

**“STUDIES ON VARIABILITY FOR SEED VIGOUR IN
DIFFERENT SUB-SPECIES OF RICE (*Oryza sativa* L.)”**

By

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B.Sc. (Ag.)

THESIS SUBMITTED TO THE
ACHARYA N.G. RANGA AGRICULTURAL UNIVERSITY
IN PARTIAL FULFILMENT OF THE REQUIREMENTS
FOR THE AWARD OF THE DEGREE OF

**MASTER OF SCIENCE IN AGRICULTURE
(SEED SCIENCE AND TECHNOLOGY)**



DEPARTMENT OF SEED SCIENCE AND TECHNOLOGY
COLLEGE OF AGRICULTURE
ACHARYA N.G. RANGA AGRICULTURAL UNIVERSITY
RAJENDRANAGAR, HYDERABAD – 500 030, ANDHRA PRADESH

AUGUST, 2004

CERTIFICATE

This is to certify that the thesis entitled “**STUDIES ON VARIABILITY FOR SEED VIGOUR IN DIFFERENT SUB-SPECIES OF RICE (*Oryza sativa* L.)**” is submitted in partial fulfillment of the requirements for the Degree of **MASTER OF SCIENCE IN AGRICULTURE** of the **Acharya N.G. Ranga Agricultural University, Hyderabad** is a record of the bonafide research work carried out by **Mr. CH. SRINIVASA RAO** under our guidance and supervision. The subject of the thesis has been approved by the Student’s Advisory Committee.

No part of the thesis has been submitted for any other Degree or Diploma. The published part has been fully acknowledged. All the assistance and help received during the course of investigation have been acknowledged by the author of the thesis.

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Mr. CH. SRINIVASA RAO has satisfactorily prosecuted the course of research and that the thesis entitled “**STUDIES ON VARIABILITY FOR SEED VIGOUR IN DIFFERENT SUB-SPECIES OF RICE (*Oryza sativa* L.)**” submitted is the result of original research work and is of sufficiently high standard to warrant its presentation to the examination. I also certify that the thesis or part thereof has not been previously submitted by him for a degree of any University.

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DECLARATION

I, **CH. SRINIVASA RAO**, hereby declare that the thesis entitled **“STUDIES ON VARIABILITY FOR SEED VIGOUR IN DIFFERENT SUB-SPECIES OF RICE (*Oryza sativa* L.)”** submitted to Acharya N.G. Ranga Agricultural University for the degree of **MASTER OF SCIENCE IN AGRICULTURE** is a result of original research work done by me. I also declare that the thesis or part thereof has not been published earlier elsewhere in any manner.

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LIST OF SYMBOLS AND ABBREVIATIONS

α	-	alpha
%	-	per cent
$\mu \text{ g g}^{-1}$	-	micro gram per gram
$\mu \text{ mhos cm}^{-2}$	-	micro mhos per square centimetre
$^{\circ}\text{C}$	-	Centigrade or Celsius
<	-	Less than
>	-	Greater than
CD	-	Critical Difference
cm	-	centimetre
<i>et al.,</i>	-	and others
fig.	-	figure
g	-	grams
GCV	-	Genotypic coefficient of variation
h^2 (b)	-	heritability in broad sense
hr	-	hours
ISTA	-	International Seed Testing Association
i.e.	-	Which is to say, in other words
L	-	Litre
L/B ratio	-	length and breadth ratio
lbs	-	pounds
m	-	metre
m ha	-	million hectare
mg	-	milligram
ml	-	millilitre

mm	-	millimetre
Mm	-	Millimolar
mt	-	million tonnes
N	-	Normality
nm	-	nanometer
NS	-	Non-significant
O.D	-	Optical Density
P	-	Phosphorus
PCV	-	Phenotypic coefficient of variation
pH	-	Negative logarithm of hydrogen ion activity
rpm	-	revolutions per minute
SE.m	-	Standard error of mean
UPOV	-	International Union for Protection of New Plant Varieties
<i>viz.</i>	-	Namely

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ACKNOWLEDGEMENTS

It is by the lavish and boundless blessing of the almighty that I have been able to complete my studies successfully hitherto and present this humble piece of work for which I am eternally indebted.

*Fervently and modestly, I extol the genuine cooperation, inspiration and affection offered to me by the Chairman of my Advisory Committee, **Dr. N. MANOHAR REDDY**, Senior Scientist (SP), National Seed Project, ANGRAU, Rajendranagar right from the initiation of the work to the ship-shaping of the manuscript. The present work bears at every stage the impression of his wise counsel and concrete suggestions, careful, seasonal criticism and meticulous attention to the details. It was indeed a rare privilege for me to work under his emending inspiration and indomitable spirit.*

*I am greatly beholden beyond words to express my deep sense of gratitude and a great privilege to work under the able and highly exceptional guidance of **Dr. L.V. SUBBA RAO**, Senior Scientist, Crop Improvement, DRR, Hyderabad and Co-Chairman of the Advisory Committee for his brilliant counsel, constructive suggestions, indefatigable guidance, evincive criticism and inspiring encouragement to embellish the present study.*

*I avail this opportunity to express my deep sense of reverence and profound gratitude to **Dr. R. ANKAIAH**, Principal Scientist (SP), National Seed Project, ANGRAU, Rajendranagar and Member of my Advisory Committee for his invaluable guidance, suggestions and support during the course of study. His keen interest, critical remarks and encouragement have enabled me to complete this work.*

*I accolade with gratitude the sumptuous suggestions and help rendered by **Sri G. KRISHNA KANT**, Assistant Professor, Department of Statistics and Mathematics, College of Agriculture, Rajendranagar and Member of my Advisory Committee.*

*I keep it on record with sincere regards for the help and guidance received from **Dr. M. GANESH**, Principal Scientist (SP) and Head, National Seed Project, ANGRAU, Rajendranagar and Professor and Head, Department of Seed Science and Technology, College of Agriculture, Rajendranagar will remain fresh for ever in my mind.*

*I feel immense pleasure in extending my deep sense of gratitude to **Dr. K. RADHIKA**, Scientist, National Seed Project, ANGRAU, Rajendranagar, for her meticulous guidance, benign attitude, generous co-operation, constructive criticism in the preparation and presentation of the thesis.*

*I wish to express my sincere thanks to staff of National Seed Project, ANGRAU, Rajendranagar **Dr. K.V.S. MEENA KUMARI**, **Dr. B. RAJESWARI**, **Sri P. SAMBASIVA RAO** and **Sri V. NARASIMHA REDDY** and **Dr. VILAS A. TOPANI**, NRCS, Rajendranagar for their generous help, valuable guidance during the course of study.*

*I place on record my profound and deep sense of gratitude to **Dr. C.L.N. REDDY**, Professor and Head, Department of Plant Physiology, College of Agriculture, Rajendranagar for allowing me to do part of my research work in their lab.*

*I deeply acknowledge with thanks to **Dr. N. RAGHUNATH** and **Dr. SUKHPAL SINGH** for providing me the seed material in time.*

*I am thankful to non-teaching staff of the Department of Seed Science and Technology Sri **RAMARAJU**, **BALANARSAIAH**, **MALLA REDDY**, **SURESH**, **SIRAJ** and **YADAIAH** for their help and care during my post-graduation.*

*Diction is not enough to express my unboundful gratitude and affection to my beloved parents **Sri Ch. CHAKRAPANESWARA RAO** and **Smt. Ch. SARASWATHI**, brother-in-law **Sri RAMANA MURTHY** and Sister **Smt. KALYANI** who constantly inspired, guided and molded me to the present position.*

*I am thankful to my colleagues **SUNIL**, **KIRAN**, **YOGINI** and **SUDHERSHAN** for their help and encouragement during my course of work. My heartfelt thanks are due to my beloved friends **KRISHNA PRASAD**, **SATISH**, **SATTI**, **MOULI**, **RAMESH**, **SOBHAN**, **NARASIMHA**, **SURI**, **SEENU**, **PASHA**, **GOPI**, **LOHIT**, **MINNU**, **SIVA**, **UDAY** and **VINOD** for their help and encouragement during the course of my study.*

The financial assistance rendered by Government of Andhra Pradesh and Acharya N.G. Agricultural University in the form of stipend during the course of study is greatly acknowledged.

*I express my sincere thanks to **M/s. APARNA COMPUTERS**, Premavathipet for clear and meticulous type work patiently carried out in getting thesis its present shape.*

I convey my whole hearted thanks to many of my well-wishers and to other friends requesting their forgiveness for not mentioning them here by name.

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Title of the Thesis : **STUDIES ON VARIABILITY FOR SEED VIGOUR IN DIFFERENT SUB-SPECIES OF RICE (*Oryza sativa* L.)**

Degree to which it is submitted : **MASTER OF SCIENCE**

Faculty : **AGRICULTURE**

Department : **SEED SCIENCE AND TECHNOLOGY**

Major Advisor : **Dr. N. MANOHAR REDDY**

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Year of submission : **2004**

ABSTRACT

Knowledge of genetic variability for seed vigour, along with biochemical manifestation is essential in formulating a successful breeding programme aimed at improving seedling vigour. Hence, the present investigation was carried out to study the variability for seed vigour among twelve genotypes belonging to different sub-species of rice at Department of Seed Science and Technology, Rajendranagar, Hyderabad. All the twelve genotypes were subjected to standard vigour tests, physiological, biochemical and stress tests.

Significant differences were observed among the genotypes used in the investigation for all seed and seedling traits indicating the existence of variability. Physiological and biochemical traits also exhibited significant variation among the seeds of twelve genotypes before and after accelerated ageing for ten days. The electrical conductivity and peroxidase activity increased, while the dehydrogenase activity and α - amylase activity decreased in aged seed.

Significant differences were not observed among the genotypes for estimated phosphorus fractions. Total phosphorus, DNA phosphorus and phosphoprotein peptide phosphorus decreased with ageing, while acid soluble phosphorus, phospholipid phosphorus and RNA phosphorus content increased.

Phosphoprotein phosphorus followed by RNA phosphorus contributed maximum to total phosphorus in fresh seed.

The difference between PCV and GCV was narrow for seed morphological characters, germination, field emergence, speed of germination, mean daily germination, peak value, rate of germination, electrical conductivity, dehydrogenase activity, peroxidase activity and α - amylase activity. The estimates of GCV and PCV were high for germination value, rate of germination, vigour index, electrical conductivity and dehydrogenase activity. High heritability coupled with high genetic advance as per cent mean was recorded for the germination in sand media, peak value, germination value, rate of germination, L/B ratio, 100-seed weight, seed density, electrical conductivity and dehydrogenase activity indicating scope for improvement of these traits through selection.

Germination per cent, seedling length, seedling dry weight, vigour index decreased significantly with increasing duration of accelerated ageing. Based on the germinability and vigour index, the genotypes were categorized as poor, moderate and good storers. The germination of all the genotypes decreased with increasing salinity and moisture stress concentrations. The genotypes were grouped as tolerant, moderately tolerant and susceptible based on the degree of tolerance to salinity and moisture stress. All the twelve genotypes under present study were classified as tolerant and susceptible based on their germinability in anaerobic condition.

The correlation studies indicated that electrical conductivity and dehydrogenase activity had a significant negative correlation with seed density. Acid soluble phosphorus and phosphoprotein peptide phosphorus were negatively correlated with germinability and vigour index while DNA phosphorus was negatively associated with vigour index only. Phospholipid phosphorus and DNA phosphorus were positively correlated with germinability and vigour index. Vigour index had a positive correlation with germination in salinity stress (1.0% & 1.5%), moisture stress (-6 bar) and anaerobic stress.

In the present study, it is evident that high genetic variability exists among the sub-species for seed, seedling and biochemical traits and could be exploited through appropriate breeding programme to improve the seedling vigour for better plant stand and realizing higher crop yield.

CHAPTER – I

INTRODUCTION

Rice (*Oryza sativa* L.) is the staple food for more than half of the world's population with an annual production of 593 million tonnes and an average productivity of 3.91 t ha^{-1} , it is grown in an area of 151.54 m ha in the world. In Asia alone, rice is grown in an area of 136.07 m ha with an annual production of 539.84 m t and average productivity of 2.97 t ha^{-1} (FAO, 2002). The population is increasing at a faster rate and the number of rice consumers will probably increase by 70 per cent during next 25 years.

In India, rice plays a pivotal role in food security and livelihood system and ranks first in area and second in production after China. It is grown in 44.6 m ha with an annual production of 89.67 m t and contributes 40 per cent to the total food grain production. However, the productivity is only 2.8 t ha^{-1} , which is very low compared to Egypt (7.9 t ha^{-1}), Japan (6.8 t ha^{-1}), USA (6.7 t ha^{-1}) and China (5.9 t ha^{-1}) (FAO, 2002). In Andhra Pradesh, rice is grown in all the seven agroclimatic zones and is the principal food crop of the state. It is grown in over four m ha in the state and accounts for 12 – 18 per cent of rice production with 9 – 10 per cent area in the country. Andhra Pradesh ranks 4th in area, 3rd in production and productivity next to Punjab and Tamil Nadu. (GOI, 2002).

The estimates indicate that 140-180 m t of rice is required to feed the teeming population of India and 380 million tonnes to feed the rice consuming

population of the world by 2020 A.D. Even sustaining what has been achieved is a challenging task in the years to come, more so in the era of fast depleting per capita availability of arable land and irrigation water. Hence innovative approaches need to be harnessed for breaking yield barriers (Mishra *et al.*, 2002).

Among the various approaches available for breaking the yield ceiling, a relook into certain aspects of seed technology would definitely augur well and provide an impetus to realize the actual genetic potential of a variety / hybrid. Seed vigour has been recognized as one of the important aspects of seed quality. It has a direct bearing on growth parameters and yield. The effects of vigour level may persist to influence plant growth, crop uniformity and yield. Redona and Mackill (1996) indicated the need for identification of genes promoting vigorous growth in young rice seedlings and to transfer them into high yielding varieties.

Identification of genotypes with higher and stable yield performance over the best cultivated variety and the knowledge of genetic variability present in the population is a prerequisite for selecting an appropriate breeding method for any crop improvement programme. Success of any breeding programme depends upon the amount of genetic variability available in the crop species, besides the efficiency of selection techniques. Unlike other cereal crops, rice is grown under different ecological conditions and has tremendous variability across the regions among different sub-species. Temperate *japonicas* are more vigorous than Tropical *japonicas* (Redona and Mackill, 1996). In India itself more than 60,000

germplasm accessions are available across the country, indicating the wide spectrum of variability for most of the characters including seed and seedling traits.

In the recent past, there had been many attempts by several researchers in standardizing a reliable test to assess seed vigour in rice. It was observed that due to wide variability among the rice cultivars, response to such vigour tests, which are based on one or more seedling growth parameters are not comparable between varieties. Since a single test does not measure all aspects of vigour, an insight into the physiological and biochemical basis of seed vigour would help in developing a reliable and reproducible vigour test. Seed germination under induced stress conditions like accelerated ageing, salinity stress and moisture stress will be a good indicator of performance of seed under adverse situations, so as in field. Very little is known about the relative efficiencies of these tests in providing good estimates of seed vigour.

Therefore, there is a need to have a clear understanding on the physiological and biochemical basis of seedling vigour. Performance of cultivars in adverse conditions and study of genetic variability for seed vigour existing among different varieties and sub-species of *O. sativa* and identification of genotypes with high seedling vigour would certainly help in augmenting the breeding programmes for evolving superior varieties or hybrids.

Taking into cognizance of the aforesaid facts, an attempt has been made in the present investigation to understand the relationship between bio-chemical manifestation of seedling vigour and also to find out the genetic variability

among different sub-species of rice for seedling vigour with the following objectives.

1. To assess the genetic variability for seed vigour among different sub-species of rice.
2. To assess the differences in α - amylase activity and phosphorus fractions in rice cultivars differing in seed vigour.

CHAPTER – II

REVIEW OF LITERATURE

Understanding physiological and biochemical basis of seedling vigour along with the knowledge of genetic variability for seed vigour among different genotypes/ sub-species of rice is a prerequisite for tailoring the breeding programmes. Genetic variability among native cultivars and traits is important in estimating the relative influence of various seedling characters such as vigour on yield and yield attributing traits. Extensive studies were conducted on standard vigour tests, physiological, biochemical and stress tests and variability, heritability, genetic advance and correlations were worked out. The literature pertaining to the present study is reviewed and presented here under.

2.1 GENETIC VARIABILITY

Knowledge of the genotypic and phenotypic variability among the different sub-species and genotypes helps in formulating sound breeding programme for evolving superior genotypes. Studies on genotypic coefficient of variation enables the breeders / seed technologists to compare the amount of genetic variability present for different characters. It gives a clear picture when it is used in conjunction with studies on heritability and genetic advance.

2.1.1 Seed morphological characters

2.1.1.1 Seed size

Chauhan and Nanda (1984) reported high and moderate variability for seed length and breadth. Significant genetic variability for length and breadth of grain exhibited by thirty rice strains was studied by De and Suriya Rao (1987). Lin (1988) observed significant differences for seed length and breadth in 31 *japonica* and 31 *indica* rice varieties.

High GCV and PCV for L/B ratio were noted by Hussain *et al.* (1987). Kihupi (1987) found significant differences for L/B ratio, while Sahay *et al.* (1989) registered non significant difference for this trait.

Low estimates of GCV for L/B ratio was stated by Deosarkar *et al.* (1989b) in rice. High GCV and PCV for L/B ratio and least GGV for grain length was obtained by Malik *et al.* (1994).

Studies on size and shape of rice seeds by Ahmed *et al.* (1995) revealed that these characters were largely controlled by polygenes. Significant variability among low land rice varieties for grain length and breadth was noticed by Reddy *et al.* (1997). Deosarkar *et al.* (1998) recorded significant additive genetic variance for length and breadth.

Studies of Chikkalingaiah *et al.* (1999) on quality traits of twenty three scented and one non-scented rice genotypes revealed the presence of high genetic variability for grain length, breadth and L/B ratio.

Satyapriya and Sreedhar (1999) concluded that both additive and non-additive gene action were important for improving L/B ratio in rice.

2.1.1.2 100-seed weight

High genotypic coefficient of variation for 100-seed weight was obtained by Shukla *et al.* (1972) and Hussain *et al.* (1987). Lal *et al.* (1983) and Dikshit *et al.* (1992) found wide variability for this trait in rice.

Jangale *et al.* (1985) predicted moderate genetic variability for 100-seed weight. Which further confirmed by Reddy *et al.* (1997) and Chikkalingaiah *et al.* (1999).

Ramesh Kumar (1989) noticed low genetic variability, while high genetic variability was noted by Angrish and Panwar (1992) for 100-seed weight in rice.

2.1.1.3 Seed density (%)

Padmajarao *et al.* (1985) observed significant variability among the rice genotypes for seed density. Similar results were reported by Padmajarao (1987), who further stated that higher grain index indicated higher yield potential with large proportion of fully filled spikelets.

Padmajarao and Venkateshwarlu (1986) found significant variability in potential grain filling which indicates the type of existing variation and the amount of scope for improvement in attaining potential yields. Mallik *et al.* (1990) recorded high variability in potential lines of rice.

Padmajarao (1987) observed wider variability among the rice genotypes for seed density. Similar results were reported by Padmajarao (1991) and further stated that higher grain index indicated higher yield potential with large proportion of fully filled spikelets.

Padmajarao (1991) found wider variability among varieties for this trait and concluded that those high-density grains had increased volume, weight, milling and head rice recovery.

High estimates of genetic variability in some traditional rice cultivars for grain density were indicated by Angrish and Panwar (1992).

Studies by Padmajarao (1994) in greenhouse involving two rice varieties revealed that the distribution pattern of spikelets, grains and high density grains between two varieties showed similar trends.

Govindaraju and Natarajan (1995) concluded that the coefficient of genetic variability was high for high density grain index in rice.

2.1.2 Germination and seedling characters

2.1.2.1 Germination

Krishnaswamy and Seshu (1989) observed maximum coefficient of variability in germination among rice cultivars. Mohanty and Sahoo (1992) recorded high germination percentage in rice genotypes.

Redona and Mackill (1996) concluded that medium duration varieties of rice exhibited higher magnitude of variability for germination.

Awasthi *et al.* (1998) recorded considerable genetic variability among fifteen upland and ten lowland rice genotypes for germination.

2.1.2.2 Seedling growth and vigour index

Sivasubramanian and Ramakrishnan (1978) reported that growth characters like length of shoot and root were highly variable.

Ample genetic variability was noted in a pool of forty six locally grown rice varieties in a study of Sharma *et al.* (1990) on seed and seedling characters and vigour index of rice.

Maximum variability for root length and shoot length was found with highly vigorous and heavy seed of rice. Heavier and bigger rice seeds recorded maximum variability for shoot, root and seedling dry weight and vigour index. However, dry weight of seedlings was found to be high in highly vigorous and heavy seeds (Mahantheshappa *et al.*, 1992).

Redona and Mackill (1996) noted higher magnitude of variability for seedling dry weight and vigour index in medium duration rice varieties.

High variability was observed among sixty nine rice cultivars for seedling shoot length, root length, seedling dry weight and vigour index by Subbarao *et al.* (1996).

Jayaraj *et al.* (1998) noticed significant variability among rice varieties in case of seedling root and shoot lengths.

2.1.3 Rate of germination

Maguire (1962) found significant variability for speed of germination among rice genotypes.

Krishnaswamy and Seshu (1989) noticed high genetic variability in 68 rice cultivars for germination rate and stated the possible causes for variability.

Subbarao *et al.* (1996) observed significant genetic variability for mean daily germination, peak value, germination value and rate of germination among 69 rice cultivars. High genotypic coefficient of variation coupled with high heritability was noticed for rate of germination.

Jhansilakshmi Kumari (2000) recorded high estimates of PCV and GCV for rate of germination in eighty three rice genotypes.

2.1.4 Biochemical traits

Sung and Chen (1988) studied the genetic variability in formazon production capability of the embryo of 21 rice cultivars.

Krishnaswamy and Seshu (1989) emphasized the contribution of total dehydrogenase activity to variability in germination rate.

Jhansilakshmi Kumari (2000) concluded that high estimates of GCV and PCV existed among eighty three rice genotypes for electrical conductivity while low GCV and PCV were recorded for α -amylase activity.

2.2 HERITABILITY AND GENETIC ADVANCE

Hanson *et al.* (1956) defined heritability in broad sense as the ratio of genotypic variance to the total variance in the non-segregating populations. Heritability (h^2) measures the relative amount of the heritable portion of variability, while the genetic advance (GA) helps to measure the amount of progress that could be expected with selection in a character. The broad sense heritability (h^2) and genetic advance as per cent of mean estimated for different characters by different workers are reviewed and presented hereunder.

2.2.1 Seed morphological characters

2.2.1.1 Seed size

High heritability coupled with high genetic advance for L/B ratio in rice was reported by several workers (Chauhan and Nanda, 1983; Maurya *et al.*, 1986 and Hussain *et al.*, 1987).

De and Suriya rao (1987) and Deosarkar *et al.* (1989b) recorded high heritability with low genetic advance for length and breadth of grain. Whereas, Marekar and Siddique (1996) noticed high heritability coupled with high genetic advance for L/B ratio and grain length.

Reddy *et al.* (1997), Chikkalingaiah *et al.* (1999) and Satyapriya and Sreedhar (1999) found high heritability with high genetic advance for grain length, breadth and L/B ratio.

2.2.1.2 100-seed weight

Lal *et al.* (1983) recorded high heritability for this trait in rice while, high heritability coupled with high genetic advance in rice was reported by Shukla *et al.* (1972), Maurya *et al.* (1986), Reddy and Reddy (1986), Deosarkar *et al.* (1989a), Roy and Kar (1992) and Chikkalingaiah *et al.* (1999).

Jangale *et al.* (1985) observed high heritability with moderate genetic advance, while Reddy *et al.* (1997) reported moderate to high heritability with high genetic advance for 100-seed weight.

High heritability with low genetic advance for 100-seed weight was recorded by De and Suriya rao (1987) and Angrish and Panwar (1992). Moderate to high heritability with low to moderate genetic advance was reported by Ramesh Kumar (1989) for this trait.

2.2.1.3 Seed density

Mallik *et al.* (1990) and Angrish and Panwar (1992) observed high estimates of heritability and genetic advance for seed density. Padmajarao (1991) recorded high heritability for seed density among five rice varieties.

2.2.1.4 Germination and seedling characters

High heritability for shoot and root length was found by Li and Rutger (1980) and Redona and Mackill (1996).

Subbarao *et al.* (1996) reported high heritability for rate of germination, vigour index and seedling dry weight, where as moderate heritability was recorded for shoot length.

2.3 STANDARD VIGOUR TESTS

One of the problems in the study of vigour is agreement on terms. Vigour may be considered from two approaches cause and effect. The definitions varied and included response to stress (Abdullahi and Vanderlip, 1972), relative stage of seedling development (Adenikinju, 1972) relative seedling growth rate measured as dry weight accumulation (Lowe *et al.*, 1972 and Turner and Ferguson, 1972) seedling survival (Mukherji *et al.*, 1971).

2.3.1 Standard germination test

Grabe (1964) reported a close association between standard germination and field emergence in corn.

Decline in germination levels resulted in reduction of vigour yield components and yield in rice (Raghavendra rao *et al.*, 1990).

Padma and Reddy (2002) reported that the range of germination between the seed lots was narrow for second count compared to first count of standard germination test.

2.3.2 Seedling growth and vigour index

Lawrence (1963) found good correlation between emergence from various sowing depths and seedling vigour in Russian wild rye grass. Seed size and speed of germination were also proved to be useful measures of seedling vigour.

Wood stock (1969) reported that seedling growth rates were sensitive indicators of seed quality. They could reveal the differences in vigour detected by the germination test. He suggested that growth provides the best sample method for vigour evaluation especially where varietal differences were not involved.

Dry weight assessment of soybean seedlings excluding the cotyledons were closely related to vigour (Edje and Burris, 1970) and seedling dry weight was related to emergence within genotypes of corn (Burris, 1975).

Abdul – Baki and Anderson (1973) recommended vigour index as a criterion for the assessment of seed vigour in soybean. Use of linear measurements of plumule growth as a vigour test was further developed by Perry (1977) in barley and wheat.

2.3.3 Field emergence

Field emergence is a significant indicator of yield performance of direct seeded crop. Germination values frequently fail to provide a relative estimate of field emergence potential (Pollock and Roos, 1972). Seed vigour tests can be

used to obtain reliable assessment of field stand [Buxton *et al.* (1977); Tekrony and Egli (1977) and Bishnoi and Delouche (1980)].

Standard germination counts like first count, final count and rate of germination had mean values higher than that of field emergence supporting the view that the standard germination tests being conducted under optimum conditions often overestimate the field emergence (Shenoy *et al.*, 1990).

2.3.4 Seed germination rate and associated characters

Takahashi (1956) studied cultivar differences in the germination speed on rice seeds and concluded that O₂ uptake and imbibitional rate were parallel to germination speed. Later, Takahashi (1960) found that the seed coat plays a dominant role on germination after the ripening stage. Takeda (1972) found the negative association of seed weight with seedling growth rate.

Maguire (1962) reported that speed of germination would aid in predicting seedling emergence and vigour in rice and in other cereal crops. He stated that speed of germination was one of the oldest concepts of seedling vigour. Seed lots with similar total germination often vary in rate of seedling emergence and rate of growth. Germination rate can also be obtained at the same time along with the germination percentage.

Pollock and Roos (1972) emphasized the importance of germination speed among the various components of seed vigour, Perry (1972) stated that seed vigor was determined by the genotype and modified by the environment.

Genotypic differences between seed vigour have been reported by Gritton and Atkins (1963), Rowe and Gorwood (1978), Agrawal (1979) and Wright (1980).

Wright (1980) recorded the positive association of germination speed or rate with seedling emergence and establishment in blue panic grass (*Panicum antidotale* Retz.).

Seshu *et al.* (1988) using rate of germination as a measure of seed vigour in rice, obtained a significant positive correlation of this trait with tiller number and grain yield per plant.

Krishnaswamy and Seshu, (1989) had grown 68 rice cultivars in the field and in the phytotron and evaluated the harvest seed for germination rate. They reported that aged seeds exhibited slow germination. One hundred seed weight was negatively correlated with germination rate. Path analysis suggested that 100-seed weight acted through a high indirect effect of free amino acid content on germination rate. Oxygen uptake and dehydrogenase activity also contributed to variability in germination rate.

Subbarao *et al.* (1996) observed significant genetic variability for mean daily germination, peak value, germination value and rate of germination studied among 69 rice cultivars.

2.4 PHYSIOLOGICAL AND BIOCHEMICAL VIGOUR TESTS

2.4.1 Electrical conductivity of seed leachates

Tatum (1954) in corn, Presley (1958) in cotton, Pollock and Toole (1966) in lima beans, Matthews and Bradnock (1967) in peas, evaluated relative vigour of seed lots and reported that lower the vigour the greater was the amount of leaching.

Siddique (1986) classified seed of five cultivars of rice as high vigour (HV), medium vigour (MV) and low vigour (LV) based on the conductance of individual seed leachate and reductions of 7.89 and 14.14% in grain yield was noted from the MV and LV seeds, respectively compared with HV seeds.

Parish and Leopold (1978) observed that leaching of electrolytes increased during accelerated ageing. Which was confirmed by Dadlani and Agrawal (1985). Krishnaswamy and Seshu (1990) further stated that percentage leaching in the seeds aged for four and eight days exhibited significant and negative association with germination.

Shenoy *et al.* (1990) concluded that electrical conductivity of seed leachate was not significantly correlated with field emergence, though this is a most frequently used parameter for assessing seed vigour.

Seshu and Dadlani (1993) evaluated three seed lots of six rice varieties and found that all laboratory tested vigour parameters except electrical conductivity of seed leachates were significantly correlated with field emergence.

Kinjinho *et al.* (1998) reported that the shorter the maturation period after heading the greater was the electrical conductivity of rice seed and increased gradually as the period of soaking rice seeds increased.

Padma and Reddy (2002) found that E.C. of seed leachates was negatively correlated with field emergence in all the rice cultivars. In soybean, this test was considered by several scientists as an effective index for seedling emergence in field (Oliviera *et al.*, 1984 and Vieira *et al.*, 1999).

2.4.2 Total dehydrogenase activity

Tetrazolium staining has been widely used to evaluate seedling vigour in many crop species (Kittock and Law, 1968; Yaklich and Kulik, 1979).

Johnston *et al.* (1986) reported that instead of using the topographic staining, the quantitative determination of solvent extract of formazon from the tetrazolium salt-stained embryo was also useful for estimating seedling vigor in wheat.

Sung and Chen (1988) studied the genetic variability in formazon production capability of the embryo and its relationship to seedling vigor, as indicated by seedling dry weight in 21 cultivars. They observed considerable variation in growth and formazon production level. Seedling vigour was positively correlated to formazon production capability of the embryo, suggesting that the formazon extraction technique would be a simple and reliable method for screening rice cultivars for seedling vigour.

Krishnaswamy and Seshu (1989) envisaged the contribution of dehydrogenase activity to variability in germination rate and their correlation with one another.

Seshu and Dadlani (1990) reported that there was a positive correlation between field emergence and total dehydrogenase activity in rice.

Shenoy *et al.* (1990) found that dehydrogenase activity had not shown linear association with field emergence in 51 rice cultivars. Several other workers observed positive correlation of dehydrogenase activity with field emergence in many crops (Grabe, 1976; Pollock and Roos, 1972 and Suryatma *et al.*, 1980).

Seshu and Dadlani (1993) found that the dehydrogenase activity of the seed was not significantly correlated with field emergence in rice.

2.4.3 Peroxidase activity

Kapur *et al.* (1988) emphasized that peroxidase activity was high in hulls of dormant seeds and very low in hulls of non-dormant seeds.

Kang and Nam (1989) studied the varietal differences of peroxidase activities, found that root and leaf blade peroxidase activities were greatest in *japonica* cultivars. Average peroxidase activity in roots was greater while that in leaf blades was low in *indica* than in *indica* x *japonica* cultivars.

Seshu and Dadlani (1991) reported that dormant cultivars had higher O₂ uptake rate and peroxidase activity than the weakly dormant ones. Hull removal substantially decreased the peroxidase activity.

Yan and Li (1995) compared seed vigour and field performance in naturally and artificially aged seeds and found good correlation between peroxidase activity and yield.

Gonzalez and Ramirez (1998) found peroxidase activity in 20 rice varieties was highly correlated with saline stress tolerance index.

Banumathy *et al.* (1999) studied peroxidase activity of five hybrids and their parents and concluded that all the hybrids recorded increased activity over their parents. In addition, male sterile (CMS) lines generally showed higher peroxidase activity than their maintainer lines.

Chen and Chen (2003) found that cultivar, storage duration and temperature significantly affected the activities of grain peroxidases.

2.4.4 α - amylase activity

Krishnaswamy and Seshu (1990) reported that cultivars with high α -amylase activity showed higher germination rate and faster seedling growth at the early stage. α - amylase isozyme pattern revealed a high mobility band on the third day after germination in cultivars with higher germination rate and on the fourth or fifth day after germination in those with slow germination rate.

Studies of Cladine *et al.* (1991) on the contribution of aleurone layer and scutellum to α -amylase synthesis and secretion in rice grains indicated that during germination and growth the aleurone layer of rice plays a predominant role in the production of α -amylase.

Karrer *et al.* (1993) observed strong positive correlation between α -amylase activity and seedling vigour. Significant reduction in seedling length, seedling vigour, speed of germination and dry matter production per plant were observed with decline in germination levels in rice after accelerated ageing (Narayana Reddy *et al.*, 1994).

Shephard *et al.* (1995) observed low α -amylase activity in aged rice seeds which indicated shorter radicle length, lower rate of germination and percentage of germination.

Shephard *et al.* (1997) found significant effect of seed size on α -amylase activity as small seeds showed greater enzyme activity and amount of enzyme activity was dependent on the stage of germination. The seeds which had produced small radicles also had low levels of α -amylase activity.

2.4.5 Phosphorus fractionation

In germinated Bauhinia and Cassia seeds, Koshti (1972) found that total acid soluble phosphorus, apparent inorganic phosphorus and true nucleic acid phosphorus (RNA-P) contents of eight days old seedlings reached more than three times that of ungerminated seeds. The increased amount of inorganic-P during germination was attributed to the fact that phosphatases are very active,

during germination, presumably inorganic-phosphorus is liberated through the action of these enzymes and distributed in all parts of germinating seedlings.

Subbarao (1984) correlated the phosphorus fractions with seed vigour in brinjal (cv. MDU-1) and reported that acid soluble phosphorus had a negative correlation with vigour and viability parameters. Phospholipid phosphorus and RNA phosphorus showed positive correlation with germinability and vigour index whereas DNA phosphorus showed positive correlation with germinability only.

Rajendraprasad (1987) studied the influence of harvesting conditions on phosphorus fractions content in seed and found that both in blackgram and greengram, seeds harvested at physiological maturity recorded higher levels of phosphorus fractions and the amounts of different phosphorus fractions declined when the harvests were delayed. Irrespective of harvesting conditions, the RNA phosphorus followed by acid soluble inorganic phosphorus amounted high, when compared to phospholipid phosphorus, phosphoprotein peptide phosphorus and DNA phosphorus.

Gupta *et al.* (2000) found that in kernel of sunflower cv. HS-1 total phosphorus, lipid phosphorus and protein phosphorus increased at low Chromium concentrations and decreased with high concentration at maturity, while acid soluble phosphorus and nucleic acid phosphorus decreased with all Chromium treatments compared with the control. In the hull total phosphorus was greatest with 0.5 ppm Chromium 30 days after flowering.

2.5 STRESS TESTS

2.5.1 Anaerobic germination test

Yamauchi (1995) developed an anaerobic sowing technology in which germinated seeds were broadcast or drill sown under the surface of flooded or water saturated soil, and concluded that use of cultivars tolerant to anaerobic conditions and with high seed vigour improved and stabilized the anaerobic seedling establishment.

Yamauchi and Winn (1996) studied the interrelationship between seed vigour and seedling growth in anaerobic soil to identify seedling characteristics that predict the establishment in the field. Seedling establishment in the field was closely correlated with the vigour index in the field, establishment and vigour index in the tray and coleoptile length in N₂ gas suggesting that these characteristics would be useful in the prediction of seedling establishment in anaerobic soil.

Winn *et al.* (1997) identified cultivars suitable for practice of anaerobic seeding by field and laboratory experiments. In the laboratory, seedling establishment followed by leaf number and mesocotyl length, showed the highest correlation coefficient with vigour index, an indicator of speed of emergence.

Yamauchi and Biswas (1997) evaluated the difference in morphogenesis of rice seeds sown in flooded and drained soils to identify the morphological characteristics responsible for successful establishment of cultivars in the

flooded soil and suggested the reason for better growth of superior cultivars in flooded soil was due to faster and longer elongation of the coleoptile in hypoxia and is able to reach the soil surface where O₂ is available.

Ruan *et al.* (2002) suggested that priming of rice seeds may contribute to improved seedling establishment in anaerobic soil.

2.5.2 Moisture stress test

Sharma (1973) used solutions of mannitol and polyethylene glycol to demonstrate differential abilities of several pasture grasses and clover to germinate in drought conditions, while Radwan (1973) used mannitol solutions to show similar differences in six pasture species. Livshin and Samygin (1973) showed that seedlings of wheat, corn and peas were more sensitive to drought injury when separated from their endosperms or cotyledons.

The availability of water in the soil is a second major factor controlling germination and establishment and is more complex to study than temperature. Hadas and Russo (1974) clearly illustrated the problems in their investigations on the water relations of chickpea, pea and vetch seeds. Using osmotic solutions of polyethylene glycol they showed that rate of water uptake was not affected between 0 and –6.0 bar.

Seshu and Sorrells (1986) reported significant and positive correlation between cold germination and preharvest sprouting and germination under moisture stress.

Krishnaswamy and Seshu (1989) found cultivar differences for germination rate following germination under moisture stress.

Shenoy *et al.* (1990) found non-linear association between germination under moisture stress and field emergence. Path analysis showed that it had no direct effect.

Krishnaswamy and Seshu (1990), found that germination under moisture stress did not correlate with storability.

Jha *et al.* (2001) obtained the differences among eight rice genotypes belonging to various agroclimatic conditions in response to induced moisture stress. Seed germination and seedling growth were reduced with increasing concentrations. They concluded that deterioration of seedling vigour with increasing moisture stress was an important parameter to distinguish tolerant and susceptible genotypes.

2.5.3 Salinity stress test

Shenoy *et al.* (1990) germination in salt solution did not record significant association with vigour parameters.

Padma and Reddy (2002) found that sodium chloride stress test did not have any association with field emergence.

2.5.4 Accelerated ageing test

Loss of germination with ageing observed in rice under ambient conditions by Sahadevan (1953), Dore (1965) and Agrawal (1977) was attributed to cultivar differences.

Delouche and Baskin (1973) observed that accelerated ageing of seeds for 4-8 days at high temperatures (40-45°C) and relative humidity (100%) could predict seed storability under ambient conditions.

Chang (1978) noticed that *indica* rice varieties were better storers than Japonicas. Purkar *et al.* (1979) noticed positive and significant correlation between grain yield and 100-grain weight after conducting accelerated ageing test. Ray and Gupta *et al.* (1979) found that ageing increased the permeability to a considerable extent as also the vigour of the seedling without significantly affecting the germination.

Studies of Likhatchev *et al.* (1984) revealed considerable and specific varietal differences in the rate of deterioration. Accelerated ageing studies have shown that seed ageing is characterized by loss of germinability, a decrease in germination rate and depression of seedling development.

Decline in germination potential and reduction in speed of germination are among the physiological changes usually reported to take place in seed during accelerated ageing and the extent of the decline is related to the initial degree of deterioration in the seed lot (Ram and Wiesner, 1988).

Krishnaswamy and Seshu (1989) stated that aged seeds exhibited slow germination. Suhaila *et al.* (1990) employed accelerated ageing to determine varietal differences for seed vigour and viability in three rice varieties and observed the loss of electrolytes into the imbibing medium increased with ageing time. Consequent to accelerated ageing treatment, seedling growth declined in all the varieties as indicated by reduced shoot and root length.

Krishnaswamy and Seshu (1990) screened sixty eight rice varieties for tolerance to accelerated ageing and observed 3 to 83 per cent decline in germination. The leaching percentage of electrolyte increased and exhibited significant and negative association with germination and rate of germination during accelerated ageing.

Ray *et al.* (1990) studied differential responses of early and late cultivars of rice seeds under accelerated ageing and observed 40-65 per cent reduction in germination after 10 days of accelerated ageing treatment. The activity of α -amylase on the other hand was found to have decreased substantially after 48 hours of soaking when seeds were subjected to 10 days of accelerated ageing.

Raghavendra Rao *et al.* (1990) reported decline in germination levels resulting in reduction of vigour, yield components and yield in rice.

Effect of age of seed on yield and its components in rice was studied by Verma *et al.* (1992). They reported that the crop raised from 20 month old seed

had more effective tillers, larger panicles, more seeds per panicle and higher seed yield per plant compared to 8 months old seed.

2.6 CORRELATION STUDIES

Correlation coefficient measures the intensity of association between two characters, which is useful for planning and evaluating breeding programme for improvement of economic characters. Correlation between characters is important for estimating the relative influence of various characters on vigour and the magnitude of direct and indirect effects on vigour.

2.6.1 Seed morphological characters

Takeda (1972) reported that seed weight and seedling rate were negatively correlated.

Suguna *et al.* (1985) observed that 100-seed weight was positively correlated with root length.

Padmajarao (1987) observed positive relationship of high density grain with grain yield.

De and Suriyarao (1987) observed significant negative correlation between length and breadth of grain where as positive correlation between length and 100-grain weight of rice.

Deosarkar *et al.* (1989b) found positive correlation between L/B ratio and grain yield, while Sreenivasa Rao (1989) reported significant negative association of this trait with grain yield in rice.

Krishnaswamy and Seshu (1989) found that 100-seed weight was negatively correlated with germination rate but positively correlated with root, shoot length and seedling dry weight.

Pandey *et al.* (1992) reported strong correlation between grain breadth and embryo weight in Japonica species and it was further elaborated by Pandey *et al.* (1994).

Marekar and Siddique (1996) found positive and significant correlation between length of grain and L/B ratio.

Reddy *et al.* (1997) observed significant positive correlation between seed length, seed breadth and 1000-grain weight.

2.6.2 Germination and seedling growth

Krishnaswamy and Seshu (1989) observed that germination was positively correlated with 100-grain weight. Narayana Reddy *et al.* (1994) studied the effect of initial germination levels on vigour and yield in rice and observed highly significant and positive correlation between initial germination levels and seedling vigour index.

Subba Rao *et al.* (1996) reported significant positive correlations among germination, mean daily germination, root length, seedling dry weight and vigour index. Shoot length was significantly and positively correlated with root length, seedling dry weight and vigour index. Redona and Mackill (1996) found significant correlation between seedling root, shoot length and seedling vigour index in *japonicas* and *indicas*.

CHAPTER – III

MATERIALS AND METHODS

The investigation entitled “Studies on variability for seed vigour in different sub-species of rice (*Oryza sativa* L.)” was conducted at Department of Seed Science and Technology, College of Agriculture, Rajendranagar, Hyderabad during 2003-04. The material used and methods employed during the course of investigation are presented in this chapter. The seeds of different sub-species of rice for the study were collected from the Directorate of Rice Research (DRR), Hyderabad.

3.1 MATERIAL

The material for the study consisted of the following lines.

Sub-species	Genotypes / lines
<i>Indicas</i>	Samba Mahsuri (BPT 5204)
	Tellahamsa
	Swarna (MTU 7029)
	Surekha (WGL-13400)
<i>Indica</i> Hybrids	DRRH-1
	Sahyadri
<i>Indica</i> Land Races	Baiku (RRPS-29)
	Jawaphool (RRPS-25)
Tropical <i>japonicas</i>	IR 65600-77-4-2-1
	IR 67962-84-2-2
Temperate <i>japonicas</i>	Akeiekari
	Taipea - 309

3.2 METHODS

The experiment was laid out in a Completely Randomized Design (CRD) with three replications. The seeds of different sub-species were subjected to following seed vigour tests.

3.2.1 Seed morphological characters

3.2.1.1 Seed length

The length of ten well filled seeds selected at random in three replicates from each sample was measured in millimetres using dial micrometer (Murthy and Govindaswamy, 1967).

Based on seed length the genotypes under study were classified as very short (<6.94 mm), short (6.94-7.92 mm), medium (7.92-9.88 mm), long (9.88 -10.86 mm) and very long (>10.86 mm) (UPOV, 2000).

3.2.1.2 Seed breadth

The breadth of the seed at widest portion was measured on ten filled seeds each in three replications using dial micrometer (Plate-1) and expressed in millimetres.

The genotypes were classified as very narrow (<1.58 mm), narrow (1.58 – 1.73), medium (1.73 – 2.03 mm), broad (2.03 – 2.28 mm) and very broad (>2.28 mm), (UPOV 2000).

3.2.1.3 Length breadth ratio (L/B ratio)

The length breadth ratio was calculated as

$$\text{L/B ratio} = \frac{\text{Mean length of seed (mm)}}{\text{Mean breadth of seed (mm)}}$$

The L/B ratio was used to classify the genotypes as long slender (>3.0) and long bold (<3.0), when the seed length was >6 mm, medium slender (2.5 mm) and as short bold (<2.5) and short slender (>3.0) when the seed was < 6 mm length (UPOV, 2000).

3.2.1.4 100-seed weight (g)

Hundred well filled seeds having moisture content between 10-12 per cent were randomly selected from each sample in each replicate and weighed to the nearest milligram on an electronic balance.

3.2.1.5 Seed density

Seed density was calculated by following the method prescribed by Padmajarao *et al.* (1985). One hundred seeds from each sample were placed in

three replications in fresh salt solution having specific gravity of 1.06 prepared by dissolving 90 g of common salt (NaCl) in one litre of distilled water. Later the level of specific gravity was tested with hydrometer. Chaffy and light seeds were discarded. Dense and submerged seeds were collected for the estimation of seed density in percentage.

3.2.2 Standard vigour tests

3.2.2.1 Standard germination test - Between paper method

Hundred seeds from each sample were subjected to germination test in three replications following between paper method as per the standard procedure (ISTA, 1993) in a seed germinator by maintaining an optimum temperature of $25 \pm 1^{\circ}\text{C}$ and relative humidity of $70 \pm 2\%$. Germination percentage was calculated using normal healthy seedlings with the following formula on 5th day (first count) and on 14th day (final count).

$$\text{Germination percentage} = \frac{\text{No. of normal seedlings}}{\text{Total no. of seeds}} \times 100$$

3.2.2.2 Sand method

Hundred seeds from each sample were sown in sterilized sand poured in plastic trays at equidistance. The sand was wetted upto 70% water holding capacity and the trays were kept in a seed germinator at $25 \pm 1^{\circ}\text{C}$ temperature and

70 $\pm$ 2% relative humidity. Number of seedlings emerged on 14th day were calculated and the germination per cent was computed.

3.2.3 Seedling growth traits

3.2.3.1 Seedling length (cm)

Ten seedlings were collected at random from each sample in three replications on 14th day from the seeds subjected to germination test using between paper method. The shoot and root length of seedling was measured in centimetres (cm) using a scale.

3.2.3.2 Seedling dry weight (g)

The randomly selected seedlings for measuring seedling length obtained after final count were dried at 70 $\pm$ 1°C for 24 hours in hot air oven, and dry weight in grams was determined by weighing them in an electronic balance.

3.2.3.3 Vigour index

Vigour index of the seedlings obtained from the germination test was calculated using the following formula (Abdul-Baki and Anderson, 1973).

Vigour index – I : Seed germination per cent x seedling length (cm)

Vigour Index-II : Seed germination per cent x seedling dry weight (g)

3.2.4 Rate of germination

The following components of rate of germination was estimated by taking daily counts during germination test using pleated paper method. A germination paper towel was folded into five pleats longitudinally and stapled at both ends. Ten seeds were placed in each pleat by adding sufficient water and the trays were kept in germinator at $24 \pm 1^{\circ}\text{C}$ and $70 \pm 2\%$ relative humidity. The germination was considered to have occurred with the appearance of radicle in this method. Number of seeds germinating on each day were calculated and by using the following indices, different components of rate of germination were calculated.

3.2.4.1 Speed of germination

The speed of germination of the given sample was calculated by using the formula given by Maguire (1962).

$$\text{Speed of germination} = \sum (N / t)$$

Where

N = No. of seeds germinated

t = Time (number of days) taken for germination

3.2.4.2 Mean daily germination

The mean daily germination was calculated by formula given by Edwards (1934).

$$\text{Mean daily germination} = \frac{\text{Final germination per cent}}{\text{Total number of days in a test}}$$

3.2.4.3 Peak value

The peak value was calculated by the method prescribed by Edwards (1934).

$$\text{Peak value} = \frac{\text{Final germination per cent}}{\text{No. of days taken to reach maximum germination per cent}}$$

3.2.4.4 Germination value

Germination value was calculated by multiplying mean daily germination with peak value (Czebator, 1962).

$$\text{Germination value} = \text{Mean daily germination} \times \text{peak value}$$

3.2.4.5 Rate of germination

The rate of germination was calculated by using following formula proposed by Krishnaswamy and Seshu, 1990.

$$\text{Rate of germination} = \frac{\text{Number of seeds germinated in 2 days}}{\text{Number of seeds germinated in 7 days}} \times 100$$

3.2.4.6 Mean germination time

The mean germination time was calculated by the following formula.

$$\text{Mean germination time} = \frac{\sum (n.t)}{\sum n}$$

3.2.4.7 Coefficient of velocity of germination

The coefficient of velocity of germination was calculated by using the formula suggested by Kotowski (1926).

$$\text{Coefficient of velocity of germination} = \frac{\sum n}{\sum (n.t)} \times 100$$

Where

n = Number of seeds germinated and

t = Time (number of days) taken for germination

3.2.5 Field emergence

Field emergence potential of seeds was measured as per the method suggested by Shenoy *et al.* (1990). Four hundred seeds were sown in four replications of hundred seeds each on raised bed (4 x 1 m) of red loamy soil with a spacing of 10 cm between the rows. The number of seeds germinated in each row were calculated on 10th day and percentage field emergence was calculated using the following formula.

$$\text{Field emergence} = \frac{\text{Number of seeds germinated}}{\text{Total number of seeds sown}} \times 100$$

3.2.6 Physiological and biochemical tests

The physiological and biochemical tests were conducted on fresh seed as well as 10 days accelerated aged seed.

3.2.6.1 Electrical conductivity of seed leachates

Four replicates of hundred seeds of each sample were weighed and placed in clean beakers to which 100 ml of distilled water was added and covered. The beakers were then kept in an incubator at $20 \pm 1^{\circ}\text{C}$. After 24 hours, the conductivity of the seed leachates was measured using digital conductivity meter (DIGISUN 2003 S) and expressed as $\mu\text{ mhos cm}^{-2}$. A beaker of distilled water without seed served as control.

3.2.6.2 Total dehydrogenase activity

The dehydrogenase activity was measured using the method followed by Shenoy *et al.*(1990). Ten rice seeds were dehulled for each variety in three replications and soaked in 2, 3, 5 – Triphenyl Tetrazolium chloride solution of 2.5 mg l^{-1} for 16 hr. Later the solution was decanted and the red formazon colour was extracted using 5 ml ethylene glycol mono- methyl ether for four hours. The colour intensity was read as absorbance at 480 nm using suitable blank in spectronic-20.

3.2.6.3 Peroxidase activity

The peroxidase activity in seeds was measured using the method suggested by Ashwanikumar *et al.* (1995). Three replications of 25 seeds each were soaked in distilled water for 24 hours. The seeds were then incubated in 2.5 ml for 20 min. Then a drop of 0.1% H₂O₂ was added and peroxidase activity was recorded after ten minutes at 480 nm in spectronic –20 and the O.D. values were reported.

3.2.6.4 α – amylase activity

Seeds of each sample in replicates of three were germinated in a seed germinator at an optimum temperature of $27 \pm 1^{\circ}\text{C}$ and a relative humidity of $75 \pm 3\%$. The radicle and plumule were removed and the tissue (seed) was used for enzyme preparation.

Enzyme extraction

The α -amylase enzyme was extracted from germinating rice seeds following the method suggested by Grosselindemann *et al.* (1991). 0.5 g of the seed tissue was homogenized in an ice cold mortar and pestle, in presence of homogenizing mixture comprising 6.0 ml of 1.0 M sodium acetate buffer (pH 5.3) containing 10 mM CaCl₂. The homogenized extract was centrifuged at 3000 rpm for 10 min. The supernatant was then heated at 60°C for 30 min to inactivate the

β -amylase and then centrifuged. The supernatant thus collected was used for α -amylase activity assay.

Determination of α -amylase

Preparation of starch solution

Starch suspension was prepared by dissolving 2 g of potato starch in 100 ml of distilled water and boiled for 1 min. cooled and then centrifuged at 10,000 rpm for 10 min. The clear supernatant was used for α -amylase activity.

Enzyme assay

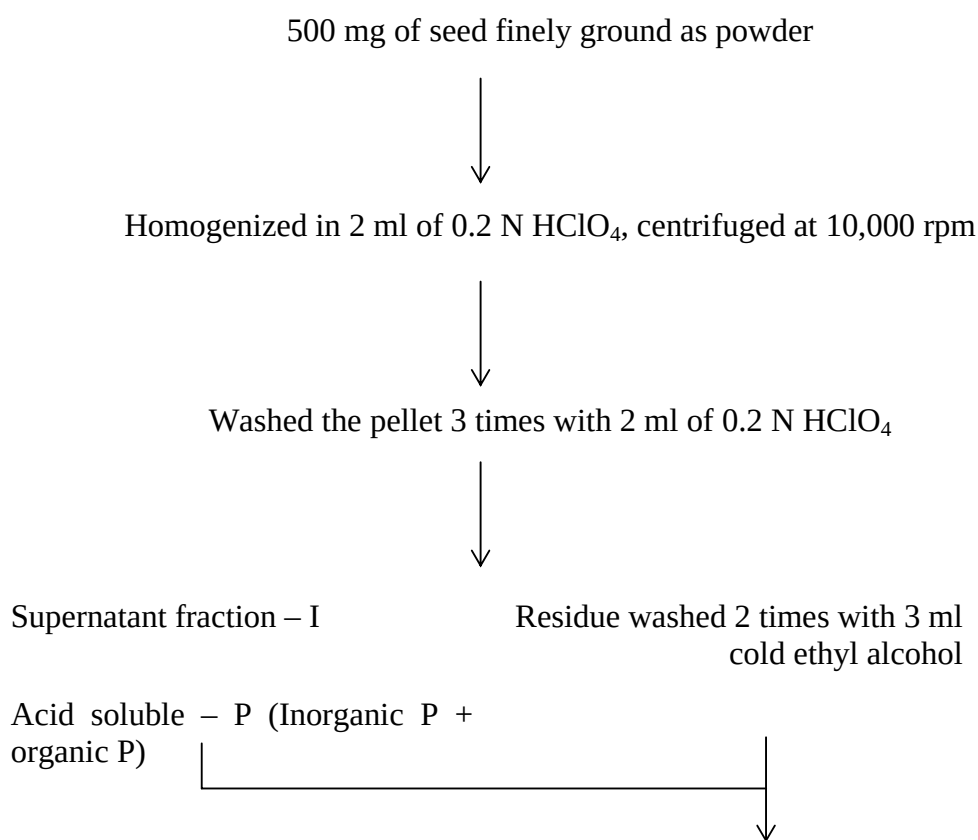
α amylase was assayed as described by Choi *et al.* (1996). An aliquot of the enzyme solution was taken in a 1.5 ml microcentrifuge tube. To this enzyme aliquot 0.2 ml of freshly prepared starch solution, 0.2 ml of 0.1 M sodium acetate buffer (pH 5.3) and 0.2 ml of 10 mM CaCl_2 were added and the final volume of solution was adjusted to 1.2 ml with distilled water. The solution was then incubated at 37°C for 10 min. The reaction was stopped by adding 0.4 ml KI/I_2 solution, and the absorbance was measured at 620 nm in Spectronic 20.

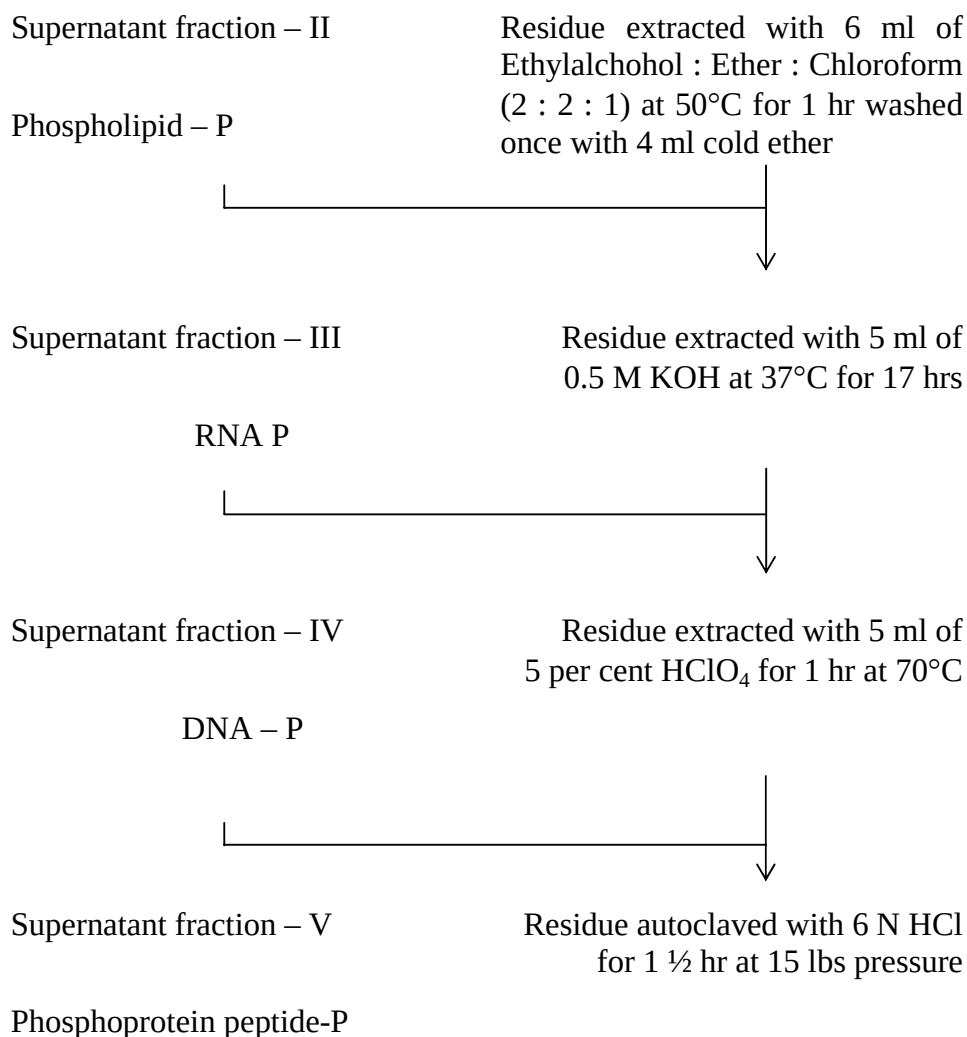
One unit of α -amylase activity was defined as decrease of 0.1 O.D. in A_{620} . Absorbance of control (without addition of enzyme solution) was 0.8 – 1.0.

3.2.6.5 Phosphorus fractionation

Five types of phosphorus fractions namely (i) acid soluble phosphorus (ii) phospholipid phosphorus (iii) RNA phosphorus (iv) DNA phosphorus (v) Phosphoproteinpeptide phosphorus were separated from five hundred mg of finely ground fresh seed powder using the method described by Hogue *et al.* (1970). Total phosphorus was calculated by adding all the fractions of phosphorus.

The separation of phosphorus fractions was carried out as detailed schematically below :





All the fractions of phosphorus were calorimetrically determined using Sumner (1944) reagents. The colour intensity was read in spectrophotometer (Spectronic-20) with red filter at 660 nm. The amount of phosphorus obtained was calculated by referring to a standard curve prepared by using pure KH_2PO_4 at different concentrations and expressed in $\mu\text{g g}^{-1}$ of seed sample.

3.2.7 STRESS TESTS

3.2.7.1 Accelerated Ageing Test

The methodology suggested by Delouche and Baskin (1973) for accelerated ageing was followed by exposing small quantity of seed of each sample to high temperatures ($40 \pm 5^\circ$) and high relative humidity ($95 \pm 5\%$) condition. Few seeds were removed from the incubator at 2 days interval upto 10 days. The seeds were dried and subjected to the following tests.

3.2.7.1.1 Germination percentage

One hundred seeds of each variety in three replications were subjected to germination test following between paper method (ISTA, 1993). On 14th day, the number of seeds germinated were counted and the germination percentage was calculated as per the formula given in 3.2.2.1.

3.2.7.1.2 Seedling length (cm)

Ten seedlings from each sample in three replications were collected at random on 14th day from the seeds subjected to germination test. The root and shoot length of seedling were measured in centimeters with a scale.

3.2.7.1.3 Seedling dry weight (g)

Seedling dry weight was recorded as per the procedure given in 3.2.3.2.

3.2.7.1.4 Vigour index

The vigour index I and II were calculated as per the formulae given in 3.2.3.3.

3.2.7.2 Salinity stress test

The salinity stress test was conducted as suggested by Padma and Reddy (2002). Twenty five seeds in three replications were placed in a petriplate lined with filter paper at $24 \pm 1^\circ\text{C}$. The seeds were wetted with saline solutions of different concentrations 0.5%, 1.0% and 1.5% prepared by dissolving 5 g, 10 g and 15 g sodium chloride (NaCl), respectively in one litre distilled water. The plate wetted with distilled water served as control. Germination per cent was calculated on the 3rd day.

3.2.7.3 Moisture stress test

The moisture stress test was conducted by following the method suggested by Shenoy *et al.* (1990). Twenty five seeds were placed in petriplates lined with filter paper in three replications. 7 ml solution of -6 bar and -9 bar osmotic potential obtained by dissolving 15.55 g and 23.33 g PEG-6000 in distilled water respectively was poured into the petriplates. The plates were kept at $24 \pm 1^\circ\text{C}$ in a germinator. Germination per cent was calculated on 3rd day. Plate with distilled water served as control.

3.2.7.4 Anaerobic germination

Twenty five seeds were placed in 100 ml beakers in three replications. Distilled water was poured upto 3 cm height and the beakers were kept in a germinator at optimum temperature ($24 \pm 1^{\circ}\text{C}$) and relative humidity ($70 \pm 3\%$). The test was continued till the tip of radicle touched the water level. Then the per cent seedlings with radicles touching the water level were calculated on 5th day and 8th day.

3.2.8 STATISTICAL ANALYSIS

The data recorded was subjected to following statistical analyses.

3.2.8.1 Analysis of variance

Difference between genotypes for various characters were tested for significance by using analysis of variance technique as suggested by Panse and Sukhatme (1985).

3.2.8.2 Genotypic and phenotypic coefficient of variation

The genotypic and phenotypic coefficient of variation were calculated by the formula given below :

$$\text{GCV (\%)} = \frac{\text{Genotypic standard deviation } (\sigma_g)}{\text{General mean } (\bar{X})} \times 100$$

$$\text{PCV (\%)} = \frac{\text{Phenotypic standard deviation } (\sigma_p)}{\text{General mean } (\bar{X})} \times 100$$

PCV and GCV were broadly classified as low (<15%), moderate (15 – 30%) and high (>30%).

3.2.8.3 Heritability in broad sense

Heritability in broad sense was estimated by the formula suggested by Allard (1960).

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

Heritability estimates were categorized as low (<30%), moderate (>30-60%) and high (>60%).

Genetic advance

From heritability estimates, the genetic advance was estimated by the formula given by Allard (1960).

$$GA = K \times \sqrt{\sigma^2_p} \times h^2(b)$$

Where

$$GA = \text{genetic advance}$$

$$\sigma^2_p = \text{phenotypic variance}$$

$$h^2(b) = \text{heritability in broad sense}$$

$$K = \text{selection differential (2.06 at 5\% level)}$$

Genetic advance as percentage of mean was calculated using the formula :

$$\frac{GA}{\bar{X}} \times 100$$

$$\text{Where } GA = \text{Genetic advance}$$

$$\bar{X} = \text{Mean of the character}$$

Genetic advance as percentage of mean was classified as low (<30%), moderate (>30 – 50%) and high (>50%).

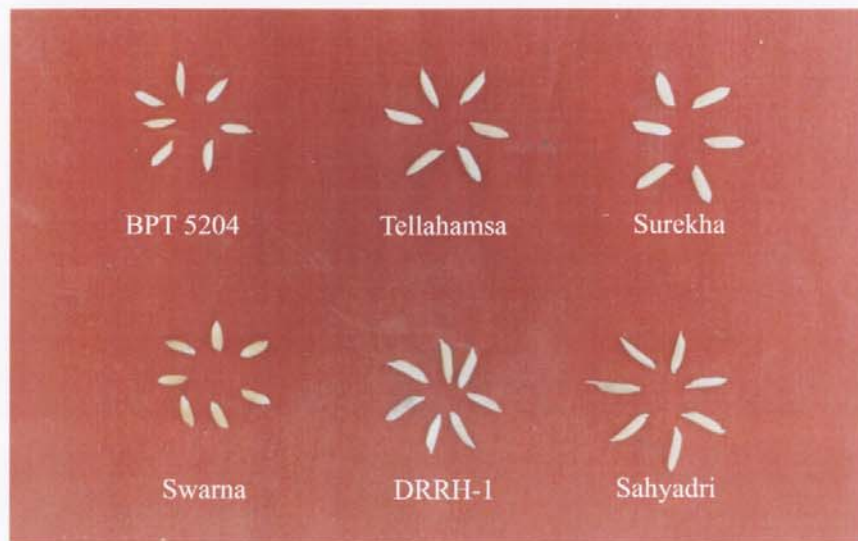


Plate 2 : Variation in seed morphology of *Indica* varieties and Hybrids

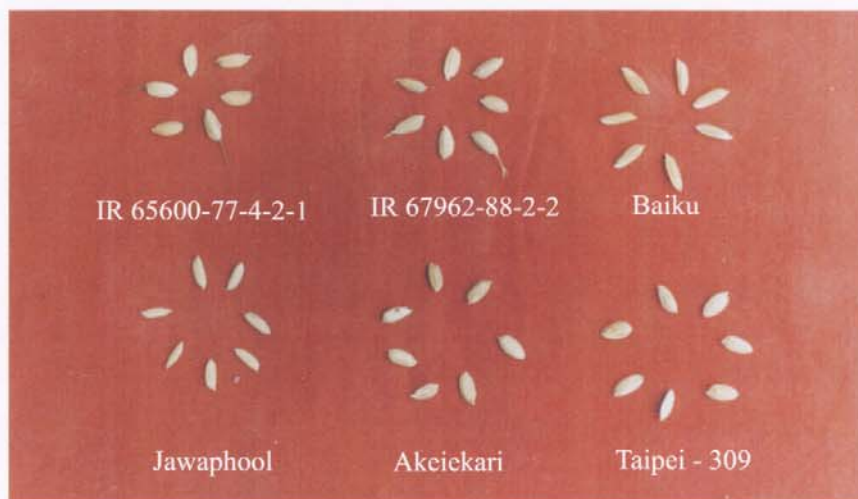


Plate 2 : Variation in seed morphology of *Indica* land races, Tropical *Japonicas* and Temperate *Japonicas*



Plate 5 : Root and shoot development in BPT 5204 (*Indica*)
before and after accelerated ageing

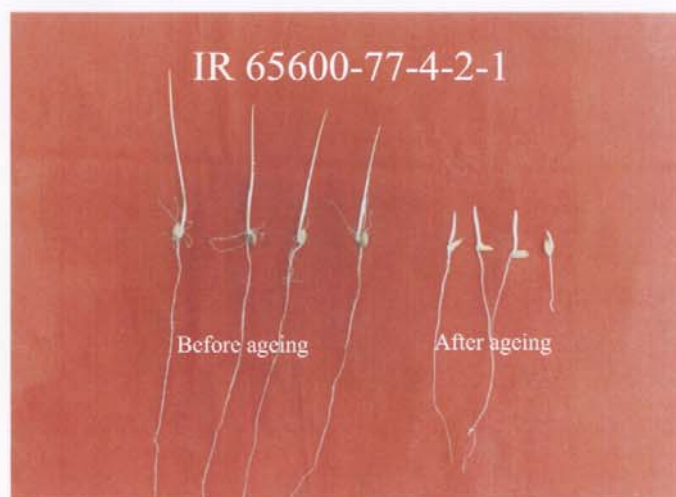


Plate 6 : Root and shoot development in IR 65600-77-4-2-1
(*Tropical Japonica*) before and after accelerated ageing



Plate 1 : Dial microguage

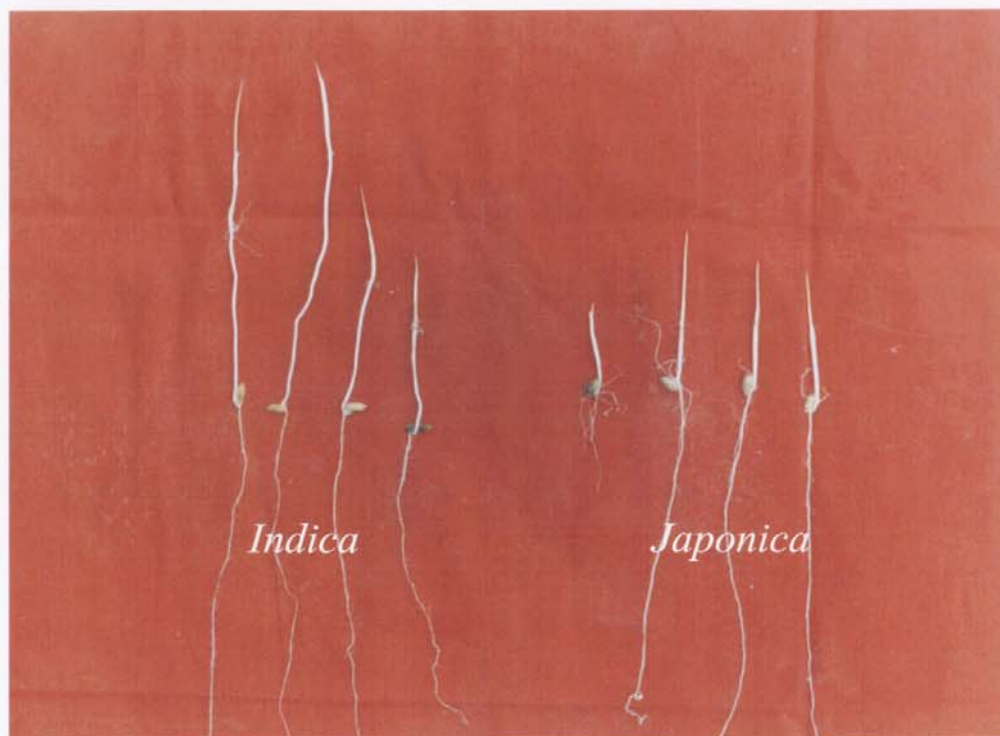


Plate 4 : Seedling differentiation in *Indica* and *Japonica* sub-species

CHAPTER – IV

RESULTS

The results crystallised from the studies on variability for seedling vigour in different sub-species of rice are presented in this chapter.

4.1 Seed morphological characters

The results obtained on morphological characters of seed are presented in Table 1.

4.1.1 Seed length (mm)

Significant differences were observed among the twelve genotypes for seed length. Hybrid seeds were more lengthier than other groups whereas Temperate *japonicas* were shorter.

The hybrid Sahyadri recorded maximum seed length (9.7 mm) followed by DRRH-1 (9.6 mm) and minimum seed length (6.5 mm) was observed in Akeiekari.

The genotypes under study were categorized based on seed length. Three genotypes viz. DRRH-I, Sahyadri and Baiku as long, Surekha as medium, seven genotypes (BPT 5204, Tellahamsa, Swarna, Jawaphool, IR 65600-77-4-2-1, IR 67962-84-2-2 and Taipei-309 as short and Akeiekari as very short.

4.1.2 Seed breadth (mm)

The differences among the genotypes for seed breadth were significant. The genotype BPT 5204 recorded minimum seed breadth (1.98 mm) whereas the genotype Taipei-309 recorded maximum seed breadth (3.62 mm) followed by IR 656000-77-4-2-1 (3.57 mm).

BPT 5204 was categorized as medium, DRRH-1 and Sahyadri as broad and remaining nine genotypes as very broad, based on the results obtained on seed breadth.

4.1.3 L/B ratio

The length breadth (L/B) ratio had shown significant differences among the genotypes. The hybrid Sahyadri recorded high L/B ratio (4.5) followed by another hybrid DRRH-1 (4.4), whereas the genotype Akeiekari exhibited lower L/B ratio (1.95). Temperate *japonicas* showed lower L/B ratios whereas hybrids had higher L/B ratios (Plate 2 and 3).

Based on the L/B ratio, the genotypes were classified as long slender (BPT 5204, Tellahamsa, Surekha, Swarna, DRRH-I, Sahyadri and Baiku) and long bold (Jawaphool, IR 65600-77-4-2-1, IR 67962-84-2-2, Akeiekari and Taipei-309).

4.1.4 Hundred seed weight (g)

Significant differences were observed among the genotypes for hundred seed weight. The genotype Taipei-309 recorded maximum hundred seed weight

(2.56 g) followed by IR 65600-77-4-2-1 (2.55 g) and Surekha (2.54 g). The Genotype BPT 5204 recorded minimum hundred seed weight (1.30 g).

4.1.5 Seed density

The genotypic differences for seed density were significant between the genotypes. The seed density was maximum in the genotype Swarna and Baiku (95.0) followed by Jawaphool (93.7). The minimum seed density (28.33) was in the genotype IR 65600-77-4-2-1. Tropical *japonicas* recorded less seed density while land races had more seed density compared to other groups.

4.2 GERMINATION PER CENT

The results on germination by first count, final count and sand method are furnished in Table 2.

Significant differences were observed for germination among the genotypes at first and final counts and also in sand method. There was an increase in germination in final count over the first count in all genotypes. Such increase was high in DRRH – 1 (6.66%) and very less in genotype BPT 5204 (0.07%).

The genotype BPT 5204 recorded high germination (97.3%) followed by Surekha (96.6%), whereas low germination was recorded by IR 67962-84-2- 2 (41.3%) during first count.

Indica varieties recorded more germination compared to other groups, whereas Tropical *japonicas* had low germination in first as well as final counts.

The genotypes BPT 5204, Surekha and Swarna recorded high germination per cent (98%) while IR 67962-84-2-2 recorded low germination per cent (45.3%) in final count. Germination decreased upto 20% in sand method when compared to final count of between paper method. The decrease was more pronounced in genotypes DRRH-1 and Sahyadri (45.6%) and low in Swarna (5%).

In sand method Swarna recorded maximum germination per cent (93.6%) followed by BPT 5204 (90.6%), whereas Sahyadri recorded minimum germination (23.3%). *Indica* hybrids recorded lower germination while *indica* varieties recorded high germination percentage over other groups.

4.3 FIELD EMERGENCE

All the genotypes showed significant differences in field emergence (Table 2). On an average 61.8% field emergence was recorded by the genotypes which was statistically on par with sand method. Swarna recorded highest field emergence (77.6%) followed by Akeiekari (77.3%) and Baiku (75.6%) while very low field emergence (33.6%) was exhibited by genotype DRRH-1. Among the sub-species Temperate *japonicas* exhibited high field emergence while *indica* hybrids recorded low field emergence.

4.4 RATE OF GERMINATION

Significant differences were observed among the genotypes for all the components of rate of germination. The results are presented in Table 3.

4.4.1 Speed of Germination

Differences in speed of germination between the genotypes were significant. The genotype Surekha recorded high speed of germination (32.65) followed by BPT 5204 (32.05) and DRRH-1 (31.79). On an average Tropical *japonicas* recorded low speed of germination compared to other groups. Among the two Tropical *japonica* genotypes IR 67962-84-2-2 recorded least speed of germination (16.67).

4.4.2 Mean daily germination

Genotypic differences for mean daily germination were significant. *Indica* varieties recorded high mean daily germination whereas, Tropical *japonicas* recorded low mean daily germination compared to other groups. The genotype IR 67962-84-2-2 recorded low mean daily germination (5.6). Swarna recorded high mean daily germination (10.0) followed by Surekha (9.8).

4.4.3 Peak value

Significant differences were observed among the genotypes for peak value. The peak value was highest in *indica* varieties and lowest in Tropical *japonicas*. The genotype Jawaphool recorded highest peak value (23.5) followed by Surekha (20.2). Lowest peak value was recorded in Tropical *japonica* genotypes viz., IR 65600-77-4-2-1 (11.5) and IR 67962-84-2-2 (11.6).

4.4.4 Germination value

The germination value was calculated on the basis of peak value and mean daily germination. Significant differences were found between the genotypes for this trait.

The genotype Jawaphool exhibited high germination value (214.6) followed by Surekha (201.4). Lower germination value was recorded by the genotype IR 67962-84-2-2 (69.1). *Indica* varieties and land races had high germination values compared to other sub-species. low germination values were obtained by Tropical *japonica* genotypes.

4.4.5 Mean germination time

Significant differences were observed among the genotypes for mean germination time. The hybrid DRRH-1 recorded low mean germination time (2.76), whereas high mean germination time was recorded by Taipei-309 (3.86).

4.4.6 Rate of germination

Genotypic differences for rate of germination were found to be significant. The rate of germination was high in hybrids as compared to Tropical *japonicas*.

The rate of germination was maximum in hybrid DRRH-1 (22.18) and minimum in IR 65600-77-4-2-1 (1.12) and Tellahamsa (2.22).

4.4.7 Coefficient of velocity of germination

All the genotypes showed significant differences for coefficient of velocity of germination. The highest and lowest coefficient of velocities of germination were, observed in DRRH-1 (35.9) and Taipei –309 (25.8) respectively.

4.5 SEEDLING GROWTH AND VIGOUR INDEX

The results pertaining to seedling growth and vigour index are presented in Table 4.

4.5.1 Seedling length (cm)

Significant differences were observed among the genotypes for seedling length. The genotype Akeiekari had high seedling length (19.98 cm) followed by Baiku (16.96 cm). Seedling length was low in IR 67962-84-2-2 (8.91 cm). Temperate *japonicas* showed lengthy seedlings when compared with other groups (Plate 4).

4.5.2 Seedling dry weight (g)

There was no significant variation for seedling dry weight among the genotypes; However it was maximum in DRRH-1 (0.24 g) followed by IR 67962-84-2-2 and BPT 5204 (0.23 g). The genotype Jawaphool recorded lowest dry weight (0.12 g).

4.5.3 Vigour index-I

Differences in the vigour index-I among the genotypes were significant. The vigour index-I ranged from 397 to 1657.

The genotype Surekha recorded maximum vigour index-I (1657) followed by Baiku (1629) which were significantly superior to all the genotypes except IR 65600-77-4-2-1 and IR 67962-84-2-2. The vigour index-1 was minimum in the genotype IR 67962-84-2-2 (397). Both the Tropical *japonica* genotypes were found to record low vigour index-I.

4.5.4 Vigour index –II

The vigour index-II based on seedling dry weight had shown significant differences among the genotypes.

High vigour index-II was observed in *indica* varieties followed by Temperate *japonicas*. Maximum vigour index-II (22) was found in BPT 5204 followed by Surekha and Swarna (20). Whereas, minimum vigour index-II was recorded by Sahyadri and IR 67962-84-2-2 (10).

4.6 PHYSIOLOGICAL AND BIOCHEMICAL TESTS

The results of physiological and biochemical tests conducted on fresh seed as well as ten days accelerated aged seeds are reported in table 5.

4.6.1 Electrical conductivity of seed leachates (μ mhos cm^{-2})

The differences among the genotypes for electrical conductivity before and after accelerated ageing were significant.

The electrical conductivity was more in acceleratedly aged seed lots over fresh lot. Such impact was high in hybrids than in remaining genotypes. The Tropical *japonicas* exhibited high electrical conductivity values both in fresh and accelerated aged seeds compared to other groups where as *indica* varieties and hybrids recorded low conductance.

Maximum and minimum electrical conductivity of seed leachates was observed in IR 67962-84-2-2 and BPT 5204 in both fresh and aged seed lots.

4.6.2 Dehydrogenase activity

Significant differences were observed among the genotypes for dehydrogenase activity both before and after accelerated ageing.

The seeds after accelerated ageing had lower dehydrogenase activity compared to fresh seed. Such decrease was not uniform in all genotypes. The decline in dehydrogenase activity over control due to accelerated ageing was high in DRRH-1 followed by IR 67962-84-2-2, while IR 65600-77-4-2-1 had shown less decrease of dehydrogenase activity. However in case of Surekha, Sahyadri and Taipei-309 aged seeds recorded slightly higher dehydrogenase activity than fresh seed.

The dehydrogenase activity in both fresh and aged seeds was high in Tropical *japonicas* and low in *indica* varieties.

4.6.3 Peroxidase activity

The differences among the genotypes for peroxidase enzyme activity were significant before and after accelerated ageing.

Before accelerated ageing the genotype DRRH-1 recorded more peroxidase activity (0.48) followed by Sahyadri (0.46) and BPT 5204 (0.45). The genotype Akeiekari (0.17) exhibited less peroxidase activity.

High peroxidase activity was recorded in the genotype Swarna (0.43) whereas low peroxidase activity was recorded in Sahyadri (0.25) after accelerated ageing.

Peroxidase activity decreased with accelerated ageing of the seed in several genotypes. However in certain genotypes such trend was not observed. *Indica* land races Tropical *japonicas* and Temperate *japonicas* registered increased peroxidase activity with ageing, whereas *indica* varieties and hybrids responded vice versa, (except Swarna).

Peroxidase activity was more in *indica* varieties and hybrids and low in Temperate *japonicas* and Tropical *japonicas* in both fresh and aged seeds.

4.6.4 α – amylase activity

Significant differences were observed among the genotypes in both fresh and aged seeds for α - amylase activity in seed.

Tropical *japonicas* and Temperate *japonicas* recorded high α - amylase activity in fresh and aged seed. The genotype IR 67962-84-2-2 recorded maximum α - amylase activity both in fresh (82.5) and aged (80.4) seed. Least α - amylase activity was noticed in genotype Tellahamsa both in fresh (68.76) and aged (63.60) seeds.

There was a general decrease in α - amylase activity (2.25) in aged seed compared to fresh seed. The decrease was more in Tellahamsa, DRRH-1 (5.1) and less in Baiku, Jawaphool and Akeiekari (1.0).

4.6.5 Phosphorus fractions

The results of phosphorus fractions before and after accelerated ageing are furnished in table 6. Significant differences were not observed among the genotypes and ageing treatments for phosphorus fractions except phosphoproteinpeptide phosphorus in aged seed.

4.6.5.1 Acid soluble phosphorus

There was an increase in acid soluble phosphorus in aged seeds over fresh seed. Such increase was not uniform in some genotypes. The genotypes Jawaphool and Akeiekari had decreased phosphorus contents with ageing. However, the increase was more in the genotype Surekha (52.4 $\mu\text{g g}^{-1}$) and less in the genotype Sahyadri (0.5 $\mu\text{g g}^{-1}$).

Among the fresh seed lots, Jawaphool recorded high acid soluble phosphorus (10.3 $\mu\text{g g}^{-1}$) followed by IR 65600-77-4-2-1 (9.2 $\mu\text{g g}^{-1}$), whereas

low acid soluble phosphorus content was recorded by Surekha ($4.3 \mu\text{g g}^{-1}$). In aged seeds maximum acid soluble phosphorus was recorded by the genotype Surekha ($56.7 \mu\text{g g}^{-1}$), whereas low acid soluble phosphorus content was recorded by Sahyadri ($7.7 \mu\text{g g}^{-1}$).

4.6.5.2 Phospholipid phosphorus ($\mu\text{g g}^{-1}$)

The fresh seed of Swarna recorded maximum phospholipid phosphorus ($13.7 \mu\text{g g}^{-1}$) followed by DRRH-1 ($9.7 \mu\text{g g}^{-1}$) where as low phospholipid phosphorus was recorded by Tellahamsa ($4.7 \mu\text{g g}^{-1}$). In case of aged seed the genotype Taipei-309 ($21.8 \mu\text{g g}^{-1}$) followed by Sahyadri ($16.2 \mu\text{g g}^{-1}$) recorded maximum while DRRH-1 ($2.0 \mu\text{g g}^{-1}$) recorded minimum phospholipid phosphorus content.

4.6.5.3 RNA phosphorus ($\mu\text{g g}^{-1}$)

The genotype BPT 5204 recorded maximum RNA-phosphorus ($30.2 \mu\text{g g}^{-1}$) followed by Surekha ($11.7 \mu\text{g g}^{-1}$) whereas minimum RNA phosphorus was recorded in Taipei-309 ($11.5 \mu\text{g g}^{-1}$) in fresh seed.

In general there was an overall increase of $0.9 \mu\text{g g}^{-1}$ RNA phosphorus in aged seed over fresh seed, but the increase was not consistent among the genotypes. In aged seed the genotypes Sahyadri and Akeiekari recorded maximum RNA phosphorus ($28.5 \mu\text{g g}^{-1}$) Tellahamsa recorded minimum RNA phosphorus ($13.7 \mu\text{g g}^{-1}$).

4.6.5.4 DNA – phosphorus (mg g^{-1})

The genotype DRRH-1 recorded higher DNA phosphorus ($23.2 \mu\text{g g}^{-1}$) followed by Taipei – 309 ($18.5 \mu\text{g g}^{-1}$) where as low DNA phosphorus was recorded in Surekha ($0.5 \mu\text{g g}^{-1}$) in fresh seed. In case of aged seed the genotype IR 67962-84-2-2 recorded higher DNA phosphorus ($1.8 \mu\text{g g}^{-1}$) followed by Taipei-309 ($9.8 \mu\text{g g}^{-1}$) and low DNA phosphorus content was recorded in Baiku ($4.6 \mu\text{g g}^{-1}$) and BPT 5204 (4.8).

Temperate *japonicas* recorded maximum DNA phosphorus compared to other sub-species both in fresh and aged treatments.

4.6.5.5 Phosphoproteinpeptide phosphorus ($\mu\text{g g}^{-1}$)

Significant differences were observed among the genotypes for phosphoproteinpeptide phosphorus in aged seed, while in fresh seed the differences were not significant.

The phosphoproteinpeptide seed phosphorus content decreased on an average up to $10.8 \mu\text{g g}^{-1}$ with ageing. The decrease was more in the genotype Taipei – 309 and low in Baiku. Surekha was the only genotype in which the phosphoproteinpeptide phosphorus increased with ageing.

The genotype Taipei-309 recorded maximum ($32.2 \mu\text{g g}^{-1}$) followed by IR 67962-84-2-2 ($31.8 \mu\text{g g}^{-1}$) and genotype Baiku recorded minimum ($13.5 \mu\text{g g}^{-1}$) phosphoproteinpeptide phosphorus in fresh seed. In case of aged seed the genotype Swarna recorded maximum ($17.5 \mu\text{g g}^{-1}$) followed by Tellahamsa and

Surekha ($1.7 \mu\text{g g}^{-1}$) and the genotype Sahyadri recorded minimum phosphoproteinpeptide phosphorus ($0.8 \mu\text{g g}^{-1}$).

4.6.5.6 Total –phosphorus content of seed

There was decrease in total phosphorus in aged seeds compared to fresh seed. Such decrease was not uniform in all the genotypes. The total phosphorus was high in the genotype DRRH-1 ($96.0 \mu\text{g g}^{-1}$) followed by Swarna ($80 \mu\text{g g}^{-1}$). Whereas, low in the genotype Surekha ($40 \mu\text{g g}^{-1}$) in fresh seeds. In case of aged seed the genotype Surekha and Swarna recorded higher total phosphorus contents ($100 \mu\text{g g}^{-1}$) while lower total P content was recorded in the genotype BPT 5204 ($50 \mu\text{g g}^{-1}$).

4.7 GENETIC VARIABILITY

The estimates of phenotypic coefficient of variation (PCV), genotypic coefficient of variation (GCV), heritability in broad sense (h^2), genetic advance as percentage of mean (GA as per cent of mean) are presented in table 7.

4.7.1 Seed length

Seed length exhibited a great deal of variability among all the rice genotypes. It ranged from 6.53 mm – 9.78 mm with a mean of 8.12 mm. Low estimates of GCV (12.9), PCV (14.1) with high heritability (83.7) and low genetic advance as per cent of mean (23.8) were recorded for this trait.

4.7.2 Seed breadth

Seed breadth ranged from 1.98-3.62 mm among the genotypes with a mean of 2.72 mm. The estimates of PCV (21.74), GCV (19.32) were moderate with high heritability (78.9) coupled with moderate genetic advance (34.7) as per cent of mean for seed breadth.

4.7.3 L/B ratio

The L/B ratio varied among the genotypes with a range of 1.95-4.5 and a mean of 3.13. Moderate estimates of GCV (26.79) and PCV (28.39), high heritability (88.5) coupled with high genetic advance as per cent of mean (50.7) were registered for this L/B ratio.

4.7.4 100 seed weight (g)

100 seed weight had a mean of 2.17 g ranging from 1.3-2.55. The GCV and PCV estimates were moderate (26.17 and 25.72 respectively) with high heritability (96.4) and high genetic advance (50.9).

4.7.5 Seed density

Seed density ranging from 28-95 was recorded with a mean of 78.4. Moderate estimates of PCV (25.7) and GCV (26.1) and high heritability (96.4) coupled with high genetic advance were recorded for this trait.

4.7.6 Germination (%)

The final count of germination conducted by between paper method ranged from 45% - 98% with a mean of 82%. The estimates of PCV and GCV were moderate (15.98 and 16.19 respectively) with high heritability (97) and moderate genetic advance (31.84). The germination in sand method had a mean of 62% with a range of 23-93%. Moderate estimates of GCV (26.72) and PCV (26.98) and high heritability (98) coupled with high genetic advance as per cent of mean (53.69) were recorded for this trait.

4.7.7 Field emergence

Field emergence ranged from 33-77% with a mean of 61.86%. Low GCV (14.83) and moderate PCV (16.79) with high heritability (77) with low genetic advance (26.44) were recorded.

4.7.8 Speed of germination

The speed of germination had recorded a mean of 26.97 ranging from 16.67-32.34 among the genotypes. The estimates of PCV and GCV were moderate (21.24 and 19.16 respectively), while heritability was high (81) and genetic advance was moderate (34.89) for this component.

4.7.9 Mean daily germination

Mean daily germination exhibited a mean range of 5.6-10.03, with a general mean of 8.53. Low GCV (13.52), moderate PCV (15.94) were observed,

while heritability in broad sense was high (71) with moderate genetic advance as per cent of mean (23.09) for mean daily germination.

4.7.10 Peak value

Among the genotypes peak value had a mean of 16.14 ranging from 11.5-23.5. Moderate estimates of GCV (23.69), PCV (25.43) and high heritability (86) with high genetic advance as per cent of mean were noticed for this trait.

4.7.11 Germination value

The germination value ranged from 69.16 – 214.6 with a mean of 135.14. The estimates of PCV and GCV were high (42.44 and 33.27 respectively) with high heritability (61) coupled with high genetic advance as per cent of mean (52.7).

4.7.12 Mean germination time

The mean germination time ranged from 2.7-3.86 with an average of 3.30 among the genotypes. Low estimates of PCV (10.96) and GCV (6.49), moderate heritability (35) and low genetic advance were recorded for this component.

4.7.13 Rate of germination

Rate of germination of twelve genotypes under study ranged from 1.12-22.18% with a mean of 9.59. High PCV (70.53) and GCV (68.99), high heritability (95) and high genetic advance as per cent of mean (136) estimates were observed for rate of germination.

4.7.14 Coefficient of velocity of germination

Coefficient of velocity of germination ranged from 25.86-35.96 with a mean of 30.88. Low estimates of PCV (10.87) and GCV (6.06) with moderate heritability (31) and low genetic advance as per cent of mean were noticed.

4.7.15 Seedling length

Seedling length ranged from 8-19 cm with an average of 14.37cm. The estimates of PCV (25.75), GCV (16.20) and heritability (39) were moderate while genetic advance as per cent of mean (20.6) was low for this trait.

4.7.16 Vigour index – I

Among the twelve genotypes studied, the vigour index-I ranged from 397-1657 with a mean of 1205. Moderate GCV (27.97), high PCV (34.73), high heritability (64) and moderate genetic advance as per cent mean (45.47) were recorded for vigour index – I.

4.7.17 Vigour index-II

Vigour index II ranged from 10.2-22.9 with a mean of 16. High estimate of PCV (31.6) and moderate GCV (23.7) were recorded while moderate heritability (55) and genetic advance as per cent of mean (36.12) were observed for this trait.

4.7.18 Electrical conductivity

The electrical conductivity of seed leachates of rice genotypes ranged from 70.3-214.6 with a mean of 101.61 μ mhos. cm^{-2} . GCV and PCV estimates were

high (38.8 and 42.5 respectively) with high heritability (83) coupled with high genetic advance as per cent of mean.

4.7.19 Dehydrogenase activity

Dehydrogenase activity exhibited a mean of 0.23, ranging from 0.09 - 0.64 among the genotypes. High PCV (69.51) and GCV (67.48) with high heritability (94) and high genetic advance as per cent of mean (129) estimates were observed.

4.7.20 Peroxidase activity

The peroxidase activity in seeds ranged from 0.17-0.48 with a mean of 0.35. Moderate estimates of GCV (27.9) and PCV (29.8) with high heritability (0.87) and low genetic advance as per cent of mean (2.8) were noticed for peroxidase activity.

4.7.21 α -amylase activity

α -amylase activity, in the genotypes ranged from 68.8-82.5, with a mean of 78.51. The estimates of PCV (4.79) and GCV (4.45) were low, while heritability was high (86) and genetic advance as per cent of mean was low (8.36) for this trait.

4.9 STRESS TESTS

4.9.1. Salinity stress test

Salinity stress significantly influenced the germination among the genotypes, treatments and their interactions (Table 8). In general, the germination

decreased with the increase in salt concentration and the reduction was drastic with increase in salt concentration from 1% to 1.5%.

The *indica* varieties and land races were comparatively less affected by salinity, and germination ranging from 2.7% to 19% even at higher level of salt concentration (1.5%). The *indica* hybrid Sahyadri failed to germinate even at 1% salinity concentration.

The genotype BPT 5204 recorded higher germination (19.3%) even at 1.5% concentration. The *indica* land races Baiku and Jawaphool were tolerant to salinity stress recording 16% and 12% germination respectively at higher salt concentration (1.5%).

4.9.2. Moisture stress test

Significant differences were observed among the genotypes, treatments and their interactions in relation to seed germinability under moisture stress induced by Poly Ethylene Glycol concentrations.

PEG affected the germination of all genotypes particularly at higher concentration (PEG –9 bars). Such decline in germination due to PEG varied with genotypes. Progressive decrease in germination with increasing PEG concentration was noticed. However, this decline was found to be rapid when induced moisture stress increased from –6 bars to –9 bars in all genotypes.

The affect of moisture stress treatment (PEG) was least on *indica* varieties BPT 5204, Tellahamsa, Surekha and Swarna, land races, (Baiku and Jawaphool)

as evidenced by high germination over other genotypes. It was found to be high in Tropical *japonicas* and Temperate *japonicas*.

Among the genotypes Swarna was least affected by moisture stress as evidenced by its high germination potential (89.7%) even at –9 bar PEG concentration (Table 9). Taipei-309 a Temperate *japonica* genotype was noted to be highly susceptible to moisture stress as it had no germinability even at –6 bar. Both the Tropical *japonicas* were also highly affected by moisture stress by retaining germinability upto –6 bars only.

4.9.3. Anaerobic germination test

The results pertaining to anaerobic germination test are presented in Table 10. Significant differences were observed among the genotypes, treatments and their interactions for germination under anaerobic situation.

There was an increase in germinability from 5th day to 8th day. The mean increase was 19.4% but it was not uniform in all the genotypes. *Indica* land races recorded higher increase in germination compared to other groups. In both the counts, germination was high in the genotype BPT 5204 (91.7% and 98.3% respectively), while it was low in Sahyadri (6.7 and 13.3) and IR 67962-84-2-2 (6.7 and 23.3).

Indica varieties and land races were found to be tolerant to anaerobic stress condition where as *indica* hybrids, Tropical *japonicas* and Temperate *japonica* (Akeiekari) were susceptible to anaerobic stress.

4.9.4. Accelerated ageing stress test

Significant differences were observed between genotypes, treatments and their interactions for germination and seedling growth parameters after accelerated ageing. The results are presented in detail below.

4.9.4.1 Germination (%)

There was a gradual decrease in germination per cent with increasing duration of accelerated ageing (Table 11). The decrease was high in Tellahamsa and low in Jawaphool.

Among the genotypes, germination was maximum in Swarna (86%) followed by Surekha (85.5%), while minimum in Sahyadri (11.5%).

Indica varieties except Tellahamsa and land races recorded higher germinability even in 10 days accelerated ageing treatment. Decline of germination due to accelerated ageing was very high in hybrids and Tropical *japonicas* as compared to other genotypes. Moderate decline of germination was observed in Temperate *japonicas* recording mean germination of 36.6% and 26.6% even at ten days ageing treatment.

4.9.4.2 Seedling length (cm)

The result pertaining to seedling length after accelerated ageing is furnished in table 12. The seedling length decreased with increasing duration of ageing. The decrease was more in Baiku and Jawaphool belonging to *indica* land races, whereas less in Temperate *japonicas* (Plate 5 and 6).

Among the genotypes seedling length was high in Surekha (18.7 cm) while low in Taipei-309 (10.16 cm).

Tropical *Japonicas*, Baiku and Surekha were found to be least susceptible to accelerated ageing as there was less decrease in seedling length, while other groups were susceptible.

4.9.4.3 Seedling dry weight (g)

There was a gradual decrease of seedling dry weight with increase in duration of accelerated ageing. The dry weight decreased to 5.6 mg from 16.8 mg after ten days of accelerated ageing (Table 13). The decrease was maximum in genotype Swarna (10.7 mg) followed by BPT 5204 (14.7 mg), and minimum in Surekha (5 mg).

Indica varieties except Swarna and Tropical and Temperate *japonica* seeds were least susceptible to accelerated ageing, while *indica* land races and hybrids were more susceptible based on their mean dry weight values.

4.9.4.4 Vigour index I

Progressive reduction in the vigour index was observed with the increase in the duration of accelerated ageing in all the genotypes. Such decrease was low in the Temperate *japonicas* and high in Tellahamsa.

Among the genotypes vigour index was high in Surekha (1639) and BPT 5204 (1242) whereas low in Sahyadri (161) (Table 14).

4.9.4.5 Vigour index II

The results pertaining to vigour index II are presented in Table 15. The vigour index II decreased gradually with the increase in accelerated ageing period. The same trend was followed in all the genotypes. Among the genotypes Surekha recorded high seedling vigour index II (12.6) followed by BPT 5204 (11.1), while minimum vigour index II was observed in Sahyadri (1).

4.8 CORRELATION STUDIES

4.8.1 Simple correlation coefficients among rate of germination components with seed germinability, field emergence and vigour index

The results of correlation studies of seed germination in different methods, field emergence and rate of germination components are presented in Table 16.

4.8.1.1 Speed of germination

Speed of germination had a significant, positive correlation with final count (0.828**), seedling vigour index (0.772**), mean daily germination (0.932**) and germination value (0.807**).

4.8.1.2 Mean daily germination

Mean daily germination also had a significant positive correlations with germination (0.958**), seedling vigour index II (0.866**) and germination value (0.826**).

4.8.1.3 Germination value

Germination value had positive, significant correlation with germination (0.798**) only, whereas rate of germination had significant positive correlation with seedling dry weight and coefficient of velocity of germination.

4.8.1.4 Mean germination time

Mean germination time had significant negative correlation with coefficient of velocity of germination (-0.910**).

4.8.1.5 Germination (%)

Final count of germination had significant positive correlation with seedling vigour index – II (0.892**) and field emergence (0.650**), whereas seedling vigour index had significant positive correlation with field emergence (0.612*).

4.8.2 Correlation coefficients among biochemical traits and germinability and vigour index

The results of correlation coefficients among biochemical traits with seed germinability and vigour index are presented in Table 17.

4.8.2.1 Seed germination (%)

The final count of germination had positive and significant correlation with vigour index I (0.89**) and field emergence (0.65**); positive, but not significant correlation with dry weight, seed density, peroxidase activity, phospholipid phosphorus, RNA phosphorus. Negative correlation was recorded

with electrical conductivity, Dehydrogenase activity, α - amylase activity, acid soluble phosphorus, DNA phosphorus and phosphoproteinpeptide phosphorus.

4.8.2.2 Seedling vigour index – II

Significant and positive correlation with field emergence (0.61*); positive non-significant correlation with seed density, peroxidase activity, phospholipid phosphorus, RNA phosphorus and DNA phosphorus. Whereas negative and non-significant correlation with electrical conductivity, dehydrogenase activity, α - amylase activity, acid soluble phosphorus and phosphoprotein peptide phosphorus.

4.8.2.3 Seed density

This trait recorded significant and negative correlation with electrical conductivity (-0.6*) and dehydrogenase activity (-0.8**), while it exhibited non-significant association with other characters.

4.8.2.4 Field emergence

Field emergence exhibited positive correlation with electrical conductivity, α – amylase activity, phospholipid phosphorus whereas negative and non-significant correlation with dehydrogenase activity, peroxidase activity, acid soluble phosphorus, RNA phosphorus, DNA phosphorus and phosphoproteinpeptide phosphorus.

4.8.2.5 Electrical conductivity

It had a significant and positive correlation with dehydrogenase activity (0.879**). It was positively correlated with α - amylase activity, acid soluble phosphorus and DNA phosphorus. Negative correlation was recorded with peroxidase activity, phospholipid Phosphorus and RNA phosphorus.

4.8.2.6 Dehydrogenase activity

It was negatively correlated with peroxidase activity and phospholipid phosphorus and positively correlated with α - amylase activity, acid soluble phosphorus, RNA-phosphorus, DNA phosphorus and phosphoproteinpeptide phosphorus.

4.8.2.7 Peroxidase activity

Peroxidase activity had negative and non significant correlation with α - amylase activity, acid soluble phosphorus, DNA phosphorus and phosphoproteinpeptide phosphorus, positive correlation with phospholipid phosphorus and RNA phosphorus.

4.8.2.8 α – amylase activity

This trait registered positive correlation with acid soluble phosphorus, phospholipid phosphorus, DNA phosphorus and phosphorproteinpeptide phosphorus whereas negative correlation with RNA phosphorus.

4.8.2.9 Acid soluble phosphorus

It showed negative correlation with phospholipid phosphorus and RNA phosphorus and positive correlation with DNA phosphorus and phosphoproteinpeptide phosphorus.

4.8.2.10 Phospholipid phosphorus

Phospholipid phosphorus exhibited positive correlations with RNA phosphorus, DNA phosphorus and phosphoproteinpeptide phosphorus.

4.8.2.11 RNA phosphorus

It had positive correlation with DNA phosphorus (0.361) and phosphoproteinpeptide phosphorus.

4.8.2.12 DNA phosphorus

It had positive correlation with phosphoproteinpeptide phosphorus.

4.8.3 Correlation among stress tests with field emergence and vigour index

The correlation coefficients worked out among various stress tests and field emergence are presented in Table 18.

4.8.4 Seed germination

The seed germination in between paper method (first count) had a significant and positive correlation with germination under moisture stress at -6 bar (0.70**) salinity stress test at all concentrations of 0.5% (0.70**), 1.0% (0.648**), 1.5% (0.597**), Anaerobic germination on 5th day (0.731**) and on 8th

day (0.844**). The final count recorded a significant positive correlations with germination in -6 bar PEG concentration (0.686*), salinity stress concentration 0.5% (0.678*), 1.0% (0.624*), 1.5% (0.574*) and anaerobic germination on 5th day (0.703*) and 8th day (0.82**).

4.8.5 Vigour index

Vigour index recorded a significant and positive correlation with germination under moisture stress (-6 bar) (0.637*), germination in salinity stress (0.559*), (0.566*) at 1.0% and 1.5%, respectively and anaerobic germination on 5th day (0.683*) and on 8th day (0.677**).

4.8.6 Field emergence

Field emergence had a positive and significant correlation with anaerobic germination on 8th day (0.594*), whereas it recorded positive non-significant correlations with other stress tests.

4.8.7 Germination under moisture stress (-6 bar)

This test had a highly significant and positive correlations with salinity stress test (0.965**, 0.886** and 0.766**) and anaerobic germination on 5th day (0.723**) and 8th day (0.757**).

4.8.8 Salinity stress (0.5 %)

It had a highly significant and positive correlation with salinity stress at 1.0% (0.922**) 1.5% (0.769**), anaerobic germination on 5th day (0.7*) and on 8th day (0.786**).

4.8.9 Salinity stress (1.0%)

It had a highly significant positive correlation with salinity stress at 1.5% (0.618*), anaerobic germination on 5th day (0.68*) and 8th day (0.739*).

4.8.10 Salinity stress (1.5%)

Salinity stress had a significant positive correlation with anaerobic germination on 5th day (0.628*) and on 8th day (0.628*).

4.8.11 Anaerobic germination on 5th day

Significant positive correlation with the anaerobic germination on 8th day (0.931*).

Table 2: Mean values of germination and field emergence of rice genotypes

Genotypes	Between paper method		Sand method	Field emergence
	First count(%)	Final count(%)		
BPT 5204	97.3 (81.07)	98 (82.05)	90.6 (72.37)	74.3 (60.12)
TELLAHAMSA	82.6 (65.41)	86.0 (68.04)	60.66 (51.17)	49.33 (44.62)
SUREKHA	96.6 (79.66)	98.3 (82.67)	82.66 (65.43)	77.6 (62.09)
SWARNA	94.6 (96.6)	98.3 (82.85)	93.6 (75.66)	74.66 (60.01)
DRRH 1	69.00 (66.18)	75.66 (60.52)	30.00 (33.20)	33.66 (35.41)
SAHYADRI	65.00 (53.74)	67.66 (55.38)	23.33 (28.80)	35.66 (36.44)
BAIKU	93.67 (75.49)	96.33 (79.14)	82.33 (65.24)	75.66 (60.50)
JAWAPHOOL	84.33 (66.71)	88.66 (70.40)	61.66 (51.76)	57.33 (49.24)
IR 65600-77-4-2-1	66.67 (54.74)	69.66 (56.60)	36.33 (37.06)	61.00 (51.38)
IR 67962-84-2-2	41.33 (40.01)	45.33 (42.32)	29.33 (32.77)	56.00 (48.45)
AKEIEKARI	66.00 (54.35)	72.33 (58.37)	75.33 (60.25)	77.33 (62.13)
TAIPEI-309	89.66 (71.31)	94.33 (76.37)	85.66 (67.80)	69.66 (56.60)
MEAN	78.91 (64.61)	82.55 (67.88)	62.63 (53.45)	61.86 (52.26)
S.Em	1.100	1.250	1.350	2.816
CD(0.01)	4.354	4.945	5.340	11.139

*Figures in the parenthesis indicate transformed values

Table 4:Mean values of seedling traits in rice genotype

Genotypes	Seedling Length(cm)	Seedling Dry weight (g)	Vigour Index-I	Vigour Index-II
BPT 5204	13.37	0.23	1310	22
Tellahamsa	11.74	0.19	1007	15
Surekha	16.85	0.21	1657	20
Swarna	15.26	0.20	1500	20
DRRH-1	15.24	0.24	1158	17
Sahyadri	13.08	0.15	885	10
Baiku	16.96	0.20	1629	19
Jawaphool	12.72	0.12	1123	11
IR 65600-77-4-2-1	13.20	0.20	918	14
IR 67962-84-2-2	8.91	0.23	397	10
Akeiekari	19.98	0.19	1445	14
Taipei-309	15.13	0.19	1429	18
Mean	14.37	0.198	1205	16
S.Em.	1.660	0.024	143.23	1.96
C.D (0.01)	6.569	NS	566.66	7.75

Table 10 :Effect of anaerobic stress on seed germination(%) in rice genotypes

Genotypes	Germination(%) on 5 th day	Germination(%) on 8 th day	Mean
BPT 5204	91.7	98.3	95
Tellahamsa	41.6	65.0	53.3
Surekha	73.7	91.7	55
Swarna	30.0	60.0	45
DRRH 1	16.7	25.0	20.8
Sahyadri	6.7	13.3	10.0
Baiku	38.3	63.3	50.8
Jawaphool	41.7	78.3	60.0
IR 65600-77-4-2-1	25.0	43.3	34.15
IR 67962-84-2-2	6.7	23.3	15.0
Akeiekari	18.3	23.3	23.3
Taipei-309	36.7	68.3	52.5
MEAN	35.5	54.9	45.2

Source	S.Em.	C.D (0.01)
Genotypes (G)	3.682	7.747
Treatments (T)	1.576	3.162
Interaction (GxT)	5.461	10.956

Table 9 :Effect of moisture stress on seed germination(%) in rice genotypes

Genotypes	T₀	T₁	T₂	Mean
BPT 5204	98	97.7	11.3	69.0
Tellahamsa	78	84.0	27.0	63.1
Surekha	97.7	88.7	2.3	62.9
Swarna	94.3	93.3	89.7	92.4
DRRH 1	24.7	24.3	16.3	21.7
Sahyadri	23.6	22.0	13.3	19.6
Baiku	89.6	76.0	64.6	76.7
Jawaphool	81.0	68.6	58.3	69.3
IR 65600-77-4-2-1	15.3	1.6	0.0	5.6
IR 67962-84-2-2	25.7	18.6	0.0	14.7
Akeiekari	52.6	4.0	1.3	19.3
Taipei-309	29.7	0.0	0.0	9.9
MEAN	59.19	48.27	24.65	44.0

Source	S.Em.	C.D (0.01)
Genotypes (G)	1.786	3.50
Treatments (T)	0.893	1.75
Interaction (GxT)	3.093	6.06

T₀: Control T₁: -6 bar PEG T₂: -9 bar PEG

Table 1:Mean values of seed morphological traits in rice genotypes

Genotypes	Seed length(mm)	Seed Breadth(mm)	L/B Ratio	Hundred Seed weight(g)	Seed density
BPT 5204	7.19	1.98	3.63	1.30	92.66
Tellahamsa	8.65	2.40	3.6	2.3	83.33
Surekha	9.30	2.50	3.58	2.54	87.33
Swarna	7.29	3.90	3.05	1.74	95.00
DRRH 1	9.60	2.18	4.40	1.91	74.66
Sahyadri	9.78	2.17	4.50	2.17	77.33
Baiku	9.02	2.83	3.18	2.36	95.00
Jawaphool	7.85	2.89	2.80	1.70	93.66
IR 65600-77-4-2-1	7.55	3.57	2.12	2.55	28.33
IR67962-84-2-2	7.46	2.74	2.77	2.45	49.00
Akeiekari	6.53	3.35	1.93	2.41	85.33
Taipei-309	7.28	3.62	2.02	2.56	79.33
Mean	8.12	2.72	3.13	2.17	78.41
S.Em.	0.268	0.157	0.1739	0.0313	2.192
C.D(0.01)	1.0603	0.621	0.687	0.1238	8.671

Table 5: Mean values of physiological and biochemical tests of rice genotypes

GENOTYPES	Accelerated Ageing treatments (days)	Electrical Conductivity (μ mohs cm^{-2})	Dehydrogenase activity	Peroxidase activity	α-amylase activityg^{-1} tissue
BPT 5204	0	68.33	0.099	0.45	78.56
	10	73.33	0.05	0.376	76.71
Tellahamsa	0	88.33	0.179	0.37	68.76
	10	83.67	0.093	0.302	63.60
Surekha	0	78.66	0.100	0.43	78.30
	10	88.00	0.183	0.408	76.40
Swarna	0	98.67	0.206	0.42	78.23
	10	96.33	0.152	0.438	76.00
DRRH 1	0	70.33	0.257	0.48	77.80
	10	91.67	0.147	0.342	71.86
Sahyadri	0	73.33	0.187	0.46	78.66
	10	93.33	0.313	0.252	76.56
Baiku	0	107.67	0.190	0.35	77.40
	10	100.67	0.150	0.426	76.16
Jawaphool	0	100.67	0.196	0.37	77.36
	10	95.33	0.087	0.38	76.53
IR 65600-77-4-2-1	0	129.33	0.443	0.25	81.60
	10	138.33	0.410	0.344	80.70
IR 67962-84-2-2	0	214.66	0.646	0.24	82.53
	10	162.67	0.447	0.376	80.43
Akeiekari	0	71.66	0.140	0.17	80.90
	10	79.00	0.072	0.335	79.86
Taipei-309	0	117.33	0.143	0.26	82.00
	10	129.67	0.185	0.271	80.30
Mean	0	101.61	0.23	0.351	78.51
	10	103.00	0.190	0.354	76.26
S.Em.	0	10.176	0.0224	0.0216	0.795
	10	3.194	0.0402	0.025	1.0156
C.D(0.01)	0	40.252	0.0885	0.0856	3.146
	10	12.635	0.1590	0.0994	4.017

Table 6:Mean values of Phosphorus fractions in rice genotypes($\mu\text{g g}^{-1}$ of seed)

Genotypes	Accelerated Ageing Treatment (days)	Acid Soluble-P	Phospho-Lipid-P	RNA-P	DNA-P	Phospho protein peptide-P	Total P
BPT 5204	0	6.7	6.0	30.2	9.7	30.0	85.0
	10	9.8	4.3	18.0	4.8	14.8	51.8
Tellahamsa	0	7.5	4.7	20.2	7.0	27.8	67.2
	10	9.7	6.5	13.7	6.1	17.0	53.0
Surekha	0	4.3	8.7	11.7	5.0	14.7	44.3
	10	56.7	4.7	19.2	6.8	17.0	104.4
Swarna	0	6.5	13.7	28.3	13.8	23.5	85.8
	10	48.2	6.8	22.0	8.0	17.5	102.5
DRRH 1	0	7.3	9.7	28.2	23.2	27.8	96.2
	10	11.3	2.0	23.0	9.0	11.8	57.2
Sahyadri	0	7.2	8.2	19.3	12.2	20.8	67.7
	10	7.7	16.2	28.5	8.7	8.8	69.8
Baiku	0	5.8	5.7	22.0	14.5	13.5	61.5
	10	9.3	9.8	21.0	4.6	10.7	55.4
Jawaphool	0	10.3	6.6	3.3	7.7	22.3	60.2
	10	9.7	5.7	23.8	9.0	17.2	65.3
IR 65600-77-4-2-1	0	9.2	5.3	17.2	11.5	22.3	65.0
	10	10.0	15.8	21.8	6.7	12.2	66.0
IR 67962-84-2-2	0	7.5	8.2	21.2	16.2	31.8	84.0
	10	15	5.1	21.0	18	14.9	73.0
Akeiekari	0	8.5	7.3	24.7	14.8	29.7	85.0
	10	8.2	3.0	28.5	6.3	11.7	57.0
Taipei-309	0	6.7	9.3	11.5	18.5	32.2	78.0
	10	10.3	21.8	17.4	9.8	13.5	72.0
Mean	0	7.3	7.8	20.6	12.8	24.7	73.2
	10	17.2	8.5	21.5	8.2	13.9	69.2
S.Em.	0	1.8	2.0	8.5	3.6	5.1	13.7
	10	17.1	7.4	5.8	4.0	1.8	21.7
C.D(0.01)	0	NS	NS	NS	NS	NS	NS
	10	NS	NS	NS	NS	.0071	NS

Table 7: Estimates of mean,range.PCV,GCV,heritability and genetic advance as per cent over mean in rice genotypes

	Mean	Range	GCV	PCV	Heritability (broad sense) $h^2(b)$	G.A.as per cent over mean
Seed length	8.12	6.5-9.78	12.97	14.17	83.5	23.89
Seed breadth	2.72	1.9-3.62	19.32	21.74	78.93	34.77
L/BRatio	3.13	1.95-4.5	26.79	28.39	88.57	50.79
100 seed weight	2.17	1.3-2.5	18.88	19.05	98.2	37.78
Seed density	78.41	95-28	25.72	26.17	96.4	50.97
Germination(%)Final count	82.55	45-98	15.98	16.19	77	26.44
Germination(%)Sand method	62.63	23-93	26.72	26.98	98	53.69
Field emergence	61.8	33-77	14.83	16.79	77	26.44
Speed of germination	26.97	16-32.6	19.16	21.24	81.0	34.85
Mean daily germination	8.53	5.6-10.3	13.52	15.94	71.0	23.09
Peak value	16.14	11.523.5	23.69	25.43	86	44.54
Germination value	135.14	69-214	33.27	42.44	61.0	52.7
Mean germination time	3.3	2.7-3.86	6.49	10.96	35	7.57
Rate of germination	9.59	1.1-22.1	68.9	70.5	95	136.28
Coefficient of velocity of germination	30.8	25-35.9	6.06	10.8	31	6.8
Seedling length	14.3	8-19	16.2	25.7	39	20.6
Vigour index I	1205	397-165	27.97	34.73	64	45.47
Vigour index II	16	10-22.9	23.7	31.68	55	36.12
Electrical conductivity	101.61	70-214	38.8	42.5	83	71.7
Dehydrogenase activity	0.232	0.09-0.6	67.4	69.5	94	129.3
Peroxidase activity	0.35	0.17-0.4	27.9	29.8	87	2.81
α -amylase activity	78.51	68-82.5	4.45	4.79	86.5	8.36

Table 11 :Effect of accelerated ageing on germination per cent of rice genotypes

Genotypes	Treatments(ageing days)						Mean
	A₀	A₁	A₂	A₃	A₄	A₅	
BPT 5204	95.7 (78.4)	98.0 (82.0)	92.0 (73.7)	82.6 (65.4)	71.0 (57.4)	57.3 (49.2)	82.3 (67.7)
Tellahamsa	85.3 (67.5)	31.0 (33.7)	15.6 (23.3)	8.6 (17.0)	6.6 (14.3)	7.0 (15.3)	26.0 (28.5)
Surekha	98.3 (82.6)	98.3 (82.6)	90.3 (71.8)	92.6 (74.5)	80.0 (63.5)	53.3 (46.9)	85 (70.3)
Swarna	97.6 (81.8)	97.3 (80.6)	96.0 (78.5)	92.3 (73.9)	83.3 (65.9)	49.6 (44.8)	86 (70.3)
DRRH 1	73.3 (59.0)	28.6 (32.3)	23.3 (28.8)	19.0 (25.8)	10.3 (18.7)	9.3 (17.7)	27 (30.4)
Sahyadri	27.3 (31.5)	22.3 (28.1)	17.0 (24.2)	2.6 (7.6)	0 (0.0)	0 (0.0)	11.5 (15.2)
Baiku	96.3 (79.1)	90.0 (71.5)	83.3 (66.3)	76.6 (61.1)	62.6 (52.3)	42.3 (40.5)	75 (61.86)
Jawaphool	88.6 (70.4)	80.6 (64.0)	84.3 (66.7)	75.6 (60.4)	58.0 (49.6)	57.3 (49.2)	74 (60.0)
IR 65600-77-4-2-1	69.6 (56.6)	58.0 (49.6)	43.3 (41.3)	33.0 (35.0)	26.0 (30.6)	21.0 (27.2)	41.0 (40.0)
IR 67962-84-2-2	45.3 (42.3)	27.0 (31.3)	21.3 (27.5)	25.0 (29.2)	16.3 (23.8)	13.3 (21.1)	24 (29.3)
Akeiekari	86.3 (68.3)	71.6 (58.0)	85.3 (67.6)	79.3 (63.1)	66.0 (54.3)	36.6 (37.2)	71 (58.1)
Taipei-309	93.0 (74.8)	93.0 (74.6)	81.3 (64.4)	30.3 (33.4)	22.3 (28.1)	26.6 (31.0)	58 (51.1)
Mean	79.7 (66.0)	66.3 (57.4)	61.1 (52.8)	51.5 (45.6)	41.9 (38.2)	31.2 (31.7)	55.2 (48.66)

Source	S.Em.	C.D (0.01)
Genotypes (G)	0.599	2.1846
Treatments (T)	0.424	1.5548
Interaction (GxT)	1.468	5.3513

*figures in the parenthesis indicate transformed values

A0: Control

A2 : Accelerated ageing for four days

A4: Accelerated ageing for eight days

A1: Accelerated ageing for two days ;

A3: Accelerated ageing for six days ;

A5: Accelerated ageing for ten days

Table 12 :Effect of accelerated ageing on seedling length(cm) of rice genotypes

Genotypes	Treatments (ageing days)						Mean
	A0	A1	A2	A3	A4	A5	
BPT 5204	18.9	17.5	13.4	13.5	12.4	12.6	14.7
Tellahamsa	17.6	18.2	13.7	13.3	13.7	13.2	14.9
Surekha	23.5	24.7	16.2	15.3	16.9	15.6	18.7
Swarna	18.6	14.4	12.9	15.6	12.3	12.4	14.3
DRRH 1	19.9	17.7	17.5	15.6	14.5	12.8	15.7
Sahyadri	14.6	12.2	15.3	14.4	14.5	12.2	13.8
Baiku	23.5	21.6	17.5	18.7	17.7	12.9	18.6
Jawaphool	22.6	23.7	15.3	13.3	12.5	6.9	15.7
IR 65600-77-4-2-1	22.5	19.5	14.4	18.0	18.4	12.9	18.4
IR 67962-84-2-2	21.5	15.8	20.2	16.8	16.2	5.2	15.9
Akeiekari	18.4	18.1	15.9	14.9	12.3	12.6	15.3
Taipei-309	12.2	11.3	8.9	10.5	8.9	9.2	10.1
Mean	19.4	19.4	15.2	15.0	14.22	11.5	15.8

Source	S.Em.	C.D (0.01)
Genotypes (G)	0.0032	0.0118
Treatments (T)	0.0023	0.0084
Interaction (GxT)	0.008	0.0290

A0 :Control

A2 : Accelerated ageing for four days

A4: Accelerated ageing for eight days

A1: Accelerated ageing for two days ;

A3: Accelerated ageing for six days ;

A5: Accelerated ageing for ten days

Table 13 : Effect of accelerated ageing on seedling dry weight (mg) of rice genotypes

Genotypes	Treatments (ageing days)						Mean
	A0	A1	A2	A3	A4	A5	
BPT 5204	21.2	16.5	12.5	10.5	9.5	6.5	12.8
Tellahamsa	15.1	13.0	13.5	8.0	8.0	6.0	10.6
Surekha	17.7	16.0	12.0	15.0	14.0	12.5	12.4
Swarna	11.2	7.5	4.0	6.0	4.0	0.50	5.5
DRRH1	13.0	15.0	13.0	7.0	7.0	5.0	10.4
Sahyadri	19.0	4.0	2.0	0.7	0.2	0.2	4.5
Baiku	19.5	16.5	11.0	8.5	1.1	1.7	9.7
Jawaphool	10.2	4.0	6.0	5.0	3.0	2.0	5.0
IR 65600-77-4-2-1	18.9	19.6	12.5	13.0	13.5	8.5	14.3
IR 67962-84-2-2	20.1	13.0	16.0	10.2	12	0.9	12.0
Akeiekari	19.5	18.5	13.5	11.5	14.5	6.5	14.0
Taipei-309	17.2	10.5	10.0	12.0	15.0	6.5	13.4
Mean	16.8	12.9	10.5	9.0	7.4	5.6	10.3

source	S.Em.	C.D(0.01)
Genotypes (G)	0.000	0.01
Treatments (T)	0.000	0.01
Interaction (GxT)	0.01	0.02

A0:Control

A2 : Accelerated ageing for four days

A4: Accelerated ageing for eight days

A1: Accelerated ageing for two days ;

A3: Accelerated ageing for six days ;

A5: Accelerated ageing for ten days

Table14 :Effect of accelerated ageing on Vigour index-I of rice genotypes

Genotypes	Treatments(ageing days)						Mean
	A0	A1	A2	A3	A4	A5	
BPT 5204	1808	1715	1214	1115	880	721	1242
Tellahamsa	1501	564	213	114	111	92.4	432
Surekha	2310	2428	1462	1416	1352	831	1639
Swarna	1210	1401	1238	1439	1024	615	1154
DRRH 1	1392	506	407	296	149	119	478
Sahyadri	398	272	260	37	00	0	161
Baiku	2263	1944	1457	1432	1108	545	1458
Jawaphool	2002	1910	1289	1005	725	395	1221
IR 65600-77-4-2-1	1566	1131	627	594	478	270	777
IR 67962-84-2-2	833	426	430	420	264	69	407
Akeiekari	1587	1300	1356	1181	881	461	1127
Taipei-309	1134	1050	723	318	198	244	611
Mean	1500	1220	889	780	597	363	891

Source	S.Em.	C.D 0.01)
Genotypes (G)	12.73	46.40
Treatments (T)	9.00	32.81
Interaction (GxT)	31.19	113.65

A0: Control

A2 : Accelerated ageing for four days

A4: Accelerated ageing for eight days

A1: Accelerated ageing for two days ;

A3: Accelerated ageing for six days ;

A5: Accelerated ageing for ten days

Table 15 :Effect of accelerated ageing on vigour index-II of rice genotypes

Genotypes	Treatments(ageing days)						Mean
	A0	A1	A2	A3	A4	A5	
BPT 5204	20.2	16.1	11.5	8.6	6.7	3.7	11.1
Tellahamsa	12.8	4.03	2.1	0.6	0.5	0.42	3.4
Surekha	17.3	15.7	10.8	13.8	11.2	6.8	12.6
Swarna	10.9	7.2	3.8	5.5	3.3	0.24	5.15
DRRH 1	9.5	4.2	3.0	1.3	0.72	0.46	31.9
Sahyadri	5.18	0.89	0.34	0.01	0	0	1.07
Baiku	18.2	14.8	9.16	6.12	0.68	0.79	8.3
Jawaphool	8.8	3.2	5.05	3.78	2.26	1.16	4.06
IR 65600-77-4-2-1	12.5	11.02	5.23	4.2	3.51	1.68	6.34
IR 67962-84-2-2	13.9	9.1	3.51	3.4	2.5	0.11	5.4
Akeiekari	16.3	12.8	11.0	8.72	9.24	2.19	10.0
Taipei-309	15.8	9.3	8.13	3.62	3.34	1.59	6.96
Mean	13.4	9.03	6.14	4.97	3.66	1.59	6.47

source	S.Em.	C.D(0.01)
Genotypes (G)	0.0959	0.3495
Treatments (T)	0.0678	0.2472
Interaction (GxT)	0.235	0.8562

A0:Control

A2 : Accelerated ageing for four days

A4: Accelerated ageing for eight days

A1: Accelerated ageing for two days ;

A3: Accelerated ageing for six days ;

A5: Accelerated ageing for ten days

Table 8:Effect of salinity stress on seed germination(%) in rice genotypes

Genotypes	T₀	T₁	T₂	T₃	Mean
BPT5204	98	81.66	62.7	19.3	65.4
Tellahamsa	78	62.7	24.3	4.0	42.2
Surekha	97	77.7	75.7	2.7	63.2
Swarna	94	88.7	82.0	8.0	68.1
DRRH 1	24.7	13.7	4.0	0.0	10.5
Sahyadri	23.7	11.7	0.0	0.0	8.87
Baiku	89.7	67	28.7	16	50.3
Jawaphool	81.0	84	52.3	12	57.3
IR 65600-77-4-2-1	15.3	15	2.0	0.0	8.07
IR 67962-84-2-2	25.3	14	17.7	0.0	14.2
Akeiekari	52.6	10.3	2.7	0.0	16.4
Taipei-309	29.66	8.3	4.0	0.0	10.4
MEAN	59.16	44.9	29.3	5.16	34.63

Source	S.Em.	C.D (0.01)
Genotypes (G)	1.335	2.618
Treatments (T)	0.771	1.511
Interaction (GXT)	2.671	5.236

T₀: Control T₁:0.5% T₂:1.0% T₃: 1.5%

Table 17; Simple correlations among germination,vigour index and biochemical traits

[illegible]

Table 18: Simple correlations among laboratory vigour tests and field emergence

[illegible]

Table-3 : Mean values of rate of germination components in rice genotypes

Genotype	Speed of germination	Mean daily germination	Peak value	Germination value	Mean germination time	Rate of germination	Coefficient of velocity of germination
BPT 5204	32.05	9.3	16.4	153.3	3.09	12.5	32.46
Tellahamsa	24.86	8.5	17.5	149.4	3.28	2.22	30.47
Surekha	32.65	9.8	20.2	201.4	3.32	9.96	30.17
Swarna	31.57	10	18.7	182.1	3.49	13.3	32.27
DRRH-1	31.79	8.9	17.7	95.80	2.76	22.1	35.96
Sahyadri	26.50	8.0	12.8	92.50	3.23	18.2	31.13
Baiku	30.61	9.6	18.7	169.4	3.05	7.36	32.82
Jawaphool	30.18	9.0	23.5	214.6	3.28	1.48	30.50
IR 65600-77-4-2-1	19.42	7.4	11.5	83.30	3.50	1.12	28.84
IR 67962-84-2-2	16.67	5.6	11.6	69.10	3.48	5.78	29.18
Akeiekari	24.58	7.9	12.0	99.10	3.25	13.5	30.93
Taipei-309	22.87	8.1	12.8	111.2	3.86	7.25	25.86
Mean	26.98	8.5	16.14	135.14	3.30	9.59	30.88
S.Em.	1.430	0.414	0.862	20.55	0.168	0.811	1.608
C.D(0.01)	5.658	1.639	3.41	81.29	0.666	3.209	6.362

CHAPTER – V

DISCUSSION

The present investigation was undertaken to study the variability existing among the sub-species of rice for seed vigour. Twelve genotypes belonging to different sub-species (*indica*, Tropical *japonica*, Temperate *japonica*) were subjected to different standard vigour tests, physiological, biochemical and stress tests and the results obtained are discussed hereunder.

5.1 SEED MORPHOLOGICAL CHARACTERS

Significant differences were observed among the genotypes for all the seed morphological characters. *Indica* varieties, hybrids and a land race (Baiku) exhibited higher seed length, L/B ratio and seed density as compared to Tropical *japonicas*, Temperate *japonicas* and Jawaphool (another land race). However, seed breadth and 100-seed weight were less in *indica* varieties as against *japonicas*. The higher density of *indica* varieties was due to lengthy caryopsis which facilitates more packing of food reserves. More seed breadth facilitates more accumulation of reserve food material thereby *japonicas* had more seed weight. Seed density had positive correlation with germination, vigour index and field emergence. Seed morphological traits variation was due to genetic constitution of the variety. Seeds of higher specific gravity/density had higher vigour index. The positive association of specific gravity of rice seed with its quality was reported by Nagoto and Tanada (1957) and Sung and Delouche, (1962). Although seed of higher weight and size had better physiological quality

as shown by longevity, germination capacity and vigour, grain yield differences among the different classes were not significant (Amaral and Dos, 1979). The smaller seeds showed greater emergence speed than the larger ones (Dhillon *et al.*, 1976). In the present study smaller seeds also produced fast root and shoot growth as indicated by the positive correlation between 100-seed weight and mean germination time. This trend was not observed with dry weight of seedling probably because higher levels of food reserves in the heavy seed may have eventually contributed to increased length and seedling dry weight. This finding is in close agreement with the results of Krishnaswamy and Seshu (1989) in rice.

5.2 SEED GERMINATION, SEEDLING TRAITS AND FIELD EMERGENCE

Analysing from the practical point of view the most important effects of vigour are those on seedling emergence, growth and ultimate field performance. However, the expression of these effects is often dependent on prevailing environmental situations immediately after sowing. Two seed lots of similar laboratory germination potential may be dissimilar when conditions are adverse. These apparent contradictory results can be explained by the interaction between vigour level and the environment.

In the present investigation between paper methods recorded high germination per cent compared to field emergence and sand method. This finding is in accordance with that of Shenoy *et al.* (1990) who stated that the standard germination tests conducted under optimum conditions, often over estimate the field emergence.

The differences between first count and final count were narrow for *indica* varieties. Similar results were also reported by Padma and Reddy (2002). Temperate *japonicas* exhibited maximum seedling length, whereas, hybrids showed maximum dry weight. The vigour index was positively and significantly correlated with germination per cent and field emergence. This is mainly due to the fact that seeds undergo deterioration at various levels during storage resulting in lowering of vigour, germination and increase in seedling abnormalities (Tonapi, 1988). However, the degree of deterioration is varied due to genetic factors. It has been well established that the various components of performance are impaired in a fairly definite sequence as seed germination falls low due to deteriorative changes such as diminished metabolic activity (Grabe, 1964), increased susceptibility to stress, decreased seedling growth and rate of germination (Grabe, 1965), decreased germination potential and increased seedling abnormalities (Delouche and Baskin, 1973) and diminishing field emergence potential (Grabe, 1964).

The wide difference between the higher values of laboratory germination and lower values of field emergence indicates the unsuitability of laboratory germination to predict field performance of a genotype. Hence, to predict the actual planting value of seeds, field emergence test is a must, since laboratory germination tends to over predict the estimates. Similar results were also observed by Pollock and Roos (1972) and Shenoy *et al.*, 1990. On the contrary, Buxton *et al.* (1977), Tekrony and Egli (1977) and Bishnoi and Delouche (1980) opined that seed vigour tests can be used to obtain reliable assessment of field stand in soybean and cotton crops. Field emergence was positively and significantly

correlated with laboratory germination and seedling vigour index. These tests will give accurate and reproducible results in predicting the planting value in field condition.

5.3 SEED GERMINATION RATE AND ASSOCIATED COMPONENTS

The relationship between rate of germination and seed vigour is well documented. The speed of germination provides a good index of seed vigour. Although differences in seedling vigour are often visually obvious, difficulty is often encountered in obtaining reproducibility in categories such as strong or weak. Seedling growth rate as determined by indices of rate of germination such as speed of germination, mean germination time, coefficient of velocity of germination allow objective evaluation of differences in growth rate which would be both reproducible and accurate.

Present study involving various genotypes belonging to different sub-species indicated that all these components of rate of germination except mean germination time was high for genotypes having higher germination. Similar trend was quoted by several researchers [Maguire (1962); Pollock and Roos (1972); Wright (1980) and Subbarao *et al.* (1996)]. However, in the present study the hybrid DRRH-1 exhibited higher mean value for all the components except mean germination time, although it's initial germination percentage and field emergence were reasonably low. It indicated that genotypes having early emergence potential will record high rate of germination, irrespective of its total germination potential. However, this is contrary to the finding of Pollock and

Roos (1972), who stated that vigorous seedlings emerge due to high synthetic ability in high vigour seed lots and vice versa.

Krishnaswamy and Seshu (1989) reported that the rate of germination is positively correlated with oxygen uptake, dehydrogenase activity, which may influence the rate of germination in two ways (i) respiratory activity provides energy to the germinating embryo and (ii) respiratory activity reflects both the integrity and overall capacity of the metabolic machinery. Takahashi (1956) and Woodstock (1973) while trying to identify the basis for cultivar differences in the velocity of germination, observed higher oxygen (O₂) uptake in the fast germinating cultivars.

In the present study *indica* varieties, hybrids and land races have recorded more rate of germination, speed of germination, coefficient of velocity of germination and lower mean germination time, when compared to *japonicas*. This clearly demonstrates that *indicas* are more vigorous than *japonicas*. Similar results were reported by Seshu and Dadlani (1993) and Redona and Mackill (1996).

5.4 PHYSIOLOGICAL AND BIOCHEMICAL TESTS

During seed deterioration irreversible degenerative changes in the quality of a seed occurs leading to low field emergence, seedling survival, yield and quality. The main aim of present investigation was to evaluate the level of these deteriorative changes through vigour tests based on biochemical changes during ageing. A range of biochemical measurements have been associated with seed

vigour, the most commonly used and few of them incorporated in this investigation were measurement of membrane integrity through electrical conductivity of seed leachate, dehydrogenase activity by tetrazolium test, peroxidase activity, α -amylase activity and phosphorus fractions in seed.

The results indicated that the electrical conductivity of seed leachates increased significantly with decreasing germination. These low vigour seeds recorded higher level of electrical conductivity and maximum solute leakage and vice versa. The results of present investigation corroborate with the findings of Presley (1958), Matthews and Bradnock (1967), Mackay (1970) and Tonapi (1988) who observed the increase in electrical conductivity of seed leachates with the decrease in level of seed vigour.

Considerable variations for electrical conductivity were observed among the genotypes before and after accelerated ageing (Fig. 1). High conductivity levels in the seed leachates might be due to the damage in cell membranes, which allow greater leakage of electrolytes. It has been Bewley and Black (1985) stated that seed deterioration is directly related to loss of membrane integrity. Percentage leaching of electrolytes (EC) increased during accelerated ageing conforming the earlier reports of Parish and Leopold (1978), Ray and Gupta (1979), Dadlani and Agrawal (1985), Herter and Burris (1989), Krishnaswamy and Seshu (1990) and Suhaila *et al.* (1990).

Correlation studies indicated that electrical conductivity was negatively correlated with germination, vigour index and field emergence, while it had a positive and significant correlation with seed density. Abdul-Baki and Anderson

(1972) reported that leaching of materials from seeds was passive diffusion and not caused by changes in membrane permeability. Leaching is related to metabolic activity of seeds. Deteriorating seeds would operate at low level of metabolic activity and materials could be leached out. But in seeds at high level of metabolic activity, materials would be utilized rather than getting leached. Thus, high vigour seeds will have high metabolic activity and will contribute to the less leaching of electrolytes.

In the present investigation, the differences in electrical conductivity of seed before and after accelerated ageing was high in hybrids compared to other groups indicating the inability of hybrids to retain leachates after ageing. The hybrids were more susceptible to ageing. However, Tropical *japonica* group, which had a low germinability and vigour index exhibited higher electrical conductivity confirming the earlier findings that low vigour seeds leach more (Parish and Leopold, 1978).

The activities of the enzymes dehydrogenase and peroxidase declined significantly with accelerated ageing in all the twelve genotypes evaluated indicating degradation of biochemical components and macro molecules in low vigour seeds; low vigour of the seeds could be either due to the genetic make up or ageing stress. These changes in major biochemical processes associated with seed deterioration occur in seeds before germinability declines as illustrated by Moore (1966), Kittock and Law (1968) and Mukherji *et al.* (1971).

Tetrazolium staining has been widely used to evaluate seedling vigour in many crop species (Kittock and Law, 1968 and Yaklich and Kulik (1979). In the

present study significant differences existed among the genotypes for seedling vigour response to dehydrogenase activity. This finding is in agreement with earlier reports Li and Rutger (1980); Chen *et al.*, (1986); Lee *et al.* (1986); and Sung and Chen (1988).

In the present study, Tropical *japonicas* recorded more dehydrogenase activity (Fig. 3), although their vigour index level was low. This may be attributed to seed size and weight. Tropical *japonicas* had higher seed size compared to other groups in the study, thereby it exposes more live tissue to the tetrazolium salt inturn, it recorded more dehydrogenase activity. This discrepancy was well explained by the Yang and Sung (1980) and Chen *et al.* (1986) and they stressed that seed weight had a role to play in determining enzyme activity. So, it can be concluded that rice seeds with same size should be used to evaluate tetrazolium salt reduction capability to assess seedling vigour relationship. The formazon production level in the embryo should be utilized to estimate the seedling vigour. Similar findings were drawn by Johnston *et al.* (1986) in wheat and Sung and Chen (1988) in rice.

Dehydrogenase activity had a negative correlation with germinability, vigour index and field emergence, but registered a significant positive correlation with electrical conductivity of seed leachates. This explains the use of dehydrogenase activity as an indirect vigour test, as that of electrical conductivity when similar sized seeds were used. This result is not in accordance with earlier reports who revealed a positive association of seedling vigour with dehydrogenase activity. This may be due to use of different sub-species with different sizes.

The genotypes had shown significant differences among them for peroxidase activity. Similar results were reported by Kang and Nam (1989) and Chen and Chen (2003). Peroxidase activity had a differential response among the sub-species towards ageing treatments. In *indica* varieties and hybrids, peroxidase activity reduced with accelerated ageing, whereas, remaining groups responded vice versa. The varietal differences among sub-species of rice for this trait were also reported by Kang and Nam (1989).

The relationship of seed dormancy with peroxidase activity was reported by Kapur *et al.* (1988) and Seshu and Dadlani (1991). In the present study, the peroxidase activity was low in the *Japonicas*, which had no dormancy, as compared to *indica* varieties and hybrids confirming the report of Kapur *et al.* (1988). The reason attributed to higher O₂ uptake rate and peroxidase activity in dormant cultivars than in weakly dormant ones (Seshu and Dadlani, 1991). Germinability, vigour index and field emergence had a positive correlation with peroxidase activity, indicating its reliability as a vigour test to compare the vigour levels of seed lots belonging to similar genotypes. These results are in unison with Yan and Li (1995). There is ample genetic variability for these biochemical traits in rice and can be utilized for breeding programmes in selecting cultivars having high seedling vigour.

The enzyme α -amylase, largely responsible for hydrolysis of reserve carbohydrate is *de novo* synthesized within the rice endosperm. In the present study, significant differences observed among the genotypes for α -amylase activity can be attributed to their wide variability in growing conditions. *Japonica*

cultivars recorded more α -amylase activity than their counterparts. Krishnaswamy and Seshu (1990) reported cultivars with high α -amylase activity showed higher germination rate and fast seedling growth at the early stage. Within *indica* varieties the genotype Tellahamsa, which had a low germinability and vigour index recorded low α -amylase activity. But among the sub species the same is not true. *Japonicas* in general had high amylase content than *indicas*. α -amylase activity decreased with accelerated ageing in all genotypes (Fig. 2). The decrease was more in *indicas* than *japonicas*. These results are in accordance with the findings of Powell and Matthews (1977), Subba Rao (1984), Karrer *et al.* (1993) and Shephard *et al.* (1995). The reduction in α - amylase activity could be due to loss in seed membrane integrity, since both mitochondria (sites of energy production) and endoplasmic reticulum (necessary for secretion of the synthesized enzymes) are dependent on ageing and is likely to be reflected in reduced α - amylase activity.

Simple correlation coefficients indicated that this trait had a negative, non significant correlation with germinability and vigour index, but positive association with field emergence indicating its suitability as a vigour test in rice which can be used to predict field emergence, rather than germinability or vigour index. The results are in accordance with Williams and Peterson (1973), but contrary to those reported by Karrer *et al.* (1993).

Phosphorus is required for the formation of nucleic acids, phospholipids, phytin *etc.*, which are ultimately connected with protein synthesis and the hereditary constitution of the plant cell (Mayer and Hayber, 1975). In seeds much

of the phosphorus is locked as phytin phosphorus. Phosphorus in seed controls the energetics of seed and maintains viability potential. Phosphatases serve as antioxidant synergistic factors. The phosphate present as phospholipid-phosphorus maintains and continues to tone up the quality of membrane (Koshti, 1972). In the absence of α - tocopherol, phosphates continue to protect seed from membrane disintegration. Field deterioration in crops due to atmospheric drought, excessive temperature in association with soil drought can largely account for drastic reductions in phosphorus content. In the present study, the phosphorus fractions in seed, both before and after accelerated ageing, had no significant differences among the genotypes indicating phosphorous content is not influenced by genetic factors.

In fresh seed lots, phosphoproteinpeptide phosphorus followed by RNA phosphorus were amounted high to total phosphorus, whereas in aged seedlots, RNA Phosphorus followed by acid soluble phosphorus were contributed more to total phosphorus in the seed (Fig.4). The amount of acid soluble phosphorus, phospholipid phosphorus and RNA phosphorus were increased with accelerated ageing, whereas DNA phosphorus and phosphoproteinpeptide phosphorous were decreased. However, the increase was more in case of acid soluble phosphorus than other fractions. The decrease of total phosphorus in seed with accelerated ageing indicate the role of phosphorus in membrane integration. The results are in accordance with those of Hall and Hodges (1966), Koshti (1972), Subbarao (1984), Rajendraprasad (1987) and Gupta *et al.* (2000). The estimated phosphorus fractions revealed positive correlation between RNA phosphorous with germinability and vigour index parallel to the results obtained by Osborne *et al.*

(1974) and Sreeramamurthy and Karivartharaju (1984) leading to imbalances in the synthesis of nucleic acids and proteins (Roberts and Osborne, 1973). According to Koostra and Harrington (1969), polar lipids comprising of phospholipids deteriorate faster due to artificial ageing when compared to natural ageing. Evidently, in the present investigation a positive correlation was observed between phospholipid – phosphorus and germinability and vigour index. These positive correlations further indicated that the exposure of seeds to the constant high temperature and high humidity maintained in the ageing cabinet during accelerated ageing had induced varied metabolic and senescent changes in them. (Banerjee, 1978). From the relationship between phospholipid phosphorus and germinability, DNA phosphorus and germinability observed in the artificially aged seeds, it appeared that the level and rate of deterioration affecting these phosphorus fractions had occurred prior to the superimposition of artificial ageing. Maroti (1957) stated that the increasing phosphorus content would increase the cell number with the increase in nucleic acid content.

Simple correlations of phosphorus fractions indicated that acid soluble-phosphorus and phosphoproteinpeptide-phosphorus were negatively correlated with germinability and vigour index, DNA phosphorus was negatively correlated with vigour index only, where as phosphoprotein-phosphorus and RNA-phosphorus were positively correlated with germination and vigour index. These are in unison with the findings of Subbarao (1984).

5.5 STRESS TESTS

Field conditions at sowing are often less than optimal for germination thereby subjecting the seed to various abiotic and biotic stresses. In these conditions, high vigour seeds have a greater potential for emergence and seedling growth. Stress tests subject seeds to the different types of stresses they encounter in the soil during imbibition and germination.

5.5.1 Accelerated ageing test

Seed deterioration is one of the important constraints encountered by rice growing farmers throughout the world. The problem is particularly important in long term storage of seeds. A more effective and economical approach to this problem would be to identify varieties tolerant to ageing. Poor quality seed, even though perform satisfactorily under optimum conditions in the laboratory, may have reduced field emergence.

Planting of low vigour seeds will result in poor and differential emergence which may be related to an inferior capacity to mobilize seed reserves. In the present investigation when the seeds were subjected to accelerated ageing seed deterioration occurred rapidly and resulted in decreased germinability, seedling length, dry matter production and seedling vigour confirming the observation made by Delouche and Baskin (1973).

Germination reduced significantly in all the genotypes with accelerated ageing. Among the genotypes, differential reduction in germination was observed with increase in the days of accelerated ageing. The decline in germination

potential and reduction in germination speed were among the physiological changes usually reported to take place in seed during accelerated ageing and the extent of decline is related to the initial degree of deterioration in the seed lot Ram and Wiesner (1988). Roberts (1972) stated that the rate of deterioration is largely determined by genetic factors and also by treatment and environment before and during storage. Decreased germination with increased ageing period was also reported by Ray *et al.* (1990) and Gowda *et al.* (1996).

Among the genotypes, decline in germination after accelerated ageing was quite perceptible and more in hybrids and Tropical *japonicas* (Fig. 5). Similar result was obtained by Ravindrababu (2003). The reduction in germination due to accelerated ageing might be due to changes that include impairment or shift in metabolic activity, decline in enzyme activities, cytological, cellular changes and differences in initial seed vigour levels (Abdul-Baki and Anderson, 1970).

Accelerated ageing employed to determine genotypic differences for seed vigour, viability, seedling growth in the genotypes is well accepted as one of the important stress test for evaluation of seed vigour (AOSA, 1983). In the present investigation, the seedling length and dry weight reduced with the increasing duration of accelerated ageing. These findings were in accordance with findings of Ray and Gupta (1979), Krishnaswamy and Seshu (1989), Suhaila *et al.* (1990), Narayana Reddy *et al.* (1994), Shephard *et al.* (1997) and Jhansilakshmi (2000).

Accelerated ageing resulted in reduction of vigour index of seed due to decreased seedling length and dry weight. Similar results were also reported by Saxena *et al.* (1985) and Ravinder (1990).

Among the genotypes, the reduction in vigour index was more in *japonicas*, hybrids while it was low in *indica* varieties and land races. The results are in confirmation with the findings of Krishnaswamy and Seshu (1989). The reduction in vigour index in the accelerated aged seed may be due to loss of membrane integrity which consequently leads to leaching of solutes and intercellular disorganization impairing the growth of the seedling by depleting substrates and metabolic intermediates [Abdalla and Roberts (1969) and Abdul-Baki and Anderson (1970)].

Based on the germination and vigour index levels after accelerated ageing the genotypes under study can be categorized as poor (Tropical *japonicas* and hybrids), moderate (Temperate *japonicas*) and good (*indica* varieties and land races) storers.

5.5.2 Salinity stress test

Significant differences among the genotypes indicated the varietal differences for tolerance to the imposed salinity stress. There was a gradual decrease in germination with increasing salt concentrations (Fig. 6). Similar results were reported by Shenoy *et al.* (1990) and Padma and Reddy (2002). Salt as an osmoticum regulates the availability of water to the seed, and salt ions may enter into embryonic cells of the seed to affect the pregerminative metabolic activities inturn affects the viability (Ruan, 1999). Based on their susceptibility to the imposed salinity concentrations, the genotypes under study were categorized as tolerant (Baiku and Jawaphool), moderately tolerant (BPT 5204, Surekha,

Swarna and Tellahamsa) and susceptible (DRRH-1, Sahyadri, IR 65600-77-4-2-1, IR 67962-88-2-2, Akeiekari and Taipei 309).

Simple correlations indicated that the germination at all the salinity concentrations were positively and significantly correlated with germination and vigour index and positive non-significant association with field emergence. Similar findings were reported by Shenoy *et al.* (1990) and Padma and Reddy (2002).

5.5.3 Moisture stress test

Moisture stress imposed externally by Poly Ethylene Glycol (PEG) solution significantly decreased the germination percentage with increasing concentration in the present study (Fig. 7). Similar findings were registered by Krishnaswamy and Seshu (1989) and Jha *et al.* (2001). Deterioration of seedling vigour with increasing moisture stress is an important parameter to distinguish tolerant and susceptible genotypes. The genotypes in the present study could be classified as tolerant (Baiku, Jawaphool, BPT 5204, Surekha, Swarna and Tellahamsa), moderately tolerant (DRRH-1, Sahyadri) and susceptible (IR 65600-77-4-2-1, IR 67962-88-2-2, Akeiekari and Taipei 309) to moisture stress. Increasing water stress reduced the levels of water and oxygen uptake rates after initial imbibition and delayed the onset of germination (Hegarty, 1977). Hegarty (1977), Singh (1992) and Adhikary *et al.* (1999) earlier reported the reduction in seedling vigour index under moisture stress.

Simple correlation studies indicated that the moisture stress with - 6 bar had significant correlation with first count and final count of germination test. The results are in accordance with those of Krishnaswamy and Seshu (1990) and Shenoy *et al.* (1990). Moisture stress had a positive association with field emergence. Similar results were reported by Shenoy *et al.* (1990).

5.5.4 Anaerobic germination stress test

Rice seeds can germinate even in anoxia but oxygen is required for seedling establishment. The coleoptile elongates further at low oxygen concentration than it does in air, but the elongation of leaf and roots are reduced at low oxygen [Alpi and Beevers (1983) and Ishizawa and Esashi (1984)]. Rice seedlings can be established in standing water when sown at the soil surface because oxygen is dissolved in water (Chapman and Peterson, 1962). When seeds are sown under the soil surface where no oxygen is present, seedling establishment becomes erratic (Jones, 1993). Seedling establishment decreases with sowing depth in flooded soil (Yamauchi and Chuong, 1995). Thus, rice seedling growth is affected by both the soil, water condition and sowing depth.

In the present investigation, significant differences were observed among the genotypes for seedling germination in anaerobic condition. The result is in unison with Yamauchi *et al.* (1993). The genotypes under study could be classified as tolerant (*indica* varieties and land races) and susceptible (hybrids, Tropical *japonicas* and Temperate *japonicas*) to anaerobic conditions.

Correlation coefficients indicated that there was a significant positive correlation between germination in between paper method and germination in anaerobic stress condition. It clearly indicates that vigorous seeds can germinate faster in anaerobic stress conditions. The results are in accordance with Yamauchi and Winn (1996) and Yamauchi and Biswas (1997) suggesting that in vigorous seed coleoptile elongates faster and longer in hypoxia. Faster coleoptile elongation in anaerobic soil may shorten the time for the seedlings to reach the oxygen on the soil surface thereby permitting successful development of leaves and roots.

5.6 GENETIC VARIABILITY

Success of any breeding programme depends on the availability of genetic variability in the population, which is however not directly measurable by itself, but has to be inferred with the phenotypic expression. The phenotype may therefore be defined as a linear function of genotype (G), environment (E) and genotype x environment (G x E) interaction effect. Though variability is available for seed and seedling traits, it needs to be partitioned into heritable and non-heritable components in order to assess their true breeding nature. The magnitude of variability provides a base for identifying the genotypes with desirable characters. High values of GCV coupled with high heritability for any character help the breeder in selection for that trait even in early generations. The results obtained in the present investigation are discussed hereunder.

The differences between values of PCV and GCV were less for all traits studied except germination value, mean germination time, coefficient of velocity

of germination, seedling length, vigour index – I and II. This suggested that these traits were less influenced by environmental interaction and hence, they could be improved by following different phenotypic selections like directional, disruptive and stabilized selections.

High PCV and GCV estimates were observed for the traits viz., germination value, rate of germination, vigour index-I, vigour index-II, electrical conductivity and dehydrogenase activity. This implies that maximum variability is existing in the genotypes for aforesaid traits and there is good scope for improvement of these characters through simple selection programme. Similar results were also reported by Subbarao *et al.* (1996) and Jhansilakshmi (2000).

Moderate PCV and GCV values were observed for the characters like germination (both final count and sand method), field emergence, speed of germination, peak value, seed length, seed breadth, L/B ratio, 100 seed weight, seed density and peroxidase activity, which suggests the presence of moderate genetic variability for the traits. These results are in conformity with those of Jangale *et al.* (1985); Reddy *et al.* (1997) and Chikkalingaiah *et al.* (1999).

The mean daily germination, mean germination time, coefficient of velocity of germination, seed length and α -amylase activity recorded low estimates of PCV and GCV implying improvement may not be possible to the desirable extent by effecting selection for these traits. The results are in accordance with Deosarkar *et al.* (1989b), Malik *et al.* (1994) and Jhansilakshmi (2000).

In the present study, high heritability estimates were recorded for all the traits except mean germination time, coefficient of velocity of germination, seedling length and vigour index-II. Similar findings were reported by several workers. High heritability supplemented with high genetic advance as percentage of mean was more useful than heritability alone in predicting the resultant effect during selection of best individual genotype. Genetic advance is the measure of genetic gain under selection and expressed as percentage of mean.

In the present study, high heritability coupled with high genetic advance as per cent of mean was recorded for characters like germination in sand method, peak value, germination value, rate of germination, L/B ratio, 100-seed weight, seed density, electrical conductivity and dehydrogenase activity. This indicates that these traits were under the influence of additive gene action and simple selection process based on phenotypic performance of these traits would be effective and the desirable genes can pyramid in the genotypes. Similar findings were reported by Chauhan and Nanda (1983), Maurya *et al.* (1986) and Hussain *et al.* (1987) for L/B ratio; Mallik *et al.* (1990), Angrish and Panwar (1992) for seed density; Shukla *et al.* (1972), Maurya *et al.* (1986), Reddy and Reddy (1986), Deosarkar *et al.* (1989a), Roy and Kar (1992) and Chikkalingaiah *et al.* (1999) for 100-seed weight and Jhansilakshmi (2000) for electrical conductivity.

High heritability and moderate genetic advance as per cent of mean values observed for the characters like germination per cent, speed of germination, mean daily germination, vigour index-I and seed breadth suggests the influence of both additive and non-additive gene action and considerable influence of environment

in the expression of these traits. These traits could, therefore, be improved through exploitation of heterosis and selection would be ineffective for improvement of these traits. Similar results were reported by De and Suriya rao (1987) and Deosarkar *et al.* (1989b).

High heritability coupled with low genetic advance as per cent over mean were recorded for field emergence, seed length, peroxidase activity and α -amylase activity. This implies that there would be poor response to selection due to lack of inherent genetic variability. Mean germination time, coefficient of velocity of germination, seedling length and vigour index-II recorded moderate heritability estimates with low genetic advance over mean indicating that they are governed by additive gene action. These results are in concurrence with Subbarao *et al.* (1996).

Genetic differences evident among cultivars in respect of seed vigour as measured by different parameters suggest that it should be possible to incorporate this trait into high yielding rice varieties through appropriate breeding methodologies. This would help to minimize the yield losses due to seed deterioration. Good quality seed should be considered as important as other crop management inputs (water, fertilizer or pesticides) for obtaining high yields. Pre and post-harvest care of seed coupled with inherent ability of the cultivar to withstand adverse post-harvest environmental conditions would contribute significantly to sustainable farming.

In the present study twelve genotypes were studied which represents the glimpse of the rice population. There is need to select more number of genotypes

from *indica*, *japonica* groups and their blends *i.e.* inter specific hybrids and its derivatives developed into varieties. The seed germination, initial vigour and seed deterioration is controlled by several internal (inherent / genetic) and external factors. Seed technologist, breeders and biochemist jointly should work together to solve the above problem, by selecting the genotypes with high germinability and high vigour. Intermating of varieties should be done and the selection criteria should be focused on early vigour which has a bearing on the population stand, good source and sink relationship and ultimately reflects the higher yield in rice.

CHAPTER – VI

SUMMARY

The present investigation “Studies on variability for seed vigour in different sub-species of rice (*Oryza sativa* L.)” was carried out with twelve genotypes belonging to *indica*, Tropical *japonica* and Temperate *japonica* sub-species at Department of Seed Science and Technology, College of Agriculture, Rajendranagar, Hyderabad during 2003-04.

Seed of all the genotypes were subjected to standard seed vigour tests, physiological, biochemical and stress tests. The quantitative and qualitative characters were analyzed for genetic variability and heritability estimations.

Indica varieties, hybrids and Baiku exhibited high seed length, L/B ratio and seed density. While Tropical *japonicas*, Temperate *japonicas* and Jawaphool had wider seed breadth and high 100-seed weight. Significant differences were observed among the genotypes for seed morphological characters, germination per cent estimated by different methods, rate of germination indices, seedling growth traits. The seeds of genotype under study were classified into long bold and long slender based on L/B ratio.

Significant differences were observed among the genotypes for electrical conductivity, dehydrogenase activity, peroxidase activity and α -amylase activity both in fresh seeds and seeds subjected to accelerated ageing for ten days. The electrical conductivity of seed leachates, peroxidase activity increased while the dehydrogenase activity and α -amylase activity reduced with ageing treatments.

Though, significant differences were not observed for the estimated phosphorus fractions among the genotypes, phosphoproteinpeptide phosphorus followed by RNA phosphorus contributed maximum to total phosphorus in fresh seeds. While RNA phosphorus followed by acid soluble phosphorus contributed maximum to total phosphorus in aged seeds. Acid soluble phosphorus and phosphoproteinpeptide phosphorus were negatively correlated with germinability and vigour index while DNA phosphorus was negatively correlated with vigour index only. Phospholipid phosphorus and RNA phosphorus were positively correlated with germination and vigour index.

The difference between genotypic coefficient of variation (GCV) and phenotypic coefficient of variation (PCV) was narrow for seed length, seed breadth, L/B ratio, 100 seed weight, seed density, germination per cent, field emergence, speed of germination, mean daily germination, peak value, rate of germination, electrical conductivity, dehydrogenase activity, peroxidase activity, α -amylase activity. High GCV and PCV estimates were recorded for germination value, rate of germination, vigour index I, II, electrical conductivity, dehydrogenase activity. Moderate PCV and GCV values were observed for germination per cent, field emergence, speed of germination, peak value, seedling length, seed breadth, L/B ratio, 100 seed weight, seed density, peroxidase activity, whereas, mean daily germination, mean germination time, coefficient of velocity of germination, seed length and α -amylase activity recorded low estimates of PCV and GCV.

Heritability studies revealed high heritability coupled with high genetic advance as per cent of mean for the estimated characters of germination in sand method, peak value, germination value, rate of germination, L/B ratio, 100-seed weight, seed density, electrical conductivity, dehydrogenase activity indicating the influence of additive gene action. The characters germination per cent, speed of germination, mean daily germination, vigour index I and seed breadth were found to be influenced by environment as they had high heritability and moderate genetic advance. High heritability with low genetic advance was recorded for field emergence, seed length, peroxidase activity and α -amylase activity, whereas, moderate heritability with low genetic advance was observed for mean germination time, coefficient of velocity of germination, seedling length and vigour index.

Germination, seedling length, seedling dry weight, vigour index decreased significantly with increasing duration of accelerated ageing. Based on the germinability and vigour index, the genotypes were categorized as poor (IR 65600-77-4-2-1, IR 67962-84-2-2, DRRH-1 and Sahyadri), moderate (Akeiekari and Taipei 309) and good (BPT 5204, Tellahamsa, Swarna, Surekha, Baiku and Jawaphool) storers.

Germination per cent decreased with increasing salinity and moisture stress concentrations. Under anaerobic situations, the germination was significantly reduced in all the genotypes. In both the tests significant differences were observed among the genotypes. Based on the results, the genotypes were classified as follows during early growth period.

For moisture stress

Tolerant	-	BPT 5204, Tellahamsa, Swarna, Surekha, Baiku and Jawaphool
Moderately tolerant	-	DRRH-1 and Sahyadri
Susceptible	-	IR 65600-77-4-2-1, IR 67962-88-2-2, Akeiekari and Taipei-309

For salinity stress

Tolerant	-	BPT 5204, Baiku and Jawaphool
Moderately tolerant	-	Swarna, Surekha and Tellahamsa
Susceptible	-	IR 65600-77-4-2-1, IR 67962-88-2-2, Akeiekari, Taipei-309, DRRH-1 and Sahyadri

For anaerobic stress

Tolerant	-	BPT 5204, Tellahamsa, Swarna, Surekha, Baiku and Jawaphool
Susceptible	-	IR 65600-77-4-2-1, IR 67962-88-2-2, Akeiekari, Taipei-309, DRRH-1 and Sahyadri

Correlation studies indicated that standard germination had a significant and positive correlation with speed of germination, mean daily germination, germination under moisture stress (-6 bar), germination under salinity stress (0.5%, 1.0% and 1.5%) and anaerobic germination. Electrical conductivity and dehydrogenase activity had a significant negative correlation with seed density, while vigour index had a significant positive correlation with field emergence, seedling dry weight, germination under -6 bar moisture stress, germination under 1.0% and 1.5% salinity stress and anaerobic germination. Electrical conductivity had a significant positive correlation with dehydrogenase activity.

The results of the study indicated that the variability observed for different seed and seedling traits can be exploited through appropriate breeding and selection methods for enhancing the seedling vigour to sustain productivity under less / unfavourable conditions.

From the results of the above study the following conclusions are drawn :

- 1) Among the different sub-species of rice *indica* varieties followed by land races were found to be highly vigorous.
- 2) All the physical, physiological, biochemical characters of seed and seedlings studied in the present investigation exhibited ample genetic variability among the different sub-species of rice which can be exploited to improve the modern rice cultivars.
- 3) First count of standard germination itself is a good indicator of vigour in rice since crop stand can be predicted through initial rather than final germination.
- 4) Tests of germination in sand media and field emergence are useful for estimating the actual planting value of seed rather than laboratory test alone.
- 5) Early germination in rice hybrids is one of the significant indices for determining the seed vigour potentiality.
- 6) The estimation of dehydrogenase, peroxidase and α -amylase activities can be helpful in predicting the vigour at laboratory level and also to aid in the selection of vigorous genotypes.
- 7) Stress tests can effectively predict the field emergence, besides being useful for screening the genotypes tolerant to stressful situation.

LITERATURE CITED

- Abdalla F H and Roberts 1969 The effects of temperature and moisture on the induction of genetic changes in seeds of barley, broad beans and peas during storage. *Annals of Botany* 33 : 153-167.
- Abdul-Baki A A and Anderson J D 1970 Viability and leachates of sugars from germinating barley. *Crop Science* 10 : 237-248.
- Abdul-Baki A A and Anderson J D 1972 Vigour determination in soybean seed by multiple criteria. *Crop Science* 13 : 630.
- Abdul-Baki A A and Anderson J D 1973 Relationship between decarboxylation of glutamic acid and vigour in soybean (*Glycine max* L.). *Crop Science* 13 : 227-232.
- Abdullahi A and Vanderlip R L 1972 Relationships of vigour tests and seed size to sorghum seedling establishment. *Agronomy Journal* 64 : 143-144.
- Adenikinju S A 1972 Effect of pod maturity on bean development, viability, mucilage content and seedling vigour in Cocoa. *Experimental Agriculture* 8 : 123-129.
- Adhikary S, Bagchi D K and Sarkar B K 1999 Studies on the extent of drought tolerance in upland super fast rice. *Oryza* 36 : 169-170.
- Agrawal P K 1977 Germination, fat acidity and leaching of sugars from five cultivars of paddy (*Oryza sativa* L.) seeds during storage. *Seed Science and Technology* 5 : 689-698.
- Agrawal P K 1979 Genotypic variation in germination and membrane permeability in wheat (*Triticum aestivum*) seed during storage under ambient conditions. *Seed Research* 7 : 120-127.
- Ahmed T, Sharma K K and Das G R 1995 Inheritance of grain size and shape in rice. *Indian Journal of Genetics* 55 : 132-137.
- Allard R W 1960 Principles of plant breeding. Jhon Willey and Sons Inc. London pp 83-108.
- Alpi A and Beevers H 1983 Effect of O₂ concentration on rice seedlings. *Plant Physiology* 71 : 30-34.
- *Amaral A and Dos S 1979 Effect of weight and size of seeds on the physiological quality and yield of rice grains. *Arrozeira* 32 : 24-26.
- Angrish R and Panwar D V S 1992 High density grain variability in some traditional rice cultures. *Oryza* 29 : 59-60.

- AOSA 1983 Seed vigor testing handbook. The Association of Official Seed Analysts pp. 33.
- Ashwani Kumar, Chowdhury R K, Kapoor R L and Dahiya O S 1995 Identification of pearl millet hybrids and their parental lines using seed and seedling characters, chemical tests and gel electrophoresis. Seed Science and Technology 23 : 21-32.
- *Awasthi L P, Maurya D M and Surendra Singh 1998 Morphological studies on seedlings of rice genotypes that are tolerant/susceptible to submergence. Bulgarian Journal of Agricultural Science 4 : 661-665.
- Banerjee S K 1978 Observations on the initiation of seed deterioration and its localization in barley and onion. Seed Science and Technology 6 : 1025-1028.
- Banumathy S, Shanti Patil and Patil S 1999 Analysis of leaf protein banding pattern and peroxidase activity in hybrids, male sterile and maintainer lines of rice. Journal of Soils and Crops 9 (1) : 5-9.
- Bewely J D and Black M 1985 Seeds : Physiology of development and germination, Plenum Press, New York and London pp. 2-4.
- Bishnoi U R and Delouche J C 1980 Relationship of vigour tests and seed lots to cotton seedling establishment. Seed Science and Technology 8 : 341-346.
- Burris J S 1975 Seedling vigour and its effect on field production of corn. Proceedings of 30th Annual Corn and Sorghum Research Conference 185-193.
- Buxton D R, Melick P J, Peterson LL and Peglo Jr E J 1977 Relationship among cotton seed vigour and emergence. Agronomy Journal 69 : 677-681.
- Chang T T 1978 Differential seed longevity of rice cultivars held in cold storage. American Society of Agronomy Abstract 109.
- Chapman A L and Peterson M L 1962 The seedling establishment of rice under water in relation to temperature and dissolved oxygen. Crop Science 2 : 391-395.
- Chauhan J S and Nanda J S 1983 Genetic variability for physico-chemical characters of rice grain segregating generations of rice (*Oryza sativa* L.). Oryza 20 : 209-215.
- Chauhan J S and Nanda J S 1984 Varietal identification in rice (*Oryza sativa* L.) by physico-chemical characters of the grain and electrophoretic variants of salt soluble seed proteins. Seed Research 12 : 78-89.

- Chen C L, Sung F J M and Li C C 1986 Physiological and genetic studies on seedling vigour in rice (*Oryza sativa* L.) I. Relations between seed weight, respiration rate and growth of rice seedlings. Journal of Agricultural Association of China 135 : 10-16.
- Chen T F and Chen C L 2003 Analyzing the freshness of intact rice grains by colour determination of peroxidase activity. Journal of the Science of Food and Agriculture 83 (12) : 1214-1218.
- Chikkalingaiah S S, Lingaraju S and Radhakrishna R M 1999 Genetic variability of plant and quality traits in promising genotypes of scented rice (*Oryza sativa* L.). Mysore Journal of Agricultural Sciences 33 : 338-341.
- Choi Y H, Kobayashi M and Sakurai A 1996 Endogenous gibberellin A₁ level and α -amylase activity in germinating rice seeds. Journal of Plant Growth Regulation 15 : 147-151.
- Cladine T, Elizabeth S C and Jean D 1991 Contribution of aleurone layer and scutellum to α -amylase synthesis and secretion of wheat and rice grains. Physiologia Plantarum 82 : 249-256.
- Czebotar F J 1962 Germination value : An index for combining speed and completeness of pine seed germination. Forest Science 8 : 386-396.
- Dadlani M and Agrawal P K 1985 Leaching of solutes during imbibition of seeds of wheat and greengram as a function of seed quality. Seed Research 13(2) : 115-122.
- De R N and Suriyarao A V 1987 Genetic variability correlation studies in rice under semi-deep water logged situation. Oryza 25 : 360-364.
- Delouche J C and Baskin C C 1973 Accelerated ageing techniques for predicting the relative storability of seed lots. Seed Science and Technology 1 : 427-452.
- Deosarkar D B, Misal Y B and Nerkar Y S 1989a Variability and correlation studies for yield and yield contributing character in breeding lines of upland rice. Journal of Maharashtra Agricultural Universities 14 : 28-29.
- Deosarkar D B, Misal M B and Nerkar Y S 1989b Variability and correlation studies for grain quality characters in breeding lines of rice. Journal of Maharashtra Agricultural Universities 14 : 124-125.
- Deosarkar D B, Nerkar Y S and Khandasgale G B 1998 Estimates of gene effects for grain quality characters in indica rice. Journal of Maharashtra Agricultural Universities 23 : 331-332.

- Dhillon G S, Kler D S and Walia A S 1976 Effect of seed vigor of maize, barley, triticale and cluster beans on the seedling establishment. In Physiology of reproduction in flowering plants (ed. Malick). Kalyani Publishers, New Delhi pp. 422-426.
- Dikshit N, Malik S S and Mahapatra P 1992 Seed protein variability in scented rices. *Oryza* 29 : 65-66.
- *Dore J 1965 Dormancy and viability of paddy seeds. *Malayan Agricultural Journal* 38 : 163-173.
- Edje C T and Burris J S 1970 Seedling vigour in soybean. *Proceedings of Association of Official Seed Analysts*. 60 : 149 – 157.
- Edwards T I 1934 Relations of germinating soybeans to temperature and length of incubation time. *Plant Physiology* 9 : 1-30.
- FAO bulletin of Statistics 2002 Food and Agriculture Organization of the United Nations, Rome 3 (1) : 22-23.
- Gonzalez L M and Ramirez R 1998 Correlation of some varietal characters with grain yield and stress tolerance index under saline conditions. *International Rice Research Notes* 23 (1) : 19-20.
- Government of India 2002 Agricultural Statistics at a glance. Ministry of Agriculture, GOI.
- Govindaraju R and Natarajan M 1995 Analysis of variability and correlation among high density grain characteristics in rice. *Madras Agricultural Journal* 82 (12) : 681-682.
- Gowda S J, Bhole N G and Raghavan G S V 1996 Prediction of seed viability in storage. *Mysore Journal of Agricultural Sciences* 30 : 164-169.
- Grabe D F 1964 Glutamic acid decarboxylase activity as a measure of seedling vigour. *Proceedings of Association of Official Seed Analysts* 54 : 100-109.
- Grabe D F 1965 Prediction of relative storability of corn seedlots. *Proceedings of Association of Official Seed Analysts* 55 : 92.
- Grabe D F 1976 Measurement of seed vigor. *Journal of Seed Technology* 1 : 18-32.
- Gritton E Y and Atkins R E 1963 Germination of grain sorghum as affected by freezing temperatures. *Agronomy Journal* 55 : 139-142.
- Grosselindemann E, Graebe J E, Stock L D and Hedden P 1991 *ent* – Kaurene biosynthesis in germinating barley (*Hordeum vulgare* L.) caryopsis and its relation to α -amylase production. *Plant Physiology* 96(4): 1099-1104.

- Gupta K, Mehta R, Kumar N and Dahiya D S 2000 Effect of chromium (VI) on phosphorus fractions in developing sunflower seeds (*Helianthus annuus* L.). Crop Research 20 (1) : 46-51.
- Hadas A and Russo D 1974 Water uptake by seeds as affected by water stress, capillary conductivity and seed-soil water contact I Experimental Study. Agronomy Journal 66(5) : 643 – 647.
- Hall J R and Hodges T K 1966 Phosphorus metabolism of germinating oat seeds. Plant Physiology 41 : 1459-1464.
- Hanson G H, Robinson H F and Comstock R E 1956 Biometrical studies of yield in segregating populations of Korean lespedza. Agronomy Journal 47 : 313-318.
- Hegarty T W 1977 Seed activation and seed germination under moisture stress. New Phytology 78 : 349-359.
- Herter U and Burris J S 1989 Evaluating drying injury on corn seed with a conductivity test. Seed Science and Technology 17 : 635-638.
- Hogue E E, Wilcox G E and Cantliffe D J 1970 Effect of soil phosphorus levels on phosphate fractions in tomato leaves. Journal of American Society for Horticultural Science 95 (1) : 174-176.
- Hussain A A, Maurya D M and Vaish C P 1987 Studies on quality status of indigenous upland rice (*Oryza sativa* L.). Indian Journal of Genetics and Plant Breeding 47 : 145-152.
- International Seed Testing Association 1993 International Rules for Seed Testing. Seed Science and Technology 21 : 1-288.
- Ishizawa K and Esashi Y 1984 Gaseous factors involved in the enhanced elongation of rice coleoptiles under water. Plant Cell Environment 7 : 239-245.
- Jabeen F, Dhanraj A, Hussain S H and Reddy B M 1991 The effect of germination levels on seedling vigour, growth and yield of castor. Journal of Research Andhra Pradesh Agricultural University 19 (2) : 59-62.
- Jangale R D, Songove R V, Ugale S D and Dumbre A D 1985 Studies on variability, heritability and genetic advance for some quantitative characters in upland paddy. Journal of Maharashtra Agricultural Universities 10 : 69-70.
- Jayaraj T K, Sujatha D S, Balaji S, Mohandas W, Wilfred Manual and Ranganathan Y B 1998 Effect of seed source on seed yield and seed quality characters in short duration rice cultivar ADT 36. Madras Agricultural Journal 85 : 349-352.

- Jha B N, Singh R A and Singh A K 2001 Seed Germination and Seedling Growth of Rice (*Oryza sativa* L.) under water stress. Seed Research 29 (1) : 118-120.
- Jhansilakshmi Kumari 2000 Studies on Genetic variability for seed and seedling traits in rice (*Oryza sativa* L.) M.Sc. (Ag.) Thesis, Acharya N.G. Ranga Agricultural University, Hyderabad.
- Johnston W J, Yusuf H A, Konzak L F and Maguire J D 1986 Tetrazolium chloride test for spring wheat seedling vigor at low temperature. Crop Science 26 : 167-169.
- Jones J W 1993 Effect of reduced oxygen pressure on rice germination. Journal of American Society of Agronomy 25 : 69-81.
- *Kang Y S and Nam M H 1989 Varietal differences of peroxidase activities and banding patterns of rice plants under flooding. Korean Journal of Crop Science 34 (3) : 270-273.
- Kapur A, Hari Singh, Sharma H L and Singh H 1988 Physiological blocks underlying dormancy of rice. Current Science 57 (7) : 386-387.
- Karrer E E, Chandler J M, Foolad M R and Rodriguez R L 1993 Correlation between α -amylase gene expression and seedling vigour in rice. Euphytica 66 : 163-169.
- Kidd F and West C 1918 Physiological pre-determinations. Annals of Applied Biology 15 : 112-142.
- Kihupi A N 1987 Grain quality characteristics of some rice varieties. International Rice Research Newsletter 12 : 13.
- *Kinjinho, Lee Sheongghum and Song Dong Seog 1998 Relationship between seed vigour and electrolyte leakage in rice seeds with different grain filling period. Korean Journal of Crop Science 43 : 147-157.
- Kittock D L and Law A G 1968 Relationship of seedling vigor to respiration and tetrazolium chloride reduction by germinating wheat seeds. Agronomy Journal 60 : 268-288.
- Koostra P T and Harrington J F 1969 Biochemical effects on age on membranal lipids of *Cucumis sativus* L. seed. Proceedings of International Seed Testing Association 34 : 329-340.
- Koshti G S 1972 Phosphatase activity and phosphorus metabolism of germinating leguminous seeds. Science culture 38 (1) : 40 - 41
- Kotowski F 1926 Temperature relations to germination of vegetable seed. Proceedings of American Society for Horticultural Sciences 23 : 176-184.

- Krishnaswamy V and Seshu D V 1989 Seed germination rate and associated characters in rice. *Crop Science* 29 : 904-908.
- Krishnaswamy V and Seshu D V 1990 Germination after accelerated ageing and associated characters in rice varieties. *Seed Science and Technology* 18 : 147-156.
- Lal J P, Richharia A K and Agrawal P K 1983 Concritability correlation and genetic parameters in semi dwarf cultures of rice. *Oryza* 20 : 195-203.
- *Lawrence T 1963 A comparison of methods of evaluating Russian wild ryegrass for seedling vigour. *Canadian Journal of Plant Science* 43 : 307 – 312.
- Lee C C, Li C C and Sung F J M 1986 Physiological and genetic studies on seedling vigor in rice (*Oryza sativa* L.). Inheritance of alpha-amylase activity and seedling vigor in rice. *Journal of Agricultural Association of China* 135 : 17-24.
- Li C C and Rutger J N 1980 Inheritance of cool temperature seedling vigour in rice and its relationship with other agronomic characters. *Crop Science* 20 : 295-298.
- Likhatchev B S, Zelensky G V, Kiashki Y U G and Shevchenko Z N 1984 Modelling of seed ageing. *Seed Science and Technology* 12 : 385-393.
- *Lin T F 1988 Study on the relationship between the morphological characters of the grain and grain chalkiness. *Bulletin of Taichung District Agricultural Improvement Station* 20 : 33-40.
- Livshin A Z and Samygin G A 1973 Causes of different resistance to drying and slow freezing of germinating seed. *Plant Physiology* 20 : 494-498.
- Lowe L B, Ayers G S and Reis R K 1972 Relationship of seed protein and amino acid composition to seedling vigour and yield of wheat. *Agronomy Journal* 64 : 608-611.
- Mackay D B 1970 Relationship between laboratory germination and field emergence in some vegetable crops. *Journal of National Institute of Agriculture and Botany*. 12 : 40 – 43.
- Maguire J D 1962 Speed of germination aid in selection and evolution for seedling emergence and vigour. *Crop Science* 2 : 176-177.
- Mahantheshappa M, Himabindu K, Aswatha Narayana S C and Mahadevappa M 1992 Effect of seed size and vigour on yield and yield attributing factors in rice. *Oryza* 29 : 200-203.
- Malik S S, Dikshit N, Dash A B and Lodh S B 1994 Studies on Agromorphological and Physico-chemical characteristics of local scented rice. *Oryza* 31 : 106-110.

- Mallik S, Aguilar A M and Vergara B S 1990 Genetic nature of grain density in rice grain. International Rice Research Notes 15 : 7-8.
- Marekar R V and Siddique M A 1996 Genetic variability and correlation studies in rice. Journal of Maharashtra Agricultural Universities, 21 : 249-251.
- Maroti M 1957 In: The germination of seeds (eds. Mayer A and Haber A P), pp. 132-133.
- Matthews S and Brandnock W T 1967 The detection of seed samples of wrinkle seeded peas (*Pisum sativum* L.) of potentially low planting value Proceedings of International Seed Testing Association. 32 : 556 – 563.
- Matthews S and Brandnock W T 1968 Relationship between seed exudation and field emergence in Peas and French beans Horticultural Research 8 : 89.
- Maurya D M, Singh S K and Singh R S 1986 Genetic variation in 48 low land rice cultivars of Uttar Pradesh, India. International Rice Research Newsletter 11 : 13.
- Mayer A M and Haber A P 1957 The germination of seeds. A Wheaton and Co. Great Britain.
- Mishra B, Sobharani N and Subbarao L V 2002 Conservation of plant bio-diversity and farmers participatory varietal approach in rice. Paper presented at Workshop on Biodiversity Conservation 12-14th August. National Institute of Rural Development, Rajendranagar, Hyderabad.
- Mohanty S K and Sahoo N C 1992 Effect of soaking period, seed size and growth regulators on imbibition and germination of seeds of some field crops. Orissa Journal of Agricultural Research 5 : 1-2.
- Moore R P 1966 Tetrazolium tests for diagnosing causes for seed weaknesses and for predicting and understanding performance. Proceedings of Association of Official Seed Analysts, 56 : 70.
- Mukherji R K, Singh R A and Khan R A 1971 Tetrazolium staining as an index of germination and vigour in soybean seeds. Bulletin of Grain Technology 9 : 211 – 213.
- Murthy P S N and Govindaswamy S 1967 Inheritance of grain size and its correlation with hulling and cooking qualities. Oryza 4 : 12-21.
- *Nagoto K and Tanada Y 1957 Studies on the qualities of rice kernel. Proceedings of Crop Science Society of Japan 26 : 85-86.
- Narayana Reddy S K, Muralimohan Reddy B and Ankaiah R 1994 Effect of initial germination levels on vigour, growth and yield in rice. Seed Research 22 : 22-25.

- Oliveira M A, Mathews S and Powell A A 1984 The role of split seed coats in determining seed vigor in commercial seeds lots of soybean as measured by the electrical conductivity test. *Seed Science and Technology* 12 : 659-668.
- *Osborne D J, Roberts B E, Payne P I and Sen S 1974 In : *Mechanisms of Regulation of Plant Growth* (eds. Bialeske R L, Ferguson A R and Crosswell M M). Bulletin 12, The Royal Society of New Zealand, Wellington. pp. 805-812
- Padma V and Muralimohan Reddy B 2002 Standardization of Laboratory vigour test for rice. *Seed Research* 30 (1) : 74-78.
- Padmajarao S 1987 Panicle type : Few structural considerations for higher yield potential in rice. *Indian Journal of Plant Physiology* 9 : 87-90.
- Padmajarao S 1991 Breaking the yield barrier in rice through enhancing high density grain. *Proceedings of International Conference of Plant Physiology*. Banaras Hindu University, India pp. 307-316.
- Padmajarao S 1994 Partitioning pattern of biomass and yield components among different tillers of rice. *Indian Journal of Plant Physiology* 3 ; 277-278.
- Padmajarao S and Venkateswarlu B 1986 Grain grade index – a new method for realizing potential yields in rice. *Current Science* 55 : 465-466.
- Padmajarao S, Venkateswarlu B and Acharyulu T L 1985 Screening technique for differentiating the degree of spikelet filling in rice. *Plant and Soil* 88 : 289-293.
- Pandey M P, Seshu D V and Akbar M 1992 Genetic variation and association of embryo size to rice seed and seedling vigour. *Indian Journal of Genetics* 52 : 310-320.
- Pandey M P, Seshu D V and Akbar M 1994 Genetics of embryosome size and its relationship with seed and seedling vigour in rice (*Oryza sativa* L.). *Indian Journal of Genetics* 54 : 258-268.
- Panse V G and Sukhatme P V 1985 *Statistical methods for Agricultural workers*. Fourth revised edition. ICAR, New Delhi.
- Parish E J and Leopold A C 1978 On the mechanism of ageing in soybean seeds. *Plant Physiology* 61 : 365-368.
- Perry D A 1972 Seed vigour and field establishment. *Horticulture Abstracts* 42 : 334-342.

- Perry D A 1977 A vigour test for seeds of barley (*Hordeum vulgare*) based on measurement of plumule growth. Seed Science and Technology 5 : 709 – 719.
- Pollock B M and Roos E E 1972 Seed and Seedling vigour. In Seed Biology I (ed. Kozlowski) Academic Press, New York and London pp 313-387.
- Pollock B M and Toole V K 1966 Imbibition period as the critical temperature sensitive stage in germination of lima bean seeds. Plant Physiology 41 : 221.
- Powell A A and Matthews S 1977 Deteriorative changes in pea seeds (*Pisum sativum* L.) stored in humid or dry condition. Journal of Experimental Botany 28 : 225-234.
- Presley J T 1958 Relations of protoplast permeability in cotton seed viability and predisposition to seedling disease. Plant Dissertation Reporter 42 : 752.
- Purkar J K, Mehra R B and Banerjee S K 1979 Effect of seed ageing on associations between the quantitative characters. Seed Research 7 : 197-213.
- *Radwan M S 1973 Germination and seedling vigour of six pasture species in relation to moisture stress and temperature. Mesopotamia Journal of Agriculture 8 : 35-40.
- Raghavendar Rao D V S, Hussain S H, Reddy B M and Ankaiah R 1990 Effect of accelerated ageing on germination and yield in rice (*Oryza sativa* L.). Extended summary, Proceedings of International Symposium of Rice Research : New frontiers November 15-18. Directorate of Rice Research, Hyderabad pp : 411-412.
- Rajendraprasad N 1987 Studies on certain aspects of harvesting conditions and their environment, seed processing and storage in cultivars of blackgram and greengram. Ph.D. Thesis, Tamil Nadu Agricultural University, Coimbatore.
- Ram C and Wiesner E 1988 Effects of artificial ageing on physiological and biochemical parameters of seed quality in wheat. Seed Science and Technology 16 : 579-587.
- Ramesh Kumar V V 1989 Genetic analysis of yield and its components in four rice crosses. Journal of Research Andhra Pradesh Agricultural University 17 : 111.
- Ravinder V 1990 Studies on the effect of accelerated ageing on germination, vigour and yield of sunflower (*Helianthus annuus* L.). M.Sc. (Ag.) Thesis, Andhra Pradesh Agricultural University, Hyderabad.

- Ravindrababu G 2003 Effect of seed vigour on morphophysiological traits and field performance in different rice genotypes. M.Sc. (Ag.) Thesis, Acharya N.G. Ranga Agricultural University, Hyderabad.
- Ray M B and Gupta K 1979 Effect of accelerated ageing on germination, vigour and membrane permeability of different varieties of rice seeds. Indian Agriculturist 23 : 225-233.
- Ray M B, Halder S and Gupta K 1990 Differential responses of early and late cultivars of rice (*Oryza sativa* L.) seeds under accelerated ageing. Seed Science and Technology 18 : 823-831.
- Reddy J N, Pani D and Roy J K 1997 Variability and character association in low land rice. Indian Agriculturist 41 : 159-165.
- *Reddy L M M and Reddy T P 1986 Correlation and path analysis in aromatic varieties of rice (*Oryza sativa* L.). Genetica Agraria 40 : 341-350.
- Redona F D and Mackill D J 1996 Genetic variation for seedling vigour traits in rice. Crop Science 36 : 285-290.
- Roberts B E and Osborne J D 1973 Protein synthesis in rye grains. In Seed Ecology (ed. Heydecker W), Butter Worths, London pp. 99-114.
- Roberts E H 1972 Loss of viability and crop yields In : Viability of Seeds. Chapman and Hall, London pp. 307-320.
- Rowe D E and Gorwood D L 1978 Effects of four major endosperm mutants on kernel vigor. Crop Science 18 : 709-712.
- Roy A and Kar M K 1992 Heritability and correlation studies in upland rice. Oryza 29 : 195-199.
- *Ruan S L 1999 Effects of priming on germination and health of rice (*Oryza sativa* L.) Seeds and Seedling emergence in flooded soil. M.Sc. Thesis, Pozan Agricultural University, Poland.
- Ruan S, Xue Q and Gylkowska K 2002 The influence of priming on germination of rice (*Oryza sativa* L.) seeds and seedling emergence and performance in flooded soil. Seed Science and Technology 30 : 61-67.
- Sahadevan P C 1953 Studies on the problem of loss of viability of rice seeds in storage. Madras Agricultural Journal 40 : 133-143.
- Sahay M N, Jaiswal D K and Das S 1989 Effect of processing conditions of harvested rice on head rice yield and quality. Oryza 26 : 386-392.
- Satyapriya lalitha V and Sreedhar N 1999 Estimates of genetic parameters for quality traits in rice. Annals of Agricultural Research 20 : 18-22.

- Saxena O P, Pakeeraiah T and Lakshmi P 1985 Studies on accelerated ageing in sorghum. Indian Journal of Plant Physiology 28 : 35-41.
- Seshu D V and Dadlani M 1990 Seed vigour in rice : its assessment and impact on crop performance. Proceedings of international conference on Seed Science and Technology, February 21 – 25, 1990, New Delhi, India.
- Seshu D V and Dadlani M 1991 Mechanism of Seed dormancy in rice. Seed Science Research 1 (3) : 187-194.
- Seshu D V and Dadlani M 1993 Seed vigour in rice : its assessment and impact on crop performance. Seed Research (special volume) 2 : 700-706.
- Seshu D V and Sorrells M E 1986 Genetic studies on seed dormancy in rice, In: Rice Genetics. Proceedings of the International Rice Genetics Symposium, IRRI, Philippines pp. 369-382.
- Seshu D V, Krishnaswamy V and Siddique S B 1988 Seed vigor in rice. In Rice seed health. International Rice Research Institute, Philippines pp. 315-329.
- Sharma J K, Singh H B and Sethi G S 1990 Analysis of seed and seedling characters of rice (*Oryza sativa* L.) in the hills. Seed Research 18 (2) : 135-138.
- Sharma M L 1973 Simulation of drought and its effect on germination of five pasture species. Agronomy Journal 65 (6) : 982-987.
- Shenoy V V, Dadlani M and Seshu D V 1990 Association of laboratory assessed parameters with field emergence in rice. The non-anoic acid stress as a seed vigour test. Seed Research 18 (1) : 60-69.
- Shephard H L, Naylor R E L and Stuchbury T 1995 The influence of seed maturity at harvest and drying method on the embryo α -amylase activity and seed vigour in Rice (*Oryza sativa* L.). Seed Science and Technology 23 : 487-499.
- Shephard H L, Stuchbury T and Naylor R E L 1997 Locating sources of error in α -amylase assay and refining the methodology. Seed Science and Technology 25 : 351-359.
- Shukla T C, Khandekar M P and Sahu R K 1972 Phenotypic variation and its heritable components in quantitative yield contributing characters in rice (*Oryza sativa*). Indian Journal of Agricultural Science 42 : 660-663.
- *Siddique S B 1986 Variability in seed dormancy and tolerance to accelerated ageing of seed in rice (*Oryza sativa* L.). Ph.D. thesis, Cornell University, USA pp. 146.
- Singh K P 1992 Seed germination and seedling growth of lentil under stimulated water stress condition. Seed Research 20 (1) : 16-21.

- Sivasubramanian S and Ramakrishnan V 1978 Identification of rice varieties by laboratory techniques. *Seed Research* 6 (1) : 71-76.
- Sreenivasa Rao G 1989 Genetic analysis of certain quantitative characters in four crosses of rice (*Oryza sativa* L.) in F₂ generation. *Journal of Research Andhra Pradesh Agricultural University* : 215.
- Sreeramamurthy P V and Karivartharaju T V 1984 Seed invigoration in relation to seedling vigour based on seed phosphorus fractions as an antioxidant synergist in tomato (*Lycopersicon esculentum* Mill.). *Indian Journal of Experimental Biology* 22 (4) : 189 – 195.
- Subbarao L V 1984 Seed management practices for storage and production of transplants in brinjal (*Solanum melongena* L.). M.Sc. Ag. Thesis, Tamil Nadu Agricultural University, Coimbatore.
- Subbarao L V, Shiv Kumar and Vanisree G 1996 Genetic variability for seedling characteristics among rice (*Oryza sativa* L.) cultivars. *Seed Research* 24 (2) : 124-128.
- Suguna C A, Gopal Singh B and Jaganmohan Rao V 1985 Study of root characters in relation to seed weight in rice and sorghum. *Seed Research* 13 (2) : 148-150.
- Suhaila A Younis, Faize I A L-Rawi and Edward G Hagop 1990 Physiological and biochemical parameters of seed quality in some rice varieties (*Oryza sativa* L.). *Seed Research* 18 (2) : 148-153.
- Sumner J B 1944 A method of calorimetric determination of phosphorus *Science* 100 : 413.
- Sung F J M and Chen J J 1988 Tetrazolium test for predicting the seedling vigour of rice at optimal and sub-optimal temperatures. *Crop Science* 28 : 1012-1014.
- Sung T Y and Delouche J C 1962 Relation of specific gravity to vigour and viability in rice seed. *Proceedings Association of Official Seed Analysts* 52 : 168.
- Suryatma G, Copeland L O and Miles D F 1980 Comparison of laboratory indices of seed vigor with field performance of Navy bean (*Phaseolus vulgaris* L.). *Agronomy Abstracts* 113.
- *Takahashi N 1956 Studies on the varietal difference in the velocity of germination of rice seeds. Report of Institute of Agricultural Research, Tohoku University 1 : 1-15.
- *Takahashi N 1960 Studies on the internal factors of rice seed regulating the germination velocity. Report of Institute of Agricultural Research. Tohoku University 11 : 1-7.

- *Takeda K 1972 Relationship between the seed weight and the seedling growth in the rice plant. I. Seedling growth depending completely on the materials in seeds. Bulletin of Fac. Agriculture. Hirosaki University 19 : 10-21.
- Tatum L A 1954 Seed permeability and 'cold test' reaction in *Zea mays*. Agronomy Journal 46 : 8.
- Tekrony D M and Egli D B 1977 Relationship between laboratory indices of soybean seed vigor and field emergence. Crop Science 17 : 573-577.
- Tonapi V A 1988 Studies on the effect of harvesting conditions on vigor potential, viability and storability of seeds in sorghum (*Sorghum bicolor* (L.) Moench). Ph.D. Thesis Tamil Nadu Agricultural University, Coimbatore.
- Turner J H and Ferguson 1972 Field performance of cotton grown from filled and partially filled seeds. Crop Science 12 : 868-871.
- UPOV 2000 Guidelines for conduct of tests for distinctness, homogeneity and stability of new varieties of plants. International Union for Protection of new plant Varieties. Geneva TG/16/4 : 52-54.
- Verma O P, Singh R K and Singh P V 1992 Effects of age of seed on yield and yield components in rice. Narendradeva Journal of Agricultural Research 7 : 91-94.
- Vieira R D, Paiva-aguero J A, Perecin D and Bitten court S M R 1999 Correlation of electrical conductivity and other vigour tests with field emergence of soybean seedlings. Seed Science and Technology 27 : 67-75.
- Williams J F and Peterson M L 1973 Relations between α -amylase activity and growth of rice seedlings. Crop Science 13 : 612-615.
- *Winn T, Yamauchi M, Soe T T, Ni S, Thein S and Garcia A G 1997 Rice (*Oryza sativa* L.) cultivars suitable for direct seedling in Myanmar. Japanese Journal of Tropical Agriculture 41 (2) : 66-73.
- Wood Stock K W 1973 Physiological and biochemical tests for seed vigor. Seed Science and Technology 1 : 127-157.
- Wood Stock L W 1969 Seedling growth as a measure of seed vigour. Proceedings of International Seed Testing Association 34 : 273-280.
- Wright L N 1980 Germination rate and growth characteristics of blue panic grass. Crop Science 20 : 42-44.
- Yaklich R W and Kulik M M 1979 Evaluation of vigor tests in soybean seeds : Relationship of the standard germination test, seedling vigour classification, seedling length and tetrazolium staining to field performance. Crop Science 19 : 247-252.

- Yamauchi M 1995 Anaerobic direct seedling of rice in the tropics. JIRCAS Journal 2 (2) : 65-78.
- Yamauchi M and Biswas J K 1997 Rice cultivar difference in seedling establishment in flooded soil. Plant and Soil 189 : 145 – 153.
- Yamauchi M and Chuong P V 1995 Rice seedling establishment as affected by cultivar, seed coating with calcium peroxide, sowing depth and water level. Field Crops Research 41 : 123-124.
- Yamauchi M and Winn T 1996 Rice seed vigour and seedling establishment in anaerobic soil. Crop Science 36 : 680-686.
- Yamauchi M, Aguliar A M, Vaughan D A and Seshu D V 1993 Rice germplasm suitable for direct sowing under flooded soil surface. Euphytica 67 : 177-184.
- Yan Q C and Li W X 1995 Relationship between seed vigour and field performance of hybrid rice. Scientia Agricultura Sinica 28 : Supplement : 90-98.
- Yang C M and Sung J M 1980 Relations between nitrate reductase activity and growth of rice seedlings. Journal of Agricultural Association of China 111 : 15-23.

*Original not seen

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- Tahir M H N, Muhammad Imran, Hussain M K 2002 Evaluation of sunflower (*helianthus annuus* L.) inbred lines for drought tolerance. International Journal of Agriculture and Biology 4 (3) : 398-400.
- Dhillon A S and Sidhu M S 2001 Impact of irrigation on sunflower (*Helianthus annuus* L.) productivity. Journal of Oilseeds Research 18 (2) : 185-186.
- Gimenez C, Fereres E and Fernandez J M 1986 Genetic variability in sunflower cultivars under drought. Australian Journal of Agricultural Research 37 : 573-582.
- Nel A A 1998 The response of germinating sunflower seed to heat tolerance induction. South African Journal of Plant and Soil 15 : 2, 90 : 2 ref.
- Senthil Kumar M, Srikanth Babu V, Raju B M, Ganesh Kumar, Shivaprakash N and Udayakumar M 2003 Screening of inbred lines to develop a thermotolerant sunflower hybrid using the temperature induction response (TIR) technique : a novel approach by exploiting residual variability. Journal of Experiences Botany 54 : 392, 2569-2578.
- Manjula K, Nadaf h L and Giriraj K 2001 Genetic diversity in non-oil seed sunflower (*Helianthus annuus* L.) genotypes. Helia 24 : 34, 17-24.
- Sujatha H L, Chikkaderaiah and Nandinin 2002 Assessment of genetic diversity among 51 inbred sunflower lines. Helia 25 : 37, 101-107.
- Subrahmanyam S V R, Kumar S S and Ranganatha A R G