CHARACTERISATION OF DROUGHT TOLERANCE IN RICE (*Oryza sativa* L.) GENOTYPES

By

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THESIS

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DECLARATION

I, **Jeevan S.** hereby declare that this thesis entitled **'Characterisation of drought tolerance in rice (*Oryza sativa* L.) genotypes'** is a bona-fide record of research done by me during the course of research and that the thesis has not previously formed the basis for the award of any degree, diploma, fellowship or other similar title, of any other University or Society.

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CERTIFICATE

Certified that this thesis, entitled **'Characterisation of drought tolerance in rice (*Oryza sativa* L.) genotypes'** is a record of research work done independently by **Jeevan S.** under my guidance and supervision and that it has not previously formed the basis for the award of any degree, diploma, fellowship or associateship to him.

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ABBREVIATIONS

%	Per cent
µg	microgram
DAS	days after sowing
DES	Directorate of Economics and Statistics
cm	Centimeter
CSI	Chlorophyll stability index
^{0}C	degree Celsius
CRD	Completely Randomised Design
FAO	Food and Agricultural Organisation
g	Gram
GA	Genetic advance
GCV	Genotypic coefficient of variation
GG	Genetic gain
h^2	Heritability
IRRI	International Rice research Institute
ISTA	International Seed Testing Association
KAU	Kerala Agricultural University
kg	Kilogram
mg	milligram
ml	milliliter
PCC	Phenotypic coefficient of variation
RBD	Randomized Block Design

Introduction

I. INTRODUCTION

Rice (*Oryza sativa* L.) is amenable for cropping under diverse ecologies ranging from irrigated to rainfed upland to rainfed lowland to deep water. World rice production in 2013 was estimated to be 475.50 million tonnes grown from 164.72 million hectares with an average productivity of 4.53 tonnes ha^{-1} (FAO, 2014). Rainfed lowland represents about 25 per cent of total rice area, accounting for 17 per cent of the rice production while upland rice accounted for 13 per cent of the world rice area contributing 4 per cent of global rice production (Bindu, 2014).

Rice has been the mainstay of farming community in the Indian sub-continent for time immemorial. In India, during 2013 -14, an area of 43.50 million hectares was under rice cultivation resulting in a production of 159.20 million tonnes and productivity of 3.66 tonnes ha^{-1} (FAO, 2014), while in Kerala, during 2012-13, it covered an area of 1.97 lakh ha with a production of 5.08 lakh tonnes and productivity of 2.57 tonnes ha^{-1} (DES, 2014).

The coverage of upland rice in India during 2011 was estimated to be 6 million hectares (Anon., 2011). Similar to the rice farming scenario in the country, rainfed uplands in Kerala constitute a negligible part of the total area under rice. NARP status report (KAU, 1984) records that upland (modan) paddy in Kerala constituted only 1.17 per cent of the total grossed cropped area in upland agro-ecology of the central region. Statistics point to the existence of 97,069 ha (2.5% of total geographical area) cultivable fallow land in Kerala during 2013-14 (DES, 2014). This is a pointer to the vast under-utilized and untapped potential of upland rice cultivation in our state.

Since, land and water is fast becoming a scarce commodity and the scope of expansion of irrigated area under rice in Kerala is very much limited, emphasis of upland rice has become imperative. In lieu of this, ample technical and financial supports from state and national agencies have been given in the recent years for promotion of upland rice in the state. During 2011-12, the Department Agriculture, Government of Kerala, had proposed to bring 8000 ha under upland rice cultivation (GOK, 2012). This effort by the Department of Agriculture, Government of Kerala paid off with an area of 6539 ha being brought under upland rice cultivation during 2011-2012 (Francies, 2013).

In uplands, rainfall is the most variable and least predictable environmental component, the amount and distribution of which determine productivity in uplands (Luo and Zhang, 2001). Variable rainfall can induce water stress to rice at any stage of crop development.

Upland rice fields seldom experience standing water, and the rice crop is by and large subjected to mild stress conditions continuously with more severe stress developing between major rainfall events, particularly under conditions with high evapo-transpiration (Kamoshita *et al.*, 2008). The varying degree and duration of drought during the crop cycle can severely reduce rice grain yield in rainfed lowlandand and upland environments (Yue *et al.*, 2006).

The degree of tolerance to same degree of water stress has been found to vary between genotypes and depends more on its genetic architecture. Rice cultivars are known to show differential tolerance to both intensity and duration of soil moisture occurring at different stages of growth (Hsiao, 1982). The native landraces are considered to be important genetic resources serve as base material for the development of new varieties with incorporated tolerance to various biotic and abiotic stresses (Ram and Vinod, 2007; Hanamaratti *et al.*, 2008 and Huang *et al.*, 2010).

Identification of genotypes best suited for a given situation and understanding the associated characters is essential for improving crop productivity under drought stress. Hence, the present study was formulated with the following objectives

1. To collect, characterize and assess variability in rice genotypes suitable for upland cultivation

2. To study the response of various rice genotypes to moisture stress at different growth stages

Review of literature

II. REVIEW OF LITERATURE

Considering the shrinking arable land and water source available for agriculture, sustaining food production to meet the needs of growing population is a challenging task faced by today's agriculture sector. A sizeable amount of rice production in India comes from rainfed ecosystem including uplands, where drought may occur at any stages of crop growth leads to severe damages to rice crop ultimately reducing the grain yield. High yield in both rainfed uplands and lowlands has always been attributed to the drought tolerant nature of the genotype. A brief review on upland rice, drought tolerance and variability in rice is reviewed under the following headings.

2.1 Rice in uplands

2.2 Response of rice genotypes to drought

2.3 Laboratory screening for elucidation of drought tolerance

2.4 Genetic variability in rice

2.5 Correlation studies

2.6 Path analysis

2.1 Rice in uplands

Upland rice is referred to as *ahu* in Assam, *aus* in West Bengal, *beali* in Orissa, *kauri* in eastern Uttar Pradesh and *modan* in Kerala. Based on the rainfall received, uplands are broadly classified into, high rainfall areas (1100-2000 mm), moderate rainfall areas (800-1100 mm) and *jhum* land in hilly terrain with shifting cultivation. North eastern upland area, parts of West Bengal, Orissa and Kerala make up most of the high rainfall area category. Rice yield in this group is low because of soil nutrient problem and short periods of moisture stress (Anon., 1986).

Water stagnation is seldom found in upland rice fields and the rice crop is subjected intermittently to mild stress conditions continuously with more severe stress developing between major rainfall events (Kamoshita *et al.*, 2008). The dry spells in uplands is unpredictable and can occur at almost any time during the rice growth period, leading to drought stress of varying intensity that may adversely affect growth and yield (Thomas *et al.*, 2003).

Although uplands in Kerala falls under the high rainfall area, moisture stress is prevalent in this ecoystem owing to the undulating topography and poor water holding capacity of laterite soils. Run-off and quick drainage of rain water received during monsoons imposes moisture stress on rice crop grown in uplands (Francies, 2013). The uplands are witness to the fact that the hydrology of rainfed rice fields does not only depend on rainfall, but, are also dependent on their position in the landscape as opined by Hijmans and Serraj (2009).

Agronomic and the genetic management are the two options advocated for the management of crops in water limiting environments (Saxena and Toole, 2002). The genetic management option involves development of drought tolerant varieties that could serve as a low cost input acceptable to resource-poor, rainfed, small land holding farmers in rainfed areas. However, it is found that responses of drought tolerant genotypes to moisture stress are highly variable. Drought tolerance and drought avoidance are two major mechanisms for drought resistance of rice. Grain yield of some genotypes is affected less than others by drought and genotypic adaptation to drought is not consistent across different drought conditions. Several factors have been suggested to be responsible for drought tolerance in rice.

In Kerala, traditional rice varieties (TRVs) *viz.*, Parambuvattan, Karuthamodan, Kattamodan, Chuvannamodan, Karanavara and Kalladiaryan and few high yielding varieties (HYVs) *viz.*, PTB 60 (Vaishak), PTB 42 (Suvarnamodan), PTB 43 (Swarna Prabha), PTB 52 (Aiswarya), PTB 50 (Kanchana), Mo 15 (Uma) and Onam are grown in uplands. High yielding varieties may require higher input for their optimum production, while traditional varieties are supposed to be adopted to low inputs (Anon., 2012). In other parts of India, IET 19253, IET 19258, IET 143959, Rajendra, Bhagwathi, Anna (R) 4, Sabhagidhan and Mandakini are the popularly grown upland varieties (Diwakar, 2012). Few internationally acclaimed varieties suitable for uplands include IRAT 13, Moroberekan, Nerica, IR 55419, IR 47686, IR 78878, NSIC9, UPLRI7 and AUS 196 (Anon., 2013).

2.2 Response of rice genotypes to drought

Several attempts to identify promising genotypes that can withstand moisture stress and the physiological and morphological characters associated with drought tolerance, have been attempted both under laboratory and field conditions. A brief insight in to the progress made is given below.

As early season drought reduces seedling growth, rapid recovery of leaf growth upon rewatering is essential for radiation interception, biomass accumulation and grain yield (Datta *et al.*, 1973). Chang *et al.* (1974) used leaf rolling and leaf death for assessing levels of field tolerance for drought, while O'Toole and Cruz (1979) found that, it could be sufficiently reliable to be used as an estimate of dehydration avoidance.

Visual scoring techniques based on either leaf rolling or leaf tip drying, were found to be highly correlated with maintenance of leaf water potential (O'Toole and Moya, 1978).

Drought was reported to decrease grain number/panicle, panicle weight, panicle length, plant height and grain yield and increased sterility/panicle (Li and Chu, 1979).

Root diameter, rooting depth and root/shoot dry weight ratio were thought to be related to drought avoidance in rice based on the positive correlations between these characters and visual scores of plant vigor in upland field drought screening trials (O'Toole and Soemartono, 1981; Yoshida and Hasegawa, 1982).

Murthy and Ramkrishnayya (1982) found that drought at tillering stage reduced plant height and leaf length, induced leaf rolling or drying and prolonged vegetative stage.

A ten day period of water stress was found to affect the relative water content and leaf water potential of rice cv. In variety Ratna. These effects could be reversed by rewatering. However the water stress lowered plant chlorophyll contents while free proline accumulation was increased. Water stress effects during the reproductive stages were not as readily reversed by rewatering as during the vegetative stages. Mild water stress during vegetative stages increased yields but during reproductive stages decreased yields (Biswas and Choudhuri, 1984).

In an assessment of twenty six varieties subjected to water stress, seedling survival rate and leaf water content at 24 h after excision were closely related to seedling drought resistance (Gao and Hu, 1984).

Association between high root length density and the amount of water extracted has been well demonstrated (Lilley and Fukai, 1994) under upland conditions particularly, these root characters contributed to high yield. According to Nguyen *et al.* (1997), upland rice genotypes usually have deep and thick root systems, which allow the crop to satisfy its water requirement.

Of six rice cultivars tested under rainfed upland conditions the local cultivars Kodibudama and Mettamolagolukulu were found superior to new cultivars in seedling vigour, drought tolerance and recovery from drought stress (Swamy and Reddy, 1998).

Genotypes may differ in their recovery growth after vegetative stage drought. This might be related to the ability to tiller after drought (Lilley and Fukai, 1994) or the amount of leaf that remained after drought (Mitchell *et al.* 1998). Valarmathi and Leenakumary (1998) reported that yield increases in upland rice, were dependent on an increase in the number of productive tillers per plant. They observed a reduction in the time to maturity in rice cultivars under direct sowing upland situation compared to lowland transplanted conditions.

In a net house pot experiment at Jorhat, Assam, ten local cultivars were subjected to water stress. Leaf area, relative leaf water content (RLWC) and root and shoot dry weight decreased significantly under stress. Cultivars Iharsal Ahu and Maibee II maintained higher RLWC and recorded lower reduction in leaf area and root and shoot dry weight than the other cultivars. Leaf chlorophyll content decreased under stress, while leaf proline content increased (Deka, 2000).

Six diverse genotypes were tested under shorter and prolonged periods of drought. Genotypes with greater seedling vigour developed a deep-root system earlier in response to drought and consumed soil water more quickly, experiencing greater reduction in transpiration, water-use efficiency and biomass production during prolonged drought. Recovery from drought was better in these genotypes under both short and prolonged stress treatments (Kamoshita, 2001).

Lafitte and Courtois (2002) found that early maturity was advantageous under drought over later flowering in terms of higher spikelet fertility, higher harvest index and higher yield even when stress was applied at specific developmental stages for each cultivar.

Leaf water potential, leaf rolling, leaf drying, canopy temperature and delay in flowering time can reflect the internal plant water status under water stress, and these traits can be considered as integrative traits to identify drought resistant genotypes (Pantuwan *et al.* 2002a; Jongdee *et al.*, 2002).

Among genotypes of a similar maturity type, genotypes that can maintain high leaf water potential are often advantageous in producing higher yield under terminal drought conditions (Jongdee *et al.* 2002; Pantuwan *et al.* 2002b).

Drought stress developed before flowering often has an effect in delaying flowering time and the delay in flowering time was negatively associated with grain yield, fertile panicle percentage and filled grain per cent in rainfed lowlands (Pantuwan *et al.*, 2002a).

Fukai and Kamoshita (2004) opined that in contrast to terminal drought, under intermittent drought a deep root system with higher root density is likely to be useful. Seedling vigor was often related to quicker development of the deep root system before drought development, which accelerated water extraction and maintained growth during intermittent drought.

Kamoshita *et al.* (2004) evaluated six diverse rice genotypes selected from rainfed lowland germplasms to examine the development of a deep root system and osmotic adjustment and their relationship with biomass production during drought and after re-watering, under two different drought durations (shorter and prolonged). Two genotypes *viz.*, NSG19 and KDML105 showed superior drought recovery even after a prolonged drought period in which they suffered a greater reduction in transpiration, water use efficiency and biomass production which was attributed to larger plant size by the end of the drought period rather than with plant water status during drought, such as osmotic adjustment or leaf water potential.

Rice reacted to drought stress with reductions in height, leaf area and biomass production, tiller abortion, changes in root dry matter and rooting depth and a delay in reproductive development (Asch, 2005).

Moisture stress at late vegetative and reproductive stages resulted in reduction of number of panicles per plant, percentage of filled grain and 1000 grain weight (Fabre *et al.*, 2005).

Terminal dry spell imposed at flowering stage was found to be more severe to reduce the crop yield as compared to dry spell given at vegetative stage. Reduction in grain yield over no dry spell was recorded about 44.1, 19.1 and 11.90 per cent in terminal stage dry spell, vegetative dry spell and early tillering dry spell, respectively. The genotype Sarjoo 52 had better ability to grow under moisture deficit condition hence, identified as more drought resistant at all the stages amongst the genotypes tested (Kumar *et al.*, 2006).

Zou *et al.* (2007) suggested that genotypes with drought resistance can be identified by measuring yield potential, delay in flowering, reduction in plant height under test environments of well-watered and drought stress.

The experiment conducted by Kato *et al.* (2007) revealed that genotypes with deep rooting cultivars maintained higher leaf water potential, accumulated more nitrogen and produced more biomass with less reduction in panicle weight.

Later maturing and longer growth duration cultivars show less growth stagnation and drought damage and have a higher yield when they encounter mild water shortages during the vegetative to panicle initiation stages (Ikeda *et al.*, 2008).

Okocha (2008) has used seedling recovery as criteria to identify the tolerant rice genotypes at seedling stage, whereas spikelet fertility has been used at reproductive stage.

Sarvestani *et al.* (2008) found that, water stress at vegetative stage significantly reduced plant height. Water stress at flowering stage had a greater grain yield reduction than water stress at other time. The reduction of grain yield largely resulted from reduction in filled grain percentage. Water deficit during vegetative flowering and grain filling stages reduced mean grain yield by 21, 50 and 21 per cent on average compared to control. Total biomass, harvest index, plant height, filled grain and 1000 grain weight were reduced under water stress in all cultivars. Water stress at vegetative stage effectively reduced total biomass due to decrease of photosynthesis rate and dry matter accumulation.

Allah *et al.* (2010) observed that the genotypes which performed better under drought conditions, remained tall under water stress (80-100 cm), had a moderate tillering ability (21-27 tiller), narrow leaf angle, good drought score (1-3), desirable leaf area (15- 21), low sterility per cent (17 - 19), deeper roots (28 - 34 cm), high root volume (30 - 34 ml) , high nitrogen content in their shoot (1.40 - 2.82) and high grain yield (8 - 9 t/ha)

Cham-um *et al.* (2010) observed reduction in relative water content, chlorophyll content and increase in proline content under reduced soil moisture condition. They also they have identified drought tolerant genotypes based on stability in panicle length and fertile grains.

The study conducted by Guan (2010), revealed three possible mechanisms that functioned together to contribute to improved drought tolerance. The most important mechanism was dehydration avoidance (DA), characterized by significantly higher growth rate and biomass of genotypes under stress and no reduction in biomass under control conditions. The second mechanism was efficient partitioning, characterized by improved harvest index, resulting primarily from heavier grain weight and/or higher spikelet fertility under control conditions, which was the major constituent of the improved yield. Drought escape (DE) by accelerated heading under drought was the third mechanism that contributed to drought tolerance.

Manickavelu, *et al.* (2010) emphasised the importance of selection pressure on days to 70 per cent RWC, panicle length, grains per panicle, harvest index, biomass yield, root/shoot ratio, dry root weight and root length in positive direction and leaf rolling, leaf drying and drought recovery rate in negative direction for improvement of yield in drought resistance breeding programme.

Lin *et al.* (2011) found that maximum root length, number of roots, fresh root weight and root relative water significantly influenced the drought resistance at seedling stage, thus could be used as comprehensive index for drought resistance at the seedling stage

According to Bocco *et al,* (2012), when water stress was imposed by stopping irrigation from 45th days after sowing, there was reduction in plant height, spikelet fertility, grain yield and leaf area at harvesting. Values of leaf temperature, leaf rolling, leaf tip drying, leaf blast, days from seeding to flowering and maturity were higher under drought.

Maiti *et al.* (2012) screened rice varieties for drought resistance at seedling stage by applying drought cycles in polyhouse. Drought resistant varieties showed high seedling survival, deep root system, stay green character and good recovery after drought period. The root system contributed more to drought resistance in these varieties.

Sikuku (2012) reported that, water deficit caused a significant reduction in physiological parameters namely growth, chlorophyll fluorescence and biochemical parameters like chlorophyll and protein content both at vegetative stage and at reproductive stage. Plant height, root length and plant dry weight were affected more by water deficit imposed at the vegetative stage as compared to water deficit imposed at the reproductive stage while chlorophyll fluorescence, chlorophyll content and protein content were affected more by water deficit imposed at reproductive stage as compared to water deficit at vegetative stage.

Bunnag and Pongthai (2013) have used plant characters such as plant height, number of tillers per plant, leaf rolling, leaf death, leaf water potential, relative leaf water content and proline content for identifying the drought tolerant, moderately tolerant and susceptible genotypes under vegetative stage drought.

A majority of the drought-tolerant landraces showed early flowering, tall plant height, low tillering and low yield compared with medium to late flowering, semi-dwarf plant height, high tillering and high yield of the high-yielding popular varieties. Some of these landraces have also been known to possess deep roots up to 70 cm below the soil surface (Henry *et al.*, 2011).

Kumar *et al.* (2013) suggested that less reduction in relative water content (RWC), chlorophyll and high content of proline and catalase activity during drought stress can be taken as screening criteria for drought stress tolerance in rice.

Drought stress at reproductive stage caused reduction in RWC (31.57 %), grain yield (55.31 %), number of effective tillers (37.70 %), and increase in grain sterility (51.5 %) and proline content (55.9 %) in rice genotypes. However, the responses varied among genotype (Kumar *et al.*, 2014).

2.3. Laboratory screening for elucidation of drought tolerance

Review with respect to effect of Polyethylene glycol (PEG) simulated moisture stress on various seedling characters of rice genotypes are enumerated below.

Lu *et al.* (2009) studied the drought tolerance in *indica/ javanica* recombinant inbred lines at the germination stage. PEG-6000 at 20 per cent was used to induce water stress. Radicle length, shoot length, and shoot dry weight were measured during exposure to water stress for seven days. Among the 270 lines, eight lines showed drought tolerance.

Vikas *et al.* (2009) assessed the drought tolerance ability of 39 genotypes using PEG-6000 induced moisture stress and found that germination, shoot length, root length, seedling dry weight, promptness index (PI), germination stress index (GSI), reduced significantly at -0.75 M.Pa. compared to control (0.00 MPa).

Seeds of rice cultivars CSAR-13, CSAR-27, CSAR-77, CSAR-148 205, CSAR-253, CSAR-256, Pant-12, Basmati-370, IET-11120 and IR-539-30-2-2-3-3 were subjected to water stress in terms of various external water potential during seed germination and seedling growth under osmoticum solution of PEG-6000. IET-11120 and IR-539-30-2-2-3-3 proved better for seedling growth under moisture stress condition (Anaytullah *et al.*, 2008).

Lum *et al.* (2014) studied the response of eight upland rice varieties subjected to different drought levels (0, -2, -4, -6, -8 bar) at germination and early seedling growth stage of plant development, found that drought tolerant variety Pulot Wangi tolerated PEG at the highest drought level (-8 bars) without showing significant difference in relation to control. However, drought-sensitive variety, Kusam was markedly affected even at the lowest drought level used.

Nagaraju *et al.* (2014) identified MTU 1010 and BPT 5204 as drought tolerant genotypes by subjecting them to simulated drought at -1.2 M. Pa. The

PEG induced water stress inhibited germination, affected both shoot and root growth of the genotypes. At -6 bar moisture stress, only nine genotypes showed more than 40 per cent germination while forty three genotypes including the susceptible control did not germinate at all. Eleven genotypes had a value less than 20 per cent and for twelve genotypes, the frequency varied between 20 – 39 per cent. Three accessions i.e. IRGC 44975, IRGC 45699 and IRGC 53989 showed more than 80 per cent germination and in comparison, the two tolerant controls showed more than 60 per cent germination only. However, when the stress was released after 10 days, the germination has gone up to 80-90 per cent in most of the genotypes (Swain *et al.*, 2014).

Response of eight upland rice varieties subjected to different drought levels were investigated in laboratory to evaluate eight local upland rice varieties against five drought levels (0, -2, -4, -6, and -8 bars) at germination and early seedling growth stage of plant development. Shoot length, root length, and dry matter yield were measured. The drought-tolerant variety, Pulot Wangi tolerated PEG at the highest drought level (-8 bar) and showed no significant difference in relation to control. However, drought-sensitive variety, Kusam was markedly affected even at the lowest drought level used (Lum *et al.*, 2014).

Gampala *et al.* (2015) studied the effect of drought stress using PEG 6000 on germination and some physiological characterization of rice varieties including germination percentage speed of germination root length, shoot length, fresh weight and dry weight. The effect of PEG 6000 was significant for germination per cent, speed of germination shoot length, fresh and dry weight, whereas it was not significant for root length.

2.4. Genetic variability in rice

The knowledge of genetic variability present for the character under improvement is of great importance for the success of any plant breeding programme. The genotypic variance and phenotypic variance influences the heritability estimates and genetic advance under selection as well. (These estimates are important selection parameters. Heritability estimates along with genetic advance are normally more helpful in predicting the genetic gain under selection than heritability estimates alone). Studies related to variability in rice are enumerated in Table 1.

2.5 Correlation analysis

The knowledge on the association between yield and yield attributes will immenly help the breeder in the improvement of yield. The correlation coefficient will help to delineate characters that have little or no importance in the selection programme. The existence of correlation may be attributed to the presence of linkage or pleiotropic effect of genes or physiological and development relationship or environmental effect or in combination of all (Oad *et al.* 2002). The review on correlation studies in rice is presented in Table 2 and 3.

2.6 Path Analysis

Path coefficient analysis is a tool which permits the partitioning of the correlation coefficient into its components, one component being the path coefficient that measures the direct effect of a predictor variable upon its response variable; the second component being the indirect effect of a predictor variable on the response variable through other predictor variables (Dewey and Lu, 1959). In agriculture, path analysis has been used by plant breeders to assist in identifying traits that are useful as selection criteria to improve crop yield (Milligan *et al.* 1990). A brief review on path analysis in rice is presented in Table 4 and 5.

Table 1. Studies on variability in rice

Characters	PCV	GCV	Heritability	Genetic gain (%)	Authors
Plant height	Low	Low	High	Moderate	Akhtar *et al.* (2011) Gampala *et al.* (2014)
	Moderate	Moderate	High	High	Ghosh *et al.* (2012) Khare *et al.* (2014) Soni *et al.* (2013) Singh *et al.* (2014)
	High	High	High	High	Pal *et al.* (2010) Kumar *et al.* (2011)
	Moderate	Low	High	Moderate	Fiyaz *et al.* (2011)
	Moderate	Moderate	High	Moderate	Quatadah *et al.* (2012)
	Moderate	High	Low	Low	Bindu *et al.* (2014)
	Low	Moderate	High	Moderate	Patel *et al.* (2014)
	Low	Moderate	Low	Low	Ramanjaneyulu *et al.* (2014)
Days to fifty per cent flowering	Moderate	Low	High	Moderate	Fiyaz *et al.* (2011) Singh *et al.* (2011)
	Moderate	Moderate	High	High	Karthikeyan *et al.* (2010) Soni *et al.* (2013)
	Low	Low	High	Moderate	Gampala *et al.* (2014) Khare *et al.* (2014) Patel *et al.* (2014) Singh, *et al.* (2014)
	Low	Low	High	Low	Quatadah *et al.* (2012)

	Low	Low	Moderate	Moderate	Bhadru *et al.* (2012)
Productive tillers per plant	Moderate	Low	High	Moderate	Karthikeyan *et al.* (2010)
	High	High	High	High	Sabesan *et al.* (2009) Ghosh *et al.* (2012) Khare *et al.* (2014) Singh, *et al.* (2014)
	High	High	High	Low	Jayasudha and Sharma (2010) Soni *et al.* (2013)
	High	Low	Moderate	Low	Fiyaz *et al.* (2011)
	High	Moderate	Low	Moderate	Bindu *et al.* (2014)
	Low	Moderate	Moderate	Moderate	Gampala *et al.* (2014)
	Low	Low	High	Moderate	Patel *et al.* (2014)
	Moderate	High	Moderate	Moderate	Ramanjaneyulu *et al.* (2014)
Panicle length	Low	Low	High	Moderate	Kumar *et al.* (2012) Bindu *et al.* (2014)
	Moderate	Low	Moderate	Moderate	Pal *et al.* (2010)
	Moderate	Moderate	High	Low	Jayasudha and Sharma (2010)
	Moderate	Low	Moderate		Idrisl *et al.* (2012)
	Low	Low	High	Low	Singh *et al.* (2011) Gampala *et al.* (2014)
	Low	Low	Moderate	Low	Bhadru *et al.* (2012)
	Moderate	Moderate	High	High	Ghosh *et al.* (2012) Khare *et al.* (2014)
	Low	Low	Moderate	Moderate	Patel *et al.* (2014)

	High	High	High	Low	Soni *et al.* (2013)
	Moderate	Moderate	High	Moderate	Singh, *et al.* (2014)
Panicle weight	High	High	High	Low	Soni *et al.* (2013)
	Moderate	Moderate	Moderate	Moderate	Veeresha *et al.* (2014)
	High	High	High	-	Chavan and Lal *et al.* (2014)
Spikelets per panicle	High	High	High	High	Singh *et al.* (2011) Khare *et al.* (2014) Soni *et al.* (2013) Ghosh *et al.* (2012)
	High	Moderate	High	High	Quatadah *et al.* (2012)
	Moderate	Moderate	High	Moderate	Gampala *et al.* (2014)
Grains per panicle	High	High	Moderate	High	Karim *et al.* (2007)
	High	High	High	High	Khare *et al.* (2014) Patel *et al.* (2014) Soni *et al.* (2013) Singh, *et al.* (2014)
	High	High	Moderate		Idrisl *et al.* (2012)
	High	High	High		Akhtar *et al.* (2011)
	Moderate	Moderate	High	High	Kumar *et al.* (2012)
	High	Moderate	Moderate	High	Bhadru *et al.* (2012)
	High	Moderate	Moderate	Moderate	Bindu *et al.* (2014)
1000 grain weight	High	High	High	High	Karim *et al.* (2007) Ramanjaneyulu *et al.* (2014)
	Moderate	Moderate	High	High	Gampala *et al.* (2014)

					Khare *et al*. (2014) Patel *et al*. (2014) Singh, *et al*. (2014)
	Moderate	Moderate	Moderate	High	Bhadru *et al*. (2012)
	Low	Low	High		Akhtar *et al*. (2011)
	High	High	High	Moderate	Soni *et al*. (2013)
Grain yield per plant	High	High	High	High	Khare *et al*. (20140 Singh, *et al*. (2014) Patel *et al*. (2014)
	High	High	Moderate	High	Karim *et al*. (2007)
	High	High	High	Moderate	Jayasudha and Sharma (2010) Soni *et al*. (2013)
	High	Moderate	High	Low	Quätadah *et al*. (2012)
	Low	Moderate	Low	Low	Gampala *et al*. (2014)
	Moderate	High	High	High	Ramanjaneyulu *et al*. (2014)
Straw yield per plant	High	High	High	High	Shet *et al*. (2012) Patel *et al*. (2014)
	Low	High	Low	Low	Ramanjaneyulu *et al*. (2014)
Chlorophyll stability index (CSI)	Moderate	Moderate	High	High	Sathya and Jebaraj (2013)

Table 2. Correlation studies of yield components with grain yield

	Phenotypic correlation		Genotypic correlation	
	Positive	**Negative**	**Positive**	**Negative**
Grain yield *vs* Plant height	Bhadru *et al.* (2012) Khare *et al.* (2014) Mohammad *et al.* (2013) Patel *et al.* (2014)	Jayasudha and Shanna (2010) Basavaraja *et al.* (2011) Kumar *et al.* (2011) Basavaraja *et al.* (2013)	Bhadru *et al.* (2012) Khare *et al.* (2014) Mohammad *et al.* (2013) Patel *et al.* (2014) Ramanjaneyulu *et al.* (2014)	Chandra *et al.* (2009) Jayasudha and Shanna (2010) Kumar *et al.* (2011) Basavaraja *et al.* (2013)
Grain yield *vs* Days to fifty per cent flowering	Bhadru *et al.* (2012) Rangare *et al.* (2012) Basavaraja *et al.* (2013) Khare *et al.* (2014) Mohammad *et al.* (2013)	Bhadru *et al.* (2011) Santhi *et al.* (2011)	Fiyaz *et al.* (2011) Rangare *et al.* (2012) Basavaraja *et al.* (2013) Khare *et al.* (2014) Mohammad *et al.* (2013)	Girolkar *et al.* (2008) Bhadru, *et al.* (2011) Santhi *et al.* (2011) Bhadru *et al.* (2012)
Grain yield *vs* CSI	Gopikannan and Ganesh (2013)		Gopikannan and Ganesh (2013)	
Grain yield *vs* Productive tillers per plant	Bhadru *et al.* (2012) Basavaraja *et al.* (2013) Mohammad *et al.* (2013) patel *et al.* (2014)	Bhadru, *et al.* (2011) Khare *et al.* (2014)	Rangare *et al.* (2012) Basavaraja *et al.* (2013) Mohammad *et al.* (2013) patel *et al.* (2014) Ramanjaneyulu *et al.* (2014)	Girolkar *et al.* (2008) Tandelkar *et al.* (2008) Bhadru, *et al.* (2011) Khare *et al.* (2014)
Grain yield *vs* Panicle length	Basavaraja *et al.* (2013) Khare *et al.* (2014) Mohammad *et al.* (2013) Patel *et al.* (2014)	Jayasudha and Shanna (2010)	Basavaraja *et al.* (2013) Khare *et al.* (2014) Mohammad *et al.* (2013) Patel *et al.* (2014)	Girolkar *et al.* (2008) Jayasudha and Shanna (2010)

Grain yield *vs* panicle weight	Jambulkar and Bose (2014) Akinwale *et al.* (2011) Zazaa and Anis (2014)		Jambulkar and Bose(2014)	
Grain yield *vs* Spikelets per panicle	Rangare *et al.* (2012) Basavaraja *et al.* (2013), Khare *et al.* (2014)		Fiyaz *et al.* (2011) Rangare *et al.* (2012) Basavaraja *et al.* (2013) Khare *et al.* (2014)	
Grain yield *vs* Grains per panicle	Santhi *et al.* (2011). Idrisl *et al.* (2012) Khare *et al.* (2014) Patel *et al.* (2014)		Santhi *et al.* (2011) Idrisl *et al.* (2012) Khare *et al.* (2014)) Patel *et al.* (2014)	
Grain yield *vs* 1000 grain weight	Bhadru *et al.* (2012) Kumar *et al.* (2011), Basavaraja *et al.* (2013) Patel *et al.* (2014) Ramanjaneyulu *et al.* (2014)	Khare *et al.* (2014) Mohammad *et al.* (2013)	Bhadru *et al.* (2012) Kumar *et al.* (2011) Basavaraja *et al.* (2013) Patel *et al.* (2014) Ramanjaneyulu *et al.* (2014)	Khare *et al.* (2014) Mohammad *et al.* (2013)
Grain yield *vs* straw yield	Mohammad *et al.* (2013) Patel *et al.* (2014) Ramanjaneyulu *et al.* (2014)		Mohammad *et al.* (2013) Ramanjaneyulu *et al.* (2014)	

Table 3. Studies on inter correlation among yield components

Charactes	Phenotypic coefficient of correlation		Genotypic coefficient of correlation	
	Positive	**Negative**	**Positive**	**Negative**
Plant height *vs* Days to fifty per cent flowering	Rangare *et al.* (2012) Basavaraja *et al.* (2013) Khare *et al.* (2014)		Rangare *et al.* (2012) Basavaraja *et al.* (2013) Khare *et al.* (2014)	Chandra *et al.* (2009)

	Mohammad *et al*. (2013) Patel *et al*. (2014)		Mohammad *et al*. (2013)) Patel *et al*. (2014)	
Plant height *vs* CSI	Gopikannan and Ganesh 2013		Gopikannan and Ganesh 2013	
Plant height *vs* productive tillers	Vinothin *et al*. (2008) Bhadru *et al*. (2011) Bhadru *et al*. (2012) Mohammad *et al*. (2013) Patel *et al*. (2014)	Jayasudha and Shanna (2010) Basavaraja *et al*. (2011) Basavaraja *et al*. (2013) Khare *et al*. (2014)	Bhadru, *et al*. (2011) Fiyaz *et al*. (2011) Rajamadhan *et al*. (2011) Basavaraja *et al*. (2013) Patel *et al*. (2014)	Jayasudha and Shanna (2010) Basavaraja *et al*. (2011) Bhadru *et al*. (2012) Khare *et al*. (2014) Mohammad *et al*. (2013)
Plant height *vs* panicle length	Bhadru *et al*. (2012) Basavaraja *et al*. (2013) Khare *et al*. (2014) Mohammad *et al*. (2013) Patel *et al*. (2014)	Bastian *et al*. (2008)	Bhadru *et al*. (2012) Kumar *et al*. (2011) Basavaraja *et al*. (2013) Khare *et al*. (2014) Mohammad *et al*. (2013) Patel *et al*. (2014)	Bastian *et al*. (2008)
Plant height *vs* panicle weight	Jambulkar and Bose (2014)		Jambulkar and Bose (2014)	
Plant height *vs* spikelets per panicle	Basavaraja *et al* . (2011) Rangare *et al*. (2012) Basavaraja *et al*. (2013) Khare *et al*. (2014)		Basavaraja *et al*. (2011) Fiyaz *et al*. (2011) Rangare *et al*. (2012) Basavaraja *et al*. (2013) Khare *et al*. (2014)	
Plant height *vs* grains per panicle	Chakraborty *et al*. (2010) Bhadru *et al*. (2011)		Chakraborty *et al*. (2010) Bhadru *et al*. (2011)	Chakravorty and Ghosh (2013)

	Chakravorty and Ghosh (2013) Khare *et al*. (2014) Patel *et al*. (2014)		Rajamadhan *et al*. (2011) Khare *et al*. (2014) Patel *et al*. (2014)	
Plant height *vs* 1000 seed weight	Basavaraja *et al*. (2013) Chakravorty and Ghosh (2013) Ramanjaneyulu *et al*. (2014)	Bhadru *et al*. (2012) Khare *et al*. (2014) Mohammad *et al*. (2013)	Chandra *et al*. (2009) Fiyaz *et al*. (2011) Chakravorty and Ghosh (2013) Ramanjaneyulu *et al*. (2014)	Bhadru *et al*. (2012) Basavaraja et al. (2013) Khare *et al*. (2014) Mohammad *et al*. (2013)
Plant height *vs* straw yield per plant	Mohammad *et al*. (2013) Patel *et al*. (2014)		Mohammad *et al*. (2013) Patel *et al*. (2014) Ramanjaneyulu *et al*. (2014)	
Days to fifty per cent flowering *vs* productive tillers	Jayasudha *et al* . (2010) Bhadru, *et al*. (2011) Rangare *et al*. (2012) Bhadru *et al*. (2012) Mohammad *et al*. (2013)	Vinothin *et al*. (2008) Basavaraja *et al*. (2011) Santhi *et al*. (2011) Basavaraja *et al*. (2013) Khare *et al*. (2014)	Fiyaz *et al*. (2011) Rajamadhan *et al*. (2011) Bhadru *et al*. (2012) Rangare *et al*. (2012) Mohammad *et al*. (2013)	Girolkar *et al*. (2008) Vinothin *et al*. (2008) Santhi *et al*. (2011) Basavaraja *et al*. (2013) Khare *et al*. (2014)
Days to fifty per cent flowering *vs* CSI	Gopikannan and Ganesh (2013)		Gopikannan and Ganesh (2013)	
Days to fifty per cent flowering *vs* panicle length	Bhadru *et al*. (2012) Rangare *et al*. (2012) Basavaraja *et al*. (2013) Khare *et al*. (2014)	Jayasudha and Shanna (2010)	Rajamadhan *et al*. (2011) Bhadru *et al*. (2012) Rangare *et al*. (2012) Basavaraja *et al*. (2013)	Girolkar *et al*. (2008) Jayasudha and Shanna (2010)

	Mohammad *et al*. (2013)		Khare *et al*. (2014) Mohammad *et al*. (2013)	
Days to fifty per cent flowering *vs* panicle weight		Jambulkar and Bose (2014)		Jambulkar and Bose (2014)
Days to fifty per cent flowering *vs* spike lets per panicle	Basavaraja *et al*. (2013) Khare *et al*. (2014)		Girolkar *et al*. (2008) Basavaraja *et al*. (2011) Fiyaz *et al*. (2011) Rangare *et al*. (2012) Basavaraja *et al* . (2013), Khare *et al*. (2014)	Tandelkar *et al* . (2008)
Days to fifty per cent flowering *vs* grains pe panicle	Vinothin *et al*. (2008) Bhadru *et al*. (2011) Khare *et al*. (2014)	Santhi *et al*. (2011)	Vinothin *et al*. (2008) Chandra *et al*. (2009) Bhadru, *et al*. (2011) Rajamadhan *et al*. (2011) Khare *et al*. (2014)	Girolkar *et al*. (2008) Tandelkar *et al*. (2008) Santhi *et al*. (2011)
Days to fifty per cent flowering *vs* 1000 seed weight	Bhadru *et al*. (2012) Khare *et al*. (2014) Patel *et al*. (2014)	Bhadru, *et al*. (2011) Basavaraja *et al*. (2013)	Bhadru *et al*. (2012) Khare *et al*. (2014) Patel *et al*. (2014)	Fiyaz *et al*. (2011) Basavaraja *et al*. (2013) Mohammad *et al*. (2013)
Days to fifty per cent flowering *vs* straw yield per plant	Mohammad *et al*. (2013) Patel *et al*. (2014)		Mohammad *et al*. (2013) Patel *et al*. (2014)	
Productive tillers *vs* CSI	Gopikannan and Ganesh (2013)		Gopikannan and Ganesh (2013)	
Productive tillers *vs* panicle length	Jayasudha and Shanna (2010) Rangare *et al*. (2012) Basavaraja *et al*. (2013)	Vinothin *et al*. (2008) Khare *et al*. (2014)	Chandra *et al*. (2009) Jayasudha and Shanna (2010) Fiyaz *et al*. (2011)	Vinothin *et al*. (2008) Khare *et al*. (2014)

	Patel *et al.* (2014)		Rajamadhan *et al.* (2011) Rangare *et al.* (2012) Basavaraja *et al.* (2013) Patel *et al.* (2014)	
Productive tillers *vs* panicle weight	Zazaa and Anis (2014)	Jambulkar and Bose (2014)		Jambulkar and Bose (2014)
Productive tillers *vs* spikelets per panicle	Basavaraja *et al.* (2011) Rangare *et al.* (2012) Basavaraja *et al.* (2013) Khare *et al.* (2014)		Basavaraja *et al.* (2011) Fiyaz *et al.* (2011) Rangare *et al.* (2012) Basavaraja *et al.* (2013)	Girolkar *et al.* (2008) Khare *et al.* (2014)
Productive tillers *vs* grains per panicle	Bhadru, *et al.* (2011) Santhi *et al.* (2011) Patel *et al.* (2014)	Vinothin *et al.* (2008) Khare *et al.* (2014)	Santhi *et al.* (2011) Rajamadhan *et al.* (2011) Patel *et al.* (2014)	Girolkar *et al.* (2008) Vinothin *et al.* (2008) Chandra *et al.* (2009) Bhadru, *et al.* (2011) Khare *et al.* (2014)
Productive tillers *vs* 1000 grain weight	Vinothin *et al.* (2008) Bhadru *et al.* (2012) Ramanjaneyulu *et al.* (2014)	Bhadru *et al.* (2011) Patel *et al.* (2014)	Vinothin *et al.* (2008) Fiyaz *et al.* (2011) Bhadru *et al.* (2012) Mohammad *et al.* (2013) Ramanjaneyulu *et al.* (2014)	Chandra *et al.* (2009) Bhadru, *et al.* (2011) Patel *et al.* (2014)
Productive tillers *vs* straw yield per plant	Patel *et al.* 2014) Ramanjaneyulu *et al.* (2014)		Ramanjaneyulu *et al.* (2014)	
Panicle length *vs* CSI	Gopikannan and Ganesh (2013)		Gopikannan and Ganesh 2013	
Panicle length *vs* panicle weight	Jambulkar and Bose (2014)		Jambulkar and Bose (2014)	

Panicle length *vs* spikelets per panice	Basavaraja *et al.* (2011) Rangare *et al.* (2012) Basavaraja *et al.* (2013) Khare *et al.* (2014)		Girolkar *et al.* (2008) Basavaraja *et al.* (2011) Fiyaz *et al.* (2011) Rangare *et al.* (2012) Basavaraja *et al.* (2013) Khare *et al.* (2014)	
Panicle length *vs* grains per panicle	Bastian *et al.* (2008) Chakraborty *et al.* (2010) Bhadru *et al.* (2011) Idrisl *et al.* (2012) Khare *et al.* (2014) Patel *et al.* (2014)	Chakravorty and Ghosh (2013)	Bastian *et al.* (2008) Chandra *et al.* (2009) Chakraborty *et al.* (2010) Bhadru, *et al.* (2011) Rajamadhan *et al.* (2011) Idrisl *et al.* (2012) Khare *et al.* (2014)) Patel *et al.* (2014)	Girolkar *et al.* (2008) Chakravorty and Ghosh (2013)
Panicle length *vs* 1000 seeds weight	Vinothin *et al.* (2008) Bhadru *et al.* (2011) Kumar *et al.* (2011) Chakravorty and Ghosh (2013) Khare *et al.* (2014)) Patel *et al.* (2014)	Basavaraja *et al.* (2013) Mohammad *et al.* (2013)	Vinothin *et al.* (2008) Chandra *et al.* (2009) Bhadru, *et al.* (2011) Kumar *et al.* (2011) Chakravorty and Ghosh (2013) Khare *et al.* (2014) Patel *et al.* (2014)	Fiyaz *et al.* (2011) Basavaraja *et al.* (2013) Mohammad *et al.* (2013)
Panicle length *vs* straw yield per plant	Patel *et al.* (2014)		Patel *et al.* (2014)	
Spikelets per panicle *vs* CSI	Gopikannan and Ganesh (2013)		Gopikannan and Ganesh (2013)	
Spikelets per panicle *vs* grain per panicle	Khare *et al.* (2014)		Girolkar *et al.* (2008) Khare *et al.* (2014)	

Spikelets per panicle *vs* 1000 grain weight		Basavaraja *et al.* (2013) Khare *et al.* (2014)	Chandra *et al.* (2009) Fiyaz *et al.* (2011)	Basavaraja *et al.* (2013) Khare *et al.* (2014)
Grains per Panicle *vs* CSI	Gopikannan and Ganesh (2013)		Gopikannan and Ganesh (2013)	
Grains per panicle *vs* 1000 grain weight	Vinothin *et al.* (2008) Akhtar *et al.* (2011) Khare *et al.* (2014)	Chakravorty and Ghosh (2013)	Vinothin *et al.* (2008) Akhtar *et al.* (2011)	Chakravorty and Ghosh (2013) Khare *et al.* (2014)
Grains per panicle *vs* panicle weight	Jambulkar and Bose (2014)		Jambulkar and Bose (2014)	
Grains per panicle *vs* straw yield per plant	Patel *et al.* (2014)		Patel *et al.* (2014)	
1000 grain weight *vs* CSI	Gopikannan and Ganesh (2013)		Gopikannan and Ganesh (2013)	
1000 grain weight *vs* straw yield per plant		Mohammad *et al.* (2013)		Mohammad *et al.* (2013)
1000 grain weight *vs* panicle weight	Zazaa and Anis (2014)	Jambulkar and Bose (2014)		Jambulkar and Bose (2014)

Table 4. Studies on direct effects of yield components on grain yield

Characters	Positive	Negative
Plant height	Girolkar *et al.* (2008) Jayasudha *et al* . (2010) Basavaraja *et al.* (2011) Rajamadhan *et al.* (2011) Suresh *et al.* (2014)	Rangare *et al.* (2012) Kumar *et al.* (2013) Mohammad *et al.* (2013) Patel *et al.* (2014) Neha and Lal. (2012) Padmaja *et al.* (2011)
Days to fifty per cent flowering	Basavaraja *et al.* (2011) Fiyaz *et al.* (2011) Santhi *et al.* (2011) Mohammad *et al.* (2013) Neha and Lal. (2012)	Tandelkar *et al.* (2008) Vinothin *et al.* (2008) Rajamadhan *et al.* (2011) Patel *et al.* (2014) Padmaja *et al.* (2011) Suresh *et al.* (2014)
CSI	Gopikannan and Ganesh (2013)	
Productive tillersper plant	Girolkar *et al.* (2008) Vinothin *et al.* (2008) Chandra *et al.* (2009) Jayasudha and Shanna (2010) Fiyaz *et al.* (2011) Padmaja *et al.* (2011)	Basavaraja *et al.* (2011) Mohammad *et al.* (2013) Patel *et al.* (2014)
Panicle length	Basavaraja *et al.* (2011) Rajamadhan *et al.* (2011) Rangare *et al.* (2012) Kumar *et al.* (2013) Mohammad *et al.* (2013) Suresh *et al.* (2014)	Jayasudha and Shanna (2010) Fiyaz *et al.* (2011) Patel *et al.* (2014) Neha and Lal. (2012) Padmaja *et al.* (2011)
Panicle weight	Samonte *et al.* (1998)	Suresh *et al.* (2014) Jambulkar and Bose (2014)
Spikelets per panicle	Girolkar *et al.* (2008) Tandelkar *et al.* (2008) Suresh *et al.* (2014)	Basavaraja *et al.* (2011) Fiyaz *et al.* (2011) Rangare *et al.* (2012) Neha and Lal. (2012)
Grains per panicle	Bastian, *et al.* (2008) Chandra *et al.* (2009) Santhi *et al.* (2011) Patel *et al.* (2014) Padmaja *et al.* (2011)	Tandelkar *et al.* (2008) Vinothin *et al.* (2008) Chakraborty *et al.* (2010) Akhtar *et al.* (2011) Rajamadhan *et al.* (2011)

		Rangare *et al.* (2012)
1000 grain weight	Chandra *et al.* (2009) Akhtar *et al.* (2011) Fiyaz *et al.* (2011) Kumar *et al.* (2013) Neha and Lal. (2012) Mohammad *et al.* (2013) Suresh *et al.* (2014)	Patel *et al.* (2014)
Straw yield per plant	Mohammad *et al.* (2013) Patel *et al.* (2014)	Neha and Lal (2012)

Table 5. Studies on indirect effects of yield components on grain yield

Characters	**Positive**	**Negative**
Indirect effects of other yield components through plant height on yield		
Day to fifty per cent flowering	Rangare *et al.* (2012) Mohammad *et al.* (2013) Neha and Lal (2012) Padmaja *et al.* (2011) Suresh *et al.* (2014)	Chandra *et al.* (2009) Jayasudha and Shanna (2010) Fiyaz *et al.* (2011) Patel *et al.* (2014)
Productive tillers	Basavaraja *et al.* (2011) Fiyaz *et al.* (2011) Rajamadhan *et al.* (2011) Mohammad *et al.* (2013)	Jayasudha and Shanna (2010) Rangare *et al.* (2012) Patel *et al.* (2014) Padmaja *et al.* (2011)
CSI	Gopikannan and Ganesh (2013)	
Panicle length	Chakraborty *et al.* (2010) Rajamadhan *et al.* (2011) Rangare *et al.* (2012) Neha and Lal (2012) Suresh *et al.* (2014)	Jayasudha and Shanna (2010) Fiyaz *et al.* (2011) Kumar et al. (2013) Mohammad *et al.* (2013)
Panicle weight	Suresh *et al.* (2014)	
Spikelets per panicle	Neha and Lal. (2012) Suresh *et al.* (2014)	Basavaraja *et al.* (2011) Rangare *et al.* (2012)
Grains per panicle	Akhtar *et al.* (2011) Rajamadhan *et al.* (2011) Padmaja *et al.* (2011)	Chakraborty *et al.* (2010) Patel *et al.* (2014)
1000 grain seeds weight	Kumar *et al.* (2013)	

	Mohammad *et al.* (2013) Neha and Lal (2012) Suresh *et al.* (2014)	Patel *et al.* (2014) Padmaja *et al.* (2011)
Straw yield per plant		Mohammad *et al.* (2013) Patel *et al.* (2014) Neha and Lal (2012)
Indirect effects of other yield components through days to 50% flowering on yield		
Plant height	Basavaraja *et al.* (2011) Fiyaz *et al.* (2011) Rajamadhan *et al.* (2011) Mohammad *et al.* (2013)	Rangare *et al.* (2012) Patel *et al.* (2014) Neha and Lal. (2012) Padmaja *et al.* (2011) Suresh *et al.* (2014)
Productive tillers	Fiyaz *et al.* (2011) Rajamadhan *et al.* (2011) Rangare *et al.* (2012) Mohammad *et al.* (2013) Padmaja *et al.* (2011)	Basavaraja *et al.* (2011) Santhi *et al.* (2011) Patel *et al.* (2014)
CSI		Gopikannan and Ganesh (2013)
Panicle length	Rangare *et al.* (2012) Mohammad *et al.* (2013) Neha and Lal (2012)	Patel *et al.* (2014) Padmaja *et al.* (2011) Suresh *et al.* (2014)
Panicle weight		Suresh *et al.* (2014)
Spikelets per panicle	Girolkar *et al.* (2008) Tandelkar *et al.* (2008) Neha and Lal. (2012)	Fiyaz *et al.* (2011) Rangare *et al.* (2012) Suresh *et al.* (2014)
Grains per panicle	Patel *et al.* (2014) Padmaja *et al.* (2011)	Chandra *et al.* (2009) Santhi *et al.* (2011)
1000 grain weight	Vinothin *et al.* (2008)	Mohammad *et al.* (2013) Patel *et al.* (2014) Padmaja *et al.* (2011) Neha and Lal (2012) Suresh *et al.* (2014)
Straw yield per plant	Mohammad *et al.* (2013) Neha and Lal (2012)	Patel *et al.* (2014)
Indirect effects of other yield components through productive tillers on yield		
Plant height	Rajamadhan *et al.* (2011) Rangare *et al.* (2012)	Jayasudha and Shanna (2010) Fiyaz *et al.* (2011)

	Mohammad *et al.* (2013)	Patel *et al.* (2014) Padmaja *et al.* (2011)
CSI	Gopikannan and Ganesh (2013)	
Days to fifty per cent flowering	Chandra *et al.* (2009) Rajamadhan *et al.* (2011) Santhi *et al.* (2011) Rangare *et al.* (2012)	Basavaraja *et al.* (2011) Mohammad *et al.* (2013) Patel *et al.* (2014) Padmaja *et al.* (2011)
Panicle length	Basavaraja *et al.* (2011) Rajamadhan *et al.* (2011) Padmaja *et al.* (2011)	Mohammad *et al.* (2013) Patel *et al.* (2014)
Spikelets per panicle		Basavaraja *et al.* (2011) Fiyaz *et al.* (2011) Rangare *et al.* (2012)
Grains per panicle	Rajamadhan *et al.* (2011) Santhi *et al.* (2011)	Patel *et al.* (2014) Padmaja *et al.* (2011)
1000 grain weight	Patel *et al.* (2014).	Mohammad *et al.* (2013) Padmaja *et al.* (2011)
Straw yield per plant		Mohammad *et al.* (2013) Patel *et al.* (2014)
Indirect effects of other yield components through panicle length on yield		
Plant height	Rajamadhan *et al.* (2011) Kumar *et al.* (2013) Mohammad *et al.* (2013) Neha and Lal (2012) Suresh *et al.* (2014)	Rangare *et al.* (2012) Patel *et al.* (2014) Padmaja *et al.* (2011)
Days to fifty per cent flowering	Rajamadhan *et al.* (2011) Rangare *et al.* (2012) Mohammad *et al.* (2013) Padmaja *et al.* (2011) Suresh *et al.* (2014)	Patel *et al.* (2014) Neha and Lal (2012)
CSI	Gopikannan and Ganesh (2013)	
Productive tillers	Jayasudha and Shanna (2010) Rajamadhan *et al.* (2011) Rangare *et al.* (2012) Mohammad *et al.* (2013)	Patel *et al.* (2014)
Panicle weight	Suresh *et al.* (2014)	
Spikelets per panicle	Girolkar *et al*. (2008) Tandelkar *et al.* (2008)	Rangare *et al.* (2012) Neha and Lal (2012)

	Suresh *et al.* (2014)	
Grains per panicle	Girolkar *et al.* (2008) Bastian, *et al.* (2008) Rajamadhan *et al.* (2011) Padmaja *et al.* (2011)	Tandelkar *et al.* (2008) Vinothin *et al.* (2008) Chandra *et al.* (2009) Chakraborty *et al.* (2010) Patel *et al.* (2014)
1000 grain weight	Kumar *et al.* (2013) Neha and Lal (2012) Padmaja *et al.* (2011) Suresh *et al.* (2014)	Mohammad *et al.* (2013) Patel *et al.* (2014)
Straw yield per plant	Mohammad *et al.*(2013) Neha and Lal (2012)	Patel *et al.* (2014)
Indirect effects of other yield components through panicle weight on yield		
Plant height	Jambulkar and Bose (2014)	Suresh *et al.* (2014)
Days to fifty per cent flowering	Jambulkar and Bose (2014)	Suresh *et al.* (2014)
Panicle length	Jambulkar and Bose (2014)	Suresh *et al.* (2014)
Spikelets per panicle		Suresh *et al.* (2014)
Grains per panicle		Jambulkar and Bose (2014)
1000 grain weight		Jambulkar and Bose (2014) Suresh *et al.* (2014)
Indirect effects of other yield components through spikelets perpanicle on yield		
Plant height	Girolkar *et al.* (2008) Neha and Lal. (2012) Suresh *et al.* (2014)	Tandelkar *et al.* (2008) Basavaraja *et al.* (2011) Rangare *et al.* (2012)
Days to fifty per cent flowering	Basavaraja *et al.* (2011) Rangare *et al.* (2012) Suresh *et al.* (2014)	Girolkar *et al.* (2008) Tandelkar *et al.* (2008) Neha and Lal (2012)
Productive tillers	Basavaraja *et al.* (2011) Rangare *et al.* (2012)	Girolkar *et al.* (2008)
Panicle length	Basavaraja *et al.* (2011) Rangare *et al.* (2012) Suresh *et al.* (2014)	Neha and Lal (2012)
CSI	Gopikannan and Ganesh (2013)	
Panicle weight	Suresh *et al.* (2014)	
Grains per panicle		Girolkar *et al.* (2008) Tandelkar *et al.* (2008)

1000 grain weight .		Girolkar *et al.* (2008) Tandelkar *et al.* (2008) Neha and Lal (2012) Suresh *et al.* (2014)
Straw yield per plant		Neha and Lal (2012)
Indirect effects of other yield components through grains per panicle on yield		
Plant height	Rajamadhan *et al.* (2011) Akhtar *et al* . (2011) Patel *et al.* (2014) Padmaja *et al.* (2011)	Bastian *et al.* (2008) Chandra *et al.* (2009)
Days to fifty per cent flowering	Bastian, *et al.* (2008) Chandra *et al.* (2009) Chakraborty *et al.* (2010)	Tandelkar *et al.* (2008) Vinothin *et al.* (2008) Santhi *et al.* (2011) Rajamadhan *et al.* (2011) Patel *et al.* (2014) Padmaja *et al.* (2011)
CSI	Gopikannan and Ganesh (2013)	
Productive tillers	Santhi *et al.* (2011) Rajamadhan *et al* . (2011) Patel *et al.* (2014)	Girolkar *et al.* (2008) Vinothin *et al.* (2008) Chandra *et al.* (2009) Padmaja *et al.* (2011)
Panicle length	Vinothin *et al.* (2008) Chandra *et al.* (2009) Chakraborty *et al* . (2010) Rajamadhan *et al.* (2011)	Girolkar *et al.* (2008) Tandelkar *et al.* (2008) Bastian, *et al.* (2008) Patel *et al.* (2014)
Panicle weight	Jambulkar and Bose (2014)	
Spikelets per panicle	Girolkar *et al.* (2008) Tandelkar *et al.* (2008)	
1000 grain weight	Chandra *et al.* (2009) Akhtar *et al.* (2011) Patel *et al.* (2014) Padmaja *et al.* (2011)	Tandelkar *et al.* (2008) Vinothin *et al.* (2008)
Straw yield per plant	Patel *et al.* (2014)	
Indirect effects of other yield components through 1000 seeds weight on yield		
Plant height	Suresh *et al.* (2014)	Kumar *et al.* (2013) Mohammad *et al.* (2013) Patel *et al.* (2014)
Days to fifty per cent	Girolkar *et al.* (2008)	Vinothin *et al.* (2008)

flowering	Tandelkar *et al.* (2008) Chandra *et al.* (2009) Padmaja *et al.* (2011) Suresh *et al.* (2014)	Mohammad *et al.* (2013) Patel *et al.* (2014) Neha and Lal (2012)
Productive tillers	Mohammad *et al.* (2013)	Chandra *et al.* (2009) Padmaja *et al.* (2011)
Panicle length	Kumar et al. (2013) Mohammad *et al.* (2013) Padmaja *et al.* (2011) Suresh *et al.* (2014)	Patel *et al* ., (2014) Neha and Lal (2012)
Panicle weight	Suresh *et al.* (2014)	
Spikelets per panicle	Neha and Lal (2012)	Suresh *et al.* (2014)
Grains per panicle	Patel *et al.* (2014) Padmaja *et al.* (2011)	
Straw yield per plant		Mohammad *et al.* (2013) Patel *et al.* (2014) Neha and Lal (2012)
Indirect effects of other yield components through straw yield per plant on yield		
Plant height	Mohammad *et al.* (2013) Patel *et al.* (2014)	Neha and Lal (2012)
Days to fifty per cent flowering	Mohammad *et al.* (2013) Patel *et al.* (2014)	Neha and Lal (2012)
Productive tillers	Mohammad *et al.* (2013) Patel *et al.* (2014)	
Panicle length	Mohammad *et al.* (2013) Patel *et al.* (2014)	Neha and Lal (2012)
Spikelets per panicle	Neha and Lal (2012)	
Grains per panicle	Patel *et al.* (2014)	
1000 grain weight	Patel *et al.* (2014) Neha and Lal (2012)	Mohammad *et al.* (2013)

Materials and methods

III. MATERIALS AND METHODS

The present investigation was conducted in Kerala Agricultural University (KAU) during 2014-2015. The study consisted of two major experiments 1) Morphological characterization of rice genotypes for yield and yield attributes (Experiment I) and 2) Characterization of rice genotypes for drought tolerance (Experiment II). Experiment II comprised of two sub experiments i) Rapid evaluation test for drought tolerance [Experiment II (A)] and ii) Characterisation of rice genotypes for drought tolerance under controlled moisture regimes [Experiment II (B)]. Both experiments were conducted in the Department of Plant Breeding and Genetics, College of Horticulture, KAU, Vellanikkara located 40 m above MSL at $10^{0}31'$ N latitude and $76^{0}13'$ E longitude. Rainfall (Figure 1) during the cropping period (May to September, 2014) and the number of rainy days (Figure 2) was high during the months of June, July and August owing to the South-west monsoons. Although there was adequate distribution of rainfall during the cropping period, undulating topography and porous soils served as contributing factors in imposing moisture stress during Experiment I (upland rice crop). The details of the material used and methods employed in the present investigation are presented below.

3.1.1 Experimental material

The material for the study comprised of 21 genotypes of rice (*Oryza sativa* L.) collected from 1) Regional Agricultural Research Station (RARS), KAU, Pattambi, Palakkad, 2) Regional Agricultural Research Station (RARS), KAU, Kayamkulam and 3) College of Horticulture, KAU, Thrissur. The list of genotypes included in the study is given in Table 6.

3.2 Method

3.2.1 Experiment I: Morphological characterization of rice genotypes for yield and yield attributes

The experiment was laid out in a randomized block design (RBD) with 21genotypes and two replications. The rainfed crop was raised in the rice block of

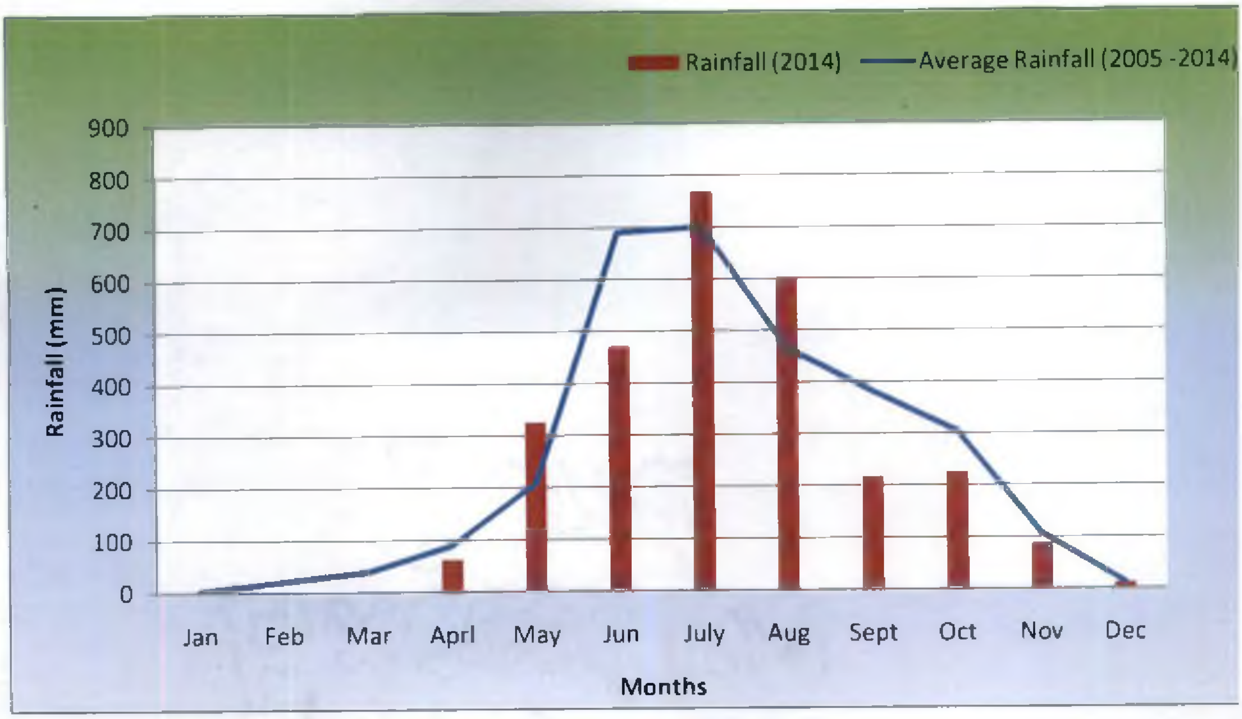

Figure 1: Rainfall distribution pattern in Kerala

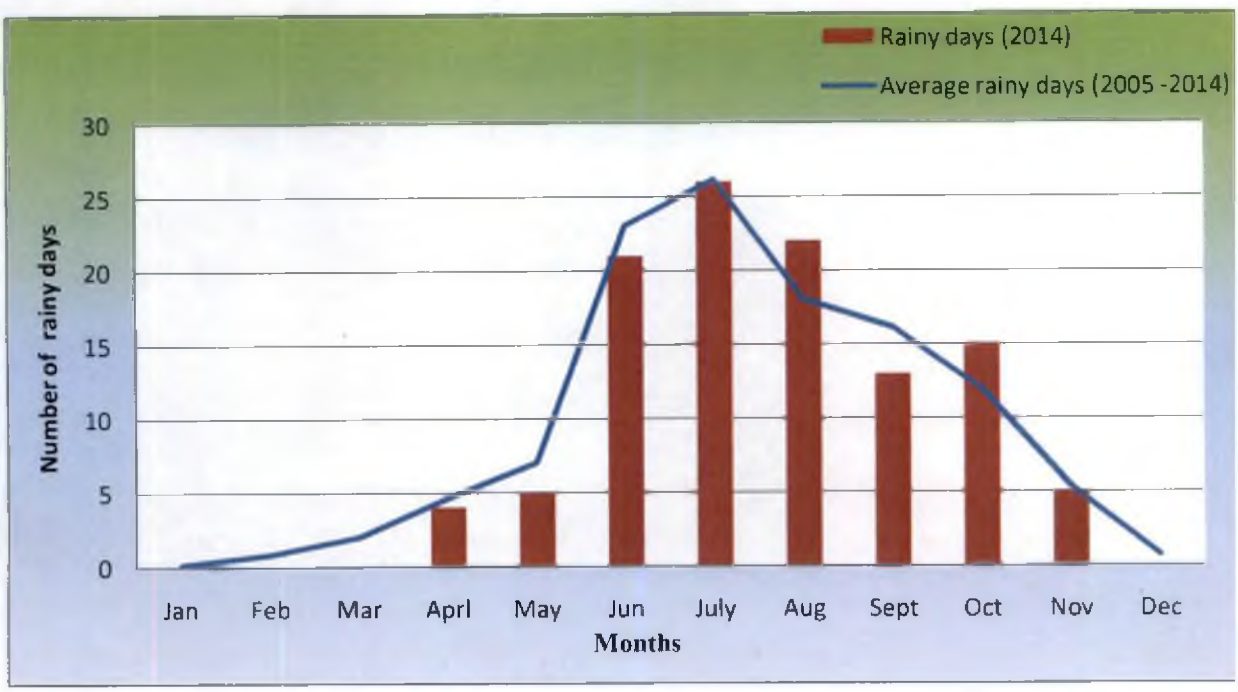

Figure 2: Number of rainy days in Kerala (2014)

Seed Technology Unit, College of Horticulture, KAU, Vellanikkara during *kharif* 2013 (May to September). In each entry, single seeds were dibbled per hill in a plot of size 5m x 2m, at spacing of 20 cm x 15 cm. Recommended agronomic practices as per package of practices (KAU, 2011) were followed during crop growth period to raise a good crop.

3.2.2 Experiment II: Characterisation of rice genotypes for drought tolerance

3.2.2.1 Experiment II (A): Rapid evaluation test for drought tolerance

Laboratory screening of the twenty one genotypes evaluated under Experiment 1 (Table 6) was undertaken via hydroponics to elucidate their response to drought. The rapid evaluation test for drought tolerance was done as advocated by Bouslam and Schapaugh (1984). The experiment was laid out as completely randomized design with twenty-one genotypes and two replications. Each replication of the genotypes screened consisted of ten germinated seedlings.

Holes were made in polystyrene (thermocol) plate covered at the bottom with nylon net to contain the germinated seeds. Three day old pre-germinated seeds were placed in the holes of the polystyrene plate. The polystyrene plate was floated in the plastic tray of 10 litre capacity filled with Yoshida's nutrient solution (Yoshida *et al.,* 1976) for a week to enable pre-conditioning. The culture solution was prepared using stock solutions prepared as per Table 7 and maintained at pH 5.0. Twelve millitre from each stock solution was taken and made up to ten litres and mixed to serve as the culture solution. After a week stress was imposed by initiating osmotic potential of -8 bars using osmoticum PEG-600. The osmotic potential of -8 bars was ensured by adding 262 g of PEG-6000 in 1 litre of nutrient solution (Michel and Kaufmann, 1973). The culture solution was renewed at weekly intervals and the pH adjusted to 5.8 – 6.0 with 1 N NaOH/HCl. A set of the twenty one genotypes grown in the nutrient medium for the same duration without the osmoticum served as the control. The culture was maintained for 14 days and observations on shoot length, root length and total biomass were recorded on the fourteenth day.

Table 6. Genotypes included in Experiment I and II (A)

Treatment	Genotypes	Source and details of genotypes
1	Parambuvattan	COH, KAU. Traditional rice variety recommended for uplands
2	Karuthamodan	RARS, Pattambi. Traditional rice variety recommended for uplands
3	Karanavara	COH, KAU Traditional rice variety recommended for uplands
4	Kalladiaryan	COH, KAU. Traditional rice variety recommended for uplands
5	Mo 16 (Uma)	RRS-Moncompu. High yielding variety released in 1998 (Mo 6 x Pokkali)
6	Thottacheera	COH, KAU. Traditional rice variety recommended for uplands
7	Karathadukkan	COH, KAU Traditional rice variety recommended for uplands
8	Chomala	COH, KAU. Traditional rice variety recommended for uplands
9	Swarnaprabha (PTB 43)	RARS, Pattambi. High yielding variety released in 1985 (Bhavani x Thiveni)
10	PTB 39 (Jyothy)	RARS, Pattambi. High yielding variety released in 1974 (PTB 10 x IR-8)
11	PTB 50 (Kanchana)	RARS, Pattambi. High yielding variety released in 1993 (IR 36 X Pavizham)
12	PTB 52 (Aiswarya)	RARS, Pattambi. High yielding variety released in 1993 (Jyothi x BR-51-46-1)
13	PTB 60 (Vaishak)	RARS, Pattambi. High yielding variety released in 2010. Pureline selection from PTB 43 (Swarna Prabha)
14	Arimodan	COH, KAU. Traditional rice variety recommended for uplands
15	Onam	RARS, Kayamkulam. High yielding variety released in 1985 (Kochuvithu x (TN 1) x Triveni)
16	Parambankayama	COH, KAU. Traditional rice variety recommended for uplands
17	PTB 55 (Harsha)	RARS, Pattambi. High yielding variety released in 2000 (M 210/ PTB 28)
18	PTB 28 (Kattamodan)	RARS, Pattambi. Traditional rice variety developed through mass selection released in 1950 and recommended for uplands
19	Chettiviruppu	COH, KAU. Traditional rice variety recommended for uplands
20	Good day (Superica)	COH, KAU. African rice variety recommended for uplands
21	Nerica	COH, KAU. Internationally acclaimed rice genotype with drought tolerance

Table 7. Nutrient composition of Yoshida's stock solution

Macronutrients	Source	g /500ml
N	Ammonium nitrate (NH_4NO_3)	45.700
P	Sodium dihydrogen phosphate (NaH_2PO_4)	17.800
K	Pottassium sulphate (K_2SO_4)	35.700
Ca	Calcium chloride ($CaCl_2.2H_2O$)	58.675
Mg	Magnesium sulphate ($MgSO_4.7H_2O$)	162.00
Micronutrients Stock solution		
Mn	Manganese chloride ($MnCl_3.4H_2O$)	0.750
Mo	Ammonium molybdate 4 hydrate (NH_4 $Mo_7O_{24}.4H_2O$)	0.0375
Zn	Zinc sulphate, 7 hydrate ($ZnSO_4.7H_2O$)	0.0175
B	(Boric acid H_3BO_3)	0.467
Cu	Cupric sulphate, 5 hydrate ($CuSO_4.5H_2O$)	0.0155
Fe	Ferric chloride ($FeCl_3.6H_2O$)	2.310
Citric acid		5.950

Germination test with four replicates of twenty five seeds in each replication of a genotype was also conducted through top of paper method. The water potential was maintained at -8 bars by dissolving PEG-6000 in distilled water as advocated by Michel and Kaufmann (1973). On fourteenth day the total number of normal seedlings were counted and expressed in per cent. The number of seeds germinated each day was also recorded until the fourteenth day to compute the speed of germination.

3.2.2.2 Experiment II (B): Characterization of rice genotypes for drought tolerance under controlled moisture regimes

Ten promising genotypes (Table 8) selected on the basis of Experiment I and Experiment II (A) formed the basis of this study. The genotypes were evaluated for response to moisture stress at different growth stages *viz.*, seedling, vegetative and reproductive phase under controlled moisture regimes along with non-stressed control (fully irrigated control) following a completely randomized design with ten treatments (genotypes) and three replications.

Four sets of the ten genotypes were raised in polythene bags of 120 cm height and diameter of 75 cm for the study. Each set consisted of a total of 120 plants comprising of twelve plants from each of the ten genotypes. Each bag contained 4 plants sown 25 cm apart. Irrigation was applied until appropriate stage of crop growth *viz.*, seedling stage (15 Days after sowing in set I), vegetative stage (35 Days after sowing in set II) and reproductive stage (50 days after sowing in set III). Stress was relieved in the relevant set at the point when 90 per cent of plant population exhibited leaf rolling score of 7 on imposition of moisture stress. Full irrigation was resumed at the end of stress until maturity. The non-stressed control was irrigated to field capacity throughout the study. The recovery of plants after moisture stress was recorded as per standard procedures after ten days of stress removal.

Table 8. List of genotypes used in Experiment II (B): Field evaluation for drought characterization

Treatment	Genotypes
1	Karanavara
2	Parambankyama
3	PTB-28 (Kattamodan)
4	Nerica
5	PTB 60 (Vaishak)
6	Karuthamodan
7	Arimodan
8	Karathadukkan
9	Parambuvattan
10	Kalladiaryan

Table 9. Leaf rolling scores

Score	Symptom
0	Leaves healthy
1	Leaves start to fold (shallow V-shape)
3	Leaves folding (deep V-shape)
5	Leaves fully cupped (U-shape)
7	Leaf margins touching (O-shape)
9	Leaves tightly rolled

(IRRI, 1996)

Table 10. Leaf drying scores

Score	Symptom
0	No symptoms
1	Slightly tip drying
3	Tip drying extended up to ¼ length in most leaves
5	One fourth to ½ of all leaves fully dried
7	More than 2/3 of all leaves fully dried
9	All plants apparently dead

(IRRI, 1996)

Standard germination test was also conducted as per procedure advocated by ISTA (1999) for top paper towel method. On fourteenth day, the total number of normal seedlings were counted and expressed in per cent.

3. 3 Observations recorded

The biometric observations enumerated below were recorded

3.3.1 Experiment I: Morphological characterization of rice genotypes for yield and yield attributes

Observations were recorded on five healthy plants per replication chosen at random in each genotype.

3. 3.1.1 Days to fifty per cent flowering

Actual number of days from sowing to ear emergence in fifty per cent of the plants was recorded

3.3.1.2 Chlorophyll stability index (CSI)

Chlorophyll stability index was determined at flowering as described by Koleyoreoas (1958). Two leaf samples of 200 mg each were taken and cut into small bits. Each sample was transferred into a test tube containing 20 ml distilled water. One test tube was kept at room temperature to serve as untreated sample and the second sample was kept in water bath at 55°C for one hour (treated sample). Chlorophyll from both the samples were extracted by macerating the leaf samples with 10 ml of 80% acetone and centrifuged at 3000 rpm for 10 minutes. The supernatant was collected and the volume was made up to 25 ml. The samples were read at 652 nm. CSI was calculated and expressed as per cent as follows.

$$CSI = \frac{\text{OD at 652 nm of treated sample}}{\text{OD at 652 nm of untreated sample}} \times 100$$

3.3.1.3 Productive tillers per plant

The total numbers of grain bearing tillers per plant were counted at maturity

3.3.1.4 Panicle length (cm)

Length of main axis of five randomly selected panicles at maturity was measured from the panicle base to the tip and mean values expressed in centimeter.

3.3.1.5 Panicle weight (g)

Weight of five randomly selected panicles at maturity was taken and mean panicle weight recorded in grams.

3. 3. 1.6 Spikelets per panicle

Number of spikelets per panicle was counted on three randomly selected panicles from each of the five representative plants at maturity and the mean value computed.

3.3.1.7 Grains per panicle

Number of filled grains per panicle was counted at maturity on three randomly selected panicles from each of the five representative plants and the mean value computed.

3.3.1.8 1000 grain weight (g)

Random sample of thousand well-developed, whole grains, dried to 13 per cent moisture content from each entry was weighed after harvest and the mean value computed and expressed in grams.

3.3.1.9 Plant height at maturity (cm)

Measured from the ground level to the tip of the flag leaf at maturity and the mean value expressed in centimeter.

3.3.1.10 Dry weight of shoot (g)

The shoot of each plant after separation from root was oven dried at 72°C for 72 hours and the mean weight recorded in grams

3.3.1.11 Grain yield per plant (g)

The weight of the dried and cleaned grains from five representative plants was taken and the mean value expressed in gram.

3.3.1.12 Straw yield per plant (g)

Total straw yield from five representative plants was weighed and the mean value expressed in gram.

Experiment II (A): Rapid evaluation test for drought tolerance

Observations were recorded on five healthy seedlings chosen at random in each genotype under items 3.3.2.2 to 3.3.2.5

3.3.2.1 Speed of germination

The speed of germination was calculated by adopting the following formula and expressed in number (Maguire, 1962).

$$\text{Speed of germination: } \frac{X_1}{Y_1} + \frac{X_2}{Y_2} + \frac{X_3}{Y_3} \ldots\ldots\ldots \frac{X_n}{Y_x}$$

Where,

Xn – Number of seeds germinated at n^{th} count

Yn – Number of days from sowing to n^{th} count

3.3.2.2 Seedling shoot length (cm)

Five seedlings were selected randomly from each replication of a treatment and the shoot length was measured from the base of primary leaf to collar region. The mean shoot length was expressed in centimeter.

3.3.2.3 Seedling root length (cm)

The five seedlings used for measuring the shoot length were used to record the root length measurement. The root length of each seedling was measured from collar region to the tip of primary root. The mean root length was expressed in centimeter.

3.3.2. 4 Shoot to root length ratio

The ratio of shoot length to root length was calculated.

3.3.2.5 Seedling vigour index

The seedling vigour index was computed by adopting the formula suggested by Abdul-Baki and Anderson (1973) and expressed in whole number.

Vigour index I = Germination (%) x Seedling length (cm)

3.3.2.6 Total biomass (g)

On measuring the shoot and root length, the seedlings were placed in a butter paper cover, dried in a hot air oven maintained at 72°C for 72 hours and weight was recorded in grams.

3.3.3. Experiment II (B): Experiment II (B): Characterization of rice genotypes for drought tolerance under controlled moisture regimes

Observations were recorded on four plants chosen at random in each genotype.

3.3.3.1 Performance of rice genotypes for growth traits before imposition of moisture stress

3.3.3.1.1 Shoot length (cm)

Measured from the base of the shoot to the tip of the tallest leaf blade and expressed in centimeters.

3.3.3.1.2 Dry weight of shoot (g)

As enumerated under **3.3.1.10**

3.3.3.1.3 Root length (cm)

Measured from the base of the root to the tip of the longest root and expressed in centimeters.

3.3.3.1.4 Root volume (ml)

The volume of root was measured using the water displacement method and expressed in milliliter.

3.3.3.1.5 Dry weight of root (g)

The root of each plant after separation from shoot was oven dried at 72°C for 72 hours and dry weight was recorded in grams.

3.3.3.1.6 Shoot to root length ratio

As enumerated under 3.3.2.3

3.3.3.1.7 Vigour index

As enumerated under **3.3.2.4**

3.3.3.1.8 Chlorophyll content (mg/g)

The chlorophyll a, chlorophyll b and total chlorophyll were estimated as per method suggested by Hiscox and Israelstam (1979). For chlorophyll estimation, 10 ml DMSO (Dimethyl sulphoxide) was added to 100 mg leaf sample and incubated in dark overnight. The final volume made up to 25 ml after filtering in the next day. The chlorophyll content was estimated in spectrophotometer at two wavelength 645 nm and 663 nm and expressed as milligram g^{-1} fresh weight of plant tissue. The amount of chlorophyll was arrived at using following formulae.

Chlorophyll 'a' = [(12.7 x A663) – (2.69 x A645)] x V/1000 x W

Chlorophyll 'b'= [(22.9 x A645) – (4.68 x A663)] x V/1000 x W

Total chlorophyll = [(20.2 x A645) + (8.02 x A663)] x V/1000 x W

Where,

A = Absorption at given wavelength

V = Total volume of sample in extraction medium

W = Weight of sample in milligrams

3.3.3.2 Performance of rice genotypes for growth traits during imposition of moisture stress

3.3.3.2.1 Leaf-drying score

Each genotype was rewatered as and when fifty per cent of the plants in that genotype exhibited a leaf rolling score of 7 (Table 9)., Degree of leaf drying was recorded immediately after rewatering as per the standard evaluation system (IRRI, 1996) under stress (Table 10).

3.3.3.2.2 Number of days to leaf rolling

Number of days taken till leaves in fifty per cent of the plants in each genotype exhibit a leaf rolling score of 7 starting from day of imposition of drought was noted.

3.3.3.2.3 Relative leaf water content (RWC %)

Fully expanded leaves were excised at 10.00 AM on the day, fifty per cent of the plants in each genotype exhibited a leaf rolling score of 7 and relative water content was determined by method of Matin *et al*, (1989).

$$RWC\ (\%) = \frac{FW - DW}{TW - DW} \times 100$$

Where,

FW= Fresh weight of the leaf samples taken immediately after excision.

TW= Fully turgid weight determined upon re-hydration of leaves by immersing them in a petridish containing distilled water for two hours.

DW= Dry weight obtained after drying at 80° C for 2 days until no further weight change occurred.

3.3.3.2.4 Chlorophyll content (µg/g)

Chlorophyll content in leaves was estimated as enumerated under 3.3.3.1.8, on the day fifty per cent of the plants in each genotype exhibited a leaf rolling score of 7.

3.3.3.2.5 Proline content (µg/g)

Proline accumulation was determined on the day; fifty per cent of the plants in each genotype exhibited a leaf rolling score of 7 as per the method described by Sadasivam and Manickam (1996). Fresh leaves (0.5 g) were ground with 10 ml of 3% sulphosalicyclic acid using mortar and pestle and the homogenate was centrifuged at 18000 rpm. The homogenate was filtered. Two ml of filtrate was added to 2 ml of glacial acetic acid and 2 ml of acid ninhydrin and test tubes were kept for 1 h at 100°C in water bath, followed by tap water cooling. The reaction mixture was vortexed with 6 ml of toluene. Toluene layer was separated and absorbance was read at 520 nm. A standard curve of proline was used for calibration.

3.3.3.3 Performance of rice genotypes for growth traits after imposition of moisture stress

3.3.3.3.1 Recovery on removal of moisture stress

Recovery scores were taken after ten days of rewatering (on removal of drought stress), based on visual observations as per the standard evaluation system (IRRI, 1996) enumerated in Table 11.

3.3.3.3.2 Flag leaf area (sq.cm)

Length and breadth of flag leaf was measured at maturity and leaf area was calculated by formula enumerated by Yoshida *et al.,* (1976) and expressed in sq.cm.

Leaf Area = Leaf length x breadth x 0.71

Table 11. Recovery rate scores

Score	Per cent of plant recovered
1	90 - 100
3	70 - 89
5	40 - 69
7	20 - 39
9	0 -19

Note: Scores are taken after ten days following soaking rain or watering (IRRI, 1996)

3.3.3.3.3 Harvest index

The proportion of economic yield was represented over biological yield, using the formula (Donald and Hamblin, 1976) and expressed as per cent.

$$\text{Harvest Index (HI)} = \frac{\text{Economic yield}}{\text{Economic yield + Biological yield}} \times 100$$

Observations on days to fifty per cent flowering, productive tillers per plant, panicle length, panicle weight, spikelet per panicle, grains per panicle, 1000 grain weight, plant height, dry weight of shoot, root length root volume, dry weight of root, grain and straw yield per plant were recorded as enumerated under 3.3.1.

3.4 Statistical Analysis

3.4.1 Experiment I: Morphological characterization of rice genotypes for yield and yield attributes

3.4.1.1 Variability studies

3.4.1.1.1 Analysis of variance:

The data collected for all the biometrical traits were subjected to an analysis of variance for randomized blocks design suggested by Panse and Sukatme (1954). Analysis was done using OPSTAT package.

Source	d.f.	Mean square	Expected mean squares
Replication	(r-1)	M_r	$\sigma^2 e + g.\ \sigma^2 r$
Genotype	(g-1)	M_g	$\sigma^2 e + r.\ \sigma^2 g$
Error	(r-1) (g-1)	M_e	$\sigma^2 e$

Where,

r = number of replications

g = number of genotypes

M_r = replication mean squares

M_g = genotypes mean squares

M_e= error variance

For the evaluation of all possible pairs of treatment means, Duncan's multiple range test (DMRT) was used.

3.4.1.1.2 Estimation of genetic parameters:

Phenotypic and Genotypic variances

These were estimated according to the method suggested by Lush (1940).

Genotypic variance ($\sigma^2 g$) = (M_g - M_e)/r

Phenotypic variance ($\sigma^2 p$) = $\sigma^2 g + \sigma^2 e$

Coefficient of variation

The components namely, phenotypic, genotypic and environmental variances were used for estimation of coefficient of variation at both phenotypic and genotypic levels for all the traits were computed by following the formula as suggested by Burton and DeVane (1953).

Phenotypic coefficient of variation (PCV)

$$PCV(\%) = \frac{\sigma p}{\overline{X}} \times 100$$

Genotypic coefficient of variation (GCV)

$$GCV(\%) = \frac{\sigma_g}{\overline{X}} \times 100$$

Where $\overline{X}$ = grand mean of the trait

σ_P = phenotypic standard deviation

σ_g = genotypic standard deviation

The PCV and GCV were classified as suggested by Sivasubramanian and Madhavamenon (1973) into low (0 - 10%), moderate (10.1 - 20%) and high (> 20%).

Heritability (h^2)

Heritability (Broad sense) for all the traits were computed by the formula suggested by Lush (1940).

$$h^2 = \frac{\sigma^2 g}{\sigma^2 p} \times 100$$

Where,

h^2 = heritability (broad sense)

σ^2_g = genotypic variance

σ^2_p = phenotypic variance

Heritability was classified as suggested by Johnson *et al.* (1955a) in to low (0 - 30%), moderate (30.1- 60%) and high (> 60%).

Genetic Advance (GA)

Genetic advance was estimated according to the formula given by Johnson *et al.* (1955b).

$$GA = h^2.K.\sigma_p$$

Where,

h^2 = heritability

σp = phenotypic standard deviation

K = standardized selection differential at given intensity and it is 2.06 at 5 per cent intensity of selection.

Genetic gain

Genetic gain = (GA / $\overline{X}$) x 100

Where, GA = Genetic advance;

$\overline{X}$ = General mean

Genetic gain was categorized as suggested by Johnson *et al.*, (1955b) as low (0 - 10%), moderate (10.1 - 20%) and high (> 20%).

3.4.1.2 Correlation Analysis

Phenotypic and genotypic correlation coefficients were calculated using the method by Johnson *et al.*, (1955b)

Phenotypic correlation coefficients

$$rp\,X.\,Y = \frac{\sigma p\,(X.\,Y)}{(\sigma^2 px.\ \sigma^2 py)^{1/2}}$$

Genotypic correlation coefficient

$$rg\,X.\,Y = \frac{\sigma g\,(X.\,Y)}{(\sigma^2 gx.\ \sigma^2 gy)^{1/2}}$$

Where,

σp (X. Y) = phenotypic covariance between X and Y

σg (X. Y) = Genotypic covariance between X and Y

3.4.1.3 Path co-efficient analysis

In path coefficient analysis, the genotypic correlation coefficient is partitioned into direct and indirect effects. Path coefficient suggested by Wright (1921) was applied to study the cause and effect relationship of yield and yield attributes. The direct and indirect effects were classified based on the scale given by Lenka and Mishra (1973)

>1.0 - very high

0.3 - 0.99 - High

0.2 - 0.29 - Moderate

0.10 - 0.19 - Low

0.00 - 0.09 - negligible

3.4.2 Experiment II (A): Rapid evaluation test for drought tolerance

The data collected for all the biometrical traits were subjected to an analysis of variance for completely randomized design as suggested by Panse and Sukatme (1954). Analysis was done using WASP 2 package.

3.4.2.1 Analysis of variance for completely randomized design

Source	d.f.	Mean square	Expected mean squares
Genotype	(g-1)	M_g	$\sigma^2e + r.\sigma^2g$
Error	g(r-1)	M_e	σ^2e

Where,

r = number of replications

g = number of genotypes

M_g = genotypes mean squares

M_e= error variance

For the evaluation of all possible pairs of treatment means, Duncan's multiple range test (DMRT) was used.

3.4.3 Experiment II (B): Experiment II (B): Characterization of rice genotypes for drought tolerance under controlled moisture regimes

The data collected for all the biometrical traits were subjected to an analysis of variance for completely randomized blocks design suggested by Panse and Sukatme (1954). Analysis was done using WASP 2 package as enumerated under 3.4.2.1.

Results

IV RESULTS

Twenty one rice genotypes were evaluated for yield and yield attributes under upland condition. Their response to moisture stress (-8 bars) regulated through PEG- 6000 was also assessed. On the basis of the two studies, ten promising genotypes were evaluated for their response to moisture stress imposed at seedling (15 DAS), vegetative (35 DAS) and reproductive stage (50 DAS). The results obtained from the present investigation are discussed hereunder.

4.1 Experiment 1: Morphological characterisations of rice genotypes for yield and yield attributes

4.1.1 Analysis of variance

The analysis of variance (Table 12) revealed the presence of high significant difference among the genotypes for yield and yield attributes studied.

4.1.2 Variability and genetic parameters for yield and yield attributes in rice genotypes

Mean performance of genotypes and estimates of genetic parameters for yield and yield attributes are detailed in Table 13 and Table 14 respectively.

4.1.2.1 Days to fifty per cent flowering

Days to fifty per cent flowering ranged between 66.50 days (Kalladiaryan) and 97.00 days (Mo 15) with majority of genotypes reaching fifty per cent flowering in 82.67 days. The genotypic coefficient of variation (GCV) and phenotypic coefficient of variation (PCV) were found to be moderate (11.27 % and 11.47 % respectively). High heritability (96.44 %) and GA as per cent mean (22.79) was observed for this attribute.

4.1.2.2 Chlorophyll stability index (CSI) (%)

A mean value of 64.63 per cent ranging from 54.88 per cent (PTB 52) to 76.44 per cent (Nerica) was recorded for this attribute. Low GCV (7.79 %), PCV

Table 12. Analysis of variance for yield and yield attributes in rice genotypes

Source	df	Mean sum of squares					
		Days to fifty per cent flowering	CSI (%)	Productive tillers per plant	Panicle length (cm)	Panicle weight (g)	Spikelets per panicle
Replication	1	0857	5.617	0.001	20.861	0.187	293.357
Treatment	20	176.717**	56.480**	2.921**	8.369**	0.508**	1008.057**
Error	20	3.207	5.766	0.067	1.890	0.047	32.913

* significant at 5% level; ** significant at 1% level

Table 12. Analysis of variance for yield and yield attributes in rice genotypes (contd.)

Source	df	Mean sum of squares					
		Grains per panicle	1000 grain weight (g)	Plant height at maturity (cm)	Dry weight of shoot (g)	Grain yield per plant (g)	Straw yield per plant (g)
Replication	1	2.987	0.310	232.180	0.227	1.827	0.255
Treatment	20	764.440**	51.016**	781.087**	9.233**	4.529**	51.329**
Error	20	7.655	1.379	38.527	0.540	0.362	4.162

* significant at 5% level; ** significant at 1% level

Table 13. Mean performance of rice genotypes

Genotypes	Days to fifty per cent flowering	CSI (%)	Productive tillers per plant	Panicle length (cm)	Panicle weight (g)	Spikelets per panicle
Parambuvattan	83.50^{e}	67.21^{bcd}	6.20^{bc}	22.10^{def}	1.60^{fgh}	80.70^{ghi}
Karuthamodan	67.50^{h}	69.57^{b}	5.00^{fgh}	26.20^{ab}	2.01^{def}	88.20^{fgh}
Karanavara	73.00^{g}	66.50^{bcde}	7.00^{a}	24.80^{abcd}	2.25^{cd}	98.60^{f}
Kalladiaryan	66.50^{h}	65.41^{bcdef}	4.50^{hij}	22.15^{def}	2.13^{cde}	125.10^{cd}
Mo 15	97.00^{a}	58.69^{gh}	5.80^{cd}	20.90^{efg}	1.75^{efg}	126.20^{abcd}
Thottacheera	84.50^{cde}	63.65^{cdefg}	4.00^{jk}	23.50^{bcde}	2.50^{abc}	114.00^{de}
Karathadukkan	85.00^{cde}	69.41^{b}	5.10^{efg}	21.60^{ef}	2.30^{bcd}	86.00^{gh}
Chomala	84.00^{de}	66.36^{bcde}	5.60^{de}	22.00^{def}	1.30^{h}	123.00^{cde}
PTB 43	96.00^{a}	58.91^{gh}	3.50^{kl}	22.60^{cde}	1.48^{gh}	125.40^{bcd}
PTB 39	91.50^{b}	55.24^{h}	3.20^{lm}	22.40^{cdef}	1.40^{gh}	86.50^{gh}
PTB 50	87.00^{cde}	61.99^{efg}	4.40^{ij}	22.30^{cdef}	1.65^{fgh}	112.90^{e}
PTB 52	95.50^{a}	54.88^{h}	4.00^{jk}	22.00^{def}	1.60^{fgh}	91.50^{fg}
PTB 60	88.00^{bc}	70.30^{b}	4.70^{ghi}	27.50^{a}	2.15^{cde}	114.30^{de}
Arimodan	74.00^{g}	67.76^{bc}	5.90^{cd}	21.55^{efg}	2.30^{bcd}	79.20^{hi}
Onam	73.00^{g}	62.58^{defg}	5.40^{def}	19.60^{fg}	2.05^{def}	133.90^{abc}
Parambankayama	78.00^{f}	70.09^{b}	4.30^{ij}	23.30^{cde}	2.80^{a}	126.60^{abc}
PTB 55	73.50^{g}	60.98^{fg}	5.60^{de}	18.70^{g}	1.40^{gh}	72.00^{i}
PTB 28	87.00^{cde}	66.76^{bcde}	6.50^{ab}	25.10^{abc}	2.55^{abc}	137.50^{a}
Chettiviruppu	87.50^{cd}	61.90^{efg}	6.60^{ab}	20.90^{efg}	1.20^{h}	89.20^{fgh}
Good day	91.50^{b}	62.71^{defg}	2.80^{m}	23.20^{cde}	2.70^{ab}	137.10^{ab}
Nerica	72.50^{g}	76.44^{a}	3.20^{lm}	23.40^{bcde}	2.70^{ab}	126.80^{abc}
Mean	82.67	64.63	4.92	22.66	1.99	108.32
CD(0.05)	3.74	5.01	0.54	2.87	0.45	11.97

Table 13. Mean performance of rice genotypes (contd.)

Genotypes	Grains per panicle	1000 grain weight (g)	Plant height at maturity (cm)	Dry weight of shoot (g)	Grain yield per plant (g)	Straw yield per plant (g)
Parambuvattan	57.50^{g}	27.00^{bcd}	125.50^{ab}	8.81^{bc}	7.28^{cd}	7.43^{cd}
Karuthamodan	73.30^{f}	29.50^{a}	132.00^{ab}	8.41^{bcd}	7.35^{cd}	6.97^{cde}
Karanavara	85.10^{d}	28.40^{abc}	137.70^{a}	11.56^{a}	8.66^{ab}	9.28^{ab}
Kalladiaryan	95.70^{c}	28.50^{abc}	123.50^{b}	7.47^{cde}	6.74^{de}	6.25^{def}
Mo 15	84.60^{d}	25.30^{de}	92.70^{cdef}	5.87^{fgh}	4.51^{fgh}	4.93^{fghi}
Thottacheera	85.00^{d}	26.10^{cde}	134.20^{ab}	5.93^{fgh}	6.75^{cde}	4.56^{ghij}
Karathadukkan	84.30^{d}	24.55^{e}	122.90^{b}	8.21^{bcd}	7.35^{cd}	7.21^{cde}
Chomala	119.30^{a}	8.50^{i}	86.33^{ef}	5.46^{ghi}	3.83^{h}	4.79^{ghi}
PTB 43	82.90^{de}	25.30^{de}	90.90^{cdef}	5.22^{ghi}	5.35^{fg}	4.68^{ghij}
PTB 39	48.20^{h}	26.35^{cde}	92.50^{cdef}	3.58^{j}	4.10^{gh}	3.28^{j}
PTB 50	75.60^{f}	20.55^{fg}	99.90^{cd}	4.12^{ij}	5.28^{fg}	3.78^{ij}
PTB 52	77.90^{ef}	19.15^{gh}	88.50^{def}	6.10^{efgh}	5.15^{fg}	5.41^{fgh}
PTB 60	84.00^{d}	25.60^{de}	131.00^{ab}	9.52^{b}	7.50^{bcd}	8.13^{bc}
Arimodan	74.40^{f}	27.75^{abcd}	123.10^{b}	7.13^{def}	6.73^{de}	5.91^{efg}
Onam	76.90^{f}	28.50^{abc}	91.60^{cdef}	5.27^{ghi}	5.58^{ef}	5.06^{fghi}
Parambankayama	106.40^{b}	26.30^{cde}	125.50^{ab}	11.35^{a}	9.16^{a}	9.56^{a}
PTB 55	50.80^{h}	21.86^{f}	82.40^{f}	6.00^{efgh}	4.90^{fgh}	4.89^{fghi}
PTB 28	111.30^{b}	20.35^{fg}	102.90^{c}	7.48^{cde}	8.00^{abc}	6.29^{def}
Chettiviruppu	58.60^{g}	17.05^{h}	80.50^{f}	4.84^{hij}	5.05^{fgh}	4.45^{hij}
Good day	92.10^{c}	27.15^{abcd}	125.70^{ab}	5.48^{ghi}	6.80^{cde}	5.07^{fghi}
Nerica	95.70^{c}	29.25^{ab}	95.90^{cde}	6.66^{efg}	7.66^{bcd}	5.95^{efg}
Mean	81.89	24.43	108.82	6.88	6.37	5.89
CD(0.05)	5.77	2.45	12.94	1.53	1.26	1.45

Table 14. Variability and genetic parameters for yield and yield attributes in rice genotypes

Traits	Range		Mean	Coefficient of variation (%)		Heritability (broad sense) %	Genetic advance	Genetic advance as per cent of mean
	Minimum	Maximum		PCV	GCV			
Days to fifty per cent flowering	66.50	97.00	82.67	11.47	11.27	96.44	18.84	22.79
CSI (%)	54.88	76.44	64.63	8.63	7.79	81.47	9.36	14.49
Productive tillers per plant	2.80	7.00	4.92	24.85	24.29	95.52	2.41	48.90
Panicle length (cm)	18.70	27.50	22.66	10.00	7.94	63.15	2.95	13.00
Panicle weight (g)	1.20	2.80	1.99	26.45	24.12	83.19	0.90	45.32
Spikelets per panicles	72.00	137.50	108.32	20.84	20.17	93.68	44.03	40.22
Grains per panicle	48.20	119.30	81.89	23.10	25.95	89.02	35.89	43.83
1000 grain weight (g)	8.50	29.50	24.43	20.95	20.39	94.74	9.99	40.89
Plant height at maturity (cm)	80.50	137.70	108.82	18.60	17.71	90.60	37.78	34.72
Dry weight of shoot (g)	3.58	11.56	6.88	32.15	30.32	88.94	4.05	58.91
Grain yield per plant (g)	3.83	9.16	6.37	24.56	22.67	85.21	2.75	43.11
Straw yield per plant (g)	9.85	28.69	17.68	29.79	27.47	85.00	9.22	52.16

(8.63%) coupled with high heritability (81.47 %) and moderate GA as per cent mean (14.49) were also observed.

4.1.2.3 Productive tillers per plant

Productive tillers per plant ranged between 2.80 (Good day) and 7.00 (Karanavara) with a mean value of 4.92. High GCV (24.29 %), PCV (24.85 %), heritability (95.52 %) and genetic advance per cent mean (48.90) was recorded for this attribute.

4.1.2.4 Panicle length (cm)

A mean value of 22.66 cm was recorded for panicle length. It ranged from 18.70 cm (PTB 55) to 27.50 cm (PTB 60). Low GCV (7.94 %) and PCV (10.00 %), high heritability (63.15%) and moderate GA as per cent mean (13.00) was recorded for this trait.

4.1.2.5 Panicle weight (g)

Mean weight of panicles was 1.99 g. Panicle weight ranged from 1.20 g (Chettiviruppu) to 2.80 g (Parambankayama). High GCV (24.12 %) and PCV (26.45 %), heritability (83.19 %) and GA as per cent mean (45.32) was observed for this attribute.

4.1.2.6 Spikelets per panicle

A mean value of 108.32 was recorded for spikelet per panicle. It ranged between 72.00 in PTB 55 and 137.50 in PTB 28. High GCV (20.17 %), PCV (20.84 %), heritability (93.68 %) and GA as per cent mean (40.22) was recorded for spikelets per panicle.

4.1.2.7 Grains per panicle

Mean number of grains/ panicle was 81.89. It ranged from 48.20 (PTB 39) to 119.30 (Chomala). High GCV (23.10 %), PCV (25.95 %) and heritability (89.02 %) and GA as per cent mean (43.83) was noticed for grains /panicle.

4.1.2.8 1000 grain weight (g)

A mean value of 24.43 g was observed for 1000 grain weight. Values ranged from 8.50 g in Chomala to 29.50 g in Karuthamodan. High GCV (20.39 %), PCV (20.95 %), heritability (94.74 %) and GA as per cent mean (40.89) was recorded for this attribute.

4.1.2.9 Plant height at maturity (cm)

Plant height at maturity ranged between 80.50 cm (Chettiviruppu) and 137.70 cm (Karanavara) with a mean value of 108.82 cm. Moderate GCV (17.71 %) and PCV (18.60 %) coupled with high heritability (90.60 %) and GA as per cent mean (34.72) were recorded for this attribute.

4.1.2.10 Dry weight of shoot (g)

A mean value of 6.88 g with a range of 3.58 g (PTB 39) to 11.56 g (Karanavara) was observed for this attribute. Dry weight of shoot recorded high estimates of GCV (30.32 %), PCV (32.15 %), heritability (88.94 %) and GA as per cent mean (58.91).

4.1.2.11 Grain yield per plant (g)

Genotypes recorded a mean yield of 6.37 g. Grain yield ranged between 3.83 g in Chomala and 9.16 g in Parambankayama. High GCV (22.67 %), PCV (24.56 %), heritability (85.21 %) and GA as per cent mean (43.11) was recorded for this attribute.

4.1.2.12 Straw yield per plant (g)

A mean value of 5.89 g was recorded for straw yield /plant. The values ranged between 3.28 g (PTB 39) and 9.56 g (Parambankayama). High GCV (27.47 %), PCV (29.79 %), heritability (85.00 %) and GA as per cent mean (52.16) were also recorded for this attribute.

4.1.3 Correlation study

Genotypic and phenotypic correlation coefficients were estimated to understand the inter-relationship between grain yield per plant and yield attributes in rice genotypes. The results are summarised in Table 15

4.1.3.1 Association of yield attributes with grain yield per plant (g)

Grain yield per plant (g) recorded a high significant positive correlation with chlorophyll stability analysis (r_p = 0.687, r_g = 0.771), panicle length (r_p = 0.514, r_g = 0.699), panicle weight (r_p = 0.782, r_g = 0.840), grains per panicle (r_p = 0.324, r_g = 0.362), thousand grain weight (r_p = 0.510, r_g = 0.568), plant height (r_p = 0.725, r_g = 0.819), dry weight of shoot (r_p = 0.821, r_g = 0.869) and straw yield per plant (r_p = 0.807, r_g = 0.894) at phenotypic and genotypic level. It also recorded a significant negative correlation with days to 50% flowering (r_p = -0.400, r_g = -0.459) at phenotypic and genotypic level.

4.1.3.2 Inter-correlation among yield attributes

4.1.3.2.1 Days to fifty per cent flowering

The attribute recorded a significant negative correlation with CSI (r_p = -0.549, r_g = -0.623), 1000 grain weight (r_p = - 0.378, r_g = -0.393), plant height (r_p = - 0.330, r_g = -0.357), dry weight of shoot (r_p = -0.388, r_g = -0.441) and straw yield per plant (r_p = -0.359, r_g = -0.438) at both phenotypic and genotypic level.

4.1.3.2.2 Chlorophyll stability index (CSI) (%)

CSI recorded a significant to high significant, positive correlation with panicle length (r_p = 0.364, r_g = 0.587), panicle weight (r_p = 0.565, r_g = 0.668), grains per panicle (r_p = 0.374, r_g = 0.424), plant height (r_p = 0.474, r_g = 0.555), dry weight of shoot (r_p = 0.583, r_g = 0.663) and straw yield (r_p = 0.591, r_g = 0.699) and negative correlation with days to 50 per cent flowering (r_p = -0.549, r_g = -0.623), at both phenotypic and genotypic level.

Table 15. Phenotypic (PCC) and genotypic (GCC) correlation coefficients among yield attributes and grain yield in rice genotypes

Traits	X_1	X_2	X_3	X_4	X_5	X_6	X_7	X_8	X_9	X_{10}	X_{11}	Y
X_1	**1.000**	-0.549**	-0.234^{NS}	-0.005^{NS}	-0.296^{NS}	0.131^{NS}	-0.032^{NS}	-0.378*	-0.330*	-0.388*	-0.359*	-0.400**
X_2	-0.623**	**1.000**	0.124^{NS}	0.364*	0.565**	0.106^{NS}	0.374*	0.225^{NS}	0.474**	0.583**	0.591**	0.687**
X_3	-0.235^{NS}	0.144^{NS}	**1.000**	-0.104^{NS}	-0.207^{NS}	-0.305*	-0.101^{NS}	-0.239^{NS}	0.012^{NS}	0.334*	0.299*	0.091^{NS}
X_4	-0.048^{NS}	0.587**	-0.128^{NS}	**1.000**	0.387*	0.213^{NS}	0.320*	0.223^{NS}	0.519*	0.448**	0.444**	0.514**
X_5	-0.334^{NS}	0.668**	-0.223^{NS}	0.517**	**1.000**	0.442**	0.546**	0.508**	0.581**	0.496**	0.489**	0.782**
X_6	0.157^{NS}	0.118^{NS}	-0.344*	0.249^{NS}	0.516**	**1.000**	0.764**	0.035^{NS}	0.038^{NS}	-0.076^{NS}	-0.062^{NS}	0.128^{NS}
X_7	-0.022^{NS}	0.424**	-0.114^{NS}	0.423**	0.595**	0.774**	**1.000**	-0.183^{NS}	0.246^{NS}	0.242^{NS}	0.231^{NS}	0.324*
X_8	-0.393*	0.297^{NS}	-0.251^{NS}	0.231^{NS}	0.580**	0.019^{NS}	-0.192^{NS}	**1.000**	0.536**	0.341*	0.332*	0.510**
X_9	-0.357*	0.555**	0.012^{NS}	0.736**	0.713**	0.045^{NS}	0.267^{NS}	0.607**	**1.000**	0.668**	0.633**	0.725**
X_{10}	-0.441**	0.663**	0.353*	0.597**	0.531**	-0.088^{NS}	0.256^{NS}	0.365*	0.743**	**1.000**	0.973**	0.821**
X_{11}	-0.438**	0.699**	0.325*	0.579**	0.564**	-0.066^{NS}	0.254^{NS}	0.365*	0.719**	0.998**	**1.000**	0.807**
Y	-0.459**	0.771**	0.107^{NS}	0.699**	0.840**	0.155^{NS}	0.362*	0.568**	0.819**	0.869**	0.894**	**1.000**

* significant at 5% level; ** significant at 1% level **PCC:** above diagonal; **GCC:** below diagonal

X_1- Days to fifty per cent flowering X_2- Chlorophyll stability index X_3- Productive tillers per plant X_4- Panicle length (cm)

X_5- Panicle weight (g) X_6- Spikelets per panicle X_7- Grains per panicle X_8-1000 grain weight (g)

X_9- Plant height at maturity (cm) X_{10}- Dry weight of shoot (g) X_{11}- Straw yield per plant (g) Y- Grain yield per plant (g)

4.1.3.2.3 Productive tillers per plant

Productive tillers per plant was found to have a significant positive correlation with dry weight of shoot (r_p = 0.334, r_g = 0.353) and straw yield per plant (r_p = 0.299, r_g = 0.325) both at genotypic and phenotypic level. The correlation was significant and negative with spikelets per panicle (r_p = -0.305, r_g = -0.344) at both phenotypic and genotypic level.

4.1.3.2.4 Panicle length

Significant to high significant positive correlation was observed with panicle weight (r_p = 0.387, r_g = 0.517), plant height (r_p = 0.519, r_g = 0.736), dry weight of shoot (r_p = 0.448, r_g = 0.597), straw yield per plant (r_p = 0.444, r_g = 0.579), grains per panicle (r_p = 0.320, r_g = 0.423) and CSI (r_p = 0.364, r_g = 0.587) at both phenotypic and genotypic level.

4.1.3.2.5. Panicle weight

A significant positive correlation has been observed by panicle weight with CSI (r_p = 0.565, r_g = 0.668), panicle length (r_p = 0.387, r_g = 0.517), spikelets per panicle (r_p = 0.442, r_g = 0.516), grains per panicle (r_p = 0.546, r_g = 0.595), 1000 grain weight (r_p = 0.508, r_g = 0.580), plant height (r_p = 0.581, r_g = 0.713), dry weight of shoot (r_p = 0.496, r_g = 0.531) and straw yield per plant (r_p = 0.489, r_g = 0.564).

4.1.3.2.6 Spikelets per panicle

Correlation between spikelets per panicle was found significant and positive at both phenotypic and genotypic level with panicle weight (r_p = 0.442, r_g = 0.516) and grains per panicle (r_p = 0.764, r_g = 0.774). It recorded negative correlation with productive tillers (r_p = -0.305, r_g = -0.344) at both phenotypic level and genotypic level

4.1.3.2.7 Grains per panicle

Grains per panicle recorded a significant positive correlation with CSI (r_p = 0.374, r_g = 0.424), panicle length (r_p = 0.320, r_g = 0.423), panicle weight (r_p =

0.546, r_g = 0.595) and spikelets per panicle (r_p = 0.764, r_g = 0.764), at both phenotypic and genotypic level.

4.1.3.2.8 1000 grain weight

A significant positive correlation was observed by 1000 grain weight with panicle weight (r_p = 0.508, r_g = 0.580) plant height (r_p = 0.536, r_g = 0.607), dry weight of shoot (r_p = 0.341, r_g = 0.365) and straw yield per plant (r_p = 0.332, r_g = 0.365) at phenotypic and genotypic level. A significant to high significant negative correlation was found with days to fifty per cent flowering (r_p = -0.378, r_g = -0.393) at both phenotypic and genotypic level.

4.1.3.2.9 Plant height

Plant height exerted significant to high significant positive correlation with dry weight of shoot (r_p = 0.668, r_g = 0.743), straw yield per plant (r_p = 0.633, r_g = 0.719), CSI (r_p = 0.474, r_g = 0.555), panicle length (r_p = 0.519, r_g = 0.736), panicle weight (r_p = 0.581, r_g = 0.713) and 1000 grain weight (r_p = 0.536, r_g = 0.607) at both phenotypic and genotypic level. It also recorded significant negative correlation with days to fifty per cent flowering (r_p = -0.330, r_g = -0.357) at both phenotypic level and genotypic level

4.1.4.2.10 Dry weight of shoot

Dry weight of shoot was found to have a significant to high significant positive correlation with straw yield per plant (r_p = 0.973, r_g = 0.869), CSI (r_p = 0.583, r_g = 0.663), productive tillers (r_p = 0.334, r_g = 0.353) panicle length (r_p = 0.448, r_g = 0.597), panicle weight (r_p = 0.496, r_g = 0.531), plant height (r_p = 0.668, r_g = 0.743) and 1000 grain weight (r_p = 0.341, r_g = 0.365), at both phenotypic and genotypic level. It recorded high significant negative correlation with days to fifty per cent flowering (r_p = -0.388, r_g = -0.441).

4.1.3.2.11 Straw yield per plant

A significant positive correlation was observed between straw yield per plant and dry weight of shoot (r_p = 0.973, r_g = 0.998), CSI (r_p = 0.591, r_g = 0.699), productive tillers (r_p = 0.299, r_g = 0.325), panicle length (r_p = 0.444, r_g = 0.579), panicle weight (r_p = 0.489, r_g = 0.564), plant height (r_p = 0.633, r_g = 0.719) and 1000 grain weight (r_p = 0.332, r_g = 0.365) at both phenotypic and genotypic level. It had also recorded high significant negative correlation with days to fifty per cent flowering (r_p = -0.359, r_g = -0.438) at phenotypic and genotypic level.

4.1.4. Path co-efficient analysis

The genotypic correlation coefficient of grain yield with yield attributes influenced by moisture stress was further partitioned into direct and indirect effects. The results are detailed in Table 16. A residual value of 0.1236 was recorded.

4.1.4.1 Direct effects

The positive direct effect on grain yield per plant ranged from 0.00151 (1000 grain weight) to 1.00066 (panicle weight). Panicle weight along with panicle length (0.55133) exerted very high direct effect on grain yield. It was observed that the effect of productive tillers per plant (0.22468) and straw yield per plant (0.27697) were moderate while dry weight of shoot (0.18202) exerted low positive direct effect on yield. The direct effects of 1000 grain weight (0.00151) were negligible. Plant height (-0.58628) and spikelets per panicle (-0.41317) were found to exert high negative direct effect on grain yield. CSI (-0.17468) and grains per panicle (-0.19541) exerted low negative direct effect compared to days to fifty per cent flowering (-0.01954) whose effect on yield was negative and negligible.

4.1.4.2 Indirect effects

4.1.4.2.1 Days to 50 per cent flowering

Days to 50 per cent flowering was found to exhibit low positive indirect effect through plant height (0.11013) and CSI (0.10754). High negative indirect effect was exerted through panicle weight (-0.30463) while its effect through straw yield (-0.11331) was low. Its indirect effects through productive tillers per plant (-0.07285), dry weight shoot (-0.07270), spikelets per panicle (-0.06432),

Table 16. Direct (diagonal) and indirect effect of yield attributes on grain yield in rice genotypes

Traits	X_1	X_2	X_3	X_4	X_5	X_6	X_7	X_8	X_9	X_{10}	X_{11}
X_1	**-0.01954**	0.10754	-0.07285	-0.00436	-0.30463	-0.06432	-0.02437	-0.00039	0.11013	-0.07270	-0.11331
X_2	0.01522	**-0.17468**	0.04457	0.24309	0.65684	-0.01872	-0.05198	0.00038	-0.25081	0.11791	0.18938
X_3	0.00549	-0.02373	**0.22468**	-0.11677	-0.17067	0.07350	-0.00994	-0.00028	-0.00533	0.05381	0.07590
X_4	0.00024	-0.09282	-0.08377	**0.55133**	0.65726	-0.09519	-0.05499	0.00042	-0.41740	0.09325	0.14085
X_5	0.00778	-0.11850	-0.05785	0.31055	**1.00066**	-0.12692	-0.07166	0.00081	-0.35958	0.09665	0.15787
X_6	-0.00989	-0.02031	-0.14988	0.27055	0.76349	**-0.41317**	-0.17482	-0.00002	-0.03733	-0.03263	-0.04074
X_7	-0.00565	-0.08508	0.03056	0.23570	0.65010	-0.26363	**-0.19541**	-0.00102	-0.10736	0.03709	0.06655
X_8	0.00754	-0.05091	-0.07135	0.14851	0.60793	0.00109	0.08393	**0.00151**	-0.33157	0.06776	0.10319
X_9	0.00594	-0.09547	0.00382	0.41611	0.75868	-0.01309	-0.02497	0.00094	**-0.58628**	0.14319	0.20959
X_{10}	0.01033	-0.11828	0.10142	0.24501	0.53736	0.03016	-0.02274	0.00050	-0.37736	**0.18202**	0.28061
X_{11}	0.01052	-0.12423	0.09354	0.24197	0.57398	0.02463	-0.02667	0.00050	-0.36117	0.18349	**0.27697**

Residual effect = 0.1236

X_1- Days to fifty per cent flowering X_2- Chlorophyll stability index X_3- Productive tillers per plant X_4- Panicle length (cm)

X_5- Panicle weight (g) X_6- Spikelets per panicles X_7- Grains per panicle X_8-1000 grain weight (g)

X_9- Plant height at maturity (cm) X_{10}- Dry weight of shoot (g) X_{11}- Straw yield per plant (g) grains per panicle (-0.02437), panicle length (-0.00436), and 1000 grain weight (0.00039) were found to be negative and negligible.

4.1.4.2.2 Chlorophyll stability index (%)

Positive indirect effects of CSI (%) on grain yield was found to be high through panicle weight (0.65684) and moderate through panicle length (0.24309), low through straw yield (0.18938) and dry weight of shoot (0.11791), and negligible through productive tillers per plant (0.04457), days to fifty per cent flowering (0.01522) and 1000 grain weight (0.00038). It exhibited moderate negative indirect effect through plant height (-0.25081) while its effect was negligible through spikelets per panicle (-0.01872) and grains per panicle (-0.05198).

4.1.4.2.3 Productive tillers per plant

Productive tillers per plant recorded negligible positive indirect effect through straw yield per plant (0.07590), spikelets per panicle (0.07350), dry weight of shoot (0.05381) and days to fifty per cent flowering (0.00549). However, it exerted low negative indirect on grain yield through panicle weight (-0.17067) and panicle length (-0.11677) and negligible through CSI (-0.02373), grains per panicle (-0.00994), plant height (-0.00533) and 1000 grain weight (-0.00028).

4.1.4.2.4 Panicle length (cm)

Panicle length recorded high positive indirect effect through panicle weight (0.65726) and negligible positive indirect effect through straw yield per plant (0.14085), dry weight of shoot (0.09325), 1000 grain weight (0.00042) and days to fifty per cent flowering (0.00024). Its negative indirect effect on grain yield was found to be high through plant height (-0.41740) and negligible through spikelets per panicle (-0.09519), CSI (-0.09282), productive tillers (-0.08377) and grains per panicle (-0.05499).

4.1.4.2.5 Panicle weight (g)

Panicle weight exhibited high positive indirect effect through panicle length (0.31055). It also recorded low positive indirect effect through straw yield (0.15787) and negligible effect through dry weight shoot (0.09665), days to fifty per cent flowering (0.00778) and 1000 grain weight (0.00081). Its negative indirect effect on grain yield through plant height (-0.35958) was high. However, it was found to exert low indirect effect on grain yield through spikelets per panicle (-0.12692) and CSI (-0.11850), and negligible effect through grains per panicle (-0.07166) and productive tillers (-0.05785).

4.1.4.2.6 Spikelets per panicle

Spikelets per panicle exerted high positive indirect effect through panicle weight (0.76349) and moderate effect through panicle length (0.27055). However, it exhibited low negative indirect effect through grains per panicle (-0.17482). Low effect was evident through productive tillers (-0.14988) and negligible effect through, straw yield (-0.04074), plant height (-0.03733), dry weight of shoot (-0.03263), chlorophyll stability index (-0.02031), days to fifty per cent flowering (-0.00989) and 1000 grain weight (-0.00002),

4.1.4.2.7 Grains per panicle

Grains per panicle was found to exhibit high positive indirect effect through panicle weight (0.65010) and moderate through panicle length (0.23570) and negligible effect through straw yield (0.06655), dry weight of shoot (0.03709) and productive tillers (0.03056). It had recorded moderate negative indirect effect on grain yield through spikelets per panicle (-0.26363) and low effect through plant height (-0.10736). Negligible negative indirect effect was observed through CSI (-0.08508) days to fifty per cent flowering (-0.00565), and 1000 grain yield (-0.00102)

4.1.4.2.8 1000 grain weight (g)

1000 grain weight recorded high positive indirect effect on grain yield through panicle weight (0.60793) and low effect through panicle length (0.14851) and straw yield per plant (0.10319). However, its positive indirect effect on grain yield was negligible through grains per panicle (0.08393), dry weight of shoot (0.06776), days to fifty per cent flowering (0.00754) and spikelets per panicle (0.00109). The attribute recorded high negative indirect effect on grain yield through plant height (-0.33157) and negligible effect through productive tillers (-0.07135) and CSI (-0.05091).

4.1.4.2.9 Plant height (cm)

Plant height has exhibited high positive indirect effect through panicle weight (0.75868) and panicle length (0.41611). Its positive indirect effect on grain yield was low through dry weight of shoot (0.14319) and negligible through day to fifty per cent flowering (0.00594), productive tillers (0.00382) and 1000 grain weights (0.00094). It also recorded negligible negative indirect effect on grain yield through CSI (-0.09547), grains per panicle (-0.02497), and spikelets per panicle (-0.01309)

4.1.4.2.10 Dry weight of shoot (g)

Dry weight of shoot was found to exhibit high positive indirect effect on grain yield through panicle weight (0.53736). Its effect was moderate through straw yield per plant (0.28061) and panicle length (0.24501), and low through productive tillers per plant (0.10142) but negligible through spikelets per panicle (0.03016), days to fifty per cent flowering (0.01033) and 1000 grain weight (0.00050). It recorded high negative indirect effect on grain yield through plant height (-0.37736), low effect through CSI (-0.11828). Its effect on grain yield was negative and negligible through grains per plant (-0.02274).

4.1.4.2.11 Straw yield per plant (g)

Straw yield per plant was found to exhibit high positive indirect effect on grain yield through panicle weight (0.57398), moderate effect through panicle length (0.24197) low positive indirect effect through dry weight of shoot (0.18349). It's positive indirect effect on grain yield was negligible through productive tillers per plant (0.09354), spikelets per panicle (0.02463), days to fifty per cent flowering (0.01052) and 1000 grain weight (0.00050). The negative indirect effect of straw yield per plant on grain yield through plant height was high while it was low in case of CSI (-0.12423) and grains per panicle (-0.02667).

4.2 Experiment II: Characterisation of rice genotypes for drought tolerance

4.2.1 Experiment II (A): Rapid evaluation test for drought tolerance

4.2.1.1 Analysis of variance

The analysis of variance for the traits studied under PEG 6000 simulated drought and non stressed control in hydroponics (Table 17 and Table 18) indicated presence of wide variability between genotypes.

.4.2.1.2 Mean performance of rice genotypes for seedling traits under moisture stress (-8 bars) and Non stressed control

Mean performance of genotypes at -8 bars water potential and non stressed control (Table 19 and Table 20) is detailed below.

4.2.1.2.1 Speed of germination

Speed of germination ranged from 0.60 (PTB 55) to 1.85 (PTB 60) with a mean of 1.12 under stress condition. Parambankayama (1.74) was found to be on par with PTB 60.

Speed of germination ranged from 3.43 (Chettiviruppu) to 5.73 (PTB 39) with a mean of 4.85 under non stressed condition. Karuthamodan (5.35), Karanavara (5.36), Kalladiaryan (5.42), Karathadukkan (5.45), PTB 43 (5.36), PTB 50 (5.13), PTB 52 (5.18), PTB 60 (5.52), Parambankayama (5.45), PTB 28 (5.54), Good day (5.67) and Nerica (5.33) were found on par with PTB 39.

Table 17. Analysis of variance for seedling traits under moisture stress (-8 bars) in rice genotypes

Source	Df	Mean sum of squares					
		Speed of germination	Shoot length (cm)	Root length (cm)	Shoot to Root length ratio	Seedling vigour index	Total biomass (g)
Genotypes	20	0.200**	13.820**	8.010**	0.200**	149750.000**	2.73E-05**
Error	21	0.014	0.230	0.150	0.050	593.000	6.84E-06

* significant at 5% level; ** significant at 1% level

Table 18. Analysis of variance for seedling traits under non stressed control in rice genotypes

Source	Df	Mean sum of squares					
		Speed of germination	Shoot length (cm)	Root length (cm)	Shoot to Root length ratio	Seedling vigour index	Total biomass (g)
Genotypes	20	1.486**	69.211**	10.974**	0.438**	1064837.000**	4.14E-05**
Error	21	0.091	0.816	0.240	0.014	16631.000	4.76E-07

* significant at 5% level; ** significant at 1% level

Table 19. Mean performance of rice genotypes for seedling traits under moisture stress (-8 bars)

Genotypes	Speed of germination	Shoot length (cm)	Root length (cm)	Shoot to Root length ratio	Seedling vigour index	Total biomass (g)
Parambuvattan	1.27^{bc}	10.75^{cd}	12.00^{a}	0.90^{hi}	1024^{a}	0.020^{abc}
Karuthamodan	1.26^{bc}	11.93^{b}	11.63^{ab}	1.03^{fgh}	942^{c}	0.019^{bc}
Karanavara	1.25^{bc}	10.49^{de}	11.11^{b}	0.95^{hi}	972^{bc}	0.020^{abc}
Kalladiaryan	1.14^{bcde}	11.00^{bcd}	9.83^{c}	1.12^{efg}	833^{d}	0.019^{bc}
Mo 15	0.93^{efg}	6.99^{jkl}	6.00^{jk}	1.17^{ef}	390^{j}	0.016^{cd}
Thottacheera	1.33^{b}	12.00^{b}	8.00^{de}	1.50^{bc}	700^{f}	0.021^{ab}
Karathadukkan	1.23^{bc}	13.95^{a}	7.33^{efgh}	1.91^{a}	851^{d}	0.019^{bc}
Chomala	0.98^{defg}	5.99^{lm}	7.10^{fghi}	0.84^{i}	393^{j}	0.009^{e}
PTB 43	1.27^{bc}	7.90^{ghij}	5.15^{l}	1.54^{b}	457^{hi}	0.019^{bc}
PTB 39	0.76^{ghi}	7.10^{ijk}	7.75^{efg}	0.92^{hi}	446^{i}	0.019^{bc}
PTB 50	1.03^{cdef}	8.80^{fg}	7.10^{fghi}	1.24^{de}	318^{k}	0.018^{bc}
PTB 52	0.76^{ghi}	9.50^{ef}	6.90^{hi}	1.38^{cd}	410^{ij}	0.019^{bc}
PTB 60	1.85^{a}	11.50^{bc}	7.90^{ef}	1.46^{bc}	776^{e}	0.020^{abc}
Arimodan	1.19^{bcd}	11.63^{bc}	11.50^{ab}	1.01^{gh}	925^{c}	0.021^{ab}
Onam	0.89^{fgh}	6.85^{kl}	7.60^{efgh}	0.91^{hi}	289^{k}	0.020^{abc}
Parambankayama	1.74^{a}	14.50^{a}	7.80^{efg}	1.86^{a}	1004^{ab}	0.024^{a}
PTB 55	0.60^{i}	7.25^{hijk}	7.00^{ghi}	1.04^{fgh}	285^{k}	0.017^{bcd}
PTB 28	1.19^{bcd}	7.30^{hijk}	7.60^{efgh}	0.96^{hi}	521^{g}	0.010^{e}
Chettiviruppu	0.65^{hi}	5.00^{m}	5.50^{kl}	0.92^{hi}	210^{l}	0.012^{de}
Good day	0.93^{efg}	8.13^{gh}	6.50^{ij}	1.26^{de}	439^{ij}	0.021^{ab}
Nerica	1.30^{b}	8.10^{ghi}	8.75^{d}	0.93^{hi}	506^{gh}	0.020^{abc}
Mean	1.12	9.36	8.10	1.18	605	0.02
CD 5%	0.24	1.01	0.81	0.15	51	14.41

Table 20. Mean performance of rice genotypes for seedling traits under non stress control

Genotypes	Speed of germination	Shoot length (cm)	Root length (cm)	Shoot to Root length ratio	Seedling vigour index	Total biomass (g)
Parambuvattan	4.91^{c}	24.50^{d}	14.10^{b}	1.74^{efghi}	3572.^{bcd}	0.025^{e}
Karuthamodan	5.35^{abc}	27.00^{c}	14.29^{b}	1.89^{def}	3609^{bcd}	0.023^{fg}
Karanavara	5.36^{abc}	30.50^{b}	15.00^{b}	2.04^{cd}	4323^{a}	0.025^{e}
Kalladiaryan	5.42^{abc}	27.50^{c}	13.99^{bc}	1.97^{def}	3734^{bc}	0.023^{g}
Mo 15	5.08^{bc}	17.50^{i}	11.63^{e}	1.51^{i}	2694^{fg}	0.021^{h}
Thottacheera	4.13^{d}	31.50^{ab}	9.93^{gh}	3.18^{a}	3728^{bc}	0.023^{g}
Karathadukkan	5.45^{abc}	30.50^{b}	13.00^{cd}	2.35^{b}	3808^{b}	0.025^{e}
Chomala	3.46^{e}	15.50^{j}	7.66^{j}	2.04^{cd}	1795^{j}	0.014^{j}
PTB 43	5.36^{abc}	31.00^{ab}	9.15^{hi}	3.39^{a}	3516^{cd}	0.022^{h}
PTB 39	5.73^{a}	20.50^{fg}	10.50^{fg}	1.96^{def}	2945^{ef}	0.023^{g}
PTB 50	5.13^{abc}	17.93^{hi}	11.75^{e}	1.53^{hi}	2597^{g}	0.022^{h}
PTB 52	5.18^{abc}	21.50^{ef}	11.50^{ef}	1.88^{def}	2888^{ef}	0.023^{fg}
PTB 60	5.52^{abc}	22.50^{e}	13.00^{cd}	1.73^{fghi}	3373^{d}	0.027^{d}
Arimodan	3.59^{de}	32.00^{ab}	16.50^{a}	1.94^{def}	4365^{a}	0.029^{c}
Onam	3.48^{e}	19.50^{gh}	12.00^{de}	1.63^{ghi}	2678^{fg}	0.031^{b}
Parambankayama	5.45^{abc}	32.50^{a}	14.50^{b}	2.25^{bc}	4113^{a}	0.033^{a}
PTB 55	3.34^{e}	17.00^{ij}	9.00^{hi}	1.89^{def}	2275^{hi}	0.023^{fg}
PTB 28	5.54^{abc}	17.75^{hi}	10.00^{gh}	1.78^{efgh}	2498^{gh}	0.024^{f}
Chettiviruppu	3.43^{e}	17.00^{ij}	8.60^{ij}	1.98^{de}	2048^{ij}	0.019^{i}
Good day	5.67^{ab}	21.50^{ef}	11.50^{ef}	1.88^{def}	2970^{e}	0.031^{b}
Nerica	5.33^{abc}	20.50^{fg}	11.50^{ef}	1.79^{efg}	2880^{ef}	0.031^{b}
Mean	4.85	23.60	11.86	2.01	3162	0.025
CD 5%	0.63	1.88	1.02	0.25	269	0.00

4.2.1.2.2 Shoot length (cm)

Shoot length ranged from 5 cm (Chettiviruppu) to 14.50 cm (Parambankayama) with a mean value of 9.36 cm under stressed condition. Karathadukkan (13.95 cm) was found to be on par with Parambankayama.

Under non stressed control, shoot length ranged from 15.50 cm (Chomala) to 32.50 cm (Parambankayama) with a mean of 23.60 cm. Thottachera (31.50 cm), PTB 43 (31.00 cm) and Arimadan (32.00 cm) were found on par with Parambankayama

4.2.1.2.3 Root length (cm)

A mean value of 8.10 cm was recorded for root length under stressed condition. It ranged from 5.15 cm (PTB 43) to 12.00 cm (Parambuvattan). Karuthamodan (11.63 cm) and Arimodan (11.50 cm) were found to be on par with Parambuvattan.

A mean value of 11.86 cm was recorded for root length under non stressed control. It ranged from 7.66 cm (Chomala) to 16.50 cm (Arimodan).

4.2.1.2.4 Shoot to root length ratio

Shoot to root length ratio ranged from 0.84 (Chomala) to 1.91 (Karathadukkan) with a mean of 1.18 under stressed condition. Parambankayama (1.86) was found to be on par with Karathadukkan

Under non stressed control, shoot to root length ratio ranged from 1.51 (Mo 15) to 3.39 (PTB 43) with a mean of 2.01. Thottacheera was found to on par with PTB 43.

4.2.1.2.5 Seedling vigour index

The estimates of seedling vigour ranged from 289 (Onam) to 1024 (Parambuvattan) with a mean value of 604 under stressed condition.

The estimates of seedling vigour ranged from 1795 (Chomala) to 4365 (Arimodan) with a mean of 3162 under non stressed control. Karanavara (4322) and Parambankayama (4113) were found on par with Arimodan.

4.2.1.2.6 Total biomass (g)

Total biomass ranged from 0.009 g (Chomala) to 0.024 g (Parambankayama) with a mean value of 0.02 g under stressed condition. African Goodday (0.021 g) was found next best to Parambankayama.

Under non stressed condition, biomass ranged from 0.014 g (Chomala) to 0.033 g (Parambankayama) with a mean of 0.025 g.

4.2.2 Experiment II (B): Characterisation of rice genotypes for drought tolerance under controlled moisture regimes

Based on the performance of the twenty one rice genotypes under field and laboratory study, ten promising genotypes where selected to evaluated the response to moisture stress imposed at different growth stages

4.2.2.1 Elucidating the response of rice genotypes prior to imposition of moisture stress

4.2.2.1.1 Analysis of variance

The analysis of variance for growth traits recorded prior to imposition of moisture stress, at seedling stage - 15 days after sowing (DAS), vegetative stage (35 DAS) and reproductive stage (50 DAS) are presented in Tables 21 to 23. Results indicated that the genotypes varied significantly from each other for all the traits at the various growth stages.

4.2.2.1.2 Mean performance of rice genotypes prior to imposition of moisture stress at different growth stages

Mean performance of genotypes for various traits before imposition of moisture stress at different growth stages are detailed in Table 24 to 26 and described below.

Table 21. Analysis of variance for growth traits in rice genotypes at seedling stage (15 DAS) prior to imposition of moisture stress

Source	df	Mean sum of squares							
		Shoot length (cm)	Dry weight of shoot (g)	Root length (cm)	Dry weight of root (g)	Shoot to root length ratio	Vigour index	Root volume (ml)	Chlorophyll content (mg/g)
genotype	9	24.88**	0.576**	23.268**	0.006**	0.358**	198017**	0.374*	0.234**
Error	20	2.100	0.006	1.542	9.33E-05	0.072	24508	0.125	0.014

* significant at 5% level; ** significant at 1% level

Table 22. Analysis of variance for growth traits in rice genotypes at vegetative stage (35 DAS) prior to imposition of moisture stress

Source	df	Mean sum of squares							
		Shoot length (cm)	Dry weight of shoot (g)	Root length (cm)	Dry weight of root (g)	Shoot to root length ratio	Vigour index	Root volume (ml)	Chlorophyll content (mg g)
genotype	9	125.106**	1.388**	86.830**	0.042**	0.190**	1320047**	3.737**	0.1015**
Error	20	5.302	0.033	6.800	0.001	0.031	66413	0.467	0.0003

* significant at 5% level; ** significant at 1% level

Table 23. Analysis of variance for growth traits in rice genotypes at reproductive stage (50 DAS) prior to imposition of moisture stress

Source	df	Mean sum of squares							
		Shoot length (cm)	Dry weight of shoot (g)	Root length (cm)	Dry weight of root (g)	Shoot to root length ratio	Vigour index	Root volume (ml)	Chlorophyll content (mg /g)
Genotype	9	575.905**	7.263**	102.726**	3.577**	0.863**	5338989**	379.022**	0.0277**
Error	20	12.758	0.135	15.633	0.038	0.086	277142	22.733	0.0002

* significant at 5% level; ** significant at 1% level

Table 24. Growth traits of rice genotypes at seedling stage (15 DAS) prior to imposition of moisture stress

Genotypes	Shoot length (cm)	Dry weight of shoot (g)	Root length (cm)	Dry weight of root (g)	Shoot to root length ratio	Vigour index	Root volume (ml)	Chlorophyll content (mg/g)
Karanavara	22.47^{cd}	1.83^{a}	14.67^{bc}	0.18^{b}	1.54^{def}	1985^{b}	2.17^{ab}	4.14^{b}
Parambankyama	20.73^{d}	0.84^{d}	11.67^{de}	0.16^{b}	1.82^{bcde}	1724^{b}	1.83^{bcd}	3.92^{cd}
PTB 28	16.53^{e}	0.68^{e}	9.33^{f}	0.09^{d}	1.78^{cde}	1284^{c}	2.33^{ab}	4.07^{bc}
Nerica	20.33^{d}	0.58^{e}	16.67^{ab}	0.23^{a}	1.22^{f}	1804^{b}	2.50^{a}	4.44^{a}
PTB 60	26.07^{a}	1.55^{b}	17.00^{a}	0.14^{c}	1.54^{def}	2310^{a}	1.83^{bcd}	3.90^{cd}
Karuthamodan	21.93^{cd}	1.10^{c}	11.17^{def}	0.18^{b}	1.98^{abcd}	1763^{b}	2.00^{abc}	3.87^{d}
Arimodan	25.33^{ab}	1.43^{b}	12.67^{cd}	0.09^{d}	2.01^{abc}	1873^{b}	1.33^{d}	4.53^{a}
Karathadukkan	23.47^{bc}	0.93^{d}	15.67^{ab}	0.13^{c}	1.50^{ef}	1901^{b}	1.83^{bcd}	4.45^{a}
Parambuvattan	22.27^{cd}	0.65^{e}	10.00^{ef}	0.09^{d}	2.26^{ab}	1837^{b}	1.50^{cd}	3.80^{d}
Kalladiaryan	25.53^{ab}	0.67^{e}	11.33^{def}	0.17^{b}	2.27^{a}	1974^{b}	2.00^{abc}	4.40^{a}
Mean	22.47	1.03	13.02	0.15	1.79	1846	1.93	4.15
CD (0.05)	2.47	0.14	2.12	0.02	0.46	267	0.60	0.19

Table 25. Growth traits of rice genotypes at vegetative stage (35 DAS) prior to imposition of moisture stress

Genotypes	Shoot length (cm)	Dry weight of shoot (g)	Root length (cm)	Dry weight of root (g)	Shoot to root length ratio	Vigour index	Root volume (ml)	Chlorophyll content (mg/g)
Karanavara	63.74^{a}	3.15^{a}	38.00^{ab}	0.43^{c}	1.69^{bc}	5755^{a}	6.00^{bc}	4.34^{f}
Parambankyama	54.69^{b}	2.36^{c}	34.33^{bcd}	0.52^{b}	1.60^{c}	4554^{cd}	6.67^{ab}	4.37^{ef}
PTB 28	43.08^{d}	1.71^{d}	20.33^{f}	0.44^{c}	2.13^{a}	3357^{f}	4.67^{de}	4.52^{bc}
Nerica	48.21^{c}	1.36^{e}	33.00^{cde}	0.69^{a}	1.47^{c}	4274^{de}	7.67^{a}	4.50^{cd}
PTB 60	56.37^{b}	3.00^{a}	35.67^{abc}	0.34^{d}	1.58^{c}	4995^{b}	4.67^{de}	4.12^{h}
Karuthamodan	56.97^{b}	2.68^{b}	39.00^{a}	0.55^{b}	1.46^{c}	4579^{bcd}	5.67^{bcd}	4.78^{a}
Arimodan	53.81^{b}	3.14^{a}	31.67^{cde}	0.34^{d}	1.56^{c}	3978^{e}	4.33^{e}	4.38^{e}
Karathadukkan	47.89^{c}	2.17^{c}	34.67^{abc}	0.34^{d}	1.68^{c}	3878^{e}	4.67^{de}	4.55^{b}
Parambuvattan	55.45^{b}	1.57^{de}	28.67^{e}	0.34^{d}	1.98^{ab}	4550^{cd}	4.33^{e}	4.48^{d}
Kalladiaryan	62.60^{a}	1.74^{d}	30.00^{de}	0.52^{b}	2.09^{a}	4844^{bc}	5.00^{cde}	4.24^{g}
Mean	54.28	2.29	32.53	0.45	1.72	4476	5.37	4.43
CD (0.05)	3.92	0.31	4.44	0.04	0.30	439	1.16	0.03

Table 26. Growth traits of rice genotypes at reproductive stage (50 DAS) prior to imposition of moisture stress

Genotypes	Shoot length (cm)	Dry weight of shoot (g)	Root length (cm)	Dry weight of root (g)	Shoot to root length ratio	Vigour index	Root volume (ml)	Chlorophyll content (mg/g)
Karanavara	102.22[a]	7.64[a]	43.00[ab]	3.91[c]	2.38[bc]	9245[a]	48.67[ab]	4.31[g]
Parambankyama	93.58[bc]	4.02[c]	31.33[e]	1.73[g]	3.03[a]	7790[b]	28.33[de]	4.38[ef]
PTB 28	62.93[e]	2.93[d]	33.00[de]	1.72[g]	1.93[cd]	4869[f]	25.33[de]	4.46[c]
Nerica	63.82[e]	2.37[d]	47.33[a]	2.58[f]	1.35[e]	5658[ef]	33.33[cd]	4.52[b]
PTB 60	100.17[a]	5.18[b]	41.00[ab]c	4.73[a]	2.45[b]	8885[a]	54.67[a]	4.44[d]
Karuthamodan	90.54[bc]	4.07[c]	35.00[cde]	3.11[e]	2.61[ab]	7278[bcd]	37.67[c]	4.37[f]
Arimodan	90.37[bc]	4.80[b]	37.67[bcde]	4.34[b]	2.47[b]	6693[cd]	50.00[ab]	4.40[e]
Karathadukkan	80.28[d]	3.65[c]	46.67[a]	3.46[d]	1.72[de]	6499[de]	46.00[b]	4.27[h]
Parambuvattan	89.38[c]	2.89[d]	39.00[bcd]	2.42[f]	2.30[bc]	7347[bcd]	28.33[de]	4.52[b]
Kalladiaryan	96.37[ab]	2.83[d]	32.00[e]	1.93[g]	3.03[a]	7455[bc]	25.00[e]	4.56[a]
Mean	86.97	4.04	38.60	2.99	2.33	7172	37.73	4.42
CD (0.05)	6.08	0.63	6.73	0.33	0.50	897	8.12	0.03

4.2.2.1.2.1 Shoot length (cm)

Shoot length at seedling stage (15 DAS) ranged from 16.53 cm (PTB 28) to 26.07 cm (PTB 60) with a mean value of 22.47 cm. Kalladiaryan (25.53 cm) and Arimodan (25.33 cm) were found to be on par with PTB 60.

Shoot length at vegetative stage (35 DAS) varied from 43.08 cm (PTB 28) to 63.74 cm (Karanavara) with a mean value of 54.28 cm. Kalladiaryan (62.60 cm) was found to be on par with Karanavara.

Shoot length at reproductive stage (50 DAS) ranged between 62.93 cm (PTB 28) and 102.22 cm (Karanavara) with a mean value of 86.97 cm. PTB 60 (100.17 cm) and Kalladiaryan (96.37 cm) were found to be on par with PTB 60.

4.2.2.1.2.2 Dry weight of shoot (g)

The estimates for dry weight of shoot ranged between 0.58 g (Nerica) and 1.83 g (Karanavara) with a mean value of 1.03 g. PTB 60 (1.55 g) and Arimodan (1.43g) were found next best to Karnavara at 15 DAS.

Dry weight of shoot at 35 DAS ranged from 1.36 (Nerica) to 3.15 (Karanavara) with a mean value of 2.29 g. Arimodan (3.14 g) and PTB 60 (3.00 g) were found to be on par with Karanavara at 35 DAS.

At 50 DAS, dry weight of shoot ranged between 2.37 g (Nerica) and 5.64 g (Karanavara) with a mean value of 4.04 g. Shoot dry weight in PTB 60 (5.18 g) was found to be on par with Karanavara at 50 DAS.

4.2.2.1.2.3 Root length (cm)

Root length ranged from 10.00 cm (Parambuvattan) to 17.00 cm (PTB 60) with a mean value of 13.02 cm. Nerica (16.67 cm) and Karathadukkan (15.67 cm) were found to be on par with PTB 60 at 15 DAS.

Root length range between 20.33 cm (PTB 28) and 39 cm (Karuthamodan) with a mean value of 32.53 cm. Karanavara (38 cm), PTB 60 (35.67 cm) and Karathadukkan (34.67 cm) were found to be on par with Karuthamodan at 35 DAS.

Root length ranged from 31.33 cm (Parambankyama) to 47.33 cm (Nerica) with a mean value of 38.60 cm. PTB 60 (41.00 cm), Karathadukkan (46.67 cm) was found to be on par with Nerica at 50 DAS.

4.2.2.1.2.4 Dry weight of root (g)

A mean value of 0.15 g, and a range of 0.09 g (PTB 28) to 0.23 g (Nerica) was recorded for dry weight of root at 15 DAS. Karanavara (0.18 g), Parambankyama (0.16 g), Karuthamodan (0.18 g) and Kalladiaryan (0.17 g) were found on par with each other and next best to Nerica.

A mean value of 0.45 g was recorded for dry weight of root at 35 DAS. It ranged from 0.34 g (Arimodan) to 0.69 g (Nerica). Parambankyama (0.52 g), Karuthamodan (0.55 g) and Kalladiaryan (0.52 g) were found next best to Nerica.

At 50 DAS, dry weight of root ranged from 1.72 g (PTB 28) to 4.73 g (PTB 60) with a mean value of 2.99 g. Arimodan (4.34 g) was found next best to PTB 28.

4.2.2.1.2.5 Shoot to root length ratio

A mean value of 1.79 with a range of 1.22 (Nerica) to 2.27 (Kalladiaryan) was observed for shoot to root length ratio at 15 DAS. Parambuvattan (2.26) Arimodan (2.01), Karuthamodan (1.98) and Parambankyama (1.82) were found to be on par with Kalladiaryan.

A mean value of 1.72 with a range of 1.46 (Karuthamodan) to 2.13 (PTB 28) was recorded at 35 DAS for shoot to root length ratio. Parambuvattan (1.98) and Kalladiaryan (2.09) were found to be on par with PTB 28.

A mean value of 2.33 with a range of 1.35 (Nerica) to 3.03 (Kalladiaryan) was noticed at 50 DAS for shoot to root length ratio. Parambankyama (3.03) and Karuthamodan (2.61) were found to be on par with Kalladiaryan

4.2.2.1.2.6 Vigour index

Vigour index ranged from 1284 (PTB 28) to 2310 (PTB 60) with an average of 1845 was observed for seedling vigour at 15 DAS.

A mean value of 4476 was recorded for vigour index at 35 DAS. It ranged from 3357 in PTB 28 to 5755 in Karanavara. PTB 60 (4995) was found next best to Karanavara.

At 50 DAS, vigour index ranged from 4869 (PTB 28) to 9245 (Karanavara). A mean value of 7172 was recorded for vigour index at 50 DAS. PTB 60 (8885) was found to be on par with Karanavara.

4.2.2.1.2.7 Root volume (ml)

The estimates of root volume ranged from 1.33 ml (Arimodan) to 2.5 ml (Nerica) with a mean of 1.93 ml at 15 DAS. Karanavara (2.17 ml), PTB 28 (2.33 ml), Karuthamoda (2.00 ml) and Kalladiaryan (2.00 ml) were found to be on par with Nerica.

Root volume ranged from 4.33 ml (Arimodan) to 7.67 ml (Nerica) with a mean of 5.37 ml at 35 DAS. Parambankyama (6.67 ml) was found to be on par with Nerica.

Root volume ranged from 25 ml (Kalladiaryan) to 54.67 ml (PTB 60) with a mean value of 37.73 ml at 50 DAS. Karanavara (48.67 ml) was found to be on par with PTB 60.

4.2.2.1.2.8 Chlorophyll content (mg/g)

Chlorophyll content ranged from 3.8 mg/g (Parambuvattan) to 4.53 mg/g (Arimodan) with a mean value of 4.15 mg/g at 15 DAS. Kalladiaryan (4.40 mg/g), Karathadukkan (4.45 mg/g) and Nerica (4.44 mg/g) were found to be on par with Arimmodan.

Chlorophyll content at 35 DAS, ranged from 4.12 mg/g (PTB 60) to 4.78 mg/g (Karuthamodan) with a mean of 4.43 mg/g. Karathadukkan (4.55 mg/g) PTB 28 (4.52 mg/g) were found next best to Karuthamodan.

At 50 DAS, chlorophyll content ranged from 4.27 mg/g (Karathadukkan) to 4.40 mg/g (Arimodan) with a mean of 4.42 mg/g. Nerica (4.52 mg/g) and Kalladiaryan (4.56 mg/g) were found next best to Arimodan.

4.3.2 Elucidating the response of rice genotypes during imposition of moisture stress

4.3.2.1 Performance of rice genotypes during moisture stress, imposed at seedling stage (15 DAS)

4.3.2.1.1 Analysis of variance

The analysis of variance for physiological traits observed during moisture stress imposed at seedling stage (15 DAS) is presented in Tables 27.The estimates for the traits recorded in the corresponding non-stressed control are detailed in Table 28. The genotypes were found to vary significantly for all the traits except for leaf drying score and days to leaf rolling in the absence of moisture stress.

4.3.2.1.2 Mean performance of rice genotypes during moisture stress, imposed at seedling stage (15 DAS)

The performance of genotypes with respect to physiological traits observed during moisture stress imposed at seedling stage (15 DAS) is presented in Table 29. The response in the corresponding non-stressed control is detailed in Table 30.

4.3.2.1.2.1 Leaf drying score

Leaf drying score on imposition of moisture stress at seedling stage (15 DAS) ranged from 1 (Nerica) to 4.33 (Karuthamodan, Parambuvattan and Kalladiaryan).The mean score was 3.00. PTB 28, Karathadukkan and PTB 60 with a score of 1.67 each, were found to be on par with Nerica.

In case of non stressed control all genotypes exhibited a score of zero.

4.3.2.1.2.2 Days to leaf rolling

Days to leaf rolling in stressed genotypes ranged between 23.33 days (Parambuvattan) and 34.33 days (Nerica) with a mean of 27.53 days on imposition of moisture stress at seedling stage (15 DAS). Karanavara, Karathadukkan and Parambankyama with 29.33, 28.67 and 27.33 days to leaf rolling days respectively, were found next best to Nerica.

Table 27. Analysis of variance for physiological traits in rice genotypes during moisture stress, imposed at seedling stage (15 DAS)

Source	df	Mean sum of squares				
		Leaf drying score	Days to leaf rolling	RWC (%)	Proline content (µg/g)	Chlorophyll content (mg/g)
Genotypes	9	5.333**	31.719**	15.590**	1883.037**	0.038**
Error	20	1.200	2.900	2.020	117.467	0.003

* significant at 5% level; ** significant at 1% level

Table 28. Analysis of variance for physiological traits in non-stressed in rice genotypes at seedling stage

Source	df	Mean sum of squares				
		Leaf drying score	Days to leaf rolling	RWC (%)	Proline content (µg/g)	Chlorophyll content (mg/g)
Genotypes	9	NS	NS	19.480**	1198.890**	0.063**
Error	20			0.945	23.467	0.001

* significant at 5% level; ** significant at 1% level

Table 29. Mean performance of rice genotypes for physiological traits during moisture stress imposed at seedling stage (15 DAS)

Ggenotypes	Leaf drying score	Days to leaf rolling	RWC (%)	Chlorophyll content (mg/g)	Proline content (µg/g)
Karanavara	3.67[ab]	29.33[bc]	72.33[b]	4.06[b]	122.67[a]
Parambankyama	3.67[ab]	27.33[bcde]	70.74[bcd]	3.82[c]	125.00[a]
PTB 28	1.67[bc]	26.33[cdef]	69.72[cd]	4.24[a]	99.00[b]
Nerica	1.00[c]	34.33[a]	71.37[bcd]	4.08[b]	139.00[a]
PTB 60	1.67[bc]	30.33[b]	71.95[bc]	4.01[b]	125.67[a]
Karuthamodan	4.33[a]	25.33[ef]	72.14[b]	4.00[b]	86.33[bc]
Arimodan	3.67[ab]	26.00[def]	69.22[d]	4.05[b]	87.00[bc]
Karathadukkan	1.67[bc]	28.67[bcd]	77.34[a]	4.00[b]	125.33[a]
Parambuvattan	4.33[a]	23.33[f]	70.57[bcd]	4.00[b]	69.33[c]
Kalladiaryan	4.33[a]	24.33[ef]	70.23[bcd]	4.18[a]	74.00[c]
Mean	3.00	27.53	71.56	4.04	105.33
CD(0.05)	1.87	2.90	2.42	0.09	18.46

Table 30. Mean performance of non-stressed rice genotypes for physiological traits at seedlings stage

Ggenotypes	Leaf drying score	Days to leaf rolling	RWC (%)	Chlorophyll content (mg/g)	Proline content (µg/g)
Karanavara	0	0	84.69[f]	4.13[d]	109.00[a]
Parambankyama	0	0	84.69[f]	4.02[e]	106.67[ab]
PTB 28	0	0	90.14[a]	4.46[a]	81.67[d]
Nerica	0	0	86.96[cd]	4.22[bc]	114.00[a]
PTB 60	0	0	88.85[ab]	4.11[d]	100.67[bc]
Karuthamodan	0	0	88.72[ab]	4.21[bc]	68.00[e]
Arimodan	0	0	81.74[g]	4.27[b]	75.33[de]
Karathadukkan	0	0	86.51[de]	4.20[c]	94.00[c]
Parambuvattan	0	0	85.07[ef]	4.22[bc]	56.00[f]
Kalladiaryan	0	0	88.30[bc]	4.48[a]	70.33[e]
Mean			86.57	4.23	87.57
CD(0.05)			1.122	0.06	8.25

In case of non stressed control all genotypes exhibited a score of zero.

4.3.2.1.2.3 Relative water content (%)

On imposition of moisture stress at seedling stage, RWC ranged from 69.22 per cent in Arimodan to 77.34 per cent in Karathadukkan with a mean RWC value of 71.56 per cent. Karanavara (72.33 %) was found to possess high RWC next to Karuthadukkan.

Relative water content in non stressed genotypes ranged from 81.74 per cent (Arimodan) to 90.14 per cent (PTB 28) with a mean value of 86.57 per cent. PTB 60 (88.85 %) and Karuthamodan (88.72 %) were found to be on par with PTB 28.

4.3.2.1.2.4 Chlorophyll content (mg/g)

When moisture stress was imposed at seedling stage (15 DAS), chlorophyll content ranged from 3.82 mg/g (Parambankyama) to 4.24 mg/g (PTB 28) with a mean value of 4.04 mg/g. Kalladiaryan (4.18 mg/g) was found to be on par with PTB 28.

Under non stressed condition, chlorophyll content ranged from 4.02 mg/g (Parambankyama) to 4.48 mg/g (Kalladiaryan) with a mean value of 4.23 mg/g. PTB 28 (4.46 mg/g) was found to be on par with Kalladiaryan.

4.3.2.1.2.5 Proline content (µg/g)

On imposition of moisture stress at seedling stage, proline accumulation ranged between 69.33 µg/g (Parambuvattan) and 139 µg/g (Nerica) with a mean value of 105.33 µg/g. Karanavara (122.67 µg/g) and Parambankyama (125.00 µg/g) were found to be on par with Nerica.

In non stressed genotypes, proline accumulation ranged from 56 µg/g (Parambuvattan) to 114 µg/g (Nerica) with a mean of 87.57 µg/g. Karanavara (109.00 µg/g) and Parambankyama (106.67 µg/g) were found to be on par with Nerica.

4.3.2.2 Performance of rice genotypes during moisture stress, imposed at vegetative stage (35 DAS)

4.3.2.2.1 Analysis of variance

The analysis of variance for physiological traits observed during moisture stress imposed at vegetative stage (35 DAS) is presented in Tables 31.The estimates for the traits recorded in the corresponding non-stressed control are detailed in Table 32. The genotypes were found to vary significantly for all the traits. However, in the absence of moisture stress, the genotypes did not vary with respect to leaf drying score and days to leaf rolling.

4.3.2.2.2 Mean performance of rice genotypes during moisture stress, imposed at vegetative stage (35 DAS)

The performance of genotypes with respect to physiological traits observed during moisture stress imposed at vegetative stage (35 DAS) is presented in Table 33. The response in the corresponding non-stressed control is detailed in Table 34.

4.3.2.2.2.1 Leaf drying score

When moisture stress was imposed at vegetative stage, leaf drying score ranged from 1.00 in Nerica to 4.33 in Karuthamodan and Parambuvattan with a mean score of 3.20. PTB 60 (1.67) and Karathadukkan (2.33) were found to be on par with Nerica.

In case of non stressed control all genotypes exhibited a score of zero

4.3.2.2.2.2 Days to leaf rolling

Days to leaf rolling ranged from 20.67 days in Arimodan to 30.33 days in Nerica with a mean of 24.77 days when moisture stress was imposed at vegetative stage (35 DAS). PTB 60 (28.33 days) was found to be on par with Nerica.

In case of non stressed control all genotypes exhibited a score of zero.

Table 31. Analysis of variance for physiological traits in rice genotypes during moisture stress imposed at vegetative stage (35 DAS)

Source	df	Mean sum of squares				
		Leaf drying score	Days to leaf rolling	RWC (%)	Proline content (μg/g)	Chlorophyll content (mg/g)
Genotypes	9	3.867**	34.596**	12.686**	4204.791**	0.072**
Error	20	1.600	1.800	3.119	445.056	0.001

* significant at 5% level; ** significant at 1% level

Table 32. Analysis of variance for physiological traits in non-stressed in rice genotypes during vegetative phase

Source	df	Mean sum of squares				
		Leaf drying score	Days to leaf rolling	RWC (%)	Proline content (μg/g)	Chlorophyll content (mg/g)
Genotypes	9	NS	NS	13.828**	2418.337**	0.130**
Error	20			3.272	105.701	0.001

* significant at 5% level; ** significant at 1% level

Table 33. Mean performance of rice genotypes for physiological traits during moisture stress imposed at vegetative stage (35 DAS)

Genotypes	Leaf drying score	Days to leaf rolling	RWC (%)	Chlorophyll content (mg/g)	Proline content (µg/g)
Karanavara	3.67^{ab}	27.67^{bc}	69.67^{c}	4.20^{c}	174.33^{bcd}
Parambankyama	3.67^{ab}	25.00^{d}	70.40^{c}	4.38^{a}	192.33^{b}
PTB 28	3.67^{ab}	25.67^{cd}	70.53^{c}	4.20^{bc}	154.78^{cde}
Nerica	1.00^{c}	30.33^{a}	70.41^{c}	4.14^{d}	260.89^{a}
PTB 60	1.67^{bc}	28.33^{ab}	73.61^{ab}	4.00^{f}	191.78^{b}
Karuthamodan	4.33^{a}	21.33^{e}	74.45^{a}	4.38^{a}	150.67^{cde}
Arimodan	3.67^{ab}	20.67^{e}	70.75^{bc}	4.24^{b}	146.55^{de}
Karathadukkan	2.33^{abc}	25.67^{cd}	75.52^{a}	4.37^{a}	186.11^{bc}
Parambuvattan	4.33^{a}	21.67^{e}	72.53^{abc}	4.05^{e}	134.00^{e}
Kalladiaryan	3.667^{ab}	21.33^{e}	70.30^{c}	3.97^{f}	142.33^{de}
Mean	3.20	24.77	71.82	4.19	173.38
CD(0.05)	2.15	2.29	3.01	0.05	35.93

Table 34. Mean performance of non-stressed rice for physiological traits at vegetative phase

Ggenotypes	Leaf drying score	Days to leaf rolling	RWC (%)	Chlorophyll content (mg/g)	Proline content (µg/g)
Karanavara	0	0	85.92^{b}	4.31^{e}	102.00^{e}
Parambankyama	0	0	84.32^{b}	4.49^{bc}	127.85^{bcd}
PTB 28	0	0	89.04^{a}	4.46^{c}	131.67^{bc}
Nerica	0	0	85.66^{b}	4.48^{bc}	199.00^{a}
PTB 60	0	0	86.64^{ab}	4.31^{e}	140.33^{b}
Karuthamodan	0	0	86.34^{ab}	3.85^{f}	110.33^{e}
Arimodan	0	0	80.53^{c}	4.39^{d}	114.67^{cde}
Karathadukkan	0	0	85.06^{b}	4.52^{ab}	113.44^{de}
Parambuvattan	0	0	85.96^{b}	4.48^{bc}	109.33^{e}
Kalladiaryan	0	0	86.02^{ab}	4.57^{a}	108.67^{e}
Mean			85.55	4.39	125.73
CD(0.05)			3.08	0.06	17.51

4.3.2.2.2.3 Relative water content (%)

When moisture stress was imposed at vegetative stage (35 DAS), relative water content ranged from 69.6 per cent (Karanavara) to 75.52 per cent (Karathadukkan) with a mean value of 71.82 per cent. PTB 60 (73.61%), Karuthamodan (74.45 %) and Parambuvattan (72.53 %) were found to be on par with the Karathadukkan.

Under non stress condition, RWC ranged from 80.53 per cent (Arimodan) to 89.04 per cent (PTB 28) with a mean value of 85.55 per cent. Karuthamodan (86.34 %) and PTB 60 (86.64 %) were found to be on par with the PTB 28.

4.3.2.2.2.4 Chlorophyll content (mg/g)

Chlorophyll content, ranged from 3.97 mg/g (Kalladiaryan) to 4.38 mg/g (Karuthamodan and Parambankyama) with a mean of 4.19 mg/g on imposition of moisture stress at vegetative stage. Karuthadukkan (4.37 mg/g) was found to be on par with Karuthamodan and Parambakyama.

Uunder non stress condition, chlorophyll content ranged from 3.85 mg/g (Karuthamodan) to 4.57 mg/g (Kalladiaryan) with a mean value of 4.39 mg/g. Karathadukkan (4.52 mg/g) was found to be on par with Kalladiaryan.

4.3.2.2.2.5 Proline content (µg/g)

A mean value of 173.38 µg/g was recorded for proline accumulation. It ranged from 134 µg/g (Parambuvattan) to 260.89 µg/g (Nerica) when moisture stress was imposed at vegetative stage. Karanavara (174.33 µg/g) and Parambankyama (192.33 µg/g) were found next best to Nerica.

Proline content ranged from 102 µg/g (Karanavara) to 199 µg/g (Nerica) with a mean value of 125.73 µg/g under non stressed control. Parambankyama (127.85 µg/g), PTB 28 (131.67 µg/g) and PTB 60 (140.33 µg/g) were found next best to Nerica.

4.3.2.3 Performance of rice genotypes during moisture stress, imposed at reproductive stage (50 DAS)

4.3.2.2.1 Analysis of variance

The analysis of variance for physiological traits observed during moisture stress imposed reproductive stage (50 DAS) is presented in Tables 35.The estimates for the traits recorded in the corresponding non-stressed control are detailed in Table 36. The genotypes were found to vary significantly for all the traits. However, in the absence of moisture stress, the genotypes did not vary with respect to leaf drying score and days to leaf rolling.

4.3.2.3.2 Mean performance of rice genotypes during moisture stress, imposed at reproductive stage (50 DAS)

The performance of genotypes with respect to physiological traits observed during moisture stress imposed at reproductive stage (50 DAS) is presented in Table 37. The response in the corresponding non-stressed control is detailed in Table 38.

4.3.2.3.2.1 Leaf drying score

On imposition of moisture stress at reproductive stage (50 DAS), leaf drying score ranged between 1.00 (Nerica) and 5.33 (Parambuvattan) with a mean score of 3.37.

In case of non stressed control, all genotypes exhibited a score of zero

4.3.2.3.2.2 Leaf rolling

It ranged between 12.67 (Parambuvattan) and 21.67 (Nerica) with a mean value of 16.00 on imposition of moisture stress at reproductive stage (50 DAS).

In case of non stressed control all genotypes exhibited a score of zero

4.3.2.3.2.3 Relative water content (%)

A mean value of 66.38 per cent was observed for relative water content on imposition of moisture stress at reproductive stage. RWC on imposition of moisture stress ranged from 59.52 per cent (Arimodan) to maximum of 72.20 per

Table 35. Analysis of variance for physiological traits in rice genotypes during moisture stress imposed at reproductive stage (50 DAS)

Source	df	Leaf drying score	Days to leaf rolling	RWC (%)	Proline content (µg/g)	Chlorophyll content (mg/g)
Genotypes	9	6.107**	24.296**	44.458**	3313.250**	0.0638**
Error	20	1.700	1.067	1.293	487.527	0.0001

* significant at 5% level; ** significant at 1% level

Table 36. Analysis of variance for physiological traits in non-stressed rice genotypes at reproductive phase

Source	Df	Leaf drying score	Days to leaf rolling	RWC (%)	Proline content (µg/g /g)	Chlorophyll content (mg/g)
Genotypes	9	NS	NS	11.238**	1446.452**	0.1145**
Error	20			1.599	318.607	0.0002

* significant at 5% level; ** significant at 1% level

Table 37. Mean performance of rice genotypes for physiological traits during moisture stress imposed at reproductive stage (50 DAS)

Ggenotypes	Leaf drying score	Days to leaf rolling	RWC (%)	Chlorophyll content (mg/g)	Proline content (µg/g)
Karanavara	3.67^{ab}	16.33^{c}	66.00^{d}	3.87^{f}	267.22^{ab}
Parambankyama	3.67^{ab}	17.00^{c}	67.67^{bcd}	4.07^{c}	277.67^{a}
PTB 28	3.67^{ab}	16.67^{c}	60.35^{e}	4.17^{a}	234.79^{bc}
Nerica	1.00^{c}	21.67^{a}	72.20^{a}	3.87^{f}	297.67^{a}
PTB 60	1.67^{ab}	19.33^{b}	69.53^{b}	3.72^{h}	277.33^{a}
Karuthamodan	4.33^{a}	14.00^{de}	66.74^{cd}	3.78^{g}	234.24^{bc}
Arimodan	4.33^{a}	13.33^{e}	59.52^{e}	4.13^{b}	232.88^{bc}
Karathadukkan	1.67^{ab}	15.33^{cd}	66.21^{d}	3.91^{e}	206.10^{c}
Parambuvattan	5.33^{a}	12.67^{e}	67.33^{cd}	3.91^{e}	200.04^{c}
Kalladiaryan	4.33^{a}	13.67^{de}	68.21^{bc}	3.99^{d}	219.33^{c}
Mean	3.37	16.00	66.38	3.94	244.73
CD(0.05)	2.22	1.76	1.94	0.02	37.61

Table 38. Mean performance of non-stressed rice genotypes for physiological traits at reproductive phase

Ggenotypes	Leaf drying score	Days to leaf rolling	RWC (%)	Chlorophyll content (mg/g)	Proline content (µg/g)
Karanavara	0	0	84.67^{bc}	4.19^{d}	157.06^{c}
Parambankyama	0	0	81.04^{d}	4.14^{e}	181.51^{bc}
PTB 28	0	0	86.53^{ab}	4.27^{b}	209.29^{ab}
Nerica	0	0	86.99^{a}	3.92^{g}	227.70^{a}
PTB 60	0	0	84.24^{c}	3.79^{h}	207.03^{ab}
Karuthamodan	0	0	83.97^{c}	4.26^{b}	176.61^{c}
Arimodan	0	0	84.94^{abc}	4.22^{c}	182.39^{bc}
Karathadukkan	0	0	82.93^{cd}	3.99^{f}	175.04^{c}
Parambuvattan	0	0	84.73^{bc}	4.47^{a}	172.60^{c}
Kalladiaryan	0	0	81.41^{d}	4.20^{cd}	167.04^{c}
Mean			84.15	4.15	185.63
CD(0.05)			2.15	0.02	30.40

cent (Nerica). Parambankyama (67.67 %) and Kalladiaryan (68.21 %) were found next best to Nerica.

Relative water content ranged from 81.04 per cent (Parambankyama) to 86.99 per cent (Nerica) with a mean of 84.15 per cent under non stressed control. PTB 28 (86.53%) and Arimodan (84.94%) were found to be on par with Nerica.

4.3.2.3.2.4 Chlorophyll content (mg/g)

Imposition of moisture stress at reproductive stage, chlorophyll content recorded a mean value of 3.94 mg/g. It ranged between 3.72 mg/g (PTB 60) and 4.17 mg/g (PTB 28). Arimodan (4.13 mg/g) was found to be on par with the PTB 28.

Chlorophyll content ranged between 3.79 mg/g (PTB 60) and 4.47 mg/g (Parambuvattan) with a mean of 4.15 mg/g under non stressed control. PTB 28 (4.27) and Karuthamodan (4.26) was found next best to Parambuvattan.

4.3.2.3.2.5 Proline content (µg/g)

Proline accumulation ranged from 200.04 µg/g (Parambuvattan) to 297.67 µg/g (Nerica) with a mean of 244.73 µg/g, on imposition of moisture stress at reproductive stage. PTB 60 (277.33 µg/g), Parambankyama (277.67 µg/g) and Karanavara (267.22 µg/g) were found to be on par with Nerica.

Proline content ranged from 157.06 µg/g (Karanavara) to 227.70 µg/g (Nerica) with a mean of 185.63 µg/g. PTB 28 (209.29 µg/g) and PTB 60 (207.03 µg/g) were found to be on par with Nerica.

4.3.3 Elucidating the response of rice genotypes on relief of moisture stress

4.3.3.1 Analysis of variance

The analysis of variance for yield and yield attributes in rice genotypes exposed to moisture stress at seedling stage (15 DAS), at vegetative stage (35 DAS), and at reproductive stage (50 DAS) and the non-stressed control (fully irrigated control) are presented in Tables 39 to 42. The mean sum of squares for

Table 39. Analysis of variance for yield and yield attributes in rice genotypes exposed to moisture stress at seedling stage (15 DAS)

Source	df	Mean sum of squares							
		Seedling recovery on removal of moisture stress	Days to fifty per cent flowering	Productive tillers per plant	Panicle length (cm)	Panicle weight (g)	Grains per panicle	Spikelets per panicle	Flag leaf area (sq. cm)
Genotypes	9	NS	89.570**	5.895**	13.200**	0.801**	772.871**	1198.655**	51.289**
Error	20	NS	2.467	0.782	1.826	0.025	29.453	26.281	7.245

* significant at 5% level; ** significant at 1% level

Table 39. Analysis of variance for yield and yield attributes in rice genotypes exposed to moisture stress at seedling stage (15 DAS) (contd.)

Source	df	Mean sum of squares								
		1000 grain weight (g)	Plant height(cm)	Dry weight of shoot (g)	Dry weight of root (g)	Rot length (cm)	Root volume (ml)	Grain yield per plant (g)	Straw yield per plant (g)	Harvest index
Genotypes	9	12.033**	211.807**	14.470**	3.395**	158.881**	511.057**	20.40**	88.710**	0.008*
Error	20	1.757	41.192	2.910	0.138	12.828	6.87	2.266	14.585	0.002

* significant at 5% level; ** significant at 1% level

Table 40. Analysis of variance for yield and yield attributes in rice genotypes exposed to moisture stress at vegetative stage (35 DAS)

Source	df	Mean sum of squares							
		Seedling recovery on removal of moisture stress	Days to fifty per cent flowering	Productive tillers per plant	Panicle length (cm)	Panicle weight (g)	Grains per panicle	Spikelets per panicle	Flag leaf area (sq. cm)
Genotypes	9	NS	104.557**	6.272**	11.711**	0.763**	671.268**	1053.353**	51.656**
Error	20	NS	1.316	0.874	0.869	0.088	40.545	61.122	5.435

* significant at 5% level; ** significant at 1% level

Table 40. Analysis of variance for yield and yield attributes in rice genotypes exposed to moisture stress at vegetative stage (35 DAS) (contd.)

Source	df	Mean sum of squares								
		1000 grain weight (g)	Plant height(cm)	Dry weight of shoot g)	Dry weight of root (g)	Rot length (cm)	Root volume (ml)	Grain yield per plant (g)	Straw yield per plant (g)	Harvest index
Genotypes	9	10.086**	317.771**	11.022**	3.005**	112.875**	606.250**	21.942**	73.917**	0.011*
Error	20	0.975	71.056	2.866	0.092	10.482	7.764	1.489	7.997	0.004

* significant at 5% level; ** significant at 1% level

Table 41. Analysis of variance for yield and yield attributes in rice genotypes exposed to moisture stress at reproductive stage (50 DAS)

Source	df	Mean sum of squares							
		Seedling recovery on removal of moisture stress	Days to fifty per cent flowering	Productive tillers per plant	Panicle length (cm)	Panicle weight (g)	Grains per panicle	Spikelets per panicle	Flag leaf area (sq. cm)
Genotypes	9	NS	176.00**	12.752**	15.273**	0.890**	627.558**	1027.147**	72.239**
Error	20	NS	2.133	0.998	1.627	0.050	18.132	13.741	9.790

* significant at 5% level; ** significant at 1% level

Table 41. Analysis of variance for yield and yield attributes in rice genotypes exposed to moisture stress at reproductive stage (50 DAS) (contd.)

Source	df	Mean sum of squares								
		1000 grain weight (g)	Plant height(cm)	Dry weight of shoot (g)	Dry weight of root (g)	Rot length (cm)	Root volume (ml)	Grain yield per plant (g)	Straw yield per plant (g)	Harvest index
Genotypes	9	17.057**	661.808**	6.078**	3.248**	146.330**	447.617**	13.257**	55.256**	0.008**
Error	20	1.066	80.304	1.382	0.105	13.544	7.491	0.846	4.581	0.001

* significant at 5% level; ** significant at 1% level

Table 42. Analysis of variance for yield and yield attributes in non-stressed rice genotypes

Source	df	Mean sum of squares							
		Seedling recovery on removal of moisture stress	Days to fifty per cent flowering	Productive tillers per plant	Panicle length (cm)	Panicle weight (g)	Grains per panicle	Spikelets per panicle	Flag leaf area (sq. cm)
Genotypes	9	Ns	158.667**	8.906**	8.871**	0.321**	775.200**	1069.559*	25.402*
Error	20	Ns	1.633	0.616	0.831	0.026	19.733	22.533	8.908

* significant at 5% level; ** significant at 1% level

Table 42. Analysis of variance for yield and yield attributes in non-stressed rice genotypes (contd.)

Source	df	Mean sum of squares								
		1000 grain weight (g)	Plant height (cm)	Dry weight of shoot (g)	Dry weight of root (g)	Rot length (cm)	Root volume	Grain yield per plant (g)	Straw yield per plant (g)	Harvest index
Genotypes	9	9.841**	273.830**	4.718**	5.044**	192.52**	618.051**	9.934**	29.432**	0.005*
Error	20	0.471	54.787	1.110	0.245	12.200	10.06	1.086	6.205	0.002

* significant at 5% level; ** significant at 1% level

genotypes was significant for yield and yield attributes, except for seedling recovery on removal of moisture stress.

4.3.3.2 Mean performance of rice genotypes for yield and yield attributes on relief of moisture stress

The mean performance of genotypes for yield and yield attributes on relief of moisture stress imposed at various growth stages are detailed in (Tables 43 to 45). The estimates for the traits recorded in the corresponding non-stressed control are detailed in Table 46.

4.3.3.1 Seedling recovery on removal of moisture stress

The genotypes did not vary with respect to the time taken to recover on removal of moisture stress.

4.3.3.2 Days to fifty per cent flowering

Days to fifty per cent flowering ranged from 74.33 days (Karuthamodan) to 91 days (PTB 28) with a mean of 79.87 days, on imposition of moisture stress at seedling stage (15 DAS). PTB 60 (85.00 days), Karathadukkan (83.00 days) and Parambuvattan (83.33 days) were on par with each other and recorded higher days to 50 per cent flowering next to PTB 28.

Days to fifty per cent flowering ranged from 76.00 days (Arimodan) to 94.00 days (PTB 28) with a mean of 82.23 days, when moisture stress was imposed at vegetative stage (35 DAS). PTB 60 (87.30 days) and Karathadukkan (87.33 days) were found to be on par with PTB 28.

Days to fifty per cent flowering ranged from 68 days (Arimodan) to 89.67 days (PTB 28) with a mean of 76.33 days, when moisture stress was imposed at reproductive stage (50 DAS). PTB 60 (84 days) and Parambuvattan (85days) were on par with each other and recorded higher days to 50 per cent flowering next to PTB 28.

Days to fifty per cent flowering ranged from 67.00 days (Arimodan) to 87.67 days (PTB 28) with a mean of 74.33 days under non stressed control.

Table 43. Yield and yield attributes of rice genotypes exposed to moisture stress at seedling stage (15 DAS)

Genotypes	Days to fifty per cent flowering	Productive tillers per plant	Panicle length (cm)	Panicle weight (g)	Grains per panicle	Spikelets per panicle	Flag leaf area (sq. cm)	1000 grain weight (g)
Karanavara	75.67[cd]	11.29[a]	22.53[cde]	2.21[e]	75.64[b]	91.31[b]	32.39[e]	28.62[abc]
Parambankyama	77.00[cd]	9.42[b]	20.70[ef]	2.81[bc]	97.00[a]	116.37[a]	44.22[ab]	26.28[d]
PTB 28	91.00[a]	10.29[ab]	24.43[abc]	2.32[de]	98.50[a]	122.03[a]	37.22[cd]	23.24[e]
Nerica	77.00[cd]	7.31[c]	25.43[ab]	3.27[a]	93.47[a]	119.62[a]	34.86[de]	30.39[a]
PTB 60	85.00[b]	10.93[a]	25.60[a]	2.83[b]	95.76[a]	117.14[a]	45.33[a]	26.34[d]
Karuthamodan	74.33[d]	7.66[c]	23.17[bcd]	2.55[cd]	75.00[b]	90.38[b]	39.44[cd]	29.30[ab]
Arimodan	74.67[d]	10.41[ab]	21.50[def]	1.74[f]	59.42[c]	74.02[c]	35.36[de]	28.43[abcd]
Karathadukkan	83.00[b]	11.37[a]	20.27[ef]	1.90[f]	73.04[b]	90.05[b]	37.42[cd]	26.66[cd]
Parambuvattan	83.33[b]	10.13[ab]	23.27[bcd]	1.67[f]	52.78[c]	65.23[d]	40.52[bc]	27.43[bcd]
Kalladiaryan	77.67[c]	10.18[ab]	19.73[f]	2.19[e]	79.61[b]	92.28[b]	35.90[de]	26.49[cd]
Mean	79.87	9.90	22.66	2.35	80.02	97.84	38.27	27.32
CD(0.05)	2.68	1.51	2.31	0.27	9.24	8.73	4.58	2.26

Table 43. Yield and yield attributes of rice genotypes exposed to moisture stress at seedling stage (15 DAS) (contd.)

Genotypes	Plant height (cm)	Dry weight of shoot (g)	Dry weight of root (g)	Rot length (cm)	Root volume (ml)	Grain yield per plant (g)	Straw yield per plant (g)	Harvest index
Karanavara	122.88^{a}	17.48^{ab}	3.51^{c}	61.45^{a}	40.76^{c}	16.29^{ab}	11.28^{ab}	0.49^{ab}
Parambankyama	103.86^{bcd}	16.10^{abc}	3.39^{c}	55.49^{ab}	36.53^{cd}	14.81^{b}	10.42^{ab}	0.47^{abc}
PTB 28	98.09^{de}	15.26^{bcd}	2.33^{e}	40.17^{e}	26.22^{g}	15.23^{b}	9.54^{bc}	0.54^{a}
Nerica	104.50^{bcd}	16.54^{abc}	2.75^{de}	51.67^{bc}	31.30^{ef}	14.27^{b}	10.11^{b}	0.48^{abc}
PTB 60	112.99^{ab}	18.49^{a}	5.58^{a}	56.00^{ab}	66.69^{a}	18.00^{a}	12.38^{a}	0.48^{ab}
Karuthamodan	110.84^{bc}	15.22^{bcd}	2.55^{de}	47.44^{cd}	27.18^{fg}	11.18^{c}	9.76^{b}	0.38^{d}
Arimodan	103.23^{bcde}	12.62^{de}	2.74^{de}	44.67^{de}	29.93^{efg}	11.48^{c}	7.51^{cd}	0.52^{a}
Karathadukkan	101.13^{cde}	16.52^{abc}	4.76^{b}	59.44^{a}	53.33^{b}	14.67^{b}	12.39^{a}	0.39^{cd}
Parambuvattan	92.69^{e}	11.20^{e}	3.05^{cd}	53.26^{bc}	33.36^{de}	9.80^{c}	6.95^{d}	0.47^{abc}
Kalladiaryan	104.17^{bcd}	14.37^{cd}	2.54^{de}	42.30^{de}	28.99^{efg}	11.66^{c}	9.18^{bc}	0.42^{bcd}
Mean	105.44	15.38	3.32	51.19	37.43	13.74	9.95	0.46
CD(0.05)	10.93	2.91	0.63	6.10	4.47	2.56	1.45	0.08

Table 44. Yield and yield attributes of rice genotypes exposed to moisture stress at vegetative stage (35 DAS)

Genotypes	Days to fifty per cent flowering	Productive tillers per plant	Panicle length (cm)	Panicle weight (g)	Grains per panicle	Spikelets per panicle	Flag leaf area (sq. cm)	1000 grain weight (g)
Karanavara	78.00^{c}	11.62^{ab}	22.59^{de}	2.24^{cde}	75.96^{cde}	90.42^{bc}	33.41^{e}	26.91^{b}
Parambankyama	78.00^{e}	9.31^{cd}	21.36^{ef}	2.62^{bc}	95.35^{ab}	115.30^{a}	44.75^{ab}	25.44^{bc}
PTB 28	94.00^{a}	10.55^{bc}	24.30^{bc}	2.44^{bcd}	96.11^{a}	120.17^{a}	36.22^{de}	22.15^{d}
Nerica	78.33^{e}	7.77^{d}	25.21^{ab}	3.28^{a}	85.19^{bc}	118.10^{a}	35.99^{de}	29.24^{a}
PTB 60	87.30^{b}	10.67^{bc}	25.91^{a}	2.90^{ab}	91.39^{ab}	111.51^{a}	47.27^{a}	25.52^{bc}
Karuthamodan	77.00^{ef}	8.14^{d}	20.67^{f}	2.51^{bc}	65.82^{ef}	84.00^{cd}	39.69^{cd}	26.21^{b}
Arimodan	76.00^{f}	11.02^{ab}	21.62^{def}	1.76^{ef}	58.96^{fg}	74.53^{de}	40.34^{c}	26.51^{b}
Karathadukkan	87.33^{b}	12.38^{a}	20.50^{f}	1.95^{def}	74.30^{de}	92.27^{bc}	38.41^{cd}	26.12^{b}
Parambuvattan	84.67^{c}	10.37^{bc}	23.19^{cd}	1.66^{f}	52.92^{g}	67.13^{e}	41.84^{bc}	26.29^{b}
Kalladiaryan	81.67^{d}	10.47^{bc}	20.73^{f}	2.23^{cde}	78.10^{cd}	97.96^{b}	39.59^{cd}	24.16^{c}
Mean	82.23	10.23	22.61	2.36	77.41	97.14	39.75	25.86
CD(0.05)	1.95	1.59	1.59	0.51	10.84	13.32	3.97	1.68

Table 44. Yield and yield attributes of rice genotypes exposed to moisture stress at vegetative stage (35 DAS) (contd.)

Genotypes	Plant height (cm)	Dry weight of shoot (g)	Dry weight of root (g)	Rot length (cm)	Root volume (ml)	Grain yield per plant (g)	Straw yield per plant (g)	Harvest index
Karanavara	133.47^{a}	18.45^{abc}	4.07^{c}	74.00^{a}	46.98^{c}	15.42^{b}	12.01^{ab}	0.43^{ab}
Parambankyama	110.24^{cde}	17.40^{abcd}	3.98^{c}	75.00^{a}	48.76^{c}	14.30^{b}	11.27^{bc}	0.43^{aab}
PTB 28	104.24^{de}	16.10^{cd}	3.35^{de}	60.99^{b}	36.92^{de}	14.61^{b}	10.11^{cde}	0.49^{a}
Nerica	108.03^{cde}	17.24^{bcd}	3.00^{e}	59.90^{b}	31.59^{f}	14.54^{b}	10.41^{bcd}	0.47^{a}
PTB 60	127.03^{ab}	20.23^{a}	6.14^{a}	61.42^{b}	78.93^{a}	17.64^{a}	13.51^{a}	0.43^{ab}
Karuthamodan	121.01^{abc}	16.29^{cd}	2.91^{e}	64.94^{b}	32.94^{ef}	10.86^{c}	10.82^{bc}	0.34^{b}
Arimodan	110.36^{cde}	14.61^{d}	3.32^{de}	61.08^{b}	38.38^{d}	10.73^{c}	8.7^{e}	0.42^{ab}
Karathadukkan	118.87^{bc}	19.99^{ab}	5.14^{b}	74.93^{a}	59.00^{b}	13.74^{b}	13.52^{a}	0.34^{b}
Parambuvattan	100.76^{e}	14.80^{d}	3.83^{cd}	64.60^{b}	39.86^{d}	9.05^{c}	9.12^{de}	0.33^{b}
Kalladiaryan	117.31^{bcd}	17.41^{abcd}	3.76^{cd}	64.16^{b}	46.36^{c}	10.52^{c}	10.04^{cde}	0.35^{b}
Mean	115.13	17.25	3.95	66.10	45.97	13.14	10.95	0.40
CD(0.05)	14.36	2.88	0.52	5.51	4.75	2.08	2.02	0.11

Table 45. Yield and yield attributes of rice genotypes exposed to moisture stress at reproductive stage (50 DAS)

Genotypes	Days to fifty per cent flowering	Productive tillers per plant	Panicle length (cm)	Panicle weight (g)	Grains per panicle	Spikelets per panicle	Flag leaf area (sq. cm)	1000 grain weight (g)
Karanavara	69.00^{e}	13.33^{ab}	24.57^{abc}	2.23^{de}	54.65^{de}	76.12^{c}	51.48^{ab}	26.36^{ab}
Parambankyama	72.67^{d}	10.66^{c}	18.97^{f}	2.99^{ab}	59.00^{d}	83.21^{bc}	54.54^{a}	25.29^{bc}
PTB 28	89.67^{a}	10.65^{c}	24.37^{abc}	2.37^{cd}	68.83^{b}	107.12^{a}	40.90^{de}	19.54^{e}
Nerica	74.67^{d}	8.07^{d}	25.60^{ab}	3.37^{a}	58.81^{d}	90.37^{b}	38.22^{e}	27.28^{a}
PTB 60	84.00^{b}	11.01^{c}	26.50^{a}	2.89^{b}	83.30^{a}	105.10^{a}	49.38^{abc}	24.04^{cd}
Karuthamodan	69.00^{e}	8.23^{d}	23.47^{bcd}	2.67^{bc}	67.12^{bc}	111.64^{a}	48.33^{bc}	24.10^{cd}
Arimodan	68.00^{e}	13.19^{ab}	21.10^{f}	1.77^{f}	38.78^{f}	61.20^{d}	45.55^{cd}	25.88^{ab}
Karathadukkan	79.00^{c}	14.23^{a}	21.93^{de}	1.93^{ef}	49.20^{e}	90.53^{b}	49.68^{abc}	23.37^{d}
Parambuvattan	85.00^{b}	11.70^{bc}	23.10^{cde}	1.73^{f}	34.07^{f}	63.72^{d}	45.15^{cd}	21.06^{e}
Kalladiaryan	72.33^{d}	10.15^{c}	21.80^{de}	2.35^{cd}	61.50^{cd}	108.25^{a}	44.57^{cd}	23.19^{d}
Mean	76.33	11.12	23.14	2.43	57.53	89.73	46.78	24.01
CD(0.05)	2.49	1.70	2.17	0.38	7.25	9.60	5.33	1.76

Table 45. Yield and yield attributes of rice genotypes exposed to moisture stress at reproductive stage (50 DAS) (contd.)

Genotypes	Plant height (cm)	Dry weight of shoot (g)	Dry weight of root (g)	Rot length (cm)	Root volume (ml)	Grain yield per plant (g)	Straw yield per plant (g)	Harvest index
Karanavara	144.18[a]	20.07[ab]	4.26[bc]	87.67[ab]	49.22[c]	9.71[bc]	13.44[ab]	0.24[bcd]
Parambankyama	107.80[d]	19.54[abc]	4.31[b]	92.00[a]	50.00[c]	8.76[c]	12.51[bc]	0.23[cd]
PTB 28	102.86[d]	18.25[bcde]	3.45[d]	65.04[e]	40.45[de]	9.32[c]	11.43[cde]	0.27[bc]
Nerica	113.38[cd]	17.77[cde]	3.39[d]	87.33[ab]	37.69[e]	10.91[ab]	10.71[f]	0.34[a]
PTB 60	132.96[ab]	21.28[a]	6.15[a]	76.00[c]	72.88[a]	12.46[a]	14.02[a]	0.29[ab]
Karuthamodan	134.85[ab]	18.20[bcde]	3.25[d]	74.33[c]	38.52[e]	6.96[d]	12.18[cd]	0.19[de]
Arimodan	126.79[bc]	17.37[e]	3.51[d]	68.00[de]	41.87[de]	6.87[d]	10.15[f]	0.23[cde]
Karathadukkan	127.17[bc]	20.88[a]	5.88[a]	84.00[b]	67.58[b]	9.85[bc]	14.48[a]	0.23[cde]
Parambuvattan	100.43[d]	17.42[de]	3.66[d]	72.00[cd]	42.32[de]	5.74[d]	11.08[def]	0.17[e]
Kalladiaryan	129.12[ab]	19.40[abcd]	3.71[cd]	75.67[c]	44.24[d]	6.99[d]	12.34[bc]	0.19[de]
Mean	121.95	19.02	4.16	78.20	48.48	8.76	12.23	0.24
CD(0.05)	15.26	2.01	0.55	6.27	4.66	1.57	1.75	0.06

Table 46. Yield and yield attributes of non-stressed rice genotypes

Genotypes	Days to fifty per cent flowering	Productive tillers per plant	Panicle length (cm)	Panicle weight (g)	Grains per panicle	Spikelets per panicle	Flag leaf area (sq. cm)	1000 grain weight (g)
Karanavara	68.67^{e}	14.09^{a}	25.17^{abc}	2.70^{b}	84.67^{d}	102.33^{d}	53.67^{bc}	28.83^{b}
Parambankyama	72.00^{d}	11.66^{c}	22.00^{ef}	2.80^{b}	109.33^{ab}	125.00^{bc}	59.35^{a}	26.80^{d}
PTB 28	87.67^{a}	13.09^{ab}	24.67^{bcd}	2.67^{b}	115.00^{ab}	132.67^{ab}	49.10^{c}	23.83^{f}
Nerica	72.00^{d}	8.91^{d}	26.00^{ab}	3.23^{a}	107.67^{b}	129.00^{b}	50.75^{bc}	30.31^{a}
PTB 60	82.00^{b}	11.84^{bc}	26.50^{a}	3.08^{a}	116.33^{a}	140.00^{a}	54.63^{ab}	27.00^{cd}
Karuthamodan	67.33^{e}	10.00^{d}	24.33^{cd}	2.78^{b}	96.00^{c}	118.00^{c}	51.62^{bc}	28.67^{b}
Arimodan	67.00^{e}	13.46^{a}	21.67^{f}	2.26^{c}	75.33^{e}	92.00^{e}	50.18^{bc}	26.96^{cd}
Karathadukkan	78.00^{c}	14.00^{a}	23.17^{def}	2.58^{b}	83.67^{d}	92.67^{e}	52.05^{bc}	28.12^{bc}
Parambuvattan	80.67^{d}	13.13^{ab}	23.33^{de}	2.15^{c}	73.33^{e}	87.33^{e}	51.43^{bc}	27.67^{bcd}
Kalladiaryan	68.00^{e}	13.04^{ab}	22.00^{ef}	2.74^{b}	100.00^{c}	120.00^{c}	51.34^{bc}	25.57^{e}
Mean	74.33	12.32	23.88	2.70	96.13	113.90	52.41	27.38
CD (0.05)	2.18	1.34	1.55	0.27	7.57	8.09	5.08	1.17

Table 46. Yield and yield attributes of non-stressed rice genotypes (contd.)

Genotypes	Plant height (cm)	Dry weight of shoot (g)	Dry weight of root (g)	Rot length (cm)	Root volume (ml)	Grain yield per plant (g)	Straw yield per plant (g)	Harvest index
Karanavara	144.67^{a}	22.39^{ab}	5.11^{cd}	76.33^{a}	59.34^{cd}	18.47^{ab}	14.66^{a}	0.42^{abcd}
Parambankyama	130.75^{b}	21.64^{bc}	5.62^{c}	72.00^{ab}	61.30^{c}	17.97^{ab}	13.74^{ab}	0.44^{abcd}
PTB 28	112.55^{d}	20.43^{cd}	3.94^{e}	54.33^{f}	44.07^{g}	18.79^{ab}	12.97^{b}	0.48^{a}
Nerica	115.67^{cd}	19.49^{d}	4.72^{de}	53.33^{f}	55.37^{de}	16.13^{cd}	11.39^{c}	0.47^{ab}
PTB 60	136.00^{ab}	24.16^{a}	7.85^{a}	68.67^{bc}	88.33^{a}	19.53^{a}	14.72^{a}	0.44^{abc}
Karuthamodan	134.67^{ab}	21.72^{bc}	3.88^{e}	57.67^{ef}	43.71^{g}	14.71^{d}	13.42^{ab}	0.37^{d}
Arimodan	127.67^{bc}	22.22^{b}	4.01^{e}	54.67^{f}	45.12^{g}	15.08^{d}	12.89^{b}	0.39^{cd}
Karathadukkan	132.67^{ab}	21.93^{bc}	6.51^{b}	62.33^{de}	73.32^{b}	17.09^{bc}	14.77^{a}	0.39^{cd}
Parambuvattan	127.83^{bc}	21.28^{bcd}	4.13^{e}	58.33^{ef}	48.54^{fg}	14.38^{d}	13.11^{b}	0.37^{d}
Kalladiaryan	134.67^{ab}	22.52^{ab}	4.61^{de}	64.67^{cd}	52.16^{f}	16.05^{cd}	13.55^{ab}	0.40^{bcd}
Mean	129.71	21.78	5.04	62.23	57.13	16.82	13.72	0.42
CD (0.05)	12.61	1.80	0.84	5.95	5.40	1.78	1.20	0.74

4.3.3.3 Productive tillers per plant

The productive tillers ranged between 7.31 (Nerica) and 11.37 (Karathadukkan) with a mean value of 9.90 on imposition of moisture stress at seedling stage (15 DAS). Karanavara (11.29), PTB 28 (10.29), PTB 60 (10.93), Arimodan (10.41), Parambuvattan (10.13) and Kalladiaryan (10.18) were found to be on par with Karathadukkan.

On imposition of moisture stress at vegetative stage (35 DAS), the mean productive tillers recorded was 10.23 with a range of 7.77 (Nerica) to 12.38 (Karathadukkan). Arimodan (11.02) and Karanavara (11.62) were found to be on par with Karathadukkan

When moisture stress was imposed at reproductive stage (50 DAS), the productive tillers recorded a mean value of 11.12. It ranged from 8.07 (Nerica) to 14.23 (Karathadukkan). Karanavara (13.33) and Arimodan (13.19) were found to be on par with Karathadukkan.

A mean value of 12.32 was recorded for productive tillers per plant in Set IV (non stressed control). The values ranged between 8.91 in Nerica to 14.09 in Karanavara. PTB 28 (13.09), Arimodan (13.46), Karathadukkan (14.00), Parambuvattan (13.13) and Kalladiaryan (13.04) were found to be on par with Karanavara.

4.3.3.4 Panicle length (cm)

A mean value of 22.66 cm was obtained for panicle length on imposition of moisture stress at seedling stage (15 DAS). It ranged between 19.73 cm (Kalladiaryan) to 25.60 cm (PTB 60). PTB 28 (24.43cm) and Nerica (25.43cm) were found to be on par with PTB 60.

Panicle length ranged from 20.50 cm (Karathadukkan) to 25.91 cm (PTB 60) with a mean value of 22.61 cm, when moisture stress was imposed at vegetative stage (35 DAS). Nerica (25.21 cm) was found to be on par with PTB 60.

A mean value of 23.14 cm with a range of 18.97cm (Parambankyama) to 26.50 cm (PTB 60) was observed for panicle length when moisture stress was imposed at reproductive stage (50 DAS). Karanavara (24.57 cm), PTB 28 (24.37cm) and Nerica (25.60 cm) were found to be on par with PTB 60.

A mean panicle length of 23.88 cm was recorde under non stressed control. It ranged between 21.67 cm (Arimodan) and 26.50 cm (PTB 60). Nerica (26.00 cm) and Karanavara (25.17 cm) were found to be on par with PTB 60.

4.3.3.5 Panicle weight (g)

A mean value of 2.35 g was recorded for panicle weight on imposition of moisture stress at seedling stage (15 DAS). Values ranged from 1.67 g (Parambuvattan) to 3.27 g (Nerica). PTB 60 (2.83 g) was found next best to Nerica.

Panicle weight recorded a mean value of 2.36 g with a range of 1.66 g (Parambuvattan) to 3.28 g (Nerica) on imposition of moisture stress at vegetative stage (35 DAS). PTB 60 (2.90 g) was found to be on par with Nerica.

Panicle weight ranged from 1.73 g (Parambuvattan) to 3.37 g (Nerica) with a mean value of 2.43 g on imposition of moisture stress at reproductive stage (50 DAS). Parambankyama (2.99 g) was found to be on par with Nerica.

Under non stressed control, panicle weight ranged between 2.15 g in Parambuvattan to 3.23 g in Nerica. A mean value panicle weight of 2.70 g was observed. PTB 60 (3.08 g) was found to be on par with Nerica.

4.3.3.6 Grains per panicle

Grains per panicle ranged between 52.78 (Parambuvattan) and 98.50 (PTB 28) with a mean of 80.02 on imposition of moisture stress at seedling stage (15 DAS). Parambankyama (97.00), Nerica (93.47) and PTB 60 (95.76) were found to be on par with PTB 28.

Grains per panicle varied between 52.92 (Parambuvattan) and 96.11 (PTB 28) with a mean value of 77.41 on imposition of moisture stress at vegetative stage (35 DAS). Parambankyama (95.35) and PTB 60 (91.39) were found to be on par with PTB 28.

Grains per panicle ranged between 34.07 (Parambuvattan) and 83.3 (PTB 60) with a mean value of 57.53 on imposition of moisture stress at reproductive stage. PTB 28 (68.83) and Karuthamodan (67.12) were found next best to PTB 60

Grains per panicle varied between 73.33 (Parambuvattan) and 115.00 (PTB 28) with a mean value of 96.13 under non stresses control. Parambankyama (109.33) and PTB 60 (116.33) were found to be on par with PTB 28

4.3.3.7 Spikelets per panicle

Spikelets per panicle ranged from 65.23 in Parambuvattan to 122.03 in PTB 28 with a mean of 97.84 on imposition of moisture stress at seedling stage (15 DAS). Parambankyama (116.37), Nerica (119.62) and PTB 60 (117.14) were found to be on par with PTB 28.

Spikelets per panicle varied from 67.13 (Parambuvattan) to 120.17 (PTB 28) with a mean of 97.14 when moisture stress was imposed at vegetative stage (35 DAS). Parambankyama (115.30), Nerica (118.10) and PTB 60 (111.51) were found to be on par with PTB 28.

Spikelets per panicle ranged from 63.72 (Parambuvattan) to 111.64 (Karuthamodan) with a mean of 89.73 when moisture stress was imposed at reproductive stage (50 DAS). PTB 28 (107.12), PTB 60(105.10) and Kalladiaryan (108.25) were found to be on par with Karuthamodan.

Spikelets per panicle varied from 87.33 in Parambuvattan to 140 in PTB 60 with a mean of 113.90 under non stressed control. PTB 28 (132.67) was found to be on par with PTB 60.

4.3.3.8 1000 grain weight (g)

1000 grain weight ranged from 23.24 g (PTB 28) to 30.39 g (Nerica) with a mean of 27.32 on imposition of moisture stress at seeling stage (15 DAS).

Karuthamodan (29.30 g) and Arimodan (28.43 g) were found to be on par with the Nerica.

1000 grain weight ranged from 22.15 g (PTB 28) to 29.24 g (Nerica) with a mean of 25.86 g on imposition of moisture stress at vegetative stage (35 DAS). All genotypes except PTB 28 (22.15 g) and Kalladiaryan (24.16 g) were found to be on par with Nerica.

1000 grain weight ranged from 19.54 g (PTB 28) to 27.28 g (Nerica) with a mean of 24.01 g on imposition of moisture stress at reproductive stage (50 DAS). Karanavara (26.36 g) and Arimodan (25.88 g) were found to be on par with Nerica.

1000 grain weight ranged from 23.83 g (PTB 28) to 30.31 g (Nerica) with a mean of 27.38 under non stressed control. Karanavara (28.83 g), Karuthamodan (28.67g), Karathadukkan (28.12 g) and Parambuvattan (27.67 g) were found to be on par with Nerica.

4.3.3.9 Flag leaf area (sq. cm)

On imposition of moisture stress at seedling stage (15 DAS), flag leaf area ranged between 32.39 sq.cm (Karanavara) to 45.33 sq.cm (PTB 60) with a mean value of 38.27 sq.cm. Parambankyama (44.22 sq.cm) was found to be on par with PTB 60.

On imposition of moisture stress at vegetative stage (35 DAS) a mean value of 39.75 sq.cm was observed for flag leaf area. It ranged from 33.41 sq.cm in Karanavara to 47.27 sq.cm in PTB 60. Parambankyama (44.75 sq.cm) was found to be on par with PTB 60.

On imposition of moisture stress at reproductive stage (50 DAS), a mean value of 46.78 sq.cm was recorded for flag leaf area. It ranged between 38.22sq.cm (Nerica) and 54.54sq.cm (Parambankyama). Karanavara (51.48 sq.cm), PTB 60 (49.38 sq.cm) and Karathadukkan (49.68 sq.cm) were found to be on par with Parambankyama.

Under non stressed control, flag leaf area varied between 49.10 sq.cm (PTB 28) and 59.35 sq.cm (Parambankyama) with a mean value of 52.41 sq.cm . PTB 60 (54.63 sq.cm) was found to be on par with Parambankyama.

4.3.3.10 Plant height (cm)

Plant height ranged from 92.69 cm (Parambuvattan) to 122.88 cm (Karanavara) with a mean value of 105.44 cm, on imposition of moistures stress at seedling stage (15 DAS). PTB 60 (112.99 cm) was found to be on par with Karanavara.

A mean value of 115.13 cm with a range between 100.76 cm (Parambuvattan) and 133.47 cm (Karanavara) was observed for plant height on imposition of moistures stress at vegetative stage (35 DAS). PTB 60 (127.03 cm) and Karuthamodan (121.01 cm) were found to be on par with Karanavara

When moisture stress was imposed at reproductive stage (50 DAS), plant height ranged from 100.43 cm (Parambuvattan) to 144.18 cm (Karanavara) with a mean of 121.95 cm . PTB 60 (132.96 cm), Karuthamodan (134.85 cm) and Kalladiaryan (129.12 cm) were found to be on par with Karanavara

Under non stress condition, plant height ranged from 112.55 cm (PTB 28) to 144.67 cm (Karanavara) with a mean of 129.71cm. PTB 60 (136.00 cm), Karuthamodan (134.67 cm), Karathadukkan (132.67 cm) and Kalladiaryan (134.67 cm) were found to be on par with Karanavara

4.3.3.11 Dry weight of shoot (g)

Dry weight of shoot ranged from 11.20 g (Parambuvattan) to 18.49 g (PTB 60) with a mean of 15.38 g on imposition of stress at seedling stage (15 DAS). Karanavara (17.48 g), Parambankyama (16.10 g), Nerica (16.54 g) and Karathadukkan (16.52 g) were found to be on par with PTB 60

On imposition of moisture stress at vegetative stage (35 DAS), dry weight of shoot ranged from 14.61 g (Arimodan) to 20.23 g (PTB 60) with a mean of

17.25 g. Karanavara (18.45 g), Parambankyama (17.40 g), Karathadukkan (19.99 g) and Kalladiaryan (17.41 g) were found to be on par with PTB 60

Dry weight of shoot varied between 17.37 g in Arimodan and 21.28 g in PTB 60 with a mean value of 19.02 g on imposition of moisture stress at (50 DAS). Karanavara (20.07 g), Parambankyama (19.54 g) and Karathadukkan (20.88 g) were found to be on par with PTB 60

Under non stress condition, dry weight of shoot ranged from 19.49 g (Nerica) to 24.16 g (PTB 60) with a mean value of 21.78 g. Karanavara (22.39 cm) was found to be on par with the PTB 60

4.3.3.12 Dry weight of root (g)

Dry weight of root ranged between 2.33 g (PTB 28) and 5.58 g (PTB 60) with a mean of 3.32 g on imposition of moisture stress at seedling stage (15 DAS). Karathadukkan (4.76 g) was found to be on par with PTB 60

On imposition of moisture stress at vegetative stage (35 DAS), dry weight of root varied from 2.91 g (Karuthamodan) to 6.14 g (PTB 60) with a mean of 3.95 g. Karathadukkan (5.14 g) was found next best to PTB 60

Dry weight of root varied between 3.25 g in Karuthamodan and 6.15 g in PTB 60 with a mean of 4.16 g on imposition of misture stress at reproductive stage (50 DAS). Karathadukkan (5.88 g) was found to be on par with PTB 60

In the non stressed control, dry weight of root ranged from 3.88 g (Karuthamodan) to 7.85 g (PTB 60) with a mean of 5.04 g. Karathadukkan (6.51 g) was found next best to PTB 60

4.3.3.13 Root length (cm)

Root length varied from 40.17 cm (PTB 28) to 61.45 cm (Karanavara) with a mean value of 51.19 cm on imposition of moisture stress at seedling stage (15 DAS). Parambankyama (55.49 cm), PTB 60 (56.00 cm) and Karathadukkan (59.44cm) were found to be on par with the Karanavara.

On imposition of moisture stress at vegetative stage (35 DAS), root length varied from 59.90 cm (Nerica) to 75 cm (Parambankyama) with a mean value of 66.10 cm. Karanavara (74.00 cm) and Karathadukkan (74.93 cm) were found to be on par with Parambankyama.

·Root length varied between 65.04 cm in PTB 28 to maximum of 92.00 cm in Parambankyama with a mean value of 78.20 cm on imposition of moisture stress at reproductive stage. Karanavara (87.67 cm) and Nerica (87.33 cm) were found to be on par with Parambankyama.

In the non stressed control, root length varied from 53.33 cm (Nerica) to 76.33 cm (Karanavara) with a mean value of 62.23 cm.. Parambankyama (72.00 cm) was found to be on par with Karanavara.

4.3.3.14 Root volume (ml)

Root volume varied between 26.22 ml (PTB 28) and 66.69 ml (PTB 60) with a mean of 37.43 ml on imposition of moisture stress at seedling stage. Karathadukkan (53.33 ml) was found next best to PTB 60.

On imposition of moisture stress at vegetative stage (35 DAS), root volume ranged from of 31.59 ml (Nerica) to 78.93 ml (PTB 60) with a mean of 45.97 ml. Karathadukkan (59.00 ml) was found next best to PTB 60.

Root volume varied from 37.69 ml in Nerica to 72.88 ml in PTB 60 with a mean of 48.48 ml on imposition of moisture stress at reproductive stage. Karathadukkan (67.58ml) was found next best to PTB 60.

In the non stressed control, root volume ranged from 43.71 ml (Karuthamodan) to 88.33 ml (PTB 60) with a mean of 57.13 ml. . Karathadukkan (73.32 ml) was found next best to PTB 60.

4.3.3.15 Grain yield per plant (g)

Grain yield varied between 9.8 g (Parambuvattan) to 18.00 g (PTB 60) with a mean of 13.74 g on imposition of moisture stress at seedling stage (15

DAS). Parambankyama (14.81 g), PTB 28 (15.23 g), Nerica (14.27 g) and Karathadukkan (14.67 g) were found to be on par with PTB 60.

On imposition of moisture stress at vegetative stage (35 DAS), grain yield ranged from 9.05 g (Parambuvattan) to 17.64 g (PTB 60) with a mean of 13.14 g. Karanavara (15.42 g), Parambankyama (14.30 g), PTB 28 (14.61 g), Nerica (14.54 g) and Karathadukkan (13.74 g) were found next best to PTB 60.

Grain yield varied between 5.74 g in Parambuvattan to 12.46 g in PTB 60 with a mean of 8.76 g on imposition of moisture stress at reproductive stage (50 DAS). Nerica (10.91 g) was found to be on par with PTB 60.

In the non stressed control, a meangrain yield of 16.82 g was recorded. Grain yield ranged from 14.38 g in Parambuvattan) to 19.53 g in PTB 60. . Karanavara (18.47 g), Parambankyama (17.97 g) and PTB 28 (18.79 g) were found to be on par with the PTB 60.

4.3.3.16 Straw yield per plant (g)

A mean value of 9.95 g with a range between 10.11 g (Nerica) and 12.39 g (Karathadukkan) was observed for straw yield per plant when moisture stress was imposed at seedling stage (15 DAS). Karanavara (11.28 g) Parambankyama (10.42 g) and PTB 60 (12.38 g) were found to be on par with Karathadukkan.

When moisture stress was imposed at vegetative stage (35 DAS), a mean value of 10.95 g with a range of 8.7 g (Arimodan) to 13.52 g (Karathadukkan) was observed for straw yield per plant. Karanavara (12.01 g) and PTB 60 (13.51 g) were found to be on par with Karathadukkan.

On imposition of moisture stress at reproductive stage, a mean straw yield of 12.23 g was recorded per plant. Straw yield per plant ranged between 10.15 g (Arimodan) to 14.48 g (Karathadukkan). Karanavara (13.44 g) and PTB 60 (14.02 g) were found to be on par with Karathadukkan.

Under non stress condition, a mean value of 13.72 g was observed for straw yield per plant. It ranged from 11.39 g (Nerica) to 14.77 g (Karathadukkan).

Karanavara (14.66 g) Parambankyama (13.74 g), PTB 60 (14.72 g), Karuthamodan (13.42 g) and Kalladiaryan (13.55 g) were found to be on par with Karathadukkan.

4.3.3.17 Harvest index

Harvest index varied between 0.39 (Karuthamodan) and 0.54 (PTB 28) with a mean of 0.46 when moisture stress was imposed at seedling stage (15 DAS). Karanavara (0.49), Parambankyama (0.47), Nerica (0.48), PTB 60 (0.48), Arimodan (0.52) and Parambuvattan (0.47) were found to be on par with PTB 28.

Harvest index ranged from 0.33 (Parambuvattan) to 0.49 (PTB 28) with a mean of 0.40 when moisture stress was imposed at vegetative stage (35 DAS). Karanavara (0.43), Parambankyama (0.43), Nerica (0.47), PTB 60 (0.43) and Arimodan (0.42) were found to be on par with PTB 28.

Harvest index varied from 0.17 in Parambuvattan to 0.34 in Nerica with a mean of 0.24, on imposition of moisture stress at reproductive stage (50 DAS). PTB 60 (0.29) was found to be on par with Nerica.

Harvest index ranged between 0.37 in Karuthamodan and 0.48 in PTB 28 with a mean of 0.42, in the non stressed control. Karanavara (0.42), Parambankyama (0.44), Nerica (0.47) and PTB 60 (0.44) were found to be on par with PTB 28.

Discussion

V. DISCUSSION

Moisture stress during the crop ontogeny has been one of the main constraints for sustainable rice productivity, especially in uplands. Crop losses vary depending upon the intensity and duration of drought and growth stages. The solution to overcome this lies in either making water available for crop growth or breeding for drought resistant cultivars. Increased irrigation inputs are not a viable option either because the water resources are unavailable or they are too expensive to implement in drought affected uplands. In a world limited by supplies of fresh water, the trend is towards greater restrictions on agricultural water use. Improvements in crop drought tolerance are therefore sought through plant breeding. Cultivars with better ability to access soil water and improved water use efficiency could increase yields in an economic and environmentally sustainable way.

In the present study, twenty one genotypes were evaluated for various yield and yield attribute traits genotypes. The germination and seedling growth characters of these genotypes to PEG stimulated moisture stress was also assessed. Based on the outcome the two studies, ten promising drought tolerant genotypes were selected and their response towards moisture stress imposed at various growth stages (seedling stage, vegetative and reproductive stage) was elucidated. The results of the present investigation are discussed below.

5.1 Morphological characterisation of rice genotypes for yield and yield attributes genotypes

5.1.1 Variability for yield and yield attributes in rice genotypes

The analysis of variance revealed existence of significant differences among the genotypes for yield and yield attributes, indicating existence of wide variability and the scope for improvement through selection.

5.1.1.1 Mean performance of rice genotypes

Grouping the rice genotypes based on duration indicated that most genotypes (16 nos) belonged to the early duration group (100-120 days) while five were of medium duration (Mo 15, Kalladiaryan, PTB 43, PTB 52, PTB 39 and Good day. Karuthamodan was found to flower before 67.50 days, followed by Nerica (72.50 days), Karanavara and Onam (73 days each), PTB 55 (73.50 days) and Arimodan (74 days).

The number of days with no rains was found between 3rd and 11th day after sowing (DAS) (8 days), 27th and 39th DAS (10 days), 79th and 86th DAS (8 days), 106th and 123th DAS (15 days). Irrespective of growth duration, all genotypes experienced moisture stress during vegetative stage. In addition, the early group ($\leq$100 days) was also exposed to moisture stress at terminal growth stage (ripening and maturity), while the mid early (> 100-115 days) and medium duration genotypes (>115-125 days) experienced moisture stress partly in reproductive and ripening phase (Figure 3).

According to Lafitte and Courtois (2002), early maturity was advantageous under drought over later flowering in terms of higher spikelet fertility, higher harvest index and higher yield even when stress was applied at specific developmental stages for each cultivar.

Nerica (76.44) ranked first with respect to chlorophyll stability index. Parambankyama, PTB 60, Karuthamodam and Karuthadukkan with a chlorophyll stability index above 69.40 were found to be superior. It was observed that all high yielding varieties except PTB 60 recorded low chlorophyll stability index values between 54.00 and 62.00. According to Mohan *et al.* (2000), chlorophyll stability index is an indication of the stress tolerance capacity of plants. A high chlorophyll stability index value means that the stress did not have much effect on chlorophyll degradation of plants. A higher chlorophyll stability index helps plants to withstand stress through better availability of chlorophyll.

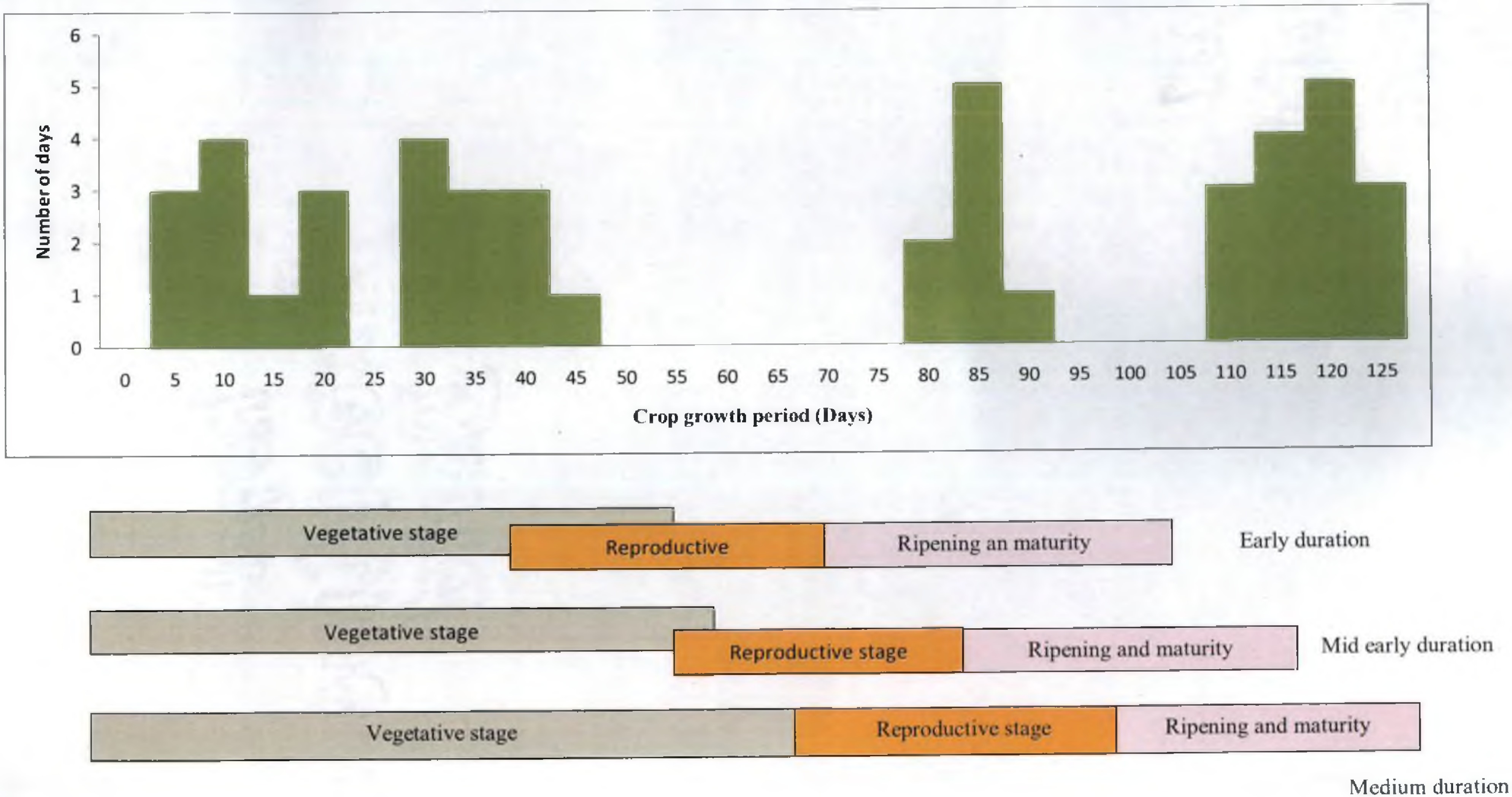

Figure 3: Pattern of dry spell during crop growth period

Number of productive tillers was found to be higher in Karanavara followed by PTB 28, Chettiviruppuiu and Parambuvattan. The least was observed in Good day. Under stress, number of productive tillers was found to be highly affected depending on genotypes. According to Kumar *et al.* (2014), drought stress at reproductive stage caused reduction in number of effective tillers (37.70 %). However, the responses varied among genotypes. Henry *et al.* (2011) found that majority of drought tolerant land races showed early flowering, low tillering and tall plant habit, compared to semi-dwarf plant habit and high tillering in high yielding popular varieties.

PTB 60 with panicle length of 27.50 cm ranked highest followed by Karuthamodan (26.20 cm) while PTB 55 (18.70 cm) ranked the least with respect to panicle length. Manickavelu *et al.* (2010) suggested that high panicle length may be emphasised for improvement of yield in drought resistance breeding programme.

Parambankayama (2.82 g) followed by Good day (2.70 g) and Nerica (2.70 g) ranked high in panicle weight. Least weight of panicle was observed in Chomala (1.30 g) Chettiviruppu (1.20 g) followed by PTB 39, PTB 55 (1.40 g) and PTB 43 (1.48 g). Kato *et al.* (2007) reported that under moisture stress, genotypes with deep root showed less reduction in panicle weight

Improved traditional rice variety PTB 28 (137.50), ranked first with respect to number of spikelets per panicle followed by Good day (137.10) and Onam (133.90) while the least number of spikelets were recorded in PTB 55 (72.00) followed by Arimodan (79.20). However, it was observed that, higher number of spikelets did not result in production of corresponding high number of grains per panicle i.e., considerable differences in spikelet fertility were observed (Table 47 and Figure 4.).

Arimodan, Chomala and Karuthadukkan proved to possess high spikelet fertility (> 90%) while high yielding variety PTB 39 recorded the least followed

Table 47. Spikelet fertility (%) in rice genotypes

Genotypes	Spikelets per panicles	Grains per panicle	Spikelet fertility (%)
Parambuvattan	80.7	57.5	**71.25**
Karuthamodan	88.2	73.3	**83.11**
Karanavara	98.6	85.1	**86.31**
Kalladiaryan	125.1	95.7	**76.50**
Mo 15	126.2	84.6	**67.04**
Thottacheera	114	85	**74.56**
Karathadukkan	86	84.3	**98.02**
Chomala	123	119.3	**96.99**
PTB 43	125.4	82.9	**66.11**
PTB 39	86.5	48.2	**55.72**
PTB 50	112.9	75.6	**66.96**
PTB 52	91.5	77.9	**85.14**
PTB 60	114.3	84	**73.49**
Arimodan	79.2	74.4	**93.94**
Onam	133.9	76.9	**57.43**
Parambankayama	126.6	106.4	**84.04**
PTB 55	72	50.8	**70.56**
PTB 28	137.5	111.3	**80.95**
Chettiviruppu	89.2	58.6	**65.70**
Good day	137.1	92.1	**67.18**
Nerica	126.8	95.7	**75.47**

Grouping of genotypes based on spikelet fertility (IRRI, 2006)

Score	**Details**	**Fertile spikelet (%)**
1	Highly fertile	> 90
3	Fertile	75 - 89
5	Partially sterile	50 -74
7	Highly sterile	< 50
9	0 %	

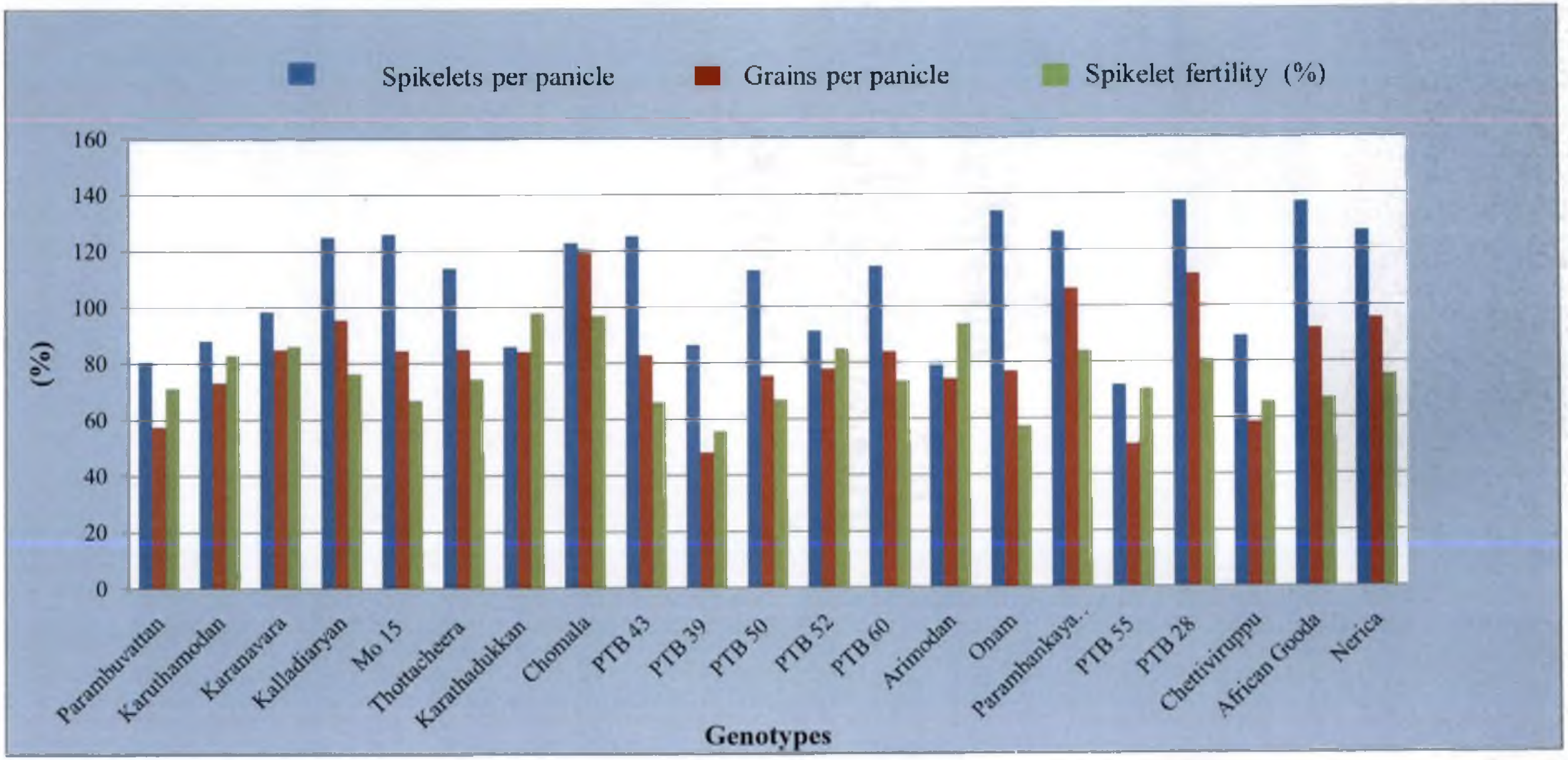

Figure 4: Spikelet fertility in rice genotypes

by Onam. All high yielding varieties including PTB 60 grouped under the partially sterile category (50 - 74 % spikelet fertility), the exception being PTB 52 (Aiswarya). Sarvestani *et al.* (2008) found that the reduction of grain yield under moistuer stress largely resulted from reduction in fertile panicle and filled grain percentage. Okocha, (2008) and Cha-Um *et al.* (2010) identified drought tolerant genotypes based on stability in panicle length and fertile grains. The least 1000 grain weight was recorded in Chomala (8.50 g), while it was highest in Karuthamodan (29.50 g). Most genotypes registered a 1000 grain weight of above 24.00 g.

Most of the traditional rice varieties (TRV) in the study were tall in stature compared to the high yielding varieties. However, in plant stature PTB 60 was found to be on par with TRV's *viz.,* Parambankayama, Parambuvattan, Karuthamodan, Thottacheera and Good day, all of which grew to over 125.00 cm. The tallest among the genotypes was Karanavara (137.70 cm). Apart from moisture stress, weed competitiveness is also found to play a key role in the productivity of upland rice crop. According to Francies (2013), in uplands of Kerala, early maturing (100 – 115 days), semi-tall to tall varieties with profuse and vigorous early vegetative growth is mostly preferred.

With respect to grain yield per plant it was observed that the traditional rice varieties performed better than the high yielding varieties, with the exception being PTB 60. PTB 60 (Vaishak) is a high yielding variety specifically bred for the uplands of Kerala. Parambankayama (9.16 g) followed by Karanavara (8.66 g), PTB 28 (8.00 g) and PTB 60 (7.50 g) ranked high in grain yield per plant. Chomala (3.83 g), PTB 39 (4.10 g) and Mo 15 (4.51 g) ranked low in grain yield per plant. Results also pointed out that, of the twenty one genotypes, medium duration varieties were poor performers with respect to grain yield when grown in uplands.

It is evident that Parambannkayama and Karanavara which ranked high in grain yield also recorded the highest dry weight of shoot and straw yield, while, PTB 39 which ranked the least with respect grain yield registered the least dry weight of shoot and straw yield. In general, it was observed that genotypes with high grain yield also recorded high dry weight of shoot and straw yields and vice–versa. Manickavelu et *al*. (2010) had suggested that selection pressure on biomass yield may be given in positive direction for yield improvement under moisture stress

The genotypes were ranked according to a modification to the method suggested by Arunachalum and Bandyopadhyay (1984), for making decisions jointly on a number of dependent characters. For each attributed studied, the genotypes were ranked based on the differences in the mean estimates as tested by Duncan's multiple range test (DMRT). Each group including the overlapping groups were assigned ranks. Individual ranks obtained by the genotype for each trait studied were added up to arrive at a total score. The genotypes were then ranked (Table 48) in descending order of numerical values of total scores.

Cafeteria of traditional rice varieties suitable for uplands of Kerala include early to mid-early maturing genotypes. The study revealed the advantage of early maturity, higher CSI, productive tillers, seed set per cent, 1000 grain weight and plant height under moisture stress. Early maturing upland genotypes Parambankayama followed by Karanavara were found to be the most promising. Nerica, Karuthamodan, Kalladiaryan, Parambuvattan and Arimodan were the other early genotypes found suitable for uplands while mid-early genotypes PTB 28, PTB 60, Karuthadukkan and Thottacheera were also promising.

5.1. 2 Genetic parameters for yield and yield attributes

5.1.2.1 Phenotypic and genotypic coefficient of variation

Genetic variability parameters provide information on the extent of variation present in the population. The absolute values of phenotypic and genotypic variances cannot be used for comparing the magnitude of variability for various traits since the mean and units of measurement of the traits may be different.

Table 48. Ranking of genotypes based on performance in Experiment 1

Genotypes	Days to fifty per cent flowering	CSI	Productive tillers per plant	Panicle length	Panicle weight	Spikelets per panicles	Grains per panicle	1000 grain weight	Plant height at maturity	Dry weight of shoot	Grain yield per plant	Straw yield per plant	Total score	Rank Expt 1
Parambuvattan	4	4	3	8	9	15	8	5	2	3	5	4	70	**7**
Karuthamodan	1	2	8	2	7	13	7	1	2	4	5	5	57	**5**
Karanavara	2	5	1	4	5	11	4	3	1	1	2	2	41	**2**
Kalladiaryan	1	6	10	8	6	7	3	3	3	5	7	6	65	**6**
Mo 15	10	11	4	10	8	5	4	7	7	9	10	9	94	**13**
Thottacheera	6	7	12	5	3	9	4	6	2	9	6	11	80	**11**
Karathadukkan	6	2	7	9	4	14	4	8	3	4	5	5	71	**8**
Chomala	5	5	5	8	11	8	1	13	9	10	12	10	97	**14**
PTB 43	10	11	13	6	10	6	5	7	7	10	9	11	105	**15**
PTB 39	9	12	14	7	10	14	9	6	7	13	11	14	126	**20**
PTB 50	6	9	11	7	9	10	7	10	5	12	9	13	108	**16**
PTB 52	10	12	12	8	9	12	6	11	8	8	9	8	113	**18**
PTB 60	8	2	9	1	6	9	4	7	2	2	4	3	57	**5**
Arimodan	2	3	4	10	4	16	7	4	3	6	7	7	73	**9**
Onam	2	8	6	11	7	3	7	3	7	10	8	9	81	**12**
Parambankayama	3	2	11	6	1	4	2	6	2	1	1	1	40	**1**
PTB 55	2	10	5	12	10	17	9	9	10	8	10	9	111	**17**
PTB 28	6	5	2	3	3	1	2	10	4	5	3	6	50	**3**
Chettiviruppu	7	9	2	10	11	13	8	12	10	11	10	12	115	**19**
Good day	9	8	15	6	2	2	3	4	2	10	6	9	76	**10**
Nerica	2	1	14	5	2	3	3	2	6	7	4	7	56	**4**

Hence, the co-efficient of variation expressed at phenotypic and genotypic levels have been used to compare the variability observed among different traits. As PCV and GCV for all traits are expressed in per cent they can be reliably used to indicate which character is more variable than the other.

The variability parameters pointed towards the existence of wide variability for the traits studied. The magnitude of phenotypic coefficient of variation was higher than genotypic coefficient of variation (Figure 5) for all the characters, which may be due to higher degree of interaction of genotypes with environment. However, the difference between the phenotypic and genotypic coefficients of variation was narrow indicating greater contribution of genotype to trait expression that may lead to high heritability.

Higher magnitude of phenotypic and genotypic coefficient of variation was recorded for productive tillers per plant, panicle weight, spikelets per panicle, grains per panicle, 1000 grain weight, dry weight of shoot, grain and straw yield per plant, suggesting presence of considerable variation among the genotypes for these traits. It also indicated the scope of further improvement through selection. Khare *et al.* (2014) and Singh *et al.* (2014) had also observed high phenotypic coefficient of variation and genotypic coefficient of variation for grain yield per plant, productive tillers per plant, spikelets per panicle, grains per panicle. They had however recorded moderate PCV and GCV for plant height. Soni *et al.* (2013) had observed high PCV and GCV for panicle weight and 1000 grain weight. The findings of Shet *et al.* (2012) and Patel *et al.* (2014) with respect to straw yield per plant corroborates the results obtained in the present study.

Moderate phenotypic and genotypic coefficient of variation was evident for days to fifty per cent flowering and plant height indicating presence of variability at moderate levels for these traits. The results are in consonance with the findings of Karthikeyan *et al.* (2010) and Soni *et al.* (2013).

Lower phenotypic and genotypic coefficient of variation was observed for CSI and panicle length. Gampala *et al.* (2014) had also observed lower phenotypic

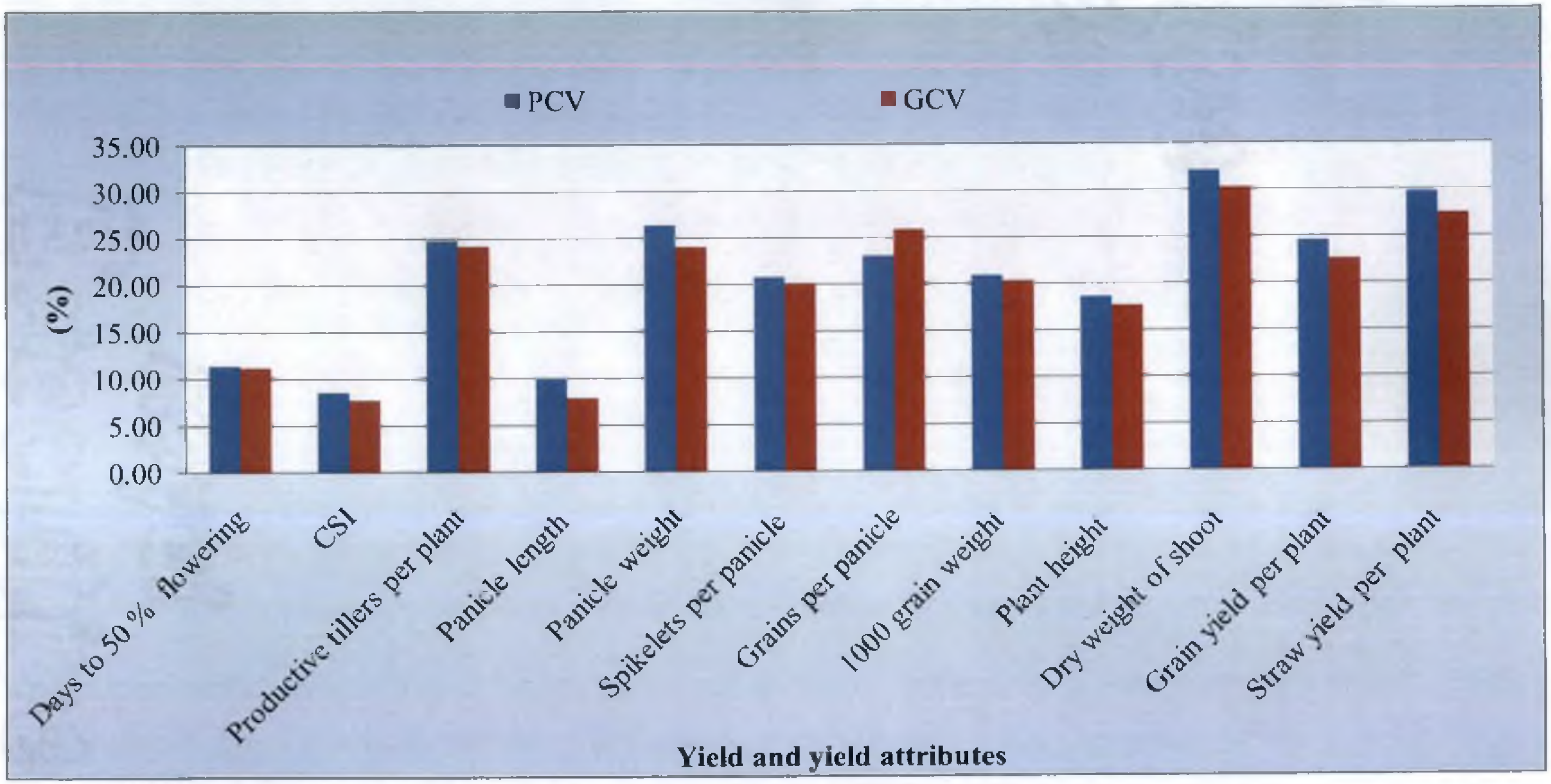

Figure 5: Coefficient of variation (%) for yield and yield attributes in rice genotypes

coefficient of variation and genotypic coefficient of variation for panicle length, while in contrast to finding of present study, Sathya and Jebaraj (2013) had observed a moderate PCV and GCV for CSI.

5.1.1.2.2 Heritability and genetic advance

While genotypic coefficient of variation indicates the amount of genetic variability present, the heritability estimates aid in determining the relative amount of heritable portion of variation. The proportion of genetic variability which is transmitted from parents to offspring is reflected by heritability (Lush, 1949). However, heritability values itself provides no indication of the amount of genetic progress that would result from selecting the best individuals (Charles and Smith, 1939; Grafius, 1964). Heritability and genetic advance as per cent of mean when considered together would prove more useful in predicting the resultant effect of selection on phenotypic expression (Johnson *et al.,* 1955a). The relative comparison of heritability values and genetic gain also gives an idea about the nature of gene action governing a particular trait.

High heritability coupled with high genetic advance as per cent of mean (Figure 6) was recorded for days to fifty per cent flowering, productive tiller tillers per plant, panicle weight (g), spikelets and grains per panicle, 1000 grain weight (cm), plant height, dry weight of shoot, grain yield and straw yield per plant. High heritability was observed for all the traits studied. High heritability along with high genetic gain indicates lesser influence of environment and prevalence of additive gene action in the expression of the trait. Results suggest that selection could be very effective for improvement of these traits. Although traits days to fifty per cent flowering and plant height had recorded high heritability and genetic advance as per cent of mean, the PCV and GCV for traits were moderate, implying possibility of only moderate improvement in these traits through selection. Khare *et al.* (2014) and Singh *et al.* (2014) reported high heritability and high genetic advance as per cent of mean for productive tiller per plant, grains per panicle, thousand grain weight, plant height and grain yield.

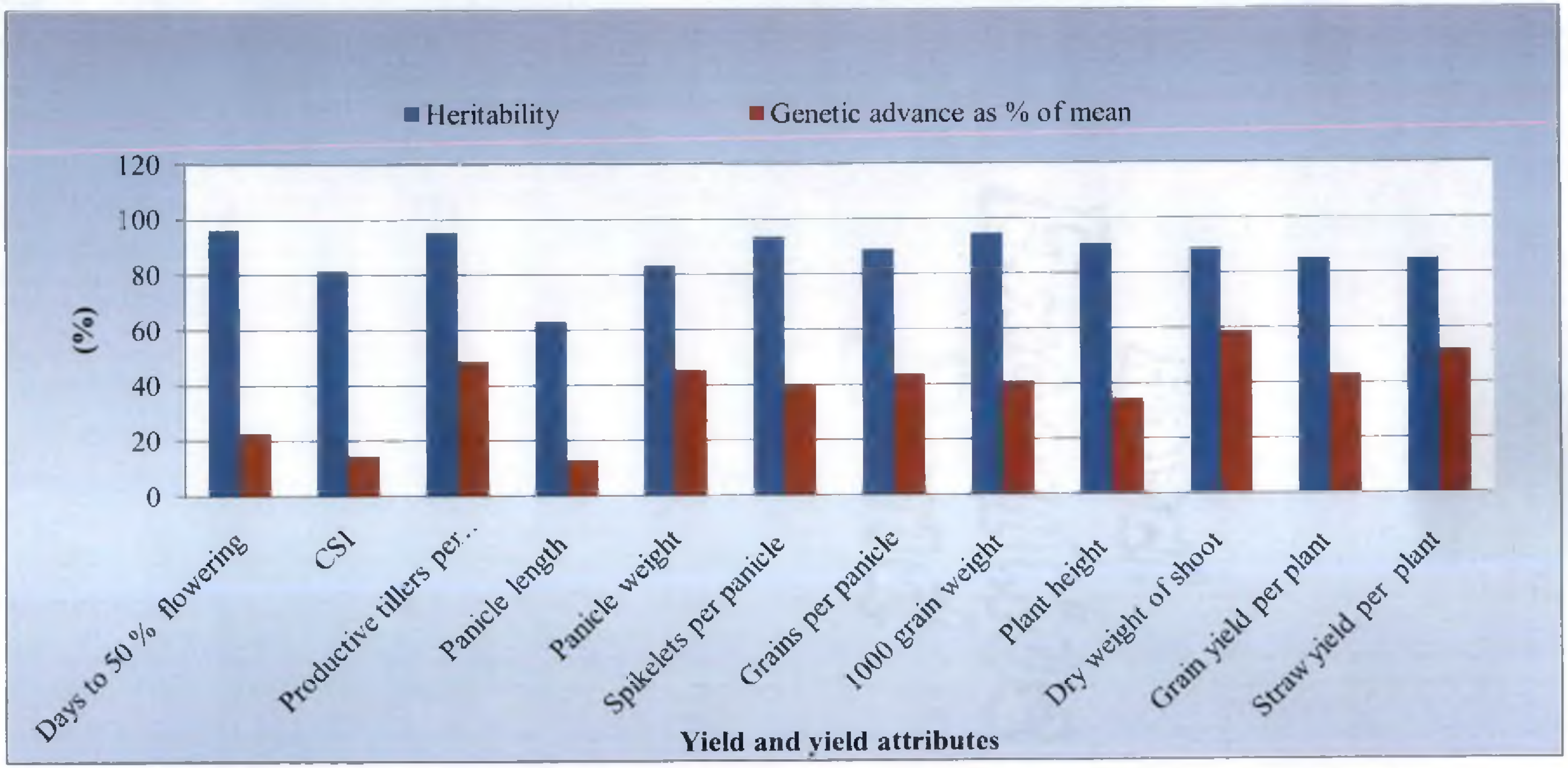

Figure 6: Heritability (broad sense) (%) and genetic advance as per cent of mean for yield and yield attributes in rice genotypes

Similar to the findings in the study, Karthikeyan *et al.* (2010) and Soni *et al.* (2013) had reported high heritability and high genetic advance as per cent of mean for days to fifty per cent flowering. Chavan and Lal (2014) observed high heritability and high genetic advance as per cent of mean for panicle weight, while, Quatadah *et al.* (2012) reported high heritability and high genetic advance as per cent of mean for spikelets per panicle. Shet *et al.* (2012) and Patel *et al.* (2014) reported high heritability and high genetic advance as per cent of mean for straw yield per plant, which corroborates the findings of the present study.

High heritability coupled with moderate genetic advance as per mean was recorded for CSI and panicle length. Singh *et al.* (2014) observed similar results for panicle length. The result indicated the presence of both additive and non-additive gene action on expression of these traits. Hence, improvement of these traits cannot be achieved through simple selection, but, a recurrent or reciprocal recurrent selection may be resorted to, in order to exploit the additive and non additive genetic components. Incidentally, the coefficients of variation for CSI and panicle length were low.

5.1.3 Correlation study

The grain yield or economic yield, in almost all the crops results from the multiplicative of several other characters that are termed as yield attributes. Thus genetic architecture of grain yield is based on the balance or overall net effect produced by various yield attributes directly or indirectly by interacting with one another. Therefore, identification of important yield attributes and information about their association with yield and also with each other is very useful for developing efficient breeding strategy for evolving high yielding varieties. In this respect, the correlation coefficient which provides symmetrical measurement of degree of association between two variables or characters, help us in understanding the nature and magnitude of association among yield and yield attributes. Hence, correlation between grain yield and yield attributes were worked out to elucidate the inter-relation among different yield contributing characters and their association with grain yield genotypes .

Plate 1: Evaluation of rice genotypes for yield and yield attributes

Plate 2: Screening rice genotypes for germination and seedling traits in response to moisture stress (-8 bars)

PTB 60

PTB 28

Parambuvattan

Arimodan

Plate 5: Promising genotypes tolerant to moisture stress - II

Plate 3: Evaluation of rice genotypes for response to moisture stress imposed at different growth stages

Nerica

Parambankayama

Plate 4: Promising genotypes tolerant to moisture stress -I

PTB 60

PTB 28

Parambuvattan

Arimodan

Plate 5: Promising genotypes tolerant to moisture stress - II

Karanavara

Karuthadukkan

Kalladiaryan

Karuthamodan

Plate 6: Promising genotypes tolerant to moisture stress - III

In general, genotypic correlation coefficients (GCC) were higher than phenotypic correlation coefficients (PCC) indicating the predominant role of genetic background rather than environmental effect for association between yield and yield attributes. Gomez and Rangasamy (2002) observed that phenotypic correlation coefficient value is lessened due to the significant interaction of environment.

In the present investigation, Chlorophyll stability index (CSI), panicle length, panicle weight, grains per panicle, 1000 grain weight, plant height, dry weight of shoot and straw yield per plant exhibited positive and significant association with grain yield at both phenotypic and genotypic levels. These points to the usefulness of yield attributes mentioned as selection indices for improvement of grain yield genotypes . Patel *et al.* (2014) had also reported positive correlation between grain yield and straw yield per plant, panicle length plant height, productive tillers, grains per panicle and 1000 grain weight. Khare *et al.* (2014) had observed positive correlation of grain yield and spikelets per panicle.

The relationship of grain yield with days to fifty per cent flowering under upland condition was found to be highly significant and negative, indicating that early maturity is preferable for improved grain yield in rice genotypes . Similar negative correlation between grain yield and days to fifty per cent flowering were also observed by Bhadru *et al.* (2011) and Santhi *et al.* (2011). Guan (2010) revealed that drought escape (DE) by accelerated heading under drought was the third mechanism that contributed to drought tolerance. The results of the present study are in contrast with the findings of Ikeda *et al.* (2008) who reported that later maturing and longer growth duration cultivars show less growth stagnation and drought damage and have a higher yield when they encounter mild water shortages during the vegetative to panicle initiation stages.

Results revealed presence of negative correlation between days to flowering and yield attributes CSI, 1000 grain weight, plant height, dry weight of shoot and straw yield per plant, all of which had exhibited high positive correlation with grain yield. Existence of such negative association between days to fifty per cent flowering and plant height results was also evident in the study conducted by Chandra *et al.* (2009), and between days to 50 per cent flowering and 1000-grain weight, and straw yield by Patel *et al.* (2014). It becomes evident that selection for earliness in flowering (short duration) will lead to simultaneous improvement of grain yield per plant and yield attributes *viz.*, CSI, 1000 grain weight, plant height, dry weight of shoot and straw yield per plant and thereby improve performance of genotypes under upland. The genetic reasons for this type of negative association may be linkage or pleiotropy.

The correlation between productive tillers and spikelets per panicle with grain yield was non-significant. Hence, it can be concluded that an increase in number of productive tillers will not lead to higher grain yield per plant genotypes . The interrelationship between productive tillers per plant and spikelets per panicle was highly significant and negative. This indicated that an increase in number of productive tillers may lead to decrease in spikelets per panicle in upland condition. However, as spikelets per panicle had exhibited non-significant correlation with grain yield per plant, an increase or decrease in spikelets per panicle may not affect grain yield per plant. Girolkar *et al.* (2008) and Khare *et al.* (2014) had also observed a negative correlation between productive tillers per plant and spikelets per panicle.

Chlorophyll stability index recorded a high significant positive association with panicle length and weight, grains per panicle, plant height, dry weight of shoot and straw weight besides grain yield per plant. This indicates that selection for higher CSI will result in simultaneous improvement in grain yield and the traits enlisted above in rice genotypes grown in uplands. CSI is an indication of the stress tolerance capacity of plants. A high CSI value means that the stress did not have much effect on chlorophyll content of plants. A higher CSI helps plants to withstand stress through better availability of chlorophyll. This leads to increased photosynthetic rate, more dry mater production, and higher productivity can perform under stress (Mohan *et al.*, 2000).

From the present study it can be summarised that emphasis may be laid on higher CSI, panicle length, panicle weight, grains per panicle, 1000 grain weight, plant height, dry weight of shoot and straw yield per plant during selection to obtain higher grain yield in rice genotypes grown in uplands. The study also implies that short duration varieties performed better genotypes and therefore selection in the negative direction for days to fifty per cent flowering may be emphasised during breeding for tolerance to moisture stress genotypes .

5.1.4 Path coefficient analysis

Path coefficient analysis is simply standardized partial regression coefficient, which splits the correlation coefficient into the measure of direct and indirect effect of a set of independent variables, on the dependant variable. Path analysis unravels whether the association of yield attribute with yield is due to their direct effect on yield, or it is a consequence of their indirect effect via some other attribute. If the correlation between yield and a character is due to the direct effect of the character, it reflects the true relation between them and selection can be practiced for such a character in order to improve yield. But if correlation is mainly due to indirect effect of the character through another component character, the breeder has to select latter character through which the indirect effect is exerted. (Singh, 2009)

The path coefficient analysis revealed that very high positive direct effect on yield was contributed by panicle weight and panicle length. The positive direct effect of straw yield on grain yield was moderate. Incidentally, these attributes had recorded high significant positive correlation with grain yield. This pointed out that selection based on panicle weight and length followed by straw yield may lead to increased yield under upland condition. Studies of Suresh *et al.* (2014) also confirmed the positive direct effects of panicle length on grain yield. However, in contrast to the findings of the study, they found that panicle weight registered a negative indirect effect on grain yield.

Number of productive tillers per plant exhibited moderate positive direct effect on yield although it had registered no significant correlation with yield. It had also exhibited low negative indirect effect on yield via panicle weight and length. As these attributes had exercised high positive direct effect as well as high significant positive correlation on yield, it would be beneficial to lay emphasis on higher panicle weight and length may rather than on productive tillers per plant lead to realise higher grain yield genotypes . The moderate positive direct effect on yield of productive tillers per plant was made possible through the negligible positive indirect effects via days to fifty per cent flowering, spikelets per panicle, dry weight of shoot and straw yield per plant. Of these days to fifty per cent flowering had registered a negative correlation with yield while spikelets per panicle exerted no significant correlation with yield.

It is observed that days to fifty per cent flowering in addition to exhibiting high significant negatively correlation had also exerted a negative direct effect on yield. This proves beyond doubt that selection for earliness in flowering would be beneficial to obtain higher yield in uplands. The indirect effect of this attribute through panicle weight was also very high and negative as found in the study conducted by Suresh *et al.* (2014).

The direct effect of CSI on yield genotypes were negative but low, as it exerted negligible to moderate negative effect through spikelets per panicle, grains per panicle and plant height and more because it exerted very high positive indirect effect through panicle weight and moderate effect through panicle length. Considering that high CSI indicates tolerance to moisture stress, under such circumstances, judicious selection programme might be formulated for simultaneous improvement of such important developmental and component attribute.

The indirect effect of most attributes on grain yield through plant height was negative and very high. However, plant height had exhibited very high positive correlation with grain yield. Such positive correlation of plant height with yield was made also possible again through the very high to high positive indirect of panicle weight and length. This once again emphasised the importance of selection based on panicle weight and length in improving yield of rice genotypes genotypes . As in the present study, Rangare *et al.* (2012) found that days to fifty per cent flowering exerted a positive indirect effect through plant height while its effects through productive tillers, spikelets per panicle was negative. Padmaja *et al.* (2011) had reported negative indirect effect of plant height as found in this study.

The above results point to the importance of higher panicle weight and length, dry weight of shoot and straw yield per plant as reliable indicators of obtaining higher yields genotypes. It was also evident that a higher plant stature does not always indicate higher grain yield potential. Early flowering genotypes may be preferred over late flowering ones, for cultivation genotypes. Early flowering was found to be advantageous genotypes since plants can escape from late season drought and avoid spikelet sterility (Lafitte and Courtois, 2002).

5.2 Experiment II: Characterisation of rice genotypes for drought tolerance

5.2.1 Experiment II (A): Rapid evaluation test for drought tolerance

The present study was undertaken to elucidate the response of twenty one rice genotypes during germination and early seedling stage to moisture stress (water potentials at -8 bars) simulated using Polyethylene glycol (PEG – 6000) and non stressed control (water potentials 0 bars) (Plate 3). The outcome on the study is described below.

5.2.1.1 Analysis of variance for seedling traits under moisture stress (-8 bars)

The analysis of variance for the traits studied under PEG 6000 simulated moisture stress and non stressed control in hydroponics, indicated presence of wide variability between genotypes with respect speed of germination, shoot length, root length, shoot to root length ratio, seedling vigour index and biomass of seedlings. Differential response of seedling characteristics under water stress conditions is known to be associated with drought resistance in rice (Akkareddy, 2011).

5.2.1.2 Mean performance of rice genotypes for seedling traits under moisture stress (-8 bars)

PEG of higher molecular weight is a non penetrating inert osmoticum lowering the water potential of nutrient solutions without being taken up or being phototoxic (Lawlor, 1970). This approach has been used to simulate drought stress in plants and selection of tolerant genotypes in rice by many workers. Screening with aqueous solutions of poly ethylene glycol- 6000 (Gampala *et al.*, 2015; Lum *et al.*, 2014; Swain *et al.*, 2014; Nagaraju *et a*l., 2014; Anaytullah *et al.*, 2008; Vikas *et al.*, 2009; Lu *et al.*, 2009; Ding *et al.*, 2013) aided the identification of cultivars having higher levels of tolerance to drought in rice by assessing the seedling characters like speed of germination, shoot length, root length, shoot to root length ratio, seedling vigour and seedling biomass. As reported by earlier workers, germination and the seedling traits was found to decrease under moisture stress in comparison to control (Table 49)

Parambankayama followed by Nerica and Thottacheera recorded higher speed of germination under -8 bars water potential. Of the eight high yielding varieties (HYV's) all except PTB 60 and PTB 43 ranked low for this trait. Incidentally PTB 60 (Vaishak) and PTB 43 (Swarnaprabha) are the two high yielding varieties recommended for uplands of Kerala.

Prambankayama (14.90 cm) and Karuthadukkan (13.95 cm) followed by Thotacheera (12.00 cm) and Karuthamodan (11.93 cm) registered high shoot length while TRV's Chettiviruppu (5.00 cm) Chomala (5.99 cm) and HYV Onam (6.85 cm) and Mo 15 (6.99 cm) possessed shorter shoot length.

Parambuvattan with 12.00 cm had the highest root length followed by Karuthamoadan (11.63 cm) while PTB 43 (5.51cm) recorded the least. According to Nguyen *et al.* (1997), upland rice genotypes usually have deep and thick root systems, which allow the crop to satisfy its water requirement.

Table 49: Per cent change in seedling traits over control under moisture stress

Genotypes	Speed of germination	Shoot length (cm)	Root length (cm)	Seedling vigour index	Shoot to root length ratio	Total biomass (g)
Parambuvattan	-74.13	-56.12	-14.89	-71.34	-48.13	-20.00
Karuthamodan	-76.45	-55.93	-18.61	-73.90	-45.50	-17.39
Karanavara	-76.66	-65.61	-25.93	-77.51	-53.32	-20.00
Kalladiaryan	-78.95	-60.00	-29.74	-77.69	-43.00	-17.39
Mo 15	-81.67	-60.06	-48.39	-85.54	-22.52	-23.81
Thottacheera	-67.76	-61.90	-19.40	-81.22	-52.76	-8.70
Karathadukkan	-77.41	-54.26	-43.62	-77.65	-18.55	-24.00
Chomala	-71.64	-61.35	-7.31	-78.13	-58.72	-35.71
PTB 43	-76.31	-74.52	-43.72	-87.01	-54.51	-13.64
PTB 39	-86.72	-65.37	-26.19	-84.87	-52.94	-17.39
PTB 50	-79.90	-50.92	-39.57	-87.75	-18.95	-18.18
PTB 52	-85.31	-55.81	-40.00	-85.80	-26.40	-17.39
PTB 60	-66.46	-48.89	-39.23	-76.99	-15.61	-25.93
Arimodan	-66.81	-63.66	-30.30	-78.81	-47.94	-27.59
Onam	-74.43	-64.87	-36.67	-89.21	-44.00	-35.48
Parambankayama	-68.04	-55.38	-46.21	-75.60	-17.15	-27.27
PTB 55	-82.01	-57.35	-22.22	-87.47	-44.97	-26.09
PTB 28	-78.50	-58.87	-24.00	-79.12	-45.92	-58.33
Chettiviruppu	-81.05	-70.59	-36.05	-89.75	-53.54	-36.84
Good day	-83.60	-62.19	-43.48	-85.23	-32.80	-32.26
Nerica	-75.59	-60.49	-23.91	-82.45	-47.90	-35.48
Mean	-76.64	-60.20	-31.40	-81.57	-40.24	-25.66

Since higher root length is considered advantageous in foraging for water under moisture stress, a lower shoot to root ratio is considered advantageous. Considering this fact, Chomala (0.84) followed by Parambuvattan, Karanavara, PTB 39, Onam, PTB 28, Chettiviruppu and Nerica ranked higher than other genotypes. However, no correspondence between shoot to root length ratio and speed of germination was observed. This may be because in most genotypes with the low shoot to root length ratio and high speed of germination, thee shoot length and root length were approximately in 1:1 proportion.

Parambuvattan followed by Parambankayama exhibited higher seedling vigour while Chettiviruppu exhibited least vigour. Most HYVs except PTB 60, recorded low seedling vigour compared to traditional variety. Seedling vigour index is a measure of the performance of seed lot. Higher seedling vigour is considered advantageous to overcome any stress imposed during the germination and initial growth. Swamy and Reddy (1998) and Fukai and Kamoshita (2004) opined that seedling vigor is often related to quicker development of the deep-root system before drought development, which accelerates water extraction and maintains growth during intermittent drought.

Parambankayama (0.024 g) followed by Good day, Arimodan and Thottacheera ranked the highest with respect to biomass while, Chomala (0.009 g) and PTB 28 (0.001 g) ranked low. Deka (2000) opined that root and shoot dry weight decreased significantly under moisture stress.

The genotypes were ranked (Table 50) according to the method described by Arunachalum and Bandyopadhyay (1984), for making decisions jointly on a number of dependent characters, considering that higher speed of germination, shoot and root length, seedling vigour index and biomass under moisture stress is indicative of the capacity of genotypes to combat moisture stress, genotype Parambuvattan followed by Arimodan were found to be the most promising. Others promising genotypes were Karuthamodan, Karanavara, Parambankayama, Kalladiaryan, Thottacheera, PTB 60, Nerica and Karuthadukkan.

Table 50. Ranking of genotypes based on performance in Experiment 2 (A)

Genotypes	Speed of germination	Shoot length (cm)	Root length (cm)	Shoot to root length ratio	Seedling vigour index	Total biomass (g)	Total score	Rank (Expt. 2(A))
	Rank							
Parambuvattan	3	5	1	2	1	3	15	1
Karuthamodan	3	2	2	4	4	4	19	3
Karanavara	3	6	3	2	3	3	20	4
Kalladiaryan	5	4	4	5	5	4	27	6
Mo 15	8	14	14	6	13	6	61	20
Thottacheera	2	2	6	9	7	2	28	7
Karathadukkan	3	1	9	11	5	4	33	10
Chomala	7	16	10	1	13	8	55	18
PTB 43	3	11	16	10	10	4	54	17
PTB 39	10	13	8	2	11	4	48	12
PTB 50	6	8	10	7	14	4	49	13
PTB 52	10	7	12	8	12	4	53	16
PTB 60	1	3	7	9	6	3	29	8
Arimodan	4	3	2	3	4	2	18	2
Onam	9	15	9	2	14	3	52	15
Parambankayama	1	1	8	11	2	1	24	5
PTB 55	12	12	11	4	14	5	58	19
PTB 28	4	12	9	2	8	8	43	11
Chettiviruppu	11	17	15	2	15	7	67	21
Good day	8	9	13	7	12	2	51	14
Nerica	2	10	5	2	9	3	31	9

The soil moisture tension in rice fields under drought stress is reported to reach as low as 80 kPa (-0.8 bars). Experiments have proved that, in the lowland field, by ten days after draining off of water, soil moisture tension was reported to reach 30 kPa (-0.3 bars) at 15 cm depth, which is below field capacity. By 15 days after draining, the free water level dropped to 70 cm below the soil surface, and remained at or below that level for the remainder of the season (Cruz *et al.*, 1986; Tuong *et al.*, 2002). Relationships between soil and plant water potentials and the dynamics of stress development under drought in upland rice grown during the dry season have been studied. Evaluation of genotypes at a soil moisture tension of 70 kPa (-0.7 bars) at 15 cm depth and 50 kPa (-0.5 bars) at 30 cm depth have been reported to help delineate genotypes tolerant to moisture stress (Turner *et al.*, 1986). The superior performance of genotypes Parambuvattan followed by Arimodan, Karuthamodan, Karanavara, Parambankayama, Kalladiaryan, Thottacheera, PTB 60, Nerica and Karuthadukkan under moisture stress (-8 bars), thus, indicate their potential of these genotypes to combat moisture stress that may occur in uplands during early seedling growth.

5.2.2 Experiment II (B): Characterisation of rice genotypes for drought tolerance under controlled moisture regimes

A set of ten rice genotypes were evaluated for their response to moisture stress at various growth stages *viz.*, seedling (15 DAS), vegetative (35 DAS) and reproductive phase (50 DAS), under controlled moisture regimes along with non stressed control (fully irrigated control). The ten promising genotypes were identified on the basis of their performance in Experiment I and Experiment II (A). The ranks obtained by individual genotypes in each experiment [Experiment I and Experiment II (A)] were considered to arrive at the final score (Table 51). Parambankayama, Karanavara, Karuthamodan, Parambuvattan, Arimodan, Kalladiyarn, PTB 60, Nerica, PTB 28 and Karuthadukkan comprised the ten promising genotypes (Plate 4, 5 avariablynd 6) selected based on this approach.

Table 51. Ranking genotypes based on performance in Experiment 1 and Experiment 2 (A)

Genotypes	A: Rank Experiment 1	B: Rank Experiment 2 (A)	Total score (A +B)	Final rank	Genotypes selected for Experiment 2(B)
Parambuvattan	7	1	8	2	1
Karuthamodan	5	3	8	2	2
Karanavara	2	4	6	1	3
Kalladiaryan	6	6	12	4	4
Mo 15	13	20	33	12	
Thottacheera	11	7	18	7	
Karathadukkan	8	10	18	7	5
Chomala	14	18	32	11	
PTB 43	15	17	32	11	
PTB 39	20	12	32	11	
PTB 50	16	13	29	10	
PTB 52	18	16	34	13	
PTB 60	5	8	13	5	6
Arimodan	9	2	11	3	7
Onam	12	15	27	9	
Parambankayama	1	5	6	1	8
PTB 55	17	19	36	14	
PTB 28	3	11	14	6	9
Chettiviruppu	19	21	40	15	
Good day	10	14	24	8	
Nerica	4	9	13	5	10

The above genotypes invariably represented the best 10 genotypes both under Experiment I (field evaluation) and Experiment II A (managed stress).

5.2.2.1 Elucidating the response of rice genotypes to moisture stress imposed at seedling stage (15 DAS)

5.2.2.1.1 Analysis of variance

The analysis of variance for the traits studied at seedling stage (15 DAS) prior to imposition of moisture stress, during the moisture stress period and after relief of moisture stress revealed occurrence of wide variability among genotypes. However, genotypes did not differ with respect to the leaf drying score and days to leaf rolling during imposition of moisture stress.The analysis of variance for the traits observed in the corresponding non-stressed control (fully irrigated control) also indicated presence of wide variability among the genotypes.

5.2.2.1.1 Performance of rice genotypes at seedling stage (15 DAS) prior to imposition of moisture stress

Among ten promising genotypes, prior to imposition of moisture stress, PTB 60 recorded high shoot length, root length and seedling vigour index. The least values for these traits were observed in PTB 28. With respect to dry shoot weight Karanavara registered the highest value followed by PTB 60 and Arimodan. Nerica had recorded the highest dry root weight, root volume, shoot to root length rato and chlorophyll content. Arimodan, Karuthadukkan, and Kalladiaryan were found to be on par with Nerica with respect to chlorophyll content. Based on the above, it can be concluded that Nerica followed by and PTB 60 and Karanavara proved to be the best genotypes before imposition of stress at seedling stage.

5.2.2.1.2 Performance of rice genotypes during moisture stress, imposed at seedling stage (15 DAS)

On imposition of stress at seedling stage, Nerica followed by PTB 60 and Karuthadukkan registered the least leaf drying score. Nerica followed by PTB 60 had also registered the highest number of days to leaf rolling. Leaf tip drying and leaf rolling are a consequence of turgor loss of the plants (Zinolabedin *et al.*, 2008). Plants roll their leaves to maintain a favourable internal water status under drought. So, genotypes with lower leaf drying score and more days to leaf rolling are advantageous.

Karuthadukkan followed by Karuthamodan and Karanavara recorded the highest RWC per cent. PTB 28 and Kalladiaryan had recorded highest chlorophyll content during stress period while other genotypes except Parambankayama were found to be on par with each other and next best the genotypes mentioned above. Decrease in RWC is due to loss of turgidity, which leads to stomatal closure and reduced photosynthetic rates (Lv *et al.*, 2007). Therefore maintenance of a relatively high RWC during drought stress is an indicative of drought tolerance (Altinkut *et al.*, 2001).

With respect to proline content, Nerica PTB 60, Karuthadukkan, Parambankayama and Karanavara were found be on par with each other while least proline content was observed in Parambuvattan followed by Kalladiaryan. Proline is one of the important osmolytes which accumulates during moisture stress. It helps to maintain turgor and promotes continued growth in low water potential soils (Mullet and Whitsitt, 1996).

In general, it was observed that RWC and Chlorophyll content decreased during stress period while proline content increased irrespective of genotypes. Cham-um *et al.* (2010) observed reduction in relative water content, chlorophyll content and increase in proline content under reduced soil moisture condition. From the above, it can be inferred that when moisture stress prevailed at seedling stage, Nerica performed best followed by PTB 60 and Karanavara. These genotypes had also ranked best prior to imposition of moisture stress.

5.2.2.1.3 Performance of rice genotypes on relief of moisture stress imposed at seedling stage (15 DAS)

In general, it was observed that even after relief of moisture stress that occurred at seedling stage, productive tillers, panicle length, panicle weight, spikelets per panicle, grains per panicle, flag leaf area, 1000 garin weight, plant height, dry weight of shoot, root volume, dry weight of root, grain yield and straw yield per plant drastically reduced in comparison to the fully irrigated control.

The study revealed that, there was an increase in days to fifty per cent flowering and harvest index in the population exposed to moisture stress at seedling stage. This may be because the decrease in straw yield was very high compared to the decrease in grain yield on imposition of stress during seedling stage.

In general, flowering was delayed by two to ten days when moisture stress was imposed at seedling stage. The delay was least in Parambuvattan (2 days) while it was for 3 days in PTB 60 and PTB 28. The delay was highest in Kalladiaryan (10 days).

PTB 60 ranked first with respect to productive tillers, panicle length, grains per panicle, spikelets per panicle, flag leaf area, dry weight of shoot, root dry weight, root volume, grain yield per plant and straw yield per plant. It ranked second for all other traits except 1000 grain weight when subjected to moisture stress at seedling stage. Similarly, Karanavara which was found to be on par with PTB 60 with respect to grain yield under stress was also found to rank high with respect to number of productive tillers, grains per panicle, spikelets per panicle, plant height, dry weight of shoot root length, straw yield per plant and harvest index. PTB 28, Parambankayama, Nerica and Karuthadukkan were on par with each other with respect to grain yield under stress and ranked third after Karanavara.

Considering the performance of genotypes under fully irrigated control it was found that PTB 60 ranked first. Karanavara and Parambankayama and PTB 28 were on par with PTB 60 with respect to grain yield.

At maturity, among the genotypes exposed to moisture stress imposed at seedling stage, it can be concluded that PTB 60, followed by Karanavara, Nerica and Parambankayama ranked superior.

5.2.2.2 Elucidating the response of rice genotypes to moisture stress imposed at vegetative stage (35 DAS)

5.2.2.2.1 Analysis of variance

The analysis of variance for the traits studied at vegetative stage (35 DAS) prior to imposition of moisture stress, during the moisture stress period and after relief of moisture stress revealed occurrence of wide variability among genotypes. However, genotypes did not differ with respect to the leaf drying score and days to leaf rolling during imposition of moisture stress.The analysis of variance for the traits observed in the corresponding non-stressed control (fully irrigated control) also indicated presence of wide variability among the genotypes.

5.2.2.2.2 Performance of rice genotypes at vegetative stage (35 DAS), prior to imposition of moisture stress

Prior to imposition of moisture stress at vegetative stage, it was observed that Karanavara recorded the highest shoot length, dry weight of shoot, and seedling vigour index. It had also registered long roots (38.00 cm) next to Karuthamodan (39.00 cm). Karuthamodan registered high shoot to root ratio and the chlorophyll content.

Based on the performance of genotypes before imposition of stress at vegetative stage, it can be summarised that Karuthamodan followed by

Karanavara and Parambankayama were more promising than the other genotypes.

5.2.2.2.3 Performance of rice genotypes during moisture stress imposed at vegetative stage (35 DAS)

In general, it was observed that irrespective of genotypes relative water content and chlorophyll content decreased during the stress period while there was an increase in proline content. The results of the present investigation were in agreement with findings of Deka (2000) and Kumar *et al.* (2014).

On imposition of stress during vegetative stage (35 DAS), Nerica (1.00) followed by PTB 60 (1.67) and Karuthadukkan (2.33) had recorded the least leaf drying score and were found to be on par with each other, indicating the ability of these genotypes to tolerate moisture stress better. This trend was also reflected in their days to leaf rolling as well as proline content. Allah *et al.* (2010) found that, the best genotypes under drought conditions, possessed good drought score (1-3).

Nerica (30.33 days) had also registered the highest days to leaf rolling as well as proline content (260.89 μg/g) on imposition of stress. PTB 60 (28.33 days) was on par with Nerica with respect to days to leaf rolling on imposition of stress but next to Nerica in proline content (191.78 μg/g). It was observed that the proline content in these genotypes were high both under stress and fully irrigated control. Leaf rolling and leaf drying can reflect the internal plant water status under water stress, and these traits can be considered as integrative traits to identify drought resistant genotypes (Jongdee *et al.*, 2002). Under water-deficit stress conditions, proteins degrade and consequently the proline content increases faster than other amino acids in plants. Thus, proline accumulation can be used as a criterion for drought stress tolerance in plants (Shao *et al.*, 2005). Increasing of free proline under moistures stress was also reported by Kumar *et al.*, 2014.

Karuthadukkan (75.52 %) and Karuthamodan (74.45 %) had registered the high relative water content as well chlorophyll content (4.38 and 4.37 mg/g respectively). However, this trend was not reflected in their leaf drying score and days to leaf rolling on imposition of stress. PTB 60 (73.61%) was found to be second best with respect to relative water content (RWC %). Mahender *et al.* (2014) recorded more than 75 per cent of RWC for drought tolerant genotypes where as susceptible genotypes have recorded in the range of 40 per cent, at vegetative stage.

In the fully irrigated control (non-stressed population), PTB 28 registered the highest relative water content and was found to be on par with PTB 60, Karuthamodan and Kalladiaryan. As for chlorophyll content, Kalladiaryan recorded the highest value (4.57 mg/g) and was found to be on par with Kruthadukkan (4.52 mg/g). However, these genotypes ranked the lowest with respect to proline content in the absence of moisture stress.

Considering the above, it may be inferred that at vegetative stage, the performance of genotypes Nerica and PTB 60 was promising both during moisture stress and non-stressed condition. In addition to the above, under non stressed condition PTB 28, Kalladiaryan and Karuthadukkan also performed better.

5.2.2.2.4 Performance of rice genotypes on relief of moisture stress imposed at vegetative stage (35 DAS)

As in the population subjected to moisture stress at seedling stage, in general, a reduction in number of productive tillers per plant, panicle length and weight, spikeltes and grain per panicle, flag leaf area, 1000 grain weight, plant height, dry weight of shoot and root, and volume, grain and straw yield per plant was observed in comparison to the fully irrigated (non-stressed) control.

Unlike in seedling stage, root length increased in the genotypes stressed at vegetative stage. Increase in root length was reported by Puckridge and O'Toole (1981) and Yoshida and Hasegawa (1982), under moisture stress. Deep root system helped quicker than others traits in accelerating water extraction and maintaining growth during intermittent drought (Fukai and Kamoshita, 2004).

In contrast to the trend observed during imposition of moisture stress at seedling stage, in the genotypes exposed to moisture stress at vegetative stage, there was a decrease in harvest index except for Karanavara and Arimodan. It was observed that the decrease in grain yield in these two genotypes was lower compared to the decrease in straw yield unlike that observed in the other genotypes leading to a higher harvest index. Decrease in harvest index was also noticed by Sarvestani *et al.* (2008) on imposition of moisture stress.

Similar to reaction of genotypes to moisture stress at seedling stage, moisture stress at vegetative stage also delayed flowering. Irrespective of the genotype, flowering there was greater delay in flowering when genotypes were exposed to moisture stress at vegetative stage compared to seedling stage. In general, flowering was delayed by 4 to 13 days. As at seedling stage stress, the delay in flowering was the least in Parambuvattan (4 days) while delay was by five days in PTB 60 and six days each in Nerica, Parambankayama, PTB 28 and Karuthadukkan. The delay in flowering was the highest in Kalladiaryan (13 days). Lafitte *et al.*, 2003 had also observed a delay in flowering date in rice, when it experiences water deficit before flowering.

Among the genotypes exposed to moisture at vegetative stage, PTB 60 ranked the highest with respect to panicle length, spikelets per panicle, flag leaf area, dry weight of shoot and root, root volume, grain and straw yield per plant. Karanavara, Parambankayama and Karuthadukkan had registered high root length and invariably ranked high with respect to productive tillers per plant, 1000 grain weight, root volume, grains and straw yield per plant and harvest index when subjected to moisture stress at vegetative stage.

In the fully irrigated control, PTB 60 was found to perform better. Karanavara, Parambankayama and Karuthadukkan were also found promising as observed when moisture stress was imposed at seedling stage.

It can be concluded that although PTB 60 did not rank high before imposition of moisture stress at vegetative stage, it proved to be the best genotype in combating moisture stress at vegetative stage by producing the highest grain yield per plant. It also proved to be the highest yielding genotype under fully irrigated control. Other promising entries on exposure to moisture stress at vegetative stage were Karanavara, Parambankayama, Karuthadukkan and Nerica.

5.2.2.3 Elucidating the response of rice genotypes to moisture stress imposed at reproductive stage (50 DAS)

5.2.2.3.1 Analysis of variance

The analysis of variance for the traits studied at reproductive stage (50 DAS), prior to imposition of moisture stress, during the moisture stress period and after relief of moisture stress revealed occurrence of wide variability among genotypes. However, genotypes did not differ with respect to the leaf drying score and days to leaf rolling during imposition of moisture stress.The analysis of variance for the traits observed in the corresponding non-stressed control (fully irrigated control) also indicated presence of wide variability among the genotyped.

5.2.2.3.2 Performance of rice genotypes at reproductive stage (50 DAS) prior to imposition of moisture stress

As observed at vegetative stage, prior to imposition of moisture stress at reproductive stage (50 DAS), Karanavara recorded the highest shoot length, dry weight of shoot, and seedling vigour index. It had also registered long roots (43.00 cm) next to Nerica (47.33 cm) and Karuthadukkan (46.67 cm). Karanavara (48.67 ml) had also recorded high root volume next to PTB 60 (54.67 ml).

Apart from being on par with Karanavara with respect to shoot length, PTB 60 had registered the highest dry weight of root, seedling vigour and root volume.

Based on the performance of genotypes before imposition of stress at reproductive stage, it can be summarised that PTB 60 and Karanavara and were more promising than the other genotypes.

5.2.2.3.3 Performance of rice genotypes during moisture stress imposed at reproductive stage (50 DAS)

As observed during imposition of moisture stress at seedling stage and vegetative stage, during exposure to moisture stress at reproductive stage too, irrespective of genotypes relative water content and chlorophyll content decreased while an increase in proline content was evident.

On imposition of stress during reproductive stage (50 DAS), Nerica (1.00) recorded the least leaf drying score. PTB 60 (1.67) and Karuthadukkan (1.67) were on par with each and found to be the least affected by moisture stress after Nerica.

Nerica (21.67 days) had also registered the highest days to leaf rolling, RWC (72.20 %) as well as proline content (297.67 µg/g) on imposition of stress. PTB 60 (19.33 days) was next best to Nerica with respect to days to leaf rolling and RWC (69.53 %) on imposition of stress. PTB 60 was also found to be on par with Nerica in proline content (277.33 µg/g). However, these genotypes did not possess high chlorophyll content.

In the fully irrigated control (non-stressed population), Nerica registered the highest relative water content and proline content followed by PTB 28 and Arimodan. As for chlorophyll content, Parambuvattan had registered the highest value (4.47 mg/g) while, PTB 28 and Karuthamodan which were on par with each other for this trait ranked the next best.

Considering the above, it may be inferred, while Nerica and PTB 60 proved to perform better during imposition of stress at reproductive stage (50 DAS), PTB 28, Arimodan and Nerica performed better in the absence of moisture stress in the corresponding period.

5.2.2.3.4 Performance of rice genotypes on relief of moisture stress imposed at reproductive stage (50 DAS)

As in the population subjected to moisture stress at seedling and vegetative stages, a reduction in number of productive tillers per plant, panicle length and weight, spikelets and grains per panicle, flag leaf area, 1000-grain weight, plant height, dry weight of shoot and root, root volume, grain and straw yield per plant and harvest index was observed in comparison to the fully irrigated (non-stressed) control. Reproductive stage stress resulted in drastic reduction in number of spikelets and grains per panicle, grain yield per plant and harvest index while the reduction was comparatively low with respect to other traits unlike in other stages of moisture stress. Terminal dry spell imposed at flowering stage was found to be more severe to reduce the crop yield as compared to dry spell given at vegetative stage (Kumar *et al.*, 2006 and Sarvestani *et al.*, 2008).

In contrast to the increase in harvest index on imposition of moisture stress at seedling stage, there was a sharp decline in the attribute under stress during reproductive stage. This may be due to a high decrease in grain yield compared to the decrease in straw yield at reproductive stage. Similar to the findings of the study, Sarvestani *et al.* (2008) had also reported reduction in harvest index in all cultivars under water stress.

It was also observed that root length tended to increase on imposition of moisture stress at reproductive stage unlike in other stages. The ability of rice genotype to modify its root distribution to explore water present at deeper soil layer looks as a promising approach for drought resistance. Under drought stress, it would help in achieving more efficient use of rainwater in order to maintain better plant growth. Several authors also reported that under drought stress deep rooted cultivars had tendency to penetrate deeper soil layer to extract more water for its survival and growth (Puckridge and O'Toole 1981; Yoshida and Hasegawa, 1982).

Although there occurred a delay in flowering on imposition of stress at reproductive stage, the delay was lower compared to that observed during other stages. Delay in flowering under drought is associated with an apparent delay in floral development. Results of the present investigation was in accordance with findings of Zou *et al.* (2007); Kumar, (2014) ; Pantuwan *et al.* (2002) and Asch (2005). The delay was found to be almost nil in case of Karanavara while it was by four days in case of Parambuvattan and Kalladiaryan. The delay in case of Parambankayama and Arimodan was only for a day while it was for two days in case of PTB 28, PTB 60, Karuthamodan and Krauthadukkan.

Among the genotypes exposed to moisture at reproductive stage, PTB 60 ranked the highest with respect to panicle length, spikelets per panicle, dry weight of shoot and root, root volume, grain (12.46 g) and straw yield per plant.

Karanavara that flowered earliest (69 days), was found to be on par with PTB 60 and also ranked high with respect to productive tillers, panicle length, flag leaf area, 1000 grain weight, plant height, dry weight of shoot and root, root length and volume and straw yield but not garin yield (9.71 g). With respect to grain yield, it was found to be on par with Nerica (10.91 g). Nerica incidentally was found next best to PTB 60 in grain yield.

When subjected to moisture stress at vegetative stage, Parambankayama was found to be on par with Karanavara for all the traits studied except for days to flowering, number of productive tillers per plant, panicle length and weight and plant height. Karuthadukkan was on par with Karanavara for most traits including grain yield per plant (9.85 g).

As described under 5.2.2.1.4, in the fully irrigated control, PTB 60, Karanavara, Parambankayama and Karuthadukkan were also found promising.

It can be concluded that although PTB 60 followed by Karanavara combated moisture stress imposed at reproductive stage (50 DAS) both before and after imposition of moisture stress. Other promising entries on exposure to moisture stress at reproductive stage were Parambankayama and Karuthadukkan and Nerica. These genotypes had also ranked high under the fully irrigated control at maturity.

5.2.2.4 Evaluation of growth traits in response to timing of moisture stress

On comparison of response of rice genotypes to moisture stress imposed at various growth stages, it was evident that there was reduction in the estimates of most of the traits recorded during exposure to moisture stress as well as after the relief of moisture stress imposed at various growth stages. However, days to fifty per cent flowering (Figure 7) and proline content had registered a decreasing trend.

Root length was found to increase on imposition of moistures stress at vegetative and reproductive stage only. In addition, harvest index had exhibited an increase on exposure to moisture stress at seedling stage only.

The magnitude of change in various traits studied varied with timing of moisture stress. It was observed that the growth traits like number of productive tillers, plant height, dry weight of root and shoot, root volume and straw yield was affected to a greater extent when moisture stress occurred at seedling stage than at at reproductive stage.

The magnitude of reduction in panicle length and panicle weight and flag leaf area was almost similar when moisture seedling and vegetative stage but it was also higher than that observed at reproductive stage. Delay in flowering (Figure 7) was the highest when genotypes were exposed to moistures stress at vegetative stress followed by that in seedling stage. However, the delay was negligible on expose to stress at reproductive stage.

The magnitude of decrease in relative water content, chlorophyll content, spikelets and grains per panicle and spikelet fertility (Figure 8), grain yield per plant and harvest index (Figure 9) and 1000 grain weight, was high when moisture

Table 52.Per cent change in various traits over fully irrigated control based on the timing of moisture stress [Experiment II (B)]

Attribute	Mean performance				Change over control (%)		
	Seedling stage	Vegetative stage	Reproductive stage	Control	Seedling stage	Vegetative stage	Reproductive stage
During imposition of stress							
Leaf drying score	3.00	3.20	3.37				
Days to leaf rolling	27.53	24.77	16.00				
RWC (%)	71.56	71.82	66.38		**-17.34**	**-16.05**	**-21.12**
Chlorophyll content (mg/g)	4.04	4.19	3.94		**-4.49**	-4.56	**-5.06**
Proline content (µg/g)	105.33	173.38	244.73		**20.28**	**37.90**	**31.84**
After imposition of stress							
Days to fifty per cent flowering	79.87	82.23	76.33	74.33	**7.45**	**10.63**	2.69
Productive tillers per plant	9.9	10.23	11.12	12.32	**-19.64**	**-16.96**	**-9.74**
Panicle length (cm)	22.66	22.61	23.14	23.88	**-5.11**	**-5.32**	**-3.10**
Panicle weight (g)	2.35	2.36	2.43	2.7	**-12.96**	**-12.59**	**-10.00**
Grains per panicle	80.02	77.41	57.53	96.13	**-16.76**	**-19.47**	**-40.15**
Spikelets per panicle	97.84	97.14	89.73	113.9	**-14.10**	**-14.71**	**-21.22**
Flag leaf area (sq. cm)	38.27	39.75	46.78	52.41	**-26.98**	**-24.16**	**-10.74**
1000 grain weight (g)	27.32	25.86	24.01	27.38	**-0.22**	**-5.55**	**-12.31**
Plant height (cm)	105.44	115.13	121.95	129.71	**-18.71**	**-11.24**	**-5.98**
Dry weight of shoot (g)	15.38	17.25	19.02	21.78	**-29.38**	**-20.80**	**-12.67**
Dry weight of root (g)	3.32	3.95	4.16	5.04	**-34.13**	**-21.63**	**-17.46**
Rot length (cm)	51.19	66.1	78.2	62.23	**-17.74**	6.22	**25.66**
Root volume (ml)	37.43	45.97	48.48	57.13	**-34.48**	**-19.53**	**-15.14**
Grain yield per plant (g)	13.74	13.14	8.76	16.82	**-18.31**	**-21.88**	**-47.92**
Straw yield per plant (g)	29.87	32.87	36.72	40.58	**-26.39**	**-19.00**	**-9.51**
Harvest index	0.46	0.4	0.24	0.42	**9.52**	-4.76	**-42.86**

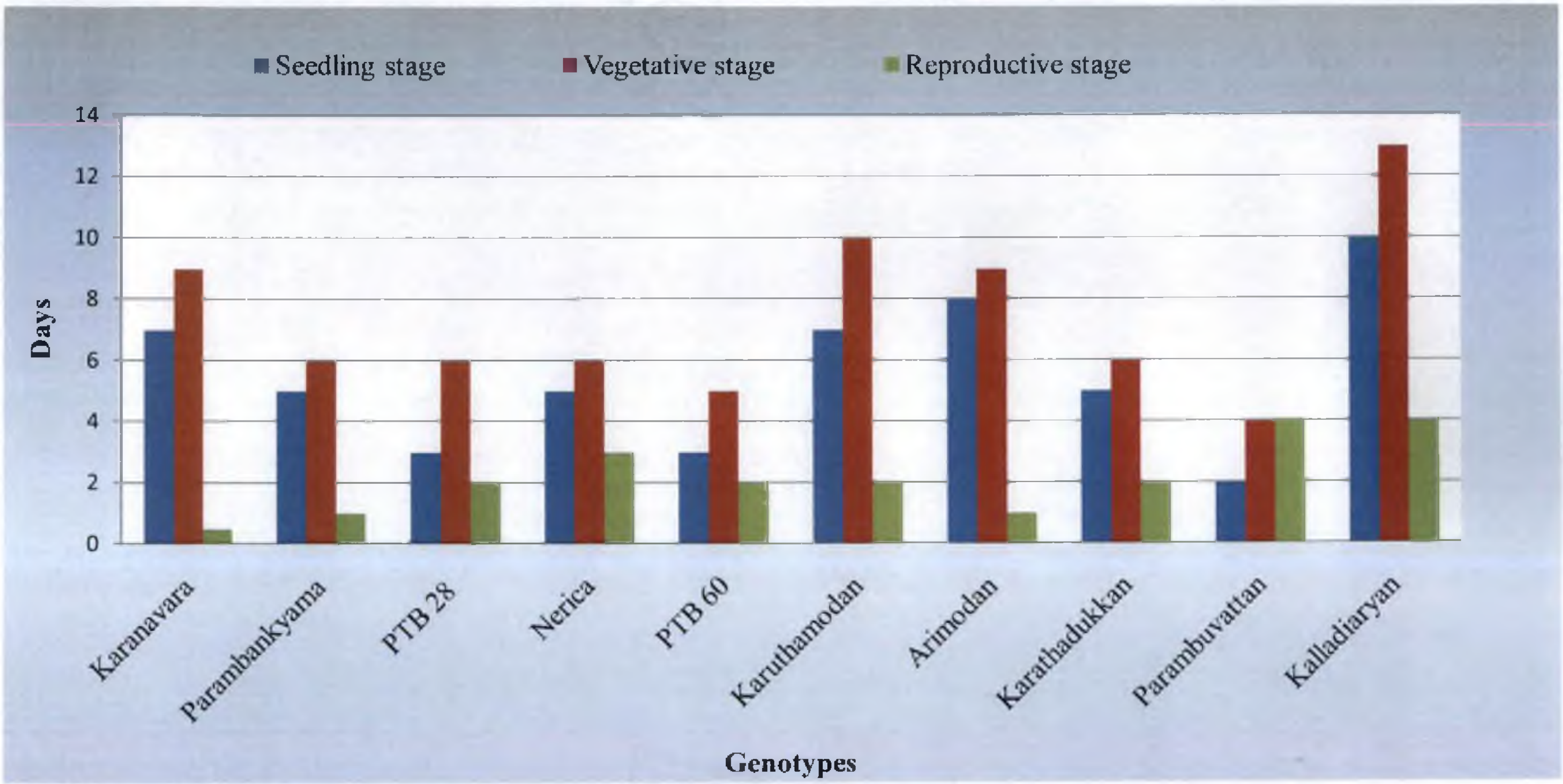

Figure 7: Delay in days to fifty per cent flowering in response to moisture stress at various growth stages

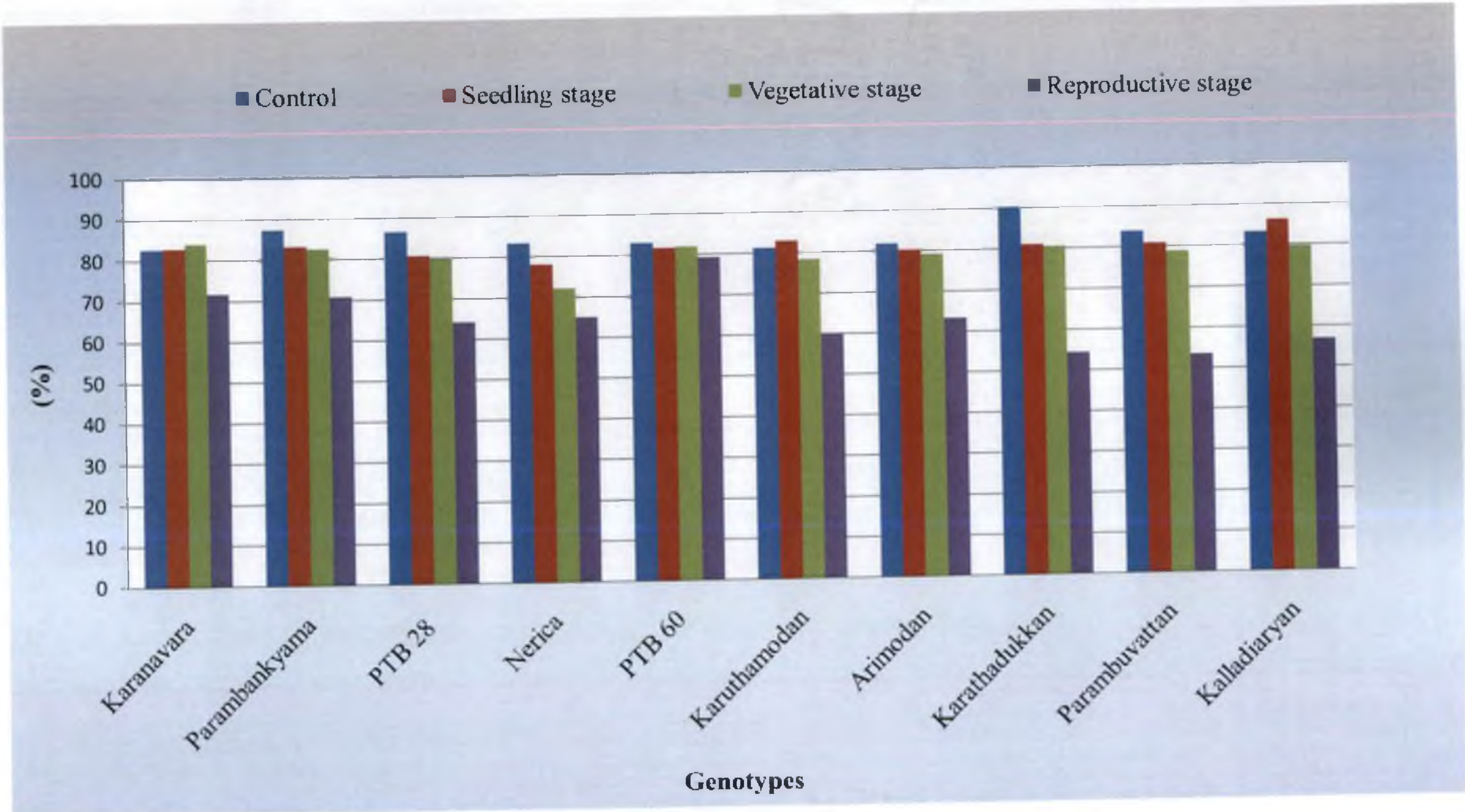

Figure 8: Spikelet fertility in response to moisture stress at various growth stages

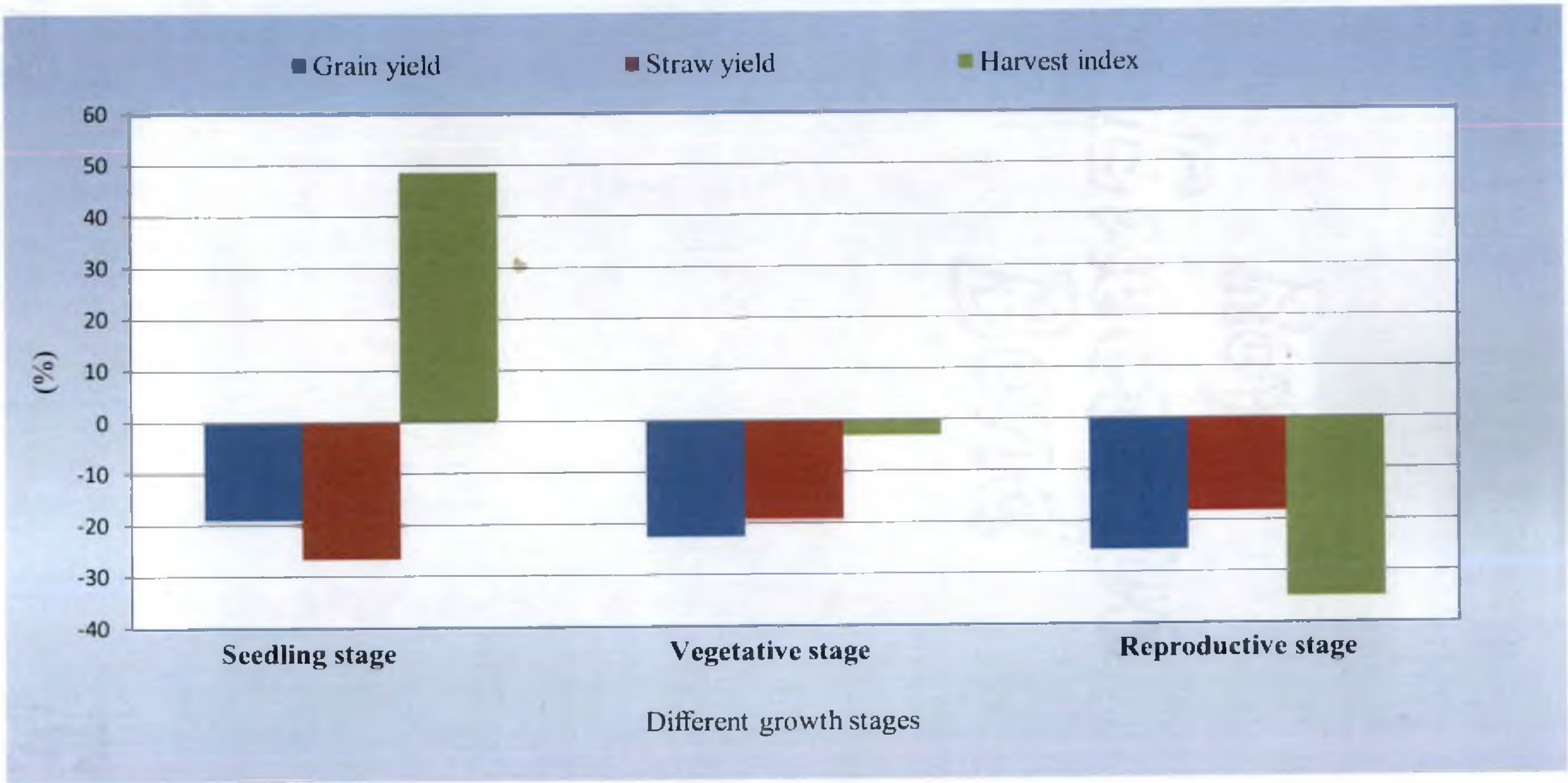

Figure 9: Per cent change in grain yield, straw yield and harvest index under moisture stress at various growth stages

stress was imposed at reproductive stage. The reduction observed in relative water content and chlorophyll content was near similar at seedling and vegetative stage.

Root length increased when plants were exposed to moisture at reproductive and vegetative stage but not at seedling stage while an increase in harvest index was observed only when exposed to moisture stress at seedling stage. However an increase in proline content occurred on exposure to stress at seedling, vegetative or reproductive stage, the increase being highest at vegetative stage followed by that at reproductive stage.

5.2.2.5 Performance evaluation of genotypes in response to timing of moisture stress

On evaluating the performance of the ten promising genotypes subjected to moisture stress at various growth stages (Table 53), it can be summarised that, prior to imposition of stress, at seedling stage genotypes PTB 60, Nerica, Karanavara, Karuthadukkan performed better. During the stress period, the Nerica, PTB 60, Karuthadukkan and Karanavara maintained their superior performance as observed before imposition of stress. At maturity, the PTB 60 followed by Karanavara, Nerica, Parambankayama, Karuthadukkan retained their superiority. Incidentally these genotypes were also found superior under fully irrigated control.

Karuthamodan, Karanavara and Parambankayama were found promising before being exposed to the moisture stress at vegetative stage. However, during imposition of stress, PTB 60 and Nerica were found more promising than other genotypes. At maturity among the genotypes exposed to moisture stress at vegetative stage, it was evident that PTB 60, Parambankayama, Karanavara, Karuthadukkan and Nerica. These genotypes were also found superior when exposed to moisture stress at seedling stage.

PTB 60 and Karanavara proved to be promising, prior to exposure to moisture stress at reproductive stage. During imposition of moisture stress, Nerica

Table 53. Ranking of genotypes based on their performance in Experiment II (B)

Genotypes	Prior to imposition of moisture stress			During imposition of moisture stress						After relief of moisture stress					
	Seedling stage (15 DAS)	Vegetative stage (35 DAS)	Reproductive stage (50 DAS)	Seedling stage (15 DAS)		Vegetative stage (35 DAS)		Reproductive stage (50 DAS)		Seedling stage (15 DAS)		Vegetative stage (35 DAS)		Reproductive stage (50 DAS)	
				S	C	S	C	S	C	S	C	S	C	S	C
Karanavara	2	2	2	3	6	6	7	5	5	2	2	2	2	2	2
Parambankyama	6	3	9	4	7	4	3	2	6	4	3	2	3	3	3
PTB 28	7	9	10	4	1	7	2	4	1	7	8	5	8	8	8
Nerica	1	4	4	1	2	2	1	1	3	3	5	4	5	5	5
PTB 60	2	5	1	2	3	3	3	3	6	1	1	1	1	1	1
Karuthamodan	6	1	7	5	5	5	7	8	4	6	7	7	7	6	7
Arimodan	4	6	3	6	8	8	6	7	2	7	10	8	10	9	10
Karathadukkan	6	5	5	2	6	1	4	6	7	5	4	3	4	4	4
Parambuvattan	8	8	6	8	9	9	5	8	3	8	9	9	9	10	9
Kalladiaryan	5	7	8	7	4	10	3	5	6	8	6	6	6	7	6

S: Stressed population; C: Fully irrigated control and PTB 60 proved promising. At maturity it was evident that PTB 60 followed by Karanavara, Parambankayama, Karuthadukkan and Nerica were superior to other genotypes. These genotypes had also performed better under fully irrigated control.

PTB 60 followed by Karanavara invariably ranked the highest when exposed to moisture stress at different growth stages (seedling stage, vegetative stage or reproductive stage). Other promising genotypes were Parambankayama and Nerica.

FUTURE LINE OF WORK

Land and water being critical inputs in agriculture a just use of these resources is needed to sustain agriculture in the future. Water scarcity is a looming danger that threatens production and productivity of crops. Being a consumer state, Kerala depends on its neighbours to satisfy its rice requirement. Hence, it is imperative to boost the rice production in Kerala to meet the increasing demand for rice by the growing population. Improving tolerance to moisture stress or drought stress is a viable alternative to increase rice production under water limiting conditions in Kerala. Therefore, an attempt was made to elucidate the response of rice genotypes recommended for upland cultivation to moisture stress, imposed at different growth stages. In future, efforts need to be directed in the following aspects:

1. The promising genotypes identified in the study can be utilised in breeding programmes aimed at developing drought tolerant rice varieties.

2. The biochemical and physiological mechanisms underlying the response of the genotypes to moisture stress may be dissected.

3. The tolerant genotypes may be used to map genes imparting tolerant to moisture stress at various growth stages in rice.

4. The results of such molecular study can become useful to hasten development of drought tolerant genotypes through marker assisted breeding programmes.

5. Similar study may be taken up to screen the rice germplasm held by KAU to identify other promising drought tolerant genotypes among the traditional rice varieties of Kerala.

Summary

VI. SUMMARY

The present study 'Characterisation of drought tolerance in rice (*Oryza sativa* L.)' was carried out at Kerala Agricultural University (KAU),Vellanikkara during 2014-2015. Twenty-one genotypes comprising of thirteen traditional rice varieties (TRV's) and nine high yielding varieties (Parambuvattan, Karuthamodan, Karanavara, Kalladiaryan, Mo 15, Thottacheera, Karathadukkan, Chomala, PTB 43, PTB 39 , PTB 50 ,PTB 52, PTB 60, Arimodan, Onam, Parambankayama, PTB 55, PTB 28, Chettiviruppu, African Gooday and Nerica) constituted the study material. The performance of these genotypes were evaluated under both uplands (Experiment I) and managed system [Experiment II (A)]. Based on the outcome of these studies, ten genotypes (Karanavara, Parambankyama, PTB 28, Nerica, PTB 60 Karuthamodan, Arimodan, Karathadukkan, Parambuvattan and Kalladiaryan) were selected and characterised for tolerance to moisture stress imposed at different growth stages [Experiment II (B)]. The experiment were conducted at College of Horticulture, KAU, Vellanikara, Thrissur.

The study envisaged the assessment of extent of variability and genetic parameters for yield and yield attributes, understanding the degree and extent of association between grain yield and its contributing characters under uplands. In addition to the above, the programme also aimed pesto elucidate the response of promising genotypes on exposure to moisture stress imposed at seedling stage (15 DAS), vegetative stage (35 DAS) and reproductive stage (50 DAS).

The salient findings of the study are summarized below

Morphological characterisation of rice genotypes for yield attributes and yield in rice under uplands Variability studies

1) Wide variability was found to exist among genotypes for yield and yield attributes studied indicating ample scope for improvement of the traits through selection.

2) Traditional rice varieties yield registered higher grain yield than the high yielding varieties, the exception being PTB 60 (Vaishak).

3) Considering the advantage of early maturity, higher CSI, productive tillers, seed set per cent, 1000 grain weight and plant height in uplands, genotype Parambankayama followed by Karanavara were found to be the most promising under uplands. Others promising genotypes for uplands include PTB 28, Nerica, PTB 60, Karuthamodan, Kalladiaryan, Parambuvattan, Karuthadukkan, Arimodan and Thottacheera.

4) The magnitude of phenotypic coefficient of variation was higher than genotypic coefficient of variation for all the characters. However, the difference between the phenotypic and genotypic coefficients of variation was narrow indicating greater contribution of genotype to trait expression leading to high heritability.

5) High PCV and GCV was recorded for productive tillers per plant, panicle weight, spikelets per panicle, grains per panicle, 1000 grain weight, dry weight of shoot, grain and straw yield per plant suggesting presence of considerable variation among the genotypes for these traits. It also indicates scope for further improvement through selection.

6) Moderate PCV and GCV was evident for days to fifty per cent flowering and plant height indicating presence of variability at moderate levels for these traits. PCV and GCV was low in case of chlorophyll stability index and panicle length.

7) High heritability and high GA as percent mean was recorded for days to fifty per cent flowering, productive tiller tillers per plant, panicle weight (g), spikelets per panicle, grains per panicle, 1000 grain weight (cm), plant

height, dry weight of shoot, grain yield and straw yield per plant. Results suggest preponderance of additive gene action in the expression of these traits

8) Moderate genetic advance as per cent of mean was recorded for CSI and panicle length indicated the presence of both additive and non-additive gene action on expression of these traits. Hence, improvement of these traits cannot be achieved through simple selection but a recurrent or reciprocal recurrent selection may be resorted to, to exploit both additive and non additive genetic components.

Trait association studies

1) CSI, panicle length, panicle weight, grains per panicle, 1000 grain weight, plant height, dry weight of shoot and straw yield per plant exhibited positive and significant association with grain yield at phenotypic and genotypic level. Hence, results point to the usefulness of yield attributes mentioned as selection indices for improvement of grain yield under uplands.

2) The relationship of grain yield with days to fifty per cent flowering under upland condition was found to be highly significant and negative indicating that early maturity is preferable for improved grain yield in rice under uplands.

3) The path coefficient analysis revealed the importance of higher panicle weight and length, dry weight of shoot and straw yield per plant as reliable indicators of obtaining higher yields under uplands.

4) It is observed that days to fifty per cent flowering in addition to exhibiting high significant negatively correlation had also exerted a

negative direct effect on yield. This proves beyond doubt that selection for earliness in flowering would be beneficial to obtain higher yield in uplands.

Rapid evaluation for drought tolerance

1) Wide variability between genotypes with respect to various seedling traits *viz.*, speed of germination, shoot length, root length, shoot to root length ratio, seedling vigour index and biomass of seedlings was observed under PEG 6000 simulated moisture stress (-8 bars) .

2) Considering that higher speed of germination, shoot land root length, seedling vigour index and biomass under moisture stress is indicative of the capacity of genotypes to combat moisture stress, genotype Parambuvattan followed by Arimodan were found to be the most promising. Others promising genotypes were Karuthamodan, Karanavara, Parambankayama, Kalladiaryan, Thottacheera, PTB 60, Nerica and Karuthadukkan.

Characterisation of rice genotypes for drought tolerance under controlled moisture regimes at various growth stages

1) The analysis of variance for the traits studied at various growth stages (seedling,- 15 DAS, vegetative - 35 DAS and reproductive stage - 50 DAS) prior to imposition of moisture stress, during imposition of moisture stress and after relief of moisture stress and corresponding non- stress control (fully irrigated control) indicated the presence of wide variability among genotypes.

2) In the population due to moisture stress at various growth stages, a reduction was observed in relative water content, chlorophyll content, number of productive tillers per plant, panicle length and weight,

spikelets and grain per panicle, flag leaf area, 1000 grain weight, plant height, dry weight of shoot and root, root volume, grain and straw yield per plant and harvest index. However, the magnitude of change in various traits studied varied with timing of moisture stress.

3) Proline content was found to increase while the flowering extended under moisture stress.

4) Vegetative stress resulted in delay in flowering rather than seedling and reproductive stage stress.

5) Root length was found to increase on imposition of moisture stress at vegetative and reproductive stage but not in seedling stage

6) Harvest index increased when moisture stress was imposed at seedling stage unlike at the other two growth stages.

7) It was observed that productive tillers plant height, dry weight of root and shoot, root volume and straw yield was affected to a greater extent when moisture stress occurred at seedling stage.

8) The extent of reduction in panicle length, panicle weight and flag leaf area was higher on exposure to moisture stress at seedling and vegetative stage compared to that at reproductive stage.

9) Genotypes that found promising on exposure to moisture stress at various growth stages are listed in table 54.

Table 54: List of promising genotypes found promising under moisture stress at various growth stages

Stage of occurrence of moisture stress	Promising genotypes
Seedling stage (15DAS)	PTB 60, Karanavara, Nerica, Parambankayama and Karathadukkan
Vegetative stage (35 DAS)	PTB 60, Karanavara, Parambankayama Karathadukkan, Nerica and PTB 28
Reproductive stage (50 DAS)	PTB 60 Karanavara Parambankayama Karathadukkan and Nerica

DAS: Days after sowing

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CHARACTERISATION OF DROUGHT TOLERANCE IN RICE (*Oryza sativa* L.) GENOTYPES

by

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ABSTRACT OF THE THESIS

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ABSTRACT

Moisture stress during the crop ontogeny has been one of the main constraints for sustainable rice productivity, especially in uplands. Crop losses vary depending upon the intensity and duration of drought and growth stages. The solution to overcome this lies in either making water available for crop growth or breeding drought resistant cultivars. Increased irrigation inputs are not a viable option because the water resources are unavailable or limited. Improvements in crop drought tolerance are, therefore, sought through plant breeding. Consequently, a need to elucidate the response of genotypes, in cultivation in the uplands of Kerala, with the timing of drought was felt. A study was thus envisaged to characterize rice genotypes suitable for upland cultivation and elucidate their response to moisture stress.

Twenty one rice genotypes consisting of nine high yielding varieties and twelve traditional rice varieties were evaluated in an upland field trial (Experiment I: Morphological characterization of rice genotypes for yield and yield attributes) as well under controlled moisture regimes (Experiment II: Characterization of rice genotypes for drought tolerance). Experiment II comprised of two sub experiments i) Rapid evaluation test for drought tolerance [Experiment II (A)] and ii) Characterisation of rice genotypes for drought tolerance under controlled moisture regimes [Experiment II (B)]. All experiments were conducted at College of Horticulture, Kerala Agricultural University, Vellanikkara during 2014-2015.

Results of the upland field experiment revealed existence of wide variability among the twenty one genotypes for yield and yield attributes indicating ample scope for improvement of the traits through selection. Early maturity, higher chlorophyll stability index (CSI), productive tillers, spikelet fertility and plant height being advantageous in uplands, genotype Parambankayama followed by Karanavara was found to be the most promising. Other promising genotypes for upland cultivation

included PTB 28, Nerica, PTB 60, Karuthamodan, Kalladiaryan, Parambuvattan, Karuthadukkan, Arimodan and Thottacheera. Most of these genotypes recorded high chlorophyll stability index.

On rapid evaluation for drought tolerance [Experiment II (A)] conducted as per the method advocated by Bouslama and Schapauugh (1984), moisture stress (- 6 bars) was found to affect the germination and early seedling growth parameters. Considering that higher speed of germination, shoot and root length, seedling vigour index and biomass under moisture stress are indicative of the capacity of genotypes to combat moisture stress, genotype Parambuvattan followed by Arimodan was found to be the most promising. Karuthamodan, Karanavara, Parambankayama, Kalladiaryan, Thottacheera, PTB 60, Nerica and Karuthadukkan were the other promising genotypes. Speed of germination and seedling vigour index were found to be high in these genotypes

Based on the outcome of upland field experiment and the laboratory screening study, ten promising drought tolerant genotypes were selected to delineate their response towards moisture stress [Experiment II (B)] imposed at seedling stage (15 day after sowing), vegetative stage (35 day after sowing) and reproductive stage (50 day after sowing). In all the population subjected to moisture stress, reduction in relative water content, chlorophyll content, number of productive tillers per plant, panicle length and weight, spikelets and grain per panicle, flag leaf area, 1000 grain weight, plant height, dry weight of shoot and root, root volume, grain and straw yield per plant and harvest index, was observed. A delay in flowering was observed on exposure to moisture stress. The magnitude of change in different traits varied with timing of moisture stress.

PTB 60 and Karanavara recorded the highest grain yield per plant, irrespective of growth stage at which moisture stress was imposed. These genotypes maintained a high number of productive tillers, grains per panicle, 1000 grain weight, dry weight of shoot and root, root length and root volume, straw yield and harvest index under stress. Invariably, on exposure to moisture stress at different growth stages, Parambankayama, Nerica and Karathadukkan were found next best to PTB 60 and Karanavara .