N. 2004. Genetic divergence in scented rice. *Oryza*. 41: 79-82

O'Toole, J. C., and Moya, T. B.1978. Genotypic variation in maintenance of leaf water potential in rice. *Crop sci*. 18:873- 876.

Osman, K. A., Mustafa, A. M., Ali, F., Yonglain, Z., and Fazhan, Q. 2012. Genetic variability for yield and related attributes of upland rice genotypes in semi arid zone (Sudan). *African J. Agric. Res*. 7(33): 4613-4619.

Pandey, S., Behura, D. D., Vilano, R., and Naik, D. 2000. *Economic Cost Of Drought And Farmers' Coping Mechanisms: A Study Of Rainfed Rice Systems In Eastern India*. International Rice Research Institute , Philippines, 47p. Available:http://books.irri.org/DPS39_content.pdf [20 Dec. 2017].

Pantuwan,G.,Fukai, S., Cooper, M., Rajatasereekul, S., and O'Toole, J. C. 2002. Yield response of rice (*Oryza sativa* L.) genotypes to drought under rainfed lowland. III. Plant factors contributing to drought resistance. *Field Crops Res*. 73(3):181-200.

Pinheiro, B., De Castro, E., and Guimaraes, C. M. 2006. Sustainability and profitability of aerobic rice production in Brazil. *Field Crops Res*. 97:34-42.

Prasad, P. V. V., Boote. K. J., Allen, L.H., Sheehy, J. E., and Thomas, J. M. G. 2006. Species, ecotype and cultivar differences in spikelet fertility and harvest index of rice in response to high temperature stress. *Field Crops Res*. 95: 398-411.

Prasad, P. V. V., Craufurd, P.Q., Kakani, V. G., Wheeler, T. R., and Boote, K. J. 2001. Influence of temperature during pre and post anthesis stages of floral development on fruit set and pollen germination in peanut. *Aust. J. Plant Physiol*. 28:233-240.

Raju, C. H. S., Rao, M. V. B., and Sudarshanam, A. 2004. Genetic analysis and character association in F_2 generation of rice. *Madras Agric. J.* 91:66-61.

Rao, S. S. and Shrivastava, M. N. 1999. Association among yield attributes in upland rice. *Oryza*. 36(1):13-15.

Rao, S.S. and Saxena, R.R.1999. Correlation and regression analysis in upland rice. *Oryza*.36:82-84.

Rathi, S., Kumar, R., Munshi, A. D., and Verma, M. 2011. Breeding potential of brinjal genotypes using D2 analysis. *Indian J. Hort*. 68(3):328-331.

Reuben, S. O. W. M. and Katuli, S. D.1990. Path analysis of yield components and selected agronomic traits of upland rice breeding lines. *IRRN*. 14:11-12.

Rieseberg, L. H., Arche, M. A. & Wayne, R. K. 1999. Transgressive segregation, adaptation and speciation. *Heredity*. 83: 363-372.

Saini, H. S. and Westgate, M. E. 2000. Reproductive development in grain crops during drought.*Adv Agron*. 68:59-95.

Saito, K., Dieng, I., Toure, A., Somado, E. A., & Wopereis, M. C. S. 2015. Rice yield growth analysis for 24 African countries over 1960–2012. *Global Food Security*. 5:62–69.

Sarvan, T., Rangare, N. R., Suresh, B. G., and Kumar R. S. 2012. Genetic variability and character association in rainfed upland ice. *J. Rice Res.* 5(2): 24-29.

Sarvastani, Z. T., Pirdashati, H., Sanavy, S. A. M. M., and Balaouchi, H. 2008. Study of water stress effect in different growth stages on yield and yield components in rice (*Oryza sativa* L.). *Indian J. Sci. Tech.* 24:1-7.

Sashidhar, H. E., Pasha, F., Janamathi, M., Vinod, M. S., and Kanbar, a. 2005. Correlation and path coefficient analysis in traditional cultivars and double haploid lines of rainfed lowland rice. *Oryza*. 42:156-159.

Shah, F., Huang, J., Cui, K., Nie, L. 2011. Impact of high-temperature stress on rice plant and its traits related to tolerance. *J. Agric. Sci.* 149(5): . 545-556

Shanmugasundaram, P.,Chandrababu, R.,Chezhian, P.,Thiruvengadam, Bhoopathi, N. M.,Chandrakala, R., and Sadasivam, S.2002, Genetic evaluation of double haploid population of rice under water stress in field condition. In: An international workshop on progress towards developing resilient crops for drought prone areas.27-30 May, 2002, IRRI, Los Banos, Philppines:144-145.

Sheela, K. R. and Alexander, V. J.1996. Physiological response of rice varieties as influenced by soil moisture and seed hardening. Indian J. Plant Physiol. 38: 269-271.

Sikuku, P. A., Netondo, G. W., Musyimi, D. M., and Onyango, J. C. 2010. Effects of water deficit on days to maturity and yield of three nerica rainfed rice varieties. *J. Agric. Biol. Sci.* 5(3): ISSN 1990-6145.

Sikuku, P. A., Netondo, G. W., Onyango, J. C., and Musyimi, D. M. 2010. Chlorophyll fluorescence, protein and chlorophyll content of three Nerica rainfed rice varieties under varying irrigation regimes. *ARPN J. Agric. Biol. Sci.* 5(2).

Simane, B., Peacock, J. M., and Struik, P. C. 1993. Differences in developmental plasticity and growth rate among drought resistant and susceptible cultivars of durum wheat(*Triticum turgidum var. durum*). *Plant Soil.*157:155-166.

Singh, N. N. and Sarkar, K. R. 1985. Physiological, genetical basis of brought tolerance in maize. *Expt. Genet.* 1:80-89.

Singh, S., and Singh, T. S.2000. Significance of leaf rolling in rice during water stess. *Indian J. Plant Physiol.* 5(3):214-218.

Subashri, M., Robn, S., Vinod, K. K., Rajeswari, S., Mohanasundaram, K., and Raveendan, T. S. 2008. Trait identification and QTL validation for reproductive stage drought resistance in rice using selective genotyping of near flowering ILs. *Euphytica.* 147(3): 221–227.

Surek, H. and Beser, N. 2003. Correlation and path coefficient analysis (*Oryza sativa* L.) Cahiers Options Mediterraneennes. 40:61-67.

Tanaka, A., Johnson, J., Senthilkumar, K., Akakpo, C., Segda, Z., Yameogo, L., and Saito, K. 2017. On-farm rice yield and its association with biophysical factors in sub-Saharan Africa. *European J. Agron.* 85: 1–11.

Turner, N. C. 1986. Adaptation to water deficits: a changing perspective. *Aust. J. Plant Physiol.* 13:175-90

Vaithiyalingan, M. and Nadarajan, N. 2006. Genetic variability, heritability and genetic advance in F_2 population of inter sub-specific crosses of rice. *Crop Res.* 31(3):476-477.

Valarmathi, G. and Leenakumary, S. 1998. Performance analysis of high yielding rice varieties of kerala under direct seeded and transplanted conditions. *Field Crops Res.* 16(2):284- 286.

van Oort, P., Saito, K., Dieng, I., Grassini, P., Cassman, K. G., and van Ittersum, M. K. 2017. Can yield gap analysis be used to inform R&D prioritisation? *Global Food Securit.* 12: 109–118.

Venkitaravana, P.1991. Studies on rice genetic variability, character association and path coefficient analysis in F_2 segregation of rice under irrigated and aerobic condition. M. Sc. (Ag) Thesis, University of Agricultural Sciences, Bangalore.

Venuprasad, R., Lafitte, H. R., and Atlin, G. N. 2007. Response to direct selection for grain yield under drought stress in rice. *Crop Sci.* 47:285–293.

Vijayalakshmi, C. And Nagarajan, M.1994. Effect of rooting pattern on rice productivity under different water regimes. *J. Agron.* 173(2):113-117.

Wopereis, M. C. S., Kropff, M. J.,Maligaya, A. R., and Tuong, T. P.1996. Drought stress responses of two lowland ice cultivars to soil water status. *Field Crops Res.* 46:21-39.

Xu, T., McCouch, S. R. and Shen, Z. 1998. Transgressive segregation of tiller angle in rice caused by complementary gene action. *Crop Sci.* 38: 12–19

Yadav, B., Tyagi, C. S., and Singh, D.1998. Genetics of transgressive segregation for yield and yield components in wheat. *Ann Appl Biol.* 133:227–235.

Yamaguchi, M.1994. Hybrid Rice Technology: new developments and further prospects, IRRI, Manila, Phillippines. 674p.

Yang, J., Zhang, J.,Wang, Z., Zhu, Q., and Wang, W. 2001. Hormonal changes in the grains of rice subjected to water stress during grain filling. *Plant Physiol.* 127: 315-323.

Yogameenakshi, P., Nadarajan and Anbumalarmathi, J. 2004. Correlation and path analysis on yield and drought tolerance in rice(*Oryza sativa* L.)under drought stress. *Oryza.* 41:68-70.

Zhang zai-jun, Lang Cheng-ye, Zhu Ying-guo. 2003. Distribution of the classification traits in the f2 progeny of two crosses of indica/japonica in rice (*Oryza sativa* L.). *Rice sci.* 11(2):23-28.

Genetic evaluation of F_2 generation for yield and water stress tolerance in upland rice

by

IVY MARY RAJAN

(2016-11-032)

Abstract of the thesis
Submitted in partial fulfilment of the
requirements for the degree of

MASTER OF SCIENCE IN AGRICULTURE

Faculty of Agriculture

Kerala Agricultural University

DEPARTMENT OF PLANT BREEDING AND GENETICS

COLLEGE OF AGRICULTURE

VELLAYANI, THIRUVANANTHAPURAM -695522

KERALA, INDIA

2018

ABSTRACT

The present study entitled "**Genetic evaluation of F_2 generation for yield and water stress tolerance in upland rice**" was carried out in the Department of Plant Breeding and Genetics, College of Agriculture, Vellayani during 2016-2018. The objective was to evaluate the pattern of variability in F_2 for yield and yield contributing traits under upland and drought situations and to select superior segregants combining drought tolerance and high yield. The study material included four parents and three F_2 populations selected from the Ph.D project entitled "Genetic analysis of drought tolerance in rice (*Oryza sativa* L.)".

The study comprised of two experiments .In experiment- I, the parents and F_2 segregants were raised under rainfed upland condition exposed to natural stress. Among the F_2 populations, Vaishak x Harsha (T_6) recorded the highest mean grain yield plant^{-1} (38.45g – 48.15g) and lowest mean spikelet sterility (7.76%-21.18%). T_6 recorded the highest mean values for number of productive tillers plant^{-1} (9 - 16) and leaf area index (mean: 1.67). Vaishak x Vyttila 6 (T_5) recorded the highest mean values for number of spikelets panicle^{-1} (149 - 178), harvest index (44.88% – 48.15%) and proline content (mean: 0.29mg g^{-1}). Thottacheera x Harsha (T_7) recorded the highest mean values for chlorophyll(mean: 1.78mg g^{-1}) and leaf soluble protein content (mean: 9.36mg g^{-1}). The data obtained was subjected to transgressive segregation analysis and in T_5 more than 50 percent positive segregants were observed for number of productive tillers plant^{-1}, spikelet sterility, number of spikelets panicle^{-1} and panicle length. T_6 recorded high percentage of positive segregants for number of productive tillers^{-1}, grain yield plant^{-1}, plant height and spikelet sterility. In T_7 percentage of positive segregants were the highest for spikelet sterility and number of productive tillers plant^{-1}. Dendrogram drawn on the basis of squared Euclidean distances classified the genotypes into four clusters. Cluster I - T_1,T_5,T_6, cluster II- T_4, cluster III -T_2,T_7 and cluster IV-T_3.

In experiment II, another set of parents and F_2 segregants were grown under rainshelter imposing reproductive stage moisture stress. Irrigation was given at 20mm depth once in seven days from panicle initiation stage onwards. Among the F_2 segregants, T_5 recorded the highest mean values for grain yield plant^{-1} (11.80g – 18.88g), number of spikelets panicle^{-1} (128 - 174), grain weight panicle^{-1} (2.60g – 4.33g), harvest index (42.44 % - 68.13%) and proline content (mean: 0.57) and the lowest for spikelet sterility (5.50% - 22.27%). T_6 recorded the highest mean value for panicle length (19.60cm – 27.50cm). T_7 marked the highest mean values for number of productive tillers plant^{-1} (3 – 7), chlorophyll (mean: 1.28mg g^{-1}) and leaf soluble protein content(mean: 8.82mg g^{-1}) and leaf area index (mean: 0.71). In T_5, more than 50 percent of positive segregants were recorded for grain weight panicle^{-1}, number of filled grains panicle^{-1} and number of spikelets panicle^{-1}. T_6 recorded higher percentage of positive segregants for straw yield plant^{-1} whereas T_7 recorded the highest positive segregants for 1000 grain weight. On the basis of dendrogram drawn the genotypes were grouped into four clusters. Cluster I -T_4 and T_6, cluster II-T_2,T_7, cluster III - T_3, T_5 and cluster IV - T_1.

Among the F_2 segregants, Vaishak x Harsha (T_6) performed well under upland condition whereas Vaishak x Vyttila 6 (T_5) performed well under stress. The high yielding variety Vaishak released for uplands might have transferred its superior yield characters to the progeny. The transgressive segregants with favourable traits thus obtained can be effectively utilised for selecting superior genotypes combining drought tolerance and high yield.