STUDIES ON VARIABILITY AND CONSERVATION OF SOME NATIVE RICES OF KERALA

Thesis submitted in part fulfilment of requirements for the Degree of Doctor of Philosophy in Botany of the University of Calicut

by

C.B.MINI

GENETICS AND PLANT BREEDING DIVISION
DEPARTMENT OF BOTANY
UNIVERSITY OF CALICUT
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CERTIFICATE

Certified that this thesis entitled **'STUDIES ON VARIABILITY AND CONSERVATION OF SOME NATIVE RICES OF KERALA'** embodies the results of a piece of bona fide research work carried out as part fulfilment of requirements for the degree of Doctor of Philosophy in Botany of the University of Calicut by Ms. C.B.Mini under my guidance and supervision and that no part of the thesis has been submitted for any other degree.

I further certify that such helps or sources of information availed of in this connection have been duly acknowledged.

Calicut University
20 October 2006

UNIVERSITY OF CALICUT
UNIVERSITY DEPARTMENT OF BOTANY

(Dr.K.V.MOHANAN)

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DECLARATION

I, C.B. Mini, hereby declare that this thesis entitled **'STUDIES ON VARIABILITY AND CONSERVATION OF SOME NATIVE RICES OF KERALA'** being submitted in partial fulfilment of the requirements for the award of Ph.D. Degree in Botany of University of Calicut embodies the results of a bona fide research work done by me under the guidance of Dr.K.V.Mohanan, Reader and Research Guide, Genetics and Plant Breeding Division, Department of Botany, University of Calicut and that no part of it has been submitted for any other degree.

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Dedicated to my

Father and Mother

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PREFACE

Rice is the staple cereal food of about half of the world's population. It is a herbaceous grass plant with erect habit and wide adaptability under terrestrial and wet land conditions. The rice plant belongs to the genus *Oryza*. *Oryza* consists of about 24 species of which two are cultivated. The two cultivated species are *Oryza sativa* L., the Asian rice and *Oryza glaberrima* Steud, the African rice. The efforts associated with green revolution have helped to improve the harvest index of *Oryza sativa* from 0.3 to 0.5, thus increasing production and productivity considerably. However, green revolution has brought about certain consequences in terms of soil decline and loss of habitat specific diversity of the crop. Ecofriendly farming practices and efforts to conserve the niche specific diversity of crops are being made now everywhere in the world. Efforts to standardise farmer friendly conservation techniques are also in progress. Under such circumstances the present study has been carried out so as to collect native rice cultivars of Kerala state of India from farmer sources, to analyse their variability and to standardise a farmer friendly cloning technology as a measure of conservation. Even though high tillering rices are being considered as high yielders, recently the concept of rice idiotype is getting modified and high density planting of optimum tillering varieties is at the onset of recommendation. Hence a study has been carried out to analyse the relative contribution of rice tillers of different status to effective yield.

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Chapter 1

INTRODUCTION

Rice is one of the staple foods of the world which feeds about half of the world's population. About 90% of the world's total rice production is from Asia and the balance from Africa and Latin America. The innumerable land races of rice distributed throughout the tropics and its wild relatives constitute the rich genetic diversity of the crop.

Oryza sativa L. (Asian rice) and *Oryza glaberrima* Steud. (African rice) are the two cultivated rice species and there are about 22 wild species of *Oryza* which contribute significantly towards the diversity of the genus (IRRI, 2006a). World rice production in 2004 was about 610 million tons. At least 114 countries grow rice and more than fifty of them have got an annual production of 100,000 tons or more.

Rice is the most important crop of India and it occupies 23.3% of gross cropped area of the country and contributes 43% of total food grain production. India has about 45 million hectares of land under rice crop and it ranks first in rice cultivated area. However, in production it is second to China (DACNET, 2006). Rice production in India is presently above 90 million tons.

Green revolution brought significant increase in rice productivity and production. Even though green revolution established the technical feasibility of maintaining rice production well ahead of the population growth in many developing countries, it virtually bypassed the poor resourced and problem soil areas. New technology areas need to be explored to increase the rice production in low income food deficit countries. Environment friendly and socio economically acceptable technologies need to be developed to optimize the use of water, fertilizers and other inputs and to enhance productivity (Riveros, 2000).

Rice is grown mainly in four ecosystems namely irrigated land, rain fed low land, upland and deep water and tidal swamps. Because of intensive cropping especially in the irrigated low lands of Asia, growth in rice yield has levelled off and in some cases declined (Riveros, 2000).

Roschevicz (1931) considered India as the region of the greatest diversity of wild rice which might have given rise to a large number of forms of cultivated rice. According to Richharia (1960) mutations, recombinations and selection for local adaptation might have played an extensive role in the origin of rice varieties. However, the advent of green revolution and the subsequent replacement of native rice genotypes by introduced and improved varieties resulted in acute erosion of the native rice genetic resources. Moreover, changes in cropping patterns and crop preferences also resulted in the

loss of rice genetic diversity. In such a critical situation any effort to study the diversity of rice genetic resources and its conservation is very important. The present study has been planned in such a way that the native rice varieties of Kerala are collected and characterized so that a back ground effort is made for their conservation.

Most of the pre green revolution rice varieties were tall and leafy with weak stems and lodging habit. Their harvest index was only around 0.3 indicating their low yield potential. During the course of development of rice varieties suitable for green revolution, the harvest index and biomass production were increased mainly by the reduction of plant height through the incorporation of the recessive gene *sd-1* for short stature from a Chinese variety Deo-Geo-Woo-Gen and also by the development of high tillering varieties. However, further studies indicated certain drawbacks in the case of the high tillering varieties like non synchronized flowering of tillers resulting in non uniform maturity.

Khush (1994) has conceptualized a new plant type in rice with lower tillering capacity, absence of unproductive tillers, higher number of grains per panicle, medium height, sturdy stems, dark green, thick and erect leaves, thickened, deepened roots, multiple disease and insect resistance and acceptable grain quality. Under these circumstances an effort has been made presently to study the

performance of different types of rice tillers in relation to relative contribution to yield.

Even though rice is traditionally seed propagated, *in vivo* and *in vitro* clonal propagation has been recommended for rice under different circumstances by earlier workers. *In vivo* clonal propagation by way of tiller splitting and transplantation at appropriate times is a farmer friendly method that can be adopted to multiply, conserve and propagate rice genotypes especially under critical conditions. The technique helps to maintain the genetic identity of rare and endangered genotypes of rice since the sexual cycle is bypassed. An effort has been made presently to standardize an effective *in vivo* clonal propagation protocol for rice.

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Chapter 2

REVIEW OF LITERATURE

2.1. The rice plant

The genus *Oryza* belongs to the family Graminae and tribe Oryzae. The tribe Oryzae is classified into two sections by Hutchinson (1934) namely Oryzinae and Zizaninae. The section Oryzinae has three genera namely *Oryza*, *Leersia* and *Hygrorphiza* and the section Zizaninae has four genera namely *Zizania*, *Zizaniopsis*, *Hydrochola* and *Luziola*.

Bentham and Hooker (1883) described the genus *Oryza* and recognized 25 species distributed in the tropical regions of which about 14 were from India. Later Roschevicz (1931) divided the genus into four sections and recognized 20 species. Chevalier (1932) divided *Oryza* into 4 sections and recognized 17 species in agreement with Roschevicz. Nayar(1973) studied the cytogenetics of rice and described 26 species under the genus *Oryza* based on cytogenetical and other data with the comment that the actual number of species may be less. Duistermat (1987) and Chang (1988) have provided revised taxonomic keys for the identification of 22 species and 10 species have been kept under doubtful validity and uncertain nomenclature. The 22 species are *Oryza sativa*, *O.nivara*, *O.grandiglumis*, *O.meridionalis*, *O.longistaminata*,

O.rufipogon, O.glumaepatula, O.australiensis, O.barthii, O.glaberrima, O.latifolia, O.alta, O.eichingeri, O.minuta, O.punctata, O.officinalis, O.granulata, O.meyeriana, O.redleyi, O.longiglumis, O.brachyantha and O.schiechieri.

The cultivated rice grown in Asia, Europe and America belongs to *O.sativa* while *O.glaberrima* is cultivated in West Africa. All cultivated rices in India have been classified under *O.sativa.* More than 8000 botanically different varieties of *O. sativa* are in existence in the world today of which more than 4000 have been identified in India. Among the several cultivated rices, two major groups present are *O. sativa* forma *indica* belonging to the tropical zones including all cultivated rices in India, Indo-china, Philippines, South China, etc. and *O.sativa* forma *japonica* confined to northern subtropical conditions including all the varieties indigenous to Japan, Korea and Northern China (Ramiah and Rao, 1953).

Chang (1976) judging the history of domestication and the extent of varietal diversity within the species has observed that differentiation of *O. sativa* predated that of *O. glaberrima* in West Africa. According to Morishima (1984) however, the Asian cultivated rice could have evolved from forms that are intermediate between the perennial and annual wild species. Recently, Sharma *et al.* (2000) proposed that basic ecotypes of *O.sativa* originated from *O.nivara* and later these basic ecotypes

hybridized in nature with O. *rufipogon* to give rise to other ecotypes. Misra and Misro (1969) established the weak polarization of the clultivars of *O.glaberrima* to form two ecogenetic groups. Miezan and Guesquiere (1986) studied the genetic structure of a traditional African cultivar of *O. sativa* and *O. glaberrima* based on morphological characters and observed "*O. glaberrima* seems to follow the same differentiation process of *O. sativa* but has remained at a primary stage". Oka (1977) suggested that lack of topographic (and climatic) variations in the home land of *O. glaberrima* might have been responsible for the lack of ecotypic differentiation in it.

Oryza sativa is an annual species and includes large number of varieties and almost all are semi aquatic. Its fibrous root system is composed of the radicle or primary root and adventitious roots. Small root hairs 0.7 – 1.0 mm long develop on both the radicle and adventitious roots. Root growth is the maximum by the time of heading and number of roots depends upon availability and type of soil and factors like water, temperature, irrigation methods, rate of fertilizer application, varietal characters etc. (Konokhova, 1985). The rice stem is a round straw divided by solid nodes into sections, the internodes. The hollow upper internodes are longer, the lower solid internodes are shorter. The internodes of deep water rices are longer and their elongation depends upon the rise of water level. Histology of stem is different according to their growing conditions such as drought, swamp, continuous submergence, etc.

The tillering node from which leaves develop is at the base of the stem. The leaf of the rice plant is long and linear and with a sheath at the base which surrounds the stem for some distance. During the development of rice plant, tillering starts with the third or fourth foliage leaf appearing on the plant. The rate of tillering varies depending upon the varieties, environmental conditions, nutrition, cultural pratices, availability of water, day length, plant density, etc. (Konokhova, 1985).

In rice there is an interval between the completion of tillering and commencement of ear formation. In very early varieties ears are formed even before the tillering phase is completed. The interval increases with the duration of the variety (Ramiah and Rao, 1953). The panicle develops from the apical growing point, which is a hemispherical protuberance covered with rudimentary leaves. The initiation of flower organs like stamens and pistil is completed by the time of anthesis. Flower formation proceeds from the top of the inflorescence and continues progressively down to base, at each branch of the inflorescence. The rice inflorescence is a terminal panicle borne on a long peduncle which is the last internode of the culm. The panicle bears spikelets arranged sparsely on the panicle branches of primary, secondary and tertiary orders. The main axis of the panicle, the primary rachis, bears a number of secondary rachii. The secondary rachis, further branches in to tertiaries, which in turn produces still smaller branches, arranged alternately

known as rachillae (small pedicels). Each rachilla bears a spikelet at its tip. Each spikelet has sterile lemmas (earlier known as sterile glumes) at its base and one fertile lemma covered with palea. Above the fertile lemma and palea are seen two fleshy lodicules (reduced perianth lobes), six stamens in two whorls of three each with basifixed anthers and a pistil with a bifid plumose stigma, short slender style and a single central ovary with an anatropous ovule (Pavithran, 2005).

Rice flowers are normally self pollinated as explained by Poehlman (1987). Generally the terminal spikelet blooms first followed by the second and after this blooming goes on from below upwards. The whole panicle finishes its blooming in 6–7days. Air temperature and humidity affect flowering and fertility of rice (Kadam and Patil, 1933). After fertilization, the ovary develops into the fruit, which is a caryopsis of various shapes and colour according to specific and varietal variations. Usually the caryopsis bears one embryo which is rich in fats. Ripening duration is 30–40 days after fertilization, but even more depending upon rice biology and air and soil temperature (Konokhova, 1985).

Kuwada (1910) studied microsporogenesis, megasporogenesis and mitosis in *Oryza sativa* and determined its somatic chromosome number as 24. Later, Parthasarathy (1938) observed 10 pairs and 4 single chromosomes. Rau (1929) observed that five pairs of *sativa* chromosomes were large, four were

medium and three small. The large chromosomes were twice as long as small ones. Nandi (1936; 1937) found that length of somatic chromosomes varied from 0.7 μ to 2.8 μ, the longest pair had a median constriction and the shortest pair was much shorter than the rest. Two pairs of chromosomes had satellites and one pair was attached to the nucleolus. The haploid complement consisted of 10 types of chromosomes, composed of two groups of five each and one chromosome duplicated in each group.

2.2. Genetic variability in rice

Roschevicz (1931) considered India as the region of the greatest diversity of wild rice which produced many mutants, which in turn might have given rise to a large number of forms of cultivated rice. According to Richharia (1960) a postulate on polyphyletic origin of rice is not needed to account for the large variability found in the crop. This is evident from the fact that rice is largely self pollinated and homozygosity is prevalent. Mutations, recombination and selection for local adaptations have played extensive roles in the origin of rice varieties and since each genotype can be designated as a variety, the potential number of varieties, even with a low estimate of 200 pairs of alleles, is quite astronomical.

Chauhan *et al.* (1989) reported the patterns of morphological variations recorded in 12 panicle and grain characters in 109 land races of rice from the

plateau region of Bihar, India. Wide variation in panicle length, panicle type, grains per panicle and panicle weight was noticed. Grain length showed the lowest level of variation while secondary branches per panicle showed the highest. Sinha and Banerjee (1987) from the analysis of data on yield per plant and 10 related traits from 74 diverse genotypes (including 6 accessions of *Oryza glaberrima*) indicated that number of ear bearing tillers made the largest direct positive contribution to yield, followed by grain number per panicle. Bai *et al.* (1992) conducted genetic variability and correlation studies in 58 medium duration rice cultivars. PCV was higher than GCV indicating the influence of environment on the characters. Plant height, flag leaf area, panicle exertion, and grain yield per plant expressed moderate to high estimates of heritability and genetic advance offering good scope for selection. Grain yield per plant was found to be positively correlated with number of productive tillers per hill, plant height, panicle length and number of grains per panicle both at genotypic and phenotypic levels. Angrish and Panwar (1992) conducted studies among 36 land races and 5 promising types were selected based on high density grain index, high density grains per m^2 and 1000 grain weight. The first two characters showed high estimates of coefficient of genetic variability, heritability and genetic advance indicating the scope for further improvement. Yadav (1992) evaluated genetic variability of 11 characters in 16 *Oryza sativa* genotypes at Raipur, Madhya Pradesh, India

and found that heritability estimates were high for plant height, yield per plant, sterility, harvest index, days to 50% flowering and days to maturity. Grain yield per plant was positively correlated with days to 50% flowering, days to maturity, panicles per plant and seeds per plant. Plant height showed high values of heritability (94.2%) indicating its high potential for selection (Lokanathan *et al.*, 1991).

Sarma and Roy (1993) evaluated genetic variability, heritability, and yield correlation for 14 genotypes from different shifting cultivation fields of the hills of Assam and observed the highest genotypic coefficient of variation for panicles per m^2 followed by 100 grain weight and grain yield per plant. High heritability and genetic advance was found for panicles per m^2, grains per panicle, grain weight and percentage of sterility. Plant height, panicles per m^2, panicle length and grain yield per plant were significantly and positively correlated with grain yield. High broad sense heritability for all yield characters except harvest index was observed by Chaubey and Richharia (1993). Path analysis indicated that panicle weight made the highest contribution to grain yield. High heritability coupled with moderate or high genetic advance indicating the predominance of additive gene action was observed by Mani *et al.* (1997) and Chauhan *et al.* (1994). Gupta *et al.* (1999) observed both additive and non additive gene action for days to flowering, biological yield per plant and grain yield per plant. According to Sarawgi and Soni (1994) heritability estimates

were the highest for plant height, grain length, 100 seed weight, spikelet density, days to 50% flowering, panicle length and fertile spikelets per panicle. Sawant and Patil (1995), Panwar *et al.* (1997), Choudhury and Das (1997) and Kumari *et al.* (1999) reported high values of heritability coupled with high genetic advance for characters like grains per panicle, plant height, grain yield per plant, 1000 grain weight, flag leaf area and straw yield. Murthy *et al.* (1999) also observed that variability, heritability and genetic advance were high for grain yield, total dry matter and leaf area at the early stage, while leaf area at flowering, leaf area duration and leaf photosynthetic rate showed high heritability with moderate genetic advance. Chikkalingaiah *et al.* (1999) derived genetic parameters for eight quality traits namely grain length, grain breadth, grain shape, kernel elongation ratio, amylase content, milling recovery, brown rice percentage and test weight in 24 rice genotypes. The same genetic parameters were derived for eight plant characters (plant height, total number of tillers, number of effective tillers, panicle length, panicle weight, grain weight per panicle, 50% flowering and harvest index). Amylose content, milling recovery, kernel elongation ratio, total number of tillers and number of effective tillers exhibited high heritability and genetic advance coupled with large genetic variability and have been recommended for use as characters for selection.

Sarawgi and Soni (1994) observed sterility to show the highest level of variability. High coefficients of variation were observed for grains per panicle, grain yield per plant and plant height by Sawant and Patil (1995) and Rathod *et al.* (1995). Pathak and Sharma (1996) calculated variability and correlation among eight physical quality characters of rice and found very little variation in the case of head rice recovery, elongation percentage (lengthening during cooking), grain length per breadth ratio and alkali value.

Marekar and Siddiqui (1996) reported high genotypic and phenotypic coefficients of variation for grain length and grain length per breadth ratio. High estimates of heritability together with genetic advance were also observed for these traits indicating their usefulness in selection. Positive significant correlation was observed between yield per plot, plant height, length of panicle, days to maturity, thousand grain weight, grain length and grain length per breadth ratio.

High genotypic and phenotypic coefficients of variation were observed for grain yield per plant, panicle weight and plant height by Gonzales and Ramirez (1998) suggesting the usefulness of these characters for plant improvement in a study under saline conditions. Filled grains per panicle, panicle weight and plant height had the largest direct effect on yield. Reddy and De (1996) suggested that grains per hill, grains per panicle and panicle weight had

the highest estimates of genotypic and phenotypic variability indicating their importance in selection for better yield.

According to Sarma *et al.* (1996) genotypic coefficient of variation was the highest for effective tillers per metre row length, followed by panicle weight, secondary branches per panicle, grain yield per metre row length and spikelets per panicle. Heritability ranged from 42.2% for grain yield to 99.9% for grain length. Effective tiller number, panicle weight, secondary branches per panicle and spikelets per panicle had high GCV and high heritability. Genetic advance was the highest for effective tiller number followed by panicle weight. The genotypes were grouped in to ten distinct clusters.

Choudhury and Das (1997) studied variability, heritability, genetic advance, coefficient of correlation and path analysis in 11 deep water rice varieties for yield and its attributing characters. High genotypic coefficient of variation was observed in the case of grain yield followed by grains per panicle. High heritability with high genetic advance was found in grains per panicle followed by grain yield. Significant positive correlation was observed for days to 50% flowering, days to maturity, plant height, grains per panicle and panicle length with yield.

Panwar *et al.* (1997) reported that the genotypic coefficient of variability was higher for

straw yield per plant followed by grain yield per panicle, grain yield per plant, plant height, total biological yield per plant and number of fertile florets per panicle in a study of 22 Indian rice genotypes.

Rather *et al.* (1998) evaluated 56 rice genotypes belonging to *indica*, *javanica*, and *japonica* races for genetic variability, heritability and genetic advance with respect to 14 traits. Significant differences were observed for all the characters among the genotypes. Spikelet sterility and grains per panicle exhibited high genotypic coefficient of variation associated with moderate heritability and high genetic advance. High heritability coupled with high genetic advance was observed for grain yield per plant and 1000 grain weight. These results indicate the scope for improvement through selection.

Kumari *et al.* (1999) evaluated 50 genotypes of upland rice for 10 quantitative traits. Genotypic coefficient of variation was the highest for grain yield per plant and also high for spikelets per panicle and grain yield per panicle. High heritability was observed for 1000 grain weight, days to flowering and grain yield per plant. Study of phenotypic and genotypic correlation coefficients among 10 quantitative characters revealed that panicle length, spikelets per panicle and grain yield per panicle were important characters for yield.

Satpute (1996) in a study with 39 rice cultivars grown under two field conditions observed

the highest variation in the case of days to 50% flowering, plant height and number of grains per panicle. Grain yield was positively correlated with days to 50% flowering and seed weight. High positive direct effects on yield were exerted by seed weight, number of fertile grains per panicle and number of ear bearing tillers.

Reddy and Kumar (1996) evaluated twelve rice cultivars and two controls for nine qualitative characters at two locations each with two spacings in 1992. Estimates of phenotypic coefficients of variation (PCV) were higher than genotypic coefficient of variation (GCV) indicating significant genotype environment interactions.

Mani *et al.* (1997) observed 24 genotypes of basmati rice for six panicle characters and observed wide range of variation for all the traits. A high estimate of heritability coupled with genetic advance obtained for number of grains per panicle suggested the predominance of additive gene action for these characters. Study of genotypic and phenotypic correlation coefficients indicated that number of secondary branches per panicle and number of filled grains per panicle were positively correlated with grain yield per panicle.

Vange and Ojo (1997) studied genetic variations, heritability and genetic advance derived from data on 12 grain yield related characters in 10 early and 12 mid season cultivars. Considerable

differences were observed for all traits in each maturity groups.

Borbora and Hazarika (1998) recognized highly significant variation among the genotypes observed between genotypic and phenotypic coefficients of variation and those were relatively low for almost all the characters except grain yield per plant.

Singh *et al.* (1998) suggested that most of the yield related characters exhibited high heritability coupled with high genetic advance in 45 indigenous genotypes from different agro climatic region of Uttar Pradesh, India. Positive and significant correlations were observed for test weight with grain density, amylose content and grain length and breadth with volume expansion and hulling percentage with milling percentage, water uptake and volume expansion.

Shrivastava and Shukla (1996) analyzed seven crosses of rice and their F_2 progenies to study the genetic variability of seven economic attributes under two fertility levels. High heritability with high genetic advance was noted for tillers per plant in one of the crosses, for 50% flowering in one cross and for biological yield per plant in two crosses. One cross exhibited high PCV associated with high GCV and high genetic advance. It is concluded that mass selection could be practiced on the basis of PCV estimates in non segregating populations.

Vanniarajan *et al.* (1996) found that heritability and genetic advance were high for grain yield in a cross. Prasad *et al.* (1996) observed that analysis of variance revealed highly significant differences among the segregants of two crosses for all the characters studied. Highest phenotypic coefficient of variation was shown by grain yield per plant in both populations while it was moderate for productive tillers per plant and spikelets per panicle.

Singh and Choudhary (1996) have given information on genetic variability, heritability and genetic advance based on data on twelve characters in the parents, F_1 and F_2 of crosses carried out during 1986-87. Phenotypic coefficients of variation were higher than genotypic coefficients of variation for all the characters studied indicating that they all interacted with the environment to some degree. Estimates of GCV and PCV were the highest for biological yield followed by number of panicles per plant, number of grains per panicle, grain yield per plant, thousand grain weight and harvest index. Heritability and genetic advance estimates were high for plant height and number of grains per panicle.

Manonmani *et al.* (1996) also investigated in to the genetic variability, heritability and genetic advance in the F_1 population of 20 cross combinations of nine short duration rice genotypes. Days to flowering, plant height, 100 grain weight, number of grains per primary ear and grain yield had high values for heritability and genetic advance.

Narendra and Reddy (1997) studied 11 hybrid rice genotypes, which exhibited high levels of variability for all seven yield components recorded. Grains per panicle and 1000 grain weight were under the influence of additive gene effects indicating their role in crop improvement. Straight selection of grain yield and straw yield per plant also indicated better scope for crop improvement. Selection through panicle length and plant height was found ineffective as they are much influenced by environmental effects.

Basavaraja *et al.* (1997) evaluated the genetic variability of ten characters and association and path coefficient among these characters in the F_4 populations of two crosses together with the pure line varieties Basmati 370 and Pusa 150 in trials conducted at Shimoga in the summer of 1992. High estimates of phenotypic coefficients of variation together with high to moderate heritability and genetic advance was observed for total tillers per plant, productive tillers per plant, panicle weight and total spikelets per panicle while grain yield per plant showed low heritability and genetic advance. Grain yield was positively and significantly associated with plant height, productive tillers per plant, panicle weight, total spikelets per panicle and spikelet fertility. Productive tillers per plant had a highly positive direct contribution towards grain yield per plant. The indirect effects of other characters through productive tillers were moderate. Thakur *et al.* (1998) observed high heritability

coupled with high genetic advance for grain yield, biological yield, panicle weight and number of tillers per plant. Correlation studies indicated that grain yield was positively associated with biological yield, number of tillers per plant, harvest index, plant height and panicle weight.

Singh *et al.* (1997) studied genetic variability parameters in a five parent rice diallele cross without reciprocals. Effective tillers per plant, grains per panicle and panicle length were potential selection criteria for yield improvement. The genetic correlations suggested that tall and late maturing plants were generally high yielders.

Ilieva *et al.* (1998) also found that both quantitative and qualitative traits showed high variability for number of productive tillers and number of grains with main panicle. The variability was higher in the F_2 generation as a result of segregation. Anand *et al.* (1998) studied genotypic and phenotypic coefficients of variation, heritability, expected genetic advance and character association of grain yield and its contributing characters in 40 F_1 hybrids and their parents under cold stress conditions. Number of filled grains per panicle, seed percentage, number of chaffy grains per panicle and grain yield per plant showed high variability, heritability and genetic advance.

Kandhola and Panwar (1999) observed genetic diversity among 52 indigenous and exotic genotypes of rice using Mahalanobis D^2 statistic in kharif 1996

under two sowing dates and two nitrogen fertilizer levels. Based on 16 agromorphological and quality characters, these genotypes were grouped in to 11 clusters. There was no association between genetic and geographic diversity. It is concluded that hybridization among genotypes drawn from widely divergent clusters with high yield potential is likely to produce heterotic combinations and wide variability in segregating generations.

Thakur *et al.* (1998) discussed genetic variability and correlation derived from data on nine yield related traits in an F_2 progeny of rice and their parents. High heritability coupled with genetic advance was estimated for grain yield, biological yield, panicle weight and number of tillers per plant. Correlation studies suggested that grain yield had a positive association with plant height, tillers per plant, panicle weight, biological yield and harvest index.

Mishra (1999) observed that grain yield had a significant association with plant height, tillers per plant, panicle weight, straw weight and biological yield in two different environments, *i.e.*, up land and irrigated conditions whereas panicle length and grains per panicle were positively correlated with grain yield only in upland conditions. Path analysis showed that biological yield under irrigated conditions and panicle weight in upland conditions are the major attributes for grain yield.

2.3. Conservation of the genus *Oryza*

Concentration on a narrow genetic base means that the genetic variability necessary to feed our growing number is being eliminated by the expansion of that same exploding population. As natural populations are destroyed, we are losing store houses of allelic diversity. Wild populations carry a vast array of genetic variability that is available to breeders who want to improve crop quality and yield or disease and stress tolerance. This makes the conservation of our native germplasm sources absolutely critical to our future breeding success and perhaps the continued survival of rice (Hancock, 2004). *Oryza* species have played an increasingly important role in continued enhancement of rice production and sustainable development of rice varieties, particularly under the circumstances that modern breeding practices and changes in crop management have accelerated the great loss of biodiversity in rice varieties (Lu, 1996).

Depending on the objective and scopes of the activity, there are two basic approaches to wild rice germplasm conservation. These are *ex situ* conservation and *in situ* conservation. *Ex situ* conservation mainly involves activities of collecting samples of seeds, tillers and individuals from the original sites and storing them in gene banks or planting them in conservation nurseries. *In situ* conservation method attempts to preserve the integrity of genetic resources by conserving them

within the evolutionary dynamic ecosystems of their original habitat or natural environment (Nanda and Sharma, 2003).

There are thousands of locally adapted rice varieties those farmers grow for generations, and over 20 wild rice species native to Asia, Africa and Latin America. Rice genetic resources are threatened with extinction in farming systems when farms adopt improved varieties and the wild species may be lost through destruction of their habitats (Jackson, 1995).

In field research, factors that affect long term viability of rice seeds have been identified leading to the introduction of modified practices for germplasm multiplication and regeneration. The value of conserved germplasm can be assessed in terms of useful traits for rice breeding and the economic impact of germplasm utilization on rice production and productivity (Jackson, 1997).

Oka (1991) found the danger of not conserving sufficient polymorphic variants of rice in gene banks and stressed the need of conservation of populations, rather than single accessions. Lizhi *et al.* (1998) have described problems associated with collecting and preserving wild rices.

Most of the countries in Asia have maintained collections of rice germplasm and the largest are in India, China, Thailand and Japan. In Africa, significant collections are maintained in Nigeria and

Madagascar while in Latin America, the largest collections are in Brazil, Peru, Cuba and Equador (FAO, 2006). All these collections conserve land race varieties as well as breeding materials. Four centres of the Consultative Group on International Agricultural Research (CGIAR) namely International Rice Research Institute (IRRI), Philippines; West Africa Rice Development Association (WARDA), Cote d'Ivoire; International Institute for Tropical Agriculture (IITA), Nigeria and International Centre for Tropical Agriculture (CIAT), Columbia also maintain rice collections (FAO, 2006).

The International Rice Gene Bank (IRG) of International Rice Research Institute started in 1997 presently maintains 107,000 accessions of the genus *Oryza* consisting of 90,348 accessions of *Oryza sativa*, 1543 collections of *Oryza glaberrima* and 4370 collections of wild species and close relatives of the genus *Oryza* (IRRI, 2006b).

Together IRRI and International Plant Genetic Resources Institute (IPGRI) have developed a list of descriptors for rice that are widely used now. With the collaboration of breeders in the National Programmes, IRRI published a standard evaluation system for rice (IRRI, 1996). IRRI has developed the International Rice Gene bank Collection Information System (IRGCIS) which is linked to System wide Information Network for Genetic Resources (SINGER). Using SINGER, CGIAR centres have

placed passport, characterization and evaluation data on the World Wide Web (FAO, 2006).

Since 1975, the International Network for Genetic Evaluation of Rice (INGER) has managed the exchange of improved germplasm of rice between National Programmes and International Centres (FAO, 2006). INGER has had an enormous impact on genetic terms and economic terms.

Presently Intellectual Property Right (IPR) policies related to biological innovations have resulted in seeking strategically valuable rights. The result is that the holder of the rights can derive income from, or sometimes block any other researcher in the field covered by IPR. Before 1980s almost no country allowed IPRs over plants or animals. However, many developed countries allowed the use of Plant Variety Protection (PVP) normally consistent with the Convention for the Protection of New Varieties of Plants (UPOV). Today, most of the countries have adopted some form of patent legislation and a system of PVP (FAO, 2006).

TRIPs (Trade Related aspects of Intellectual Property rights) agreement commits the more than 140 members of World Trade Organization (WTO) to providing the minimum standards of IPR protection, including PVP by patent, an effective *sui generis* system or a combination of the two (FAO, 2006).

Article 15 adopted in the Convention for Biological Diversity (CBD) held at Reo in 1992 was

motivated as the perceived need to balance the expansion of IPR over genetic resources (Correa, 2000).

Article 15 recognized national sovereignty over genetic resources and established a framework for agreements to grant access to resources based on the concepts prior informed consent and mutually agreed terms (Lettington, 2000).

The International Treaty on Plant Genetic Resources for Food and Agriculture adopted in the FAO Conference on 3rd November 2001 recognizes the innate value of agrobiodiversity and the need for international cooperation in the management of *ex situ* and *in situ* germplasm (FAO, 2006).

Scientists have made efforts to collect, characterize and conserve locally available diversity of rice in different parts of the world, as a part of individual efforts of conservation. Pant and Negi (1997) reported collection and characterization of rice germplasm from eight hill districts of Uttar Pradesh and four districts of the gangetic plains of India. During 1985–94, 510 land races of paddy rice were collected and details concerning growth period, height, aroma, taste and palatability characteristics, yield, drought tolerance, pest, disease and lodging resistance, growth habit and farmer preferences were recorded. A total of 176 accessions were deposited in the Conservation Division of NBPGR, New Delhi, for long term storage.

Kochhar and Chandel (1996) found that Arunachal Pradesh provided one area of rice crop species diversity which could be conserved on farm for future generations. In addition to consideration of the five major agroclimatic zones of Arunachal Pradesh, a list of local rice germplam prevalent in various districts have been described by them.

Bellon *et al.* (1997) discussed some important issues related to on farm conservation of rice like the nature of on farm conservation, the genetic and evolutionary implications of farmers' management of diversity, the role of institutions in on farm conservation and some of the research needs in this area.

2.4. Propagation of rice

2.4.1. Seed propagation

Rice requires at least twenty seven percent of moisture in the soil for germination and after absorption of water the primary root breaks out of the coleorhiza and grows down into the soil and very soon 2–3 secondary roots develop. The mode of seed germination and seedling growth in rice greatly varies between strains due to the interaction between genetic potentialities and environmental conditions. Varietal differences in seed germination and seedling growth as observed in response to temperature, light, quality and intensity, gas tension, moisture content and salt nutrient concentration determine cultivar adaptability

(Takahashi, 1984). In general, wild plants show much stronger seed dormancy than cultivated plants. Strains of *Oryza perennis* vary between perennial and annual types and the seed dormancy of annuals is more pronounced (Oka and Morishima, 1967).

2.4.2. *In vivo* clonal propagation of rice

The potential of clonal propagation in rice has been described by Capinpin and Villamayor in 1948. New seedlings that are sexually produced result from the process of cyclic juvenescence resulting from sporogenesis and fertilization (Richharia and Pavithran, 1987). Juvenescence is achieved by continuous cloning also (Brink, 1962) but without variation or with little variation only. However response of varieties to vegetative propagation is genetically controlled (Richharia and Pavithran, 1987). *In vivo* clonal propagation of rice by growing separated tillers established thousands of successfully developed tiller plants within a short time, without losing the genetic purity (Richharia and Misro, 1960; Richharia *et al.*, 1964a; Richharia *et al.*, 1964b; Richharia and Pavithran, 1987; Mohanan and Pavithran, 2001). It is reported that plants develop from separated tillers of any rank, irrespective of their age and stage of development probably due to the autotrophic status after detachment (Tanaka, 1961). The significance of clones in the study of phenotypic plasticity and expressivity of morphological characters has been

emphasized by Bradshaw (1964) and Pavithran (1975).

Fujisaka *et al.* (1991) reported a technique known as 'beushaning' which refers to the practice of ploughing young rice plants in 5–10 cm of standing water followed by laddering, redistributing seedlings to fill gaps and hand weeding. Sahoo and Lenka (1992) indicated that even though beushaning increased tillering ability, it decreased the number of hills per m^2. Mohanan (1992) has standardized the system of tiller propagation of rice through periodic splitting and transplanting of the tillers at the three tiller stage. The perennating habit of the rice plant and its photosensivity has been exploited in developing clonal propagation technology for rice cultivation (Richharia, 1987). An improved system of tiller propagation as a farmer practicable technique for rapid multiplication of planting material has also been suggested by Mohanan (1993). Yamamoto *et al.* (1994) have reported differences in grain productivity in tiller plants of different orders.

2.4.3. *In vitro* cloning of rice

In vitro propagation or micro propagation has been recognized as one of the basic tools for the rapid propagation of crop plants. Redifferentiation and plant restoration in rice callus (Nishi *et al.*,

1968; Bajaj and Bidami, 1980; Heyser *et al.*, 1983; Maheswaran and Rangaswamy, 1989; Wu *et al.*, 1992; Ratisoontron *et al.*, 1993), regeneration from seminal root derived callus (Kawata and Ishihara, 1968), regeneration from internodes and roots (Reddy and Rutger, 1980), callus initiation and plant regeneration from haploid internodes (Reddy, 1982), regeneration from protoplast (Xiang, 1992), seed and anther culture (Jasbirkaur *et al.*, 1993), L-proline mediated high frequency regeneration (Sureshkumar *et al.*, 1993), sustained regeneration from suspension cultures (Biswas and Zapata, 1992), direct somatic embroyogenesis from root culture (Sticklen, 1991), anther culture (Nizeki and Oono, 1971; Sree Rangasamy *et al.*, 1988; Mercy, 1991) and indefinite culture of young seedling nodes (Furuhashi and Yatazawa, 1964) are some of the significant studies on *in vitro* cloning.

Shoot base segments of *japonica* rice have been explanted from seedlings and grown on agar solidified MS medium supplemented with different concentrations of cytokinins (Greco *et al.*, 1990). After one month, segments were explanted from proliferated roots and sub cultured. BAP was found to be the most effective in inducing shoot proliferation. Shoot base segments were sub cultured fifteen times consecutively on seven different concentrations of BAP. Shoots grown in the presence of 5 mgl^{-1} of BAP proliferated an average of 12 normal shoots for each base segment throughout the 15 subcultures. The shoots rooted easily on

hormone free medium and therefore it could be suggested an effective method for clonal propagation of rice. Finch *et al.* (1992) have developed a method for the *in vitro* clonal propagation of shoots from a range of wild rice species. Sandhu *et al.* (1995) obtained viable seedlings from the *indica* rice variety Jaya using MS medium supplemented with hormones. Profuse rooting was obtained on transfer to MS liquid medium containing IBA. The plants were successfully transferred to soil and grown to maturity. .An efficient clonal propagation procedure for a Brazilian *indica* rice subspecies was developed with shoot apex explants by Padua *et al.* (1998). Shoot apices excised from four day old seedlings were cultured on MS medium supplemented with 6 benzyl adenine. The efficiency of shoot production was influenced by growth regulators and light treatments. Yang *et al.* (1999) have developed an efficient culture procedure for micropropagation of *indica* rice. N6 medium supplemented with 3% sucrose, 1 gm proline and 32 mg 2,4-D per litre produced good regeneration and the plants were further transferred to rooting medium which resulted in the production of healthy plants. Anther derived embryogenesis and green plant regeneration frequencies of *indica* rice varieties were studied by Ranjan *et al.* (1998). Anthers were cultured on N6 medium supplemented with different concentrations and combinations of growth regulators. Callus index frequency varied from 0.3% to 12.27% and green plant regeneration frequency varied from 0-26.86%. Three varieties, Basmathi 370, Tulsi and

Tetep showed satisfactory regeneration indicating varietal differences in regeneration.

Callus initiation and plant regeneration was studied from immature embryos of three *indica* rice varieties by Sharma *et al.* (1999). MS medium supplemented with 100 mgl^{-1} of Adenine sulphate and phytohormones 2,4-D (2mgl^{-1}) and BAP (0.5 mgl^{-1}) was found suitable for callus initiation. Callus proliferation and shoot bud regeneration was achieved on MS medium with Adenine sulphate 100 mgl^{-1}, BAP 2.0 mgl^{-1}, and NAA 1.0 mgl^{-1}. Root initiation was effective in MS medium with kinetin 1.0 mgl^{-1} and NAA 5.0 mgl^{-1}. Regeneration was found to be varietal specific. Anther culture derived double haploids and F_2 generations of *indica-japonica* crosses in rice have been evaluated by Narasimman *et al.* (2000). Characters of anther culture derived plants showed differential segregation in the F_2 generation.

Under the above circumstances, the present experiments have been designed so as to generate additional information on genetic variability of native rice varieties of Kerala, the importance of their conservation and their propagation through *in vivo* cloning. An investigation has also been attempted into the tillering behaviour of rice and the performance of tillers of different ranks and their contribution to effective yield.

STUDIES ON VARIABILITY AND CONSERVATION OF SOME NATIVE RICES OF KERALA

Thesis submitted in part fulfilment of requirements for the Degree of Doctor of Philosophy in Botany of the University of Calicut

by

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Chapter 3

MATERIALS AND METHODS

Rice, *Oryza sativa* L. is a genetically diverse species with heavy intraspecific variability. Cultivated rice is an annual erect herb which is usually seed propagated. However, rice has got the potential of clonal propagation. Rice plant developing from the germinated seed is initially with single tiller but it produces different numbers of tillers of primary, secondary and tertiary status. Tillering potential and response to clonal peopagation are varietal characteristics in rice. Kerala state of India, even though a traditionally rice cultivated area, is facing acute threat of erosion of the genetic diversity of rice due to different social and agricultural changes. The present study is an effort to investigate into the genetic variability of native rice varieties of Kerala, their tillering behaviour and *in vivo* cloning potential. An effort to characterise and conserve them has also been made.

The experiments were carried out in the experimental net house of genetics and Plant Breeding division of Department of Botany of University of Calicut, Kerala, India during 2002-2005. The University of Calicut is situated 24 km south of Calicut city and the region enjoys tropical climate enriched by the south west monsoon from June to August and the north east monsoon from October to November with occasional pre monsoon

showers in April, May and September and post monsoon showers in December. Rice farming in the area is mainly based on the monsoon system with three crop seasons, the first season from May to August, second season from September to December and the third season from January to April. Two crops are made in rain fed low lands and three crops in irrigated lands. The climate of the area is generally hot and humid, with a temperature range from 20°C to 35°C. The annual rainfall is about 250 cm with 75% of rain being received from the south west monsoon.

3.1. Genetic variability

Variability of native rice cultivars of Kerala has been studied presently in relation to morphological and yield characters of 39 cultivars collected from different parts of the state (Table 3.1).

Table 3.1. Native rice cultivars of Kerala used for the study

Sl. No	Variety	Place of collection
1	Chitteni	Angadippuram – Malappuram
2	Thekkan chitteni	Angadippuram – Malappuram
3	Ponni	Malappuram - Malappuram
4	Chemmeen	Mala – Thrissur
5	Cheru vellari	Edavannappara – Malappuram
6	Vellari vembala	Muyyam – Kannur
7	Chettadi	Karimba – Palakkad
8	Ponmani	Mala – Thrissur

9	Gandhakasala	Meenangadi – Wayanad
10	Veliyan	Dwaraka - Wayanad
11	Chuvanna chitteni	Pannithadam - Thrissur
12	Punjakaima	Rajapuram- Kasaragod
13	Kaima	Thaliparamba – Kannur
14	Ponnariyan	Thrithala – Palakkad
15	Vithandan	Chelannur – Kozhikode
16	Chomala	Puthurvayal – Wayanad
17	Kottarakkara	Wandoor – Malappuram
18	Arikkinai	Vatakara – Kozhikode
19	Athian	Ollur – Thrissur
20	Muttuppatta	Vatakara – Kozhikode
21	Palakkadan	Malappuram - Malappuram
22	Kunhukunhu	Chelakkara – Palakkad
23	Orkazhama	Pariyaram – Kannur
24	Navara	Panamukku – Thrissur
25	Kuttadan	Villunniyal – Malappuram
26	Mundakan	Cherthala – Alappuzha
27	Kuthiru	Pariyaram – Kannur
28	Aruvakkari	Karimba – Palakkad
29	Vellarian	Thrithala – Palakkad
30	Kuruva	Pannithadam – Thrissur
31	Thondi	Meenangadi - Wayanad
32	Punnadan thondi	Meenangadi – Wayanad
33	Marathondi	Meenangadi – Wayanad
34	Adukkan	Meenangadi – Wayanad

35	Allikkannan	Pariyaram – Kannur
36	Kururai	Pariyaram – Kannur
37	Vrischikappandi	Pannithadam – Thrissur
38	Kuttiveliyan	Meenangadi - Wayanad
39	Jeerakasala	Meenangadi - Wayanad

The cultivars were grown under experimental conditions in the net house of the Genetics and Plant Breeding Division of the Department of Botany of University of Calicut in completely randomised design in experimental pots of 20 cm diameter, on one plant per pot basis during the first crop season of 2002 with 9 replications. Observations were made on 7 plant characters and 9 yield characters (Table 3.2). The plants were maintained under standard cultural conditions with paddy soil, sand and enriched compost mixed at 4:1:1 ratio used as planting medium and application of 1 gm of Factamfos per plant at monthly intervals starting from 30th day of planting till flower initiation. Wetland condition was maintained in the pots. Data were analysed for intra varietal and inter varietal variability of the rice cultivars and its significance.

Table 3.2. Plant and yield characters of rice studied.

Sl. No.	Character
Plant characters	
1	Age at tiller initiation (days)
2	Age at flowering (days)

3	Total duration (days)
4	Number of tillers at flowering
5	Tiller number at harvest
6	EBT number
7	Plant height (cm)
Yield characters	
1	Panicle length (cm)
2	Spikelets per panicle
3	Seeds per panicle
4	Panicle density
5	Grain length (mm)
6	Grain thickness (mm)
7	100 grain weight (gm)
8	Fertility percentage
9	Yield per plant (gm)

3.1.1. Analysis of variance

Analysis of variance (ANOVA) was carried out to test the significance of variations between the cultivars. Test of significance was done with reference to standard F-Table (Fischer and Yates, 1963).

3.1.2. Phenotypic and genotypic variances

Phenotypic and genotypic variances for the different characters studied were estimated as per Singh and Choudhary (1985).

Genotypic Variance (σ^2g) =

$$\frac{\text{MSS for treatment - MSS for error}}{\text{Number of replications.}}$$

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

where σ^2e is error variance.

3.1.3. Coefficients of variation

Phenotypic and genotypic coefficients of variation were estimated following Burton and Devane (1953).

Genotypic coefficient of variation (GCV) = $\frac{\sigma g \times 100}{\bar{X}}$

where σg = the genotypic standard deviation and

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

Phenotypic coefficient of variation (PCV) = $\frac{\sigma p \times 100}{\bar{X}}$

where σp = the phenotypic standard deviation.

3.1.4. Heritability (broad sense)

Heritability (broad sense) is the fraction of the total variance that is heritable and is estimated as the percentage of genotypic variance over phenotypic variance (Jain, 1982).

Heritability (broad sense) (H^2)= $\frac{\sigma^2g \times 100}{\sigma^2p}$

3.1.5. Genetic advance under selection

Genetic advance under selection was calculated using the following formula (Abraham 2000):

$$GA = \frac{KH^2 \sigma p}{\overline{X}}$$

where H^2 = heritability (broad sense); σp = phenotypic standard deviation; K = selection differential which is 2.06 at 5% intensity of selection in large samples (Allard, 1960).

3.1.6. Correlation of characters

Correlation of the characters studied has been found out as per Rangaswamy (1995).

3.1.7. Character association

Study of association of characters is being carried out for data reduction so as to find out the characters useful in selection. Factor analysis by means of principal component analysis has been done for the purpose presently using the statistical software STATISTICA.

3.1.8. Genetic divergence

Different genotypes of plant species can be grouped into different clusters based on genetic divergence studies. The 39 accessions of native rices of Kerala were subjected to cluster analysis based on 15 phenotypic characters using the software STATISTICA following UPGMA procedure

(unweighted pair group mathematical average procedure) (Sneath and Sokal, 1973).

3.1.9. Genetic control of morphometric and yield characters

The seven morphometric plant characters and nine yield characters studied presently have been subjected to analysis of their genetic control based on the nature of their frequency distributions. Data on 3 plants each of 39 accessions were grouped together for frequency analysis.

3.2. Characterization and conservation of native rices of Kerala

Thirty nine accessions of native rices of Kerala (Table 3.1) have been characterized based on 16 characters (Table 3.2). Their locations were listed, and seeds collected and grown in the net house of the Genetics and Plant Breeding Division of Department of Botany of Calicut University.

3.3. Tillering potential and tiller behaviour in rice

Rice germinates as a single culmed seedling but soon it starts tillering. Tillering potential of rice is a varietal character and the tillering phase of a variety depends upon its duration and morphology. The first produced tillers in rice are primary in nature followed by secondary and tertiary tillers. However, late emerging tillers may not contribute towards the yield of mature grains at harvest. A

study was designed presently to analyse the tillering potential and the behaviour of tillers in terms of their emergence and performance in the case of 10 native rice cultivars of Kerala (Table 3.3) in relation to 9 characters (Table 3.4) with 3 plants per variety in the 1st crop season of 2003. The plants were grown in 20 cm pots filled with paddy soil + sand + enriched compost in 4:1:1 proportion under wetland condition with one plant per pot and applying 1 gm Factamfos per plant at monthly intervals starting from 30th day onwards till flowering. Performance of tillers of different ranks has been analysed based on mean, standard deviation and comparison of means by t test in relation to the characters studied.

Table 3.3. Cultivars of rice studied for tillering potential and tiller behaviour

Sl. No.	Variety
1	Chuvanna chitteni
2	Chuvanna vattan
3	Thekkan cheera
4	Thekkan chitteni
5	Thondi
6	Chemmeen
7	Kuruva
8	Chitteni
9	Vellariyan
10	Kunhukunhu

Table 3.4. Tiller related characters of rice studied

Sl. No.	Characters
Plant characters	
1	Days taken for emergence
2	Days taken for flowering
3	Number of leaves
4	Tiller height (cm)
Yield characters	
1	Panicle length (cm)
2	Spikelets per panicle
3	Seeds per panicle
4	Panicle density
5	Fertility percentage

3.4. *In vivo* cloning of rice

In vivo clonal propagation of rice has been recommended as a method to multiply and conserve rare seed stock, to bypass sexual generations and also for the instant multiplication of planting material under critical situations (Richharia 1987; Mohanan, 1993; Mohanan and Pavithran, 2001). *In vivo* cloning of rice was attempted presently by successive splitting of rice plants at 3 tiller stage and planting the tillers separately starting from the 30th day and progressively repeating the process three times (Table 3.5 & Fig.3.1) in the case of 9 native rice cultivars (Table 3.6) of Kerala starting with 3 plants per cultivar and finally selecting the best

performer. The tiller plants were studied based on 13 characters (Table 3.7) in the second crop season of 2004 and in comparison with their seed crop grown simultaneously for the purpose. The plants were grown under wetland condition in 20 cm pots filled with paddy soil + sand + enriched compost in 4:1:1 on one plant per pot basis and applying 1 gm Factomfos per plant at monthly intervals starting from the 30th day of planting till flowering. Nine plants per variety were grown as control, the clonal plants were comparatively analyzed with seed plants for the 13 morphometric characters based on mean, standard deviation and comparison of means by t test.

Table 3.5. Pattern of tiller splitting of rice plants carried out.

Day of tiller splitting	Number of plants split	Number of tiller plants obtained
15th day after keeping for germination	1	3
30th day after keeping for germination (15th day after 1st splitting)	3	9
45th day after keeping for germination (15th day after 2nd splitting)	9	27

Fig. 3.1. Tillers split in the three tiller stage of a rice plant for planting individually.

Table 3.6. Rice varieties studied for *in vivo* cloning

Sl. No.	Varieties
1	Chuvanna vattan
2	Thekkan cheera
3	Vellarian
4	Chettadi
5	Chuvanna chitteni
6	Chitteni
7	Poojyam pathu
8	Palakadan
9	Kuruva

Table 3.7. Plant characters studied in the case of *in vivo* cloning of rice

Sl. No.	Character
Plant characters	
1	Days to flower
2	Duration (days)
3	Number of tillers at flowering
4	Tiller number at harvest
5	EBT number
6	Plant height (cm)
Yield characters	
1	Panicle length (cm)
2	Spikelet number
3	Grain number

4	Panicle density
5	100 grain weight
6	Sterility (%)
7	Yield per plant

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Chapter 4

RESULTS AND DISCUSSION

Kerala state of India is a traditional rice cultivating area and it is rich in diversity and variability of the crop. However, presently the genetic diversity of rice in the state is under threat due to changes in cropping patterns, crop preferences and also due to the spread of intensive agriculture using improved and introduced varieties. The present study has been carried out under such a situation so as to assess the variability of native rice cultivars available in the state, their genetic parameters and tillering behaviour. An effort has also been made to study the efficiency of *in vivo* clonal propagation of rice as a method of conservation.

4.1. Genetic variability

Intraspecific variability of a crop evolves in relation to the peculiarities of the habitat of each and every population. Kerala State is a traditional rice cultivating area which had a very rich diversity of native cultivars suited for specific habitats and cultural practices. Variability of 39 native rice cultivars of Kerala collected for the present study has been analysed based on seven plant characters and nine yield characters as detailed elsewhere. The plants were grown under nursery conditions (CRD) with nine replications.

The rice plant germinates as single culm but after a few days it produces accessory branches known as tillers of primary, secondary and tertiary nature. Tillering is a varietal character and the general observation is that native rices of Kerala are medium to low tillering.

Seven growth characters in the case of the 39 native rice cultivars grown for the purpose were studied presently to access the extent of variability among the cultivars (Tables 4.1 & 4.2). Tiller initiation started the earliest in Ponmani (16th day) and the latest in Chomala (34th day), indicating that it is a varietal character. The earliest flowering cultivar among the 39 cultivars studied was Navara (71.11 days) and the latest flowering was Kuttadan (216.67 days) which is photosensitive. Total duration was also minimum in Navara and maximum in Kuttadan. The study shows that native rice cultivars of Kerala are medium to long duration types. Number of tillers at flowering ranged from 10-39 with the minimum tiller number in Navara and maximum in Aruvakkari. However, tiller number at harvest was minimum in Kunhukunhu and it was maximum in Aruvakkari itself. Number of ear bearing tillers (EBT) varied from 8-28 in the different varieties studied. Allikkannan with 8 EBT on the average showed the minimum and Palakkadan with 28 EBT showed the maximum. This shows that the native rices of Kerala range from low tillering to high tillering types. Plant height was the minimum in Kunhukunhu and maximum in

Kururai (66.61 cm - 162.60 cm) indicating that they are mostly medium to tall in nature.

Table 4.1. Variability of growth characters in the 39 cultivars of rice studied: 1. Age at tiller initiation, age at flowering and total duration.

Sl. No.	Variety	Age at tiller initiation (days) **	Age at flowering (days) **	Total duration (days) **
1	Chitteni	19.22±1.79	195.33±4.36	225.33±4.36
2	Thekkan chitteni	21.00±1.00	190.22±12.37	220.22±12.37
3	Ponni	18.89±0.60	165.00±3.16	195.00±3.16
4	Chemmeen	19.22±0.83	175.44±19.49	205.44±19.49
5	Cheru vellari	18.33±0.71	195.11±4.14	225.11±4.14
6	Vellari vembala	18.33±0.50	189.78±7.65	219.78±7.65
7	Chettadi	19.89±0.93	130.56±4.50	160.56±4.50
8	Ponmani	16.22±0.66	182.89±8.88	212.89±8.88
9	Gandhakasala	18.00±0.01	129.56±4.07	159.56±4.07
10	Veliyan	19.22±0.44	179.22±5.21	209.22±5.21
11	Chuvanna chitteni	18.11±0.33	157.00±5.79	187.00±5.79
12	Punjakaima	19.33±0.50	203.11±2.37	233.11±2.37
13	Kaima	19.56±0.88	134.00±2.69	164.00±2.69
14	Ponnariyan	18.56±0.53	101.11±2.47	131.11±2.47
15	Vithandan	19.33±0.50	211.11±3.06	241.11±3.06
16	Chomala	33.56±1.66	167.00±6.65	197.00±6.65
17	Kottarakkara	24.44±0.88	201.89±0.93.	231.89±0.93
18	Arikkinai	20.56±0.52	196.00±1.00	226.00±1.00
19	Athian	20.44±0.52	197.33±5.45	227.33±5.45
20	Muttuppatta	19.56±0.52	128.22±1.09	158.22±1.09

21	Palakkadan	19.22±0.44	208.00±4.03	238.00±4.03
22	Kunhukunhu	21.33±0.50	88.22±2.54	118.22±2.54
23	Orkazhama	22.00±0.50	102.67±0.71	132.67±0.71
24	Navara	22.00±0.71	71.11±4.54	101.11±4.54
25	Kuttadan	20.56±0.52	216.67±2.24	246.67±2.24
26	Mundakan	20.22±1.09	209.33±5.70	239.33±5.70
27	Kuthiru	19.78±0.44	132.67±4.74	162.67±4.94
28	Aruvakkari	20.00±0.01	199.44±11.98	229.44±11.33
29	Vellarian	18.44±0.52	183.33±2.55	213.33±2.55
30	Kuruva	22.33±0.50	140.33±3.20	170.33±3.20
31	Thondi	18.33±0.50	126.44±5.36	156.44±5.37
32	Punnadan thondi	22.00±0.01	120.11±4.62	150.11±4.62
33	Mara thondi	21.00±0.01	111.11±4.65	141.11±4.65
34	Adukkan	18.33±0.50	116.33±3.67	146.33±3.67
35	Allikkannan	18.22±0.44	107.00±4.58	137.00±4.58
36	Kururai	23.44±0.52	106.89±2.67	136.89±2.67
37	Vrischika ppandi	21.00±0.01	144.67±1.80	174.67±1.80
38	Kuttiveliyan	21.22±0.44	135.00±1.32	165.00±1.32
39	Jeerakasala	30.00±0.87	140.44±2.92	170.44±2.92

**: significant at 1% level

Table 4.2. Variability of growth characters in the 39 cultivars of rice studied: 2. Number of tillers at flowering, number of tillers at harvest, ear bearing tiller (EBT) number and plant height.

Sl. No.	Variety	Number of tillers at flowering **	Number of tillers at harvest **	EBT Number **	Plant height (cm) **
1	Chitteni	30.22±3.60	31.33±4.18	23.78±1.71	98.54±5.10
2	Thekkan chitteni	33.11±3.89	34.74±3.90	24.00±7.30	82.80±11.24
3	Ponni	30.56±3.36	31.33±3.74	22.11±4.31	87.24±4.48
4	Chemmeen	19.78±4.89	20.56±5.77	15.67±6.24	87.52±8.20
5	Cheru vellari	23.00±10.16	24.00±10.33	19.78±10.13	86.56±6.69
6	Vellari vembala	26.89±3.62	27.33±3.46	18.44±3.32	103.28±12.45
7	Chettadi	24.11±4.17	25.11±4.20	18.33±4.00	98.53±9.22
8	Ponmani	31.89±8.89	32.56±8.85	25.44±8.83	75.19±7.59
9	Gandhaka sala	11.44±2.88	11.78±2.95	11.00±2.92	97.10±5.22
10	Veliyan	31.44±6.80	32.33±6.65	25.44±6.06	101.61±7.20
11	Chuvanna chitteni	27.67±8.85	28.67±8.97	21.00±5.12	82.16±8.20
12	Punjakaima	25.56±2.60	26.33±1.87	22.67±3.54	98.89±5.06
13	Kaima	28.67±2.96	26.33±3.35	16.11±2.26	90.59±5.15
14	Ponnariyan	16.22±2.82	15.33±3.08	12.78±2.33	105.44±5.95
15	Vithandan	35.22±3.87	37.78±5.67	26.11±3.62	81.37±4.95
16	Chomala	20.89±3.86	21.67±4.39	16.22±3.35	92.79±3.96
17	Kottarakkara	24.89±4.65	25.00±4.44	17.00±4.33	86.78±3.73
18	Arikkinai	30.33±2.29	31.89±1.67	18.22±3.11	98.07±7.40
19	Athian	32.33±4.15	32.89±4.14	24.89±6.47	95.72±7.73
20	Muttuppatta	31.89±6.73	30.89±6.41	24.33±4.56	82.27±5.97
21	Palakkadan	37.11±5.75	38.00±5.59	27.78±3.46	106.10±8.46
22	Kunhukunhu	10.56±1.40	9.89±1.36	8.78±0.97	66.61±2.43
23	Orkazhama	14.00±2.87	14.33±2.87	9.56±2.07	119.68±7.39
24	Navara	9.67±2.82	23.89±4.83	21.11±3.98	96.73±11.00
25	Kuttadan	36.78±6.57	37.89±6.81	25.89±3.76	77.00±6.80
26	Mundakan	34.56±9.02	37.78±11.00	25.89±7.90	87.76±8.37

27	Kuthiru	17.33±3.67	16.78±3.60	9.22±0.83	101.54±9.47
28	Aruvakkari	39.33±6.75	39.33±6.75	27.56±7.36	79.97±5.81
29	Vellarian	26.44±3.97	27.56±3.78	20.44±2.74	88.40±5.62
30	Kuruva	25.44±7.13	26.00±7.07	20.22±4.12	77.26±1.66
31	Thondi	17.89±4.68	20.33±4.03	14.11±2.15	101.20±10.35
32	Punnadan thondi	19.33±4.58	19.33±3.64	14.78±3.87	104.42±9.07
33	Marathondi	16.33±5.27	17.11±5.28	12.22±3.87	97.01±10.23
34	Adukkan	24.67±6.95	22.44±6.52	12.33±2.35	98.83±7.15
35	Allikkannan	9.78±1.99	10.00±2.00	8.11±1.62	139.84±22.42
36	Kururai	12.89±2.71	11.67±2.78	8.78±3.27	162.58±27.25
37	Vrischika ppandi	24.89±6.45	25.22±6.38	19.78±4.92	94.09±7.20
38	Kuttiveliyan	17.22±3.80	18.00±4.12	13.22±2.17	105.91±11.44
39	Jeerakasala	18.44±4.33	21.33±4.39	13.44±2.70	101.58±4.80

**: significant at 1% level

Variability among the 39 cultivars was also studied in relation to 9 yield characters (Tables 4.3, 4.4, 4.5). Panicle length among the cultivars ranged from 14.7 cm to 23.9 cm and it was the minimum in Vellarian and maximum in Ponnariyan respectively. Mean number of spikelets per panicle was minimum in Vithandan (31.44) and maximum in Allikkannan (113.56). In the case of seeds per panicle the minimum value of 21.67 was shown by Kuttadan and the maximum of 97.44 by Ponnariyan. The lowest panicle density (1.86) was shown by Vithandan and the highest by Kunhukunhu (5.29). Grain length was the minimum in Kuruva (6.19 mm) and maximum in Kuthiru (8.85 mm) and grain thickness was the minimum in Muttuppatta and maximum in Thekkan chitteni. Hundred grain weight was the lowest in Gandhakasala (1.03 gm)

and the highest in Kuthiru (2.44 gm). Fertility percentage was the lowest in Punnadan thondi (59.94%) and the highest in Ponnariyan (90.74%) and yield per plant was the lowest in Gandhakasala (4.70 gm) and the highest in Navara (24.53 gm).

Table 4.3. Variability of yield characters in the 39 cultivars of rice studied: 1. Panicle length, spikelets per panicle and seeds per panicle.

Sl. No.	Variety	Panicle length (cm) **	Spikelets per panicle **	Seeds per panicle **
1	Chitteni	17.48±1.62	42.67±6.87	41.44±8.40
2	Thekkan chitteni	16.72±2.26	39.00±18.75	30.78±14.09
3	Ponni	18.24±2.07	58.22±12.13	44.33±10.69
4	Chemmeen	20.97±2.88	59.67±18.84	54.89±13.72
5	Cheru vellari	16.47±1.82	36.78±9.35	30.44±11.06
6	Vellari vembala	17.42±1.67	44.33±7.98	37.33±7.16
7	Chettadi	21.33±1.99	79.44±13.30	71.00±14.93
8	Ponmani	16.89±1.39	44.44±12.25	36.33±10.42
9	Gandhakasala	19.67±2.60	58.67±16.20	42.22±11.95
10	Veliyan	16.16±2.68	40.33±9.11	30.33±7.48
11	Chuvanna chitteni	16.96±1.57	34.22±7.08	27.67±6.58
12	Punjakaima	16.51±2.01	37.67±13.82	31.22±12.80
13	Kaima	20.34±1.48	78.00±13.44	58.00±14.53
14	Ponnariyan	23.88±1.64	107.33±13.84	97.44±13.05
15	Vithandan	16.63±1.39	31.44±5.08	24.00±3.00
16	Chomala	16.98±1.99	40.67±8.99	32.78±10.21
17	Kottarakkara	16.84±1.15	41.89±9.41	29.82±13.12
18	Arikkinai	17.57±0.57	49.67±6.44	43.56±6.58

19	Athian	15.51±1.86	38.33±5.48	30.89±7.03
20	Muttuppatta	19.91±1.03	87.33±15.24	69.33±11.62
21	Palakkadan	15.74±0.88	35.56±6.77	31.00±5.70
22	Kunhukunhu	20.28±1.44	107.89±19.90	95.33±16.37
23	Orkazhama	23.73±1.08	87.33±13.71	57.56±11.17
24	Navara	18.44±2.62	67.89±21.55	64.00±22.30
25	Kuttadan	16.77±1.02	31.67±6.82	21.67±4.58
26	Mundakan	17.62±0.77	41.56±6.35	32.67±6.73
27	Kuthiru	23.24±3.00	83.89±17.75	64.78±14.78
28	Aruvakkari	16.01±1.32	33.89±5.51	25.67±4.61
29	Vellarian	14.72±1.07	36.44±4.85	27.44±5.86
30	Kuruva	16.51±1.33	47.67±9.03	40.22±8.07
31	Thondi	23.19±2.59	66.00±15.96	45.22±8.73
32	Punnadan thondi	18.83±2.03	50.00±15.19	30.78±14.05
33	Marathondi	21.98±1.03	74.78±6.52	47.78±6.02
34	Adukkan	18.11±0.37	55.00±7.09	38.00±6.56
35	Allikkannan	23.76±4.29	113.56±53.98	80.33±46.63
36	Kururai	23.14±2.18	94.44±25.15	62.56±20.92
37	Vrischika ppandi	17.19±1.82	42.78±6.85	30.33±5.59
38	Kuttiveliyan	20.00±1.82	68.11±17.14	42.89±15.76
39	Jeerakasala	22.20±2.41	63.78±15.38	50.78±14.06

**: significant at 1% level

Table 4.4. Variability of yield characters in the 39 cultivars of rice studied: 2. Panicle density, grain length and grain thickness.

Sl. No.	Variety	Panicle density **	Grain length (mm) **	Grain thickness (mm) **
1	Chitteni	2.44±0.31	7.85±0.32	2.33±0.37
2	Thekkan chitteni	2.25±0.70	7.83±0.45	2.39±0.32
3	Ponni	3.19±0.59	7.15±0.37	1.84±0.27
4	Chemmeen	2.84±0.34	7.85±0.72	2.34±0.42
5	Cheru vellari	2.21±0.37	7.83±0.33	2.04±0.19
6	Vellari vembala	2.43±0.32	8.18±0.49	2.19±0.25
7	Chettadi	3.71±0.47	7.88±0.90	1.76±0.16
8	Ponmani	2.61±0.57	7.67±0.59	2.14±0.24
9	Gandhakasala	2.95±0.28	6.53±0.14	1.73±0.13
10	Veliyan	2.48±0.26	7.64±0.31	2.18±0.13
11	Chuvanna chitteni	2.00±0.33	8.55±0.48	2.07±0.15
12	Punjakaima	2.22±0.57	7.86±0.18	2.14±0.10
13	Kaima	3.84±0.62	7.50±0.19	1.85±0.24
14	Ponnariyan	4.49±0.45	8.50±0.19	1.85±0.18
15	Vithandan	1.86±0.25	8.16±0.64	2.28±0.20
16	Chomala	2.37±0.31	7.70±0.48	2.08±0.14
17	Kottarakkara	2.37±0.34	7.36±0.24	2.05±0.16
18	Arikkinai	2.88±0.32	7.53±0.18	2.21±0.27
19	Athian	2.29±0.54	7.88±0.13	2.37±0.24
20	Muttupatta	4.37±0.61	7.64±0.29	1.64±0.17
21	Palakkadan	2.24±0.31	8.35±0.10	2.23±0.20
22	Kunhukunhu	5.29±0.65	8.15±0.46	1.77±0.20

23	Orkazhama	3.67±0.47	8.83±0.26	2.17±0.19
24	Navara	3.64±0.75	7.57±0.30	1.93±0.18
25	Kuttadan	1.87±0.30	8.08±0.43	2.16±0.25
26	Mundakan	2.36±0.36	7.79±0.35	2.02±0.12
27	Kuthiru	3.59±0.41	8.85±0.30	2.29±0.13
28	Aruvakkari	2.13±0.37	7.57±0.37	1.97±0.10
29	Vellarian	2.47±0.20	7.63±0.42	2.14±0.26
30	Kuruva	2.87±0.38	6.19±0.22	2.24±0.44
31	Thondi	2.84±0.56	7.60±0.16	2.03±0.06
32	Punnadan thondi	2.62±0.57	7.81±0.12	2.25±0.13
33	Marathondi	3.40±0.24	7.90±0.20	2.09±0.08
34	Adukkan	3.03±0.34	8.02±0.24	2.42±0.08
35	Allikkannan	4.56±1.55	8.47±0.19	2.28±0.24
36	Kururai	4.05±0.92	8.43±0.22	2.31±0.10
37	Vrischika ppandi	2.48±0.27	7.73±0.49	2.24±0.36
38	Kuttiveliyan	3.38±0.65	7.54±0.30	2.25±0.17
39	Jeerakasala	2.85±0.48	7.52±0.29	1.80±0.06

**: significant at 1% level

Table 4.5. Variability of yield characters in the 39 cultivars of rice studied: 3. Hundred grain weight, fertility percentage and yield per plant.

Sl. No.	Variety	100 grain weight (gm) **	Fertility percentage **	Yield per plant (gm) **
1	Chitteni	1.96±0.11	84.91±1.94	17.11±3.65
2	Thekkan chitteni	2.04±0.16	79.62±11.26	14.27±7.32
3	Ponni	1.52±0.08	75.97±9.98	14.10±4.48
4	Chemmeen	1.72±0.16	74.70±13.35	11.69±5.41
5	Cheruvellari	2.12±0.19	80.74±12.19	11.86±6.16
6	Vellari vembala	2.12±0.12	84.27±6.75	14.54±3.45
7	Chettadi	1.31±0.30	88.82±5.00	16.87±5.26
8	Ponmani	1.84±0.25	83.52±10.15	16.04±2.77
9	Gandhaka sala	1.03±0.11	70.23±10.82	4.70±1.43
10	Veliyan	2.00±0.18	76.27±8.22	14.98±3.07
11	Chuvanna chitteni	2.30±0.23	80.79±7.66	13.17±2.18
12	Punjakaima	2.07±0.12	82.24±6.81	11.05±3.30
13	Kaima	1.43±0.40	75.21±13.72	12.94±3.43
14	Ponnariyan	1.77±0.31	90.74±1.63	21.19±5.34
15	Vithandan	2.30±0.27	75.46±7.57	13.24±3.36
16	Chomala	1.94±0.11	77.01±9.90	10.81±4.31
17	Kottarakkara	1.87±0.07	81.33±2.83	9.98±0.34
18	Arikkinai	1.89±0.08	90.40±5.49	15.34±2.74
19	Athian	2.08±0.12	78.38±14.96	16.16±5.87
20	Muttupatta	1.21±0.19	76.36±8.19	21.39±5.70
21	Palakkadan	2.06±0.20	82.95±9.12	16.08±3.06
22	Kunhukunhu	1.55±0.34	88.77±2.20	13.83±3.80

23	Orkazhama	2.42±0.25	66.46±10.21	13.76±4.30
24	Navara	1.76±0.26	90.23±9.10	24.53±12.71
25	Kuttadan	1.92±0.26	69.52±11.18	10.88±1.91
26	Mundakan	2.03±0.28	75.80±9.28	14.88±2.60
27	Kuthiru	2.44±0.23	79.27±14.70	15.22±3.47
28	Aruvakkari	1.85±0.17	76.92±5.56	13.47±3.24
29	Vellarian	1.83±0.01	76.87±12.10	10.81±1.89
30	Kuruva	1.20±0.15	82.12±9.82	10.22±3.42
31	Thondi	2.13±0.10	61.86±5.56	14.53±3.69
32	Punnadan thondi	2.00±0.25	59.94±12.89	8.47±5.37
33	Marathondi	2.22±0.18	64.28±8.68	13.08±2.45
34	Adukkan	2.02±0.06	67.99±3.60	12.25±2.10
35	Allikkannan	2.39±0.19	63.79±13.29	14.06±6.81
36	Kururai	2.31±0.11	65.76±9.94	13.39±6.61
37	Vrischika ppandi	1.91±0.28	70.58±8.01	11.42±3.74
38	Kuttiveliyan	2.18±0.32	64.49±9.52	12.62±5.07
39	Jeerakasala	1.49±0.06	78.17±5.48	10.32±2.22

**: significant at 1% level

The extent of genetic variability present among the cultivars studied has been analysed presently based on ANOVA, genotypic and phenotypic variations, heritability (broad sense) and genetic advance under selection (Tables 4.1, 4.2, 4.3, 4.4, 4.5 & 4.6).

Table 4.6. Mean, range, genotypic variance, phenotypic variance, GCV(%), PCV(%), Heritability % (broad sense) and genetic advance (%) of characters in the case of the 39 cultivars of rice studied.

Sl. No	Character	Mean	Range	Genotypic variance	Phenotypic variance	GCV (%)	PCV (%)	Heritability (%)	Genetic advance (%)
Growth characters									
1	Age at tiller initiation (days)	20.54	16 - 34	9.79	10.27	15.23	15.60	95.33	30.64
2	Age at flowering (days)	156.15	71.11 - 216.67	1632.83	1666.43	25.88	26.14	97.98	52.77
3	Total duration (days)	185.15	101.11 - 246.67	1589.03	1625.07	21.53	21.77	97.78	43.86
4	Number of tillers at flowering	24.33	9.67 - 39.33	65.68	93.03	33.31	39.64	70.60	57.66
5	Number of tillers at harvest	25.55	9.89 - 39.33	65.69	94.68	32.10	38.54	69.38	55.08
6	Number of Ear bearing tillers	18.37	8.11 - 27.78	33.34	54.11	31.43	40.04	61.62	50.83
7	Plant height (cm)	95.59	66.61 - 162.58	280.26	365.98	17.51	20.01	76.58	31.57
Yield characters									
1	Panicle length (cm)	18.82	14.72 - 23.88	6.91	10.59	13.97	17.29	62.25	23.24
2	Spikelets per panicle	57.75	31.44 - 113.56	513.94	749.07	39.26	47.39	68.61	66.98
3	Seeds per panicle	44.94	21.67 - 97.44	339.91	523.20	41.03	50.90	64.97	68.11
4	Panicle density	2.95	1.86 - 5.29	0.65	0.94	27.33	32.87	69.15	46.82
5	Grain length (mm)	7.82	6.19 - 8.85	0.26	0.38	6.52	7.88	68.42	11.11

6	Grain thick ness (mm)	2.10	1.64 - 2.39	0.04	0.09	9.52	14.29	44.44	13.08
7	Hund red grain weight (gm)	1.90	1.03 - 2.44	0.12	0.17	18.23	21.70	70.59	31.56
8	Ferti lity percent age	76.74	59.94 - 90.74	59.11	146.99	10.02	15.80	40.21	13.09
9	Yield per plant (gm)	13.72	4.70 - 24.53	10.22	31.04	23.30	40.61	32.93	27.55

4.1.1. ANOVA (Analysis of variance)

Analysis of variance is a statistical procedure to compare the extent of variations between populations with the extent of variations within populations so as to determine the significance of variability between populations or accessions. All the thirteen characters studied namely age at tiller initiation, age at flowering, total duration, number of tillers at flowering, number of tillers at harvest, ear bearing tiller number, plant height, panicle length, spikelets per panicle, seeds per panicle, panicle density, grain length, grain thickness, hundred grain weight, fertility percentage and yield per plant showed statistically significant variations between the cultivars studied (Table 4.1, 4.2, 4.3, 4.4 and 4.5), indicating definite morphological and genetic differences between them. Assessment of the statistical significance of variability in the case of morphological characters is an effective tool to identify genotypes with favourable characters and the technique has been used in different crops like rice (Shobha, 1993), medicinal plants (Misra *et al.*,

1998), coffee (Nikhila *et al.*, 2002; Raghu *et al.*, 2003), tea (Ramasubramanian, 2005) and cardamom (Radhakrishnan *et al.*, 2006), etc. by different workers.

4.1.2. Genotypic and phenotypic variation

Genotypic variation between cultivars or populations is the expression of their genetic differences and phenotypic variation is the result of interaction between genetic differences and environment. Genotypic and phenotypic variations have been studied presently in the case of thirty nine accessions of native rices of Kerala based on genotypic variance, phenotypic variance, genotypic coefficient of variation and phenotypic coefficient of variation (Table 4.6).

In all the cases phenotypic variance was higher than the genotypic variance indicating the polygenic nature of the characters under study and also the involvement of additive genes in the control of the characters. Genotypic coefficients of variation were also lower in all the cases when compared to phenotypic coefficients of variation showing the different levels of influence of environmental factors on the expression of the characters under study. Among the growth characters the highest GCV and PCV were shown by number of tillers at flowering followed by number of tillers at harvest and number of ear bearing tillers showing the wide variability of these characters among the cultivars studied and suggesting the feasibility of selection of high tillering

native rices especially in the present era of evergreen revolution and organic farming thus improving the sustainability of rice farming in Kerala using niche specific high tillering and high yielding cultivars. Among the yield characters seeds per panicle showed the highest variation followed by spikelets per panicle as revealed by their highest GCV and PCV (Table 4.6). This shows that there is enough scope for selection using these characters so as to improve the yield of native rice varieties cultivated in Kerala.

Studies on genetic variability of rice has been carried out by different workers like Chauhan *et al.*, 1989; Lokanathan *et al.*, 1991; Angrish and Panwar, 1992; Yadav, 1992; Vivekanandan *et al.*, 1992; Sarma and Roy 1993; Sarawgi and Soni 1994; Sawant and Patil 1995; Marekar and Siddiqui 1996; Sarma *et al.*, 1996; Satpute 1996; Reddy and Kumar 1996; Shrivastava and Shukla 1996; Singh and Choudhary 1996; Manonmani *et al.*, 1996; Choudhury and Das 1997; Panwar *et al.*, 1997; Mani *et al.*,1997; Vange and Ojo 1997; Basavaraja *et al.*, 1997; Singh *et* al., 1997; Rather *et al.*, 1998; Borbora and Hazarika, 1998; Gonzales and Ramirez, 1998; Ilieva *et al.*, 1998; Thakur *et al.*, 1998; Kandhola and Panwar 1999; Chikkalingaiah *et al.*, 1999; Kumari *et al.*, 1999; etc. based on different morphological characters and under different agroclimatic conditions and cultural practices and they have reported differential variability in the case of different characters. The present study also

provides information on the extent of variability existing among the traditional rice cultivators of Kerala and also shows that many of such varieties are high tillering and high yielding.

4.1.3. Heritability (broad sense)

Most of the agronomic characters of rice are polygenic in nature and they show different levels of heritability based on the influence of environment on them. Seven growth characters and nine yield characters of rice was studied presently for the analysis of broad sense heritability (Table 4.6). The highest heritability was shown by age at flowering (97.98%) and total duration followed by age at tiller initiation (95.33%) and plant height (76.58%). Heritability of number of tillers at flowering, number of tillers at harvest and number of ear bearing tillers was comparatively low thus showing the influence of environment on the expression of these characters. Among the yield characters hundred grain weight showed the highest heritability indicating the varietal nature of the character. It was closely followed by panicle density, spikelets per panicle, grain length, seeds per panicle and panicle length. Heritability value was the lowest in yield per plant followed by fertility percentage indicating the impact of environment on these characters.

Heritability of the agronomic characters of rice has been studied by several earlier workers under diverse conditions as described elsewhere (Lokanathan *et al.*, 1991; Bai *et al.*, 1992; Angrish

and Panwar, 1992; Vivekanandan *et al.*, 1992; Santhalingam *et al.*, 1992; Sarma and Roy, 1993; Chaubey and Richharia, 1993; Chauhan *et al.*, 1994; Sarawgi and Soni 1994; Sawanth and Patil, 1995; Marekar and Siddiqui 1996; Sarma *et al.*, 1996; Shrivastava and Shukla 1996; Vanniarajan *et al.*, 1996; Singh and Choudhary, 1996; Manonmani *et al.*, 1996; Panwar *et al.*, 1997; Mani *et al.*, 1997; Choudhury and Das, 1997; Basavaraja *et al.*, 1997; Rather *et al.*, 1998; Anand *et al.*, 1998; Thakur *et al.*, 1998; Singh *et al.*, 1998; Murthy *et al.*, 1999; Kumari *et al.*, 1999; Chikkalingaiah *et al.*, 1999).

4.1.4. Genetic advance under selection

Percentage of genetic advance possible under selection is a parameter that can be used to find out the utility of characters in crop improvement programmes. Among the growth characters, genetic advance was found to be the highest in the case of characters associated with tiller number followed by age at flowering and duration (Table 4.6). This shows that these characters can be effectively used for selecting superior genotypes. Among the yield characters seeds per panicle showed the highest genetic advance followed by spikelets per panicle indicating that these are the characters to be considered first when selection is practiced for yield characters. Similar studies on the use of genetic advance to target characters the most useful for selection have been carried out by earlier workers who conducted studies on genetic variability,

heritability and genetic advance as described elsewhere.

4.1.5. Correlation of characters

The efficiency of selection of desirable genotypes in a plant breeding programme depends upon the identification of characters that are to be targeted for selection. Most of the agronomic characters of crop plants are polygenic in nature and hence they are interrelated to each other and influenced by environment. Correlation analysis helps to identify the relationship between characters so that characters related to agronomic and other desirable parameters can be used as lead characters. The present study has indicated positive and significant correlation between many characters and negative correlation between some others (Table 4.7).

Age at tiller initiation showed significant positive correlation with none of the other characters while age at flowering showed significant positive correlation with total duration, number of tillers at flowering, number of tiller at harvest and number of ear bearing tillers and significant negative correlation with panicle length, spikelet number per panicle, seed number per panicle and panicle density.

Table 4.7. Correlation of characters studied in the case of the 39 cultivars of native rices of Kerala.

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
2	-0.10														
3	-0.14	+0.99 **													
4	-0.21	+0.82 **	+0.83 **												
5	-0.17 •	+0.79 **	+0.80 **	+0.96 **											
6	-0.21	+0.74 **	+0.76 **	+0.88 **	+0.95 **										
7	+0.09	-0.36	-0.35	-0.46	-0.49	-0.49									
8	+0.07	-0.73 **	-0.73 **	-0.71 **	-0.75 **	-0.79 **	+0.52 *								
9	0.00	-0.81 **	-0.81 **	-0.71 **	-0.75 **	-0.74 **	+0.44	+0.88 **							
10	-0.02	-0.74 **	-0.74 **	-0.63 **	-0.65 **	-0.61 **	+0.29	+0.77 **	+0.95 **						
11	-0.02	-0.81 **	-0.81 **	-0.64 **	-0.68 **	-0.66 **	+0.32	+0.74 **	+0.97 **	+0.94 **					
12	-0.12	-0.12	-0.09	-0.11	-0.15	-0.21	+0.36	+0.35	+0.30	+0.27	+0.19				
13	-0.08	+0.30	+0.32	+0.16	+0.13	+0.07	+0.27	-0.23	-0.34	-0.40	-0.41	+0.28			
14	-0.07	+0.14	+0.15	-0.03	-0.03	-0.09	+0.40	+0.07	-0.09	-0.21	-0.42	+0.72 **	+0.67 **		
15	-0.03	+0.22	+0.21	+0.22	+0.30	+0.34	-0.38	-0.31	-0.10	+0.14	+0.01	-0.04	-0.27	-0.32	
16	-0.21	-0.20	-0.18	+0.07	+0.19	+0.24	+0.05	+0.15	+0.32	+0.42	+0.37	+0.33	-0.16	+0.06	+0.47

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

Characters: 1. Age at tiller initiation 2. Age at flowering 3. Total duration
4. Number of tillers at flowering 5. Number of tillers at harvest 6. Number of ear bearing tillers
7. Plant height 8. Panicle length 9. Spikelet number per panicle
10. Seed number per panicle 11. Panicle density 12. Grain length
13. Grain thickness 14. 100 grain weight 15. Fertility percentage 16. Yield per plant

Total duration shows significant positive correlation with age at flowering, number of tillers at flowering, number of tillers at harvest and number of ear bearing tillers and significant negative correlation with panicle length, spikelet number per panicle, seed number per panicle and panicle density. Number of tillers at flowering shows significant positive correlation with age at flowering, total duration, number of tillers at harvest and number of ear bearing tillers and significant negative correlation with panicle length, spikelet number per panicle, seed number per panicle and panicle density. Number of tillers at harvest showed significant positive correlation with age at flowering, total duration, number of tillers at flowering and number of ear bearing tillers and significant negative correlation with panicle length, spikelet number per panicle, seed number per panicle and panicle density. Number of ear bearing tillers showed significant positive correlation with age at flowering, total duration, number of tillers at flowering and number of tillers at harvest and significant negative correlation with panicle length, spikelet number per panicle, seed number per panicle and panicle density. Plant height showed significant positive correlation with panicle length only. Panicle length showed significant positive correlation with plant height, spikelet number per panicle, seed number per panicle and panicle density. Spikelet number per panicle showed significant positive correlation with panicle length, seed number per panicle and panicle density. Seed number per panicle showed

significant positive correlation with panicle length, spikelet number per panicle and panicle density. Panicle density showed significant positive correlation with panicle length, spikelet number per panicle and seed number per panicle. Grain length showed significant positive correlation with hundred grain weight only and grain thickness also showed significant positive correlation with hundred grain weight. Hundred grain weight showed significant positive correlation with grain length and grain thickness. Fertility percentage and yield per plant were found to be only non significantly correlated with other parameters studied. The study has shown that tillering parameters and panicle characters are interrelated. Characters that show strong positive correlation may usually show covariation and selection of such characters can be done considering them as single units. Similar approaches of selection have already been utilized in different crops like cardamom (Radhakrishnan, 2003) and tea (Ramasubramanian, 2005).

4.1.6. Character association in rice

Most of the agronomic characters of rice are polygenic and they show different levels of interrelationships. Study of character association helps to identify lead variables and also to reduce the complexity of handling bulky data in field experiments. Factor analysis has been carried out presently to study character association in the case of sixteen morphological characters of rice using the statistical software "STATISTICA" (Tables 4.8, 4.9

and 4.10). The characters could be grouped into three groups as shown in Table 4.9 and 4.10, the first group with six characters, second group with one character and the third group with nine characters.

Table 4.8. Factor analysis of characters in the case of the thirty nine cultivars of native rices of Kerala studied (percentage of variance contributed by each factor and the cumulative percentages of variance).

Factor	Eigen value	Percentage of variance	Cumulative Eigen value	Cumulative percentage of variance
1	7.732235	48.32647	7.73224	48.32647
2	2.744646	17.15404	10.47688	65.48051
3	2.089060	13.05662	12.56594	78.53713

Table 4.9. Factor analysis of characters in the case of the thirty nine cultivars of native rices of Kerala studied (factor loadings).

Sl. No.	Characters	F_1	F_2	F_3
1	Age at tiller initiation	**0.117363**	-0.043270	-0.442957
2	Age at flowering	-0.913614	-0.101663	**0.072424**
3	Total duration	-0.916988	-0.109869	**0.101530**
4	Number of tillers at flowering	-0.878038	0.131001	**0.240019**
5	Number of tillers at harvest	-0.896347	0.186304	**0.275093**
6	Number of ear bearing tillers	-0.872734	0.263033	**0.268179**
7	Plant height	**0.510903**	-0.557255	0.112992
8	Panicle length	**0.888524**	-0.112798	0.077941
9	Spikelet number per panicle	**0.944666**	0.122579	0.192245
10	Seed number per panicle	**0.864549**	0.329315	0.302641
11	Panicle density	**0.892817**	0.283683	0.185148
12	Grain length	0.255017	-0.498750	**0.679177**
13	Grain thickness	-0.287114	-0.770965	**0.141116**

14	100 grain weight	-0.039127	-0.849824	**0.408453**
15	Fertilitypercentage	-0.208367	**0.623018**	0.406736
16	Yield per plant	0.164248	0.344403	**0.822773**

Table 4.10. Factor analysis of characters in the case of the thirty nine cultivars of native rices of Kerala studied (character association).

Factor	Characters associated
1	Spikelet number per panicle, panicle density, panicle length, seed number per panicle, plant height, age at tiller initiation.
2	Fertility percentage
3	Yield per plant, grain length, 100 grain weight, number of tillers at harvest, number of ear bearing tillers, number of tillers at flowering, grain thickness, total duration, age at flowering.

The first group consists of spikelet number per panicle, panicle density, panicle length, seed number per panicle, plant height and age at tiller initiation. The second group consists of fertility percentage and the third group consists of yield per plant, grain length, 100 grain weight, number of tillers at harvest, number of ear bearing tillers, number of tillers at flowering, grain thickness, total duration and age at flowering.

Spikelet number per panicle showed the highest factor loading in the first group and yield per plant showed the highest factor loading in the second group. The third group stands distinct with a single character fertility percentage. Characters with the highest factor loading can be considered

lead variables for selection (Table 4.9). The cumulative percentage of variance contributed by the three groups is 78.54 (Table 4.8) indicating that 78.54 percentage of the variability between the genotypes is produced by the sixteen characters studied presently.

Factor analysis has been used to find out character association and to group them into different groups by earlier workers in different crops (Rao *et al.,* 1981; Abraham *et al.*, 2002; Radhakrishnan, 2003; Ramasubramanian, 2005).

4.1.7. Genetic divergence

Study of genetic divergence among the thirty nine genotypes of native rices of Kerala was carried out by principal component analysis using the statistical software "STATISTICA" following UPGMA procedure. The study showed that at a linkage distance of 1.0 the plants could be grouped into sixteen clusters. Among the sixteen, thirteen were clusters of individual genotypes containing only one genotype each and two clusters consisted of twelve genotypes each, one cluster consisted of two genotypes (Table 4.11 & Fig. 4.1). Jeerakasala, Kuttiveliyan, Vrischikappandi, Kururai, Allikkannan, Adukkan, Marathondi, Punnadanthondi, Thondi, Kuruva, Vellarian and Aruvakkari belonged to one cluster; Kuthiru, Mundakan, Kuttadan, Navara, Orkazhama, Arikkinai, Kottarakkara and Chomala formed another cluster and Ponmani and Chettadi formed a third cluster. Vithandan, Ponnariyan,

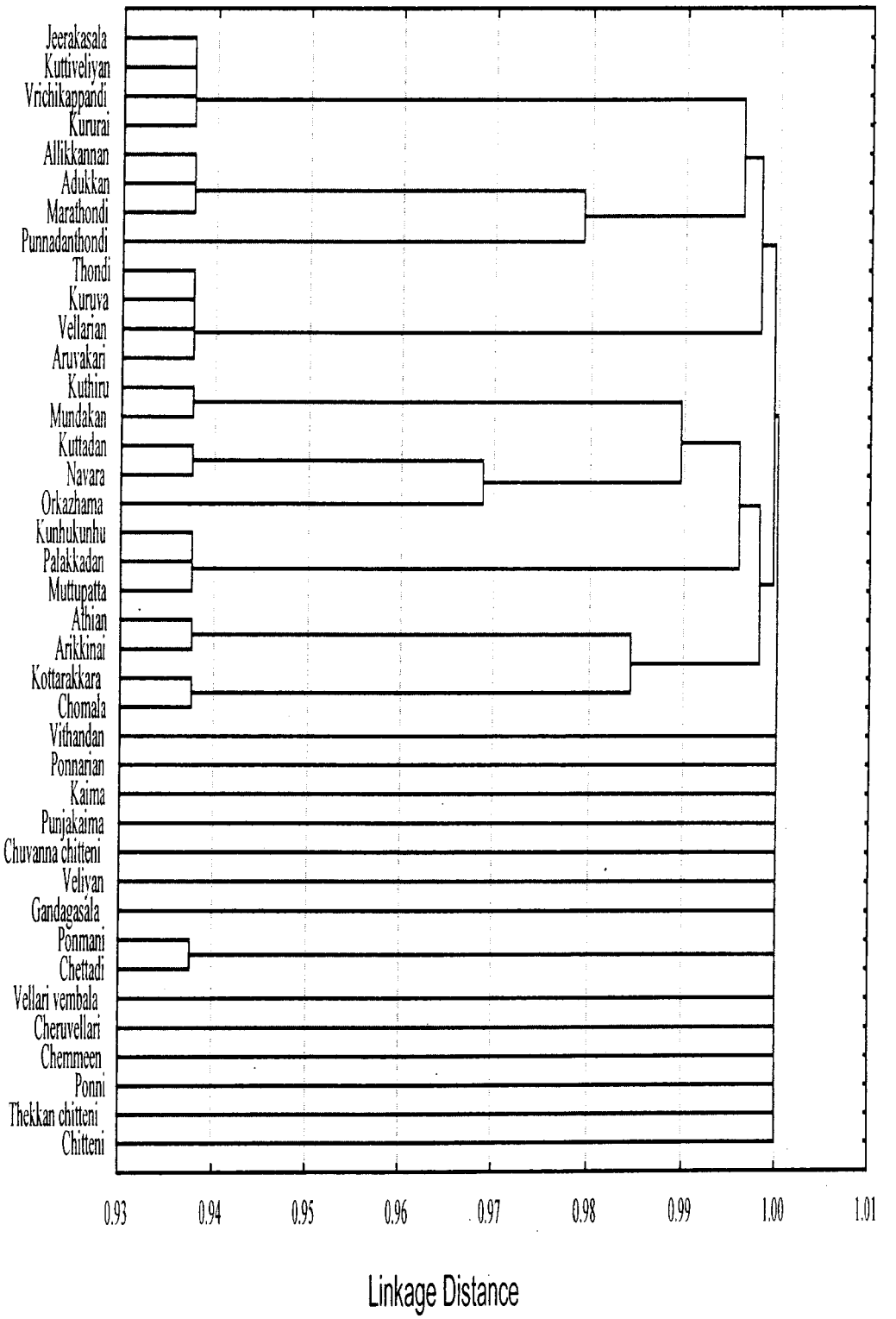
Gandhakasala, Vellarivembala, Cheruvellari, Chemmeen, Ponni, Thekkan Chitteni and Chitteni formed distinct clusters of individual genotypes. This shows that the genotypes under analysis are genetically diverse and distinct. However analysis at lower levels of linkage distances has shown differential affinities between genotypes. Jeerakasala, Kuttiveliyan, Vrischikappandi and Kururai; Allikannan, Adukkan and Marathondi; Thondi, Kuruva, Vellariayan, and Aruvakkari; Kuthiru and Mundakan; Kuttadan and Navara; Kunhukunhu, Palakkadan and Muttuppatta; Athian and Arikkinai; Kottarakkara and Chomala and Ponmani and Chettadi proved to be closely related genotypes.

Genotypes belonging to distant clusters are considered to be genetically diverse and such genotypes can be used for hybridization programmes to bring their dominant alleles together. Cluster analysis has been used by earlier workers like Misra *et al.* (1990) in dahlia, Indira (1994) in capsicum, Srivastava *et al.* (2000) in coriander, Radhakrishnan (2003) in cardamom and Ramasubramanian (2005) in tea for similar studies.

Table. 4.11. Cluster analysis of characters in the case of the thirty nine cultivars of native rices of Kerala studied.

Cluster No.	Accessions
1	Chitteni
2	Thekkan chitteni
3	Ponni
4	Chemmeen
5	Cheruvellari
6	Vellari vembala
7	Chettadi, Ponmani
8	Gandhagasala
9	Veliyan
10	Chuvanna chitteni
11	Punjakaima
12	Kaima
13	Ponnariyan
14	Vithandan
15	Chomala, Kottarakkara, Arikkinai, Athian, Muttuppatta, Palakkadan, Kunhukunhu, Orkazhama, Navara, Kuttadan, Mundakan, Kuthiru.
16	Aruvakkari, Vellarian, Kuruva, Thondi, Punnadanthaondi, Marathondi, Adukkan, Allikkannan, Kururai, Vrischikappandi, Kuttivelian, Jeerakasala.

Fig. 4.1. Clustering of genotypes in the case of the 39 accessions of native rices of Kerala studied.



4.1.8. Genetic control of characters

A preliminary study of the genetic control of sixteen agronomic characters of rice has been attempted presently based on frequency distribution analysis (Table 4.12 & Fig. 4.2). All the characters under study proved to be polygenic in nature as revealed by their continuous distribution. However, differential distribution patterns of alleles were evident from the different levels of skewness shown by different characters. Age at tiller initiation showed higher frequencies towards the left side of the curve indicating the early tillering nature of many of the genotypes. However, the frequency of late flowering and late maturing plants were higher in the study population. Most of the native rices of Kerala are either medium duration or long duration varieties and this type of a distribution pattern of plants with regard to flowering and maturity is quite expected.

Table. 4.12. Frequency distributions of the characters studied in the case of the 39 accessions of native rice cultivars of Kerala.

Character/ Distribution	Number of plants
1. Age at tiller initiation (days)	
15-20	49
20-25	60
25-30	2
30-35	5
35-40	1
2. Age at flowering (days)	
70-100	7

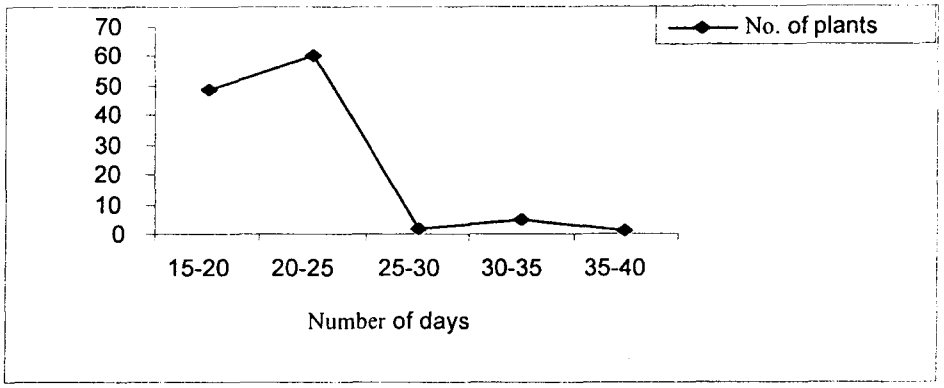
100-130	28
130-160	22
160-190	21
190-220	39
3. Duration (days)	
100-130	7
130-160	28
160-190	25
190-220	20
220-250	36
4. Number of tillers at flowering	
01 - 10	4
10 - 20	34
20 - 30	41
30 - 40	33
40 - 50	5
5. Tiller number at harvest	
1-10	3
10-20	31
20-30	44
30-40	33
40-50	6
6. Number of ear bearing tillers	
7-13	30
13-19	31
19-25	31
25-31	19
31-37	6
7. Plant height (cm)	
65-80	18
80-95	40
95-110	48
110-125	4

125-140	2
140-155	1
155-170	4
8. Panicle length (cm)	
13-16	17
16-19	52
19-22	26
22-25	20
25-28	2
9. Spikelets per panicle	
20-50	58
50-80	39
80-110	15
110-140	4
140-170	1
10. Seeds per panicle	
15-40	63
40-65	33
65-90	17
90-115	3
115-140	1
11. Panicle density	
1.21-2.28	34
2.28-3.35	51
3.35-4.42	25
4.42-5.49	5
5.49-6.56	2
12. Grain length (mm)	
6.0-6.7	6
6.7-7.4	12
7.4-8.1	64
8.1-8.8	32
8.8-9.5	3

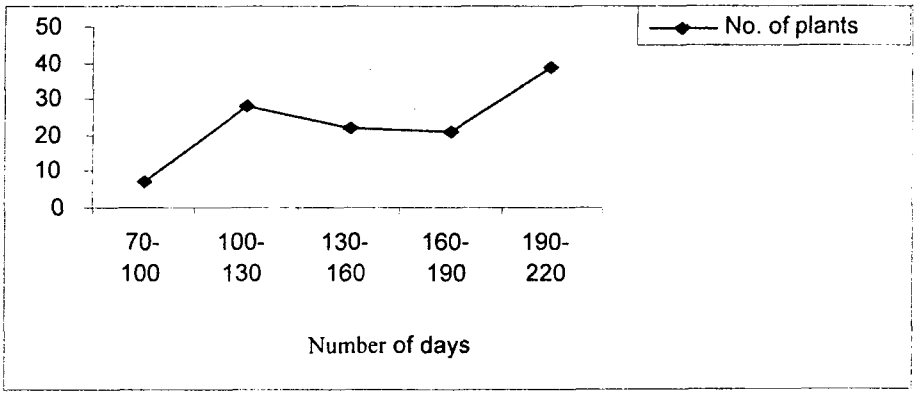
13. Grain thickness (mm)	
1.5-1.8	15
1.8-2.1	41
2.1-2.4	48
2.4-2.7	12
2.7-3.0	1
14. Hundred grain weight (gm)	
1.0-1.4	10
1.4-1.8	14
1.8-2.2	46
2.2-2.6	39
2.6-3.0	8
15. Fertility percentage	
45-55	10
55-65	15
65-75	27
75-85	36
85-95	29
16. Yield per plant (gm)	
4.0-9.0	18
9.0-14.0	48
14.0-23.0	45
23.0-28.0	1
28.0-33.0	2

Fig. 4.2. Frequency curves of the characters studied in the case of the 39 accessions of native rice cultivars of Kerala.

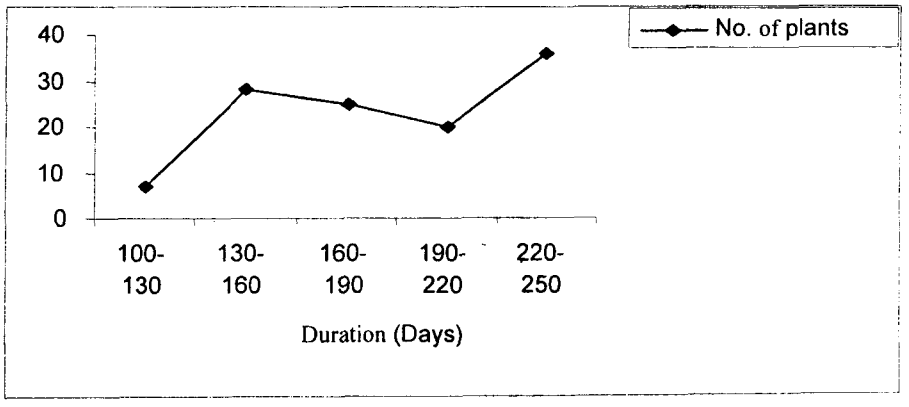
1. Age at tiller initiation (days)



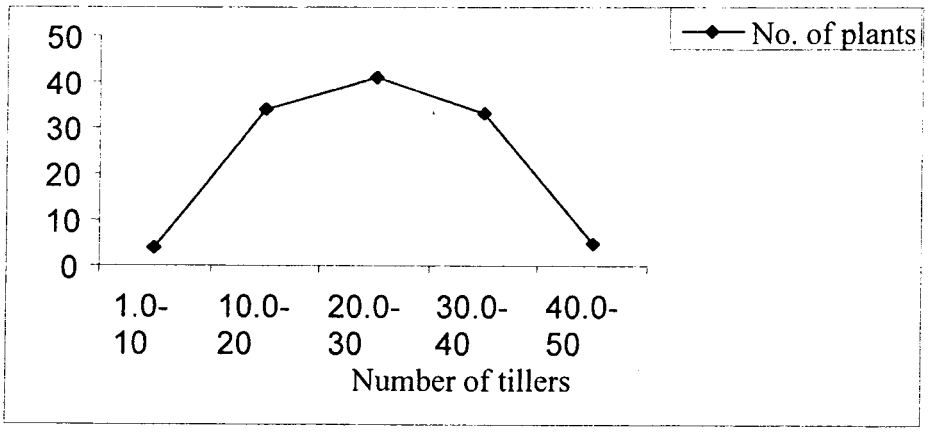
2. Age at flowering (days)



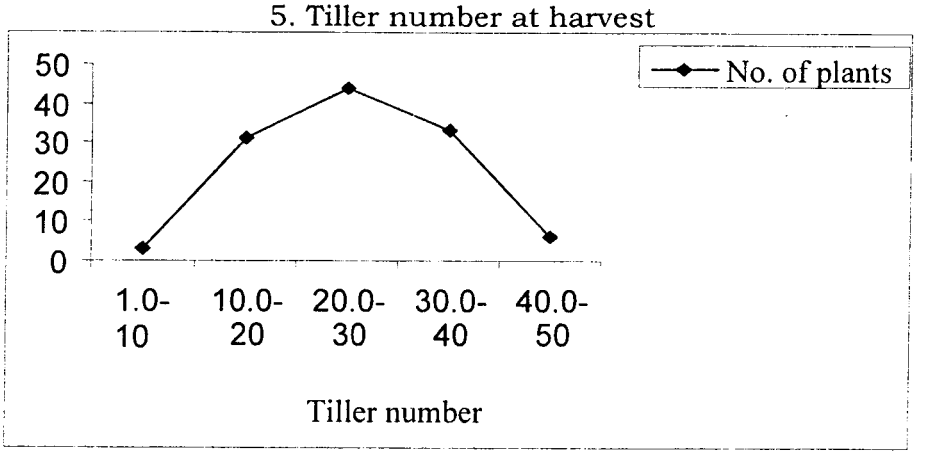
3. Duration (days)



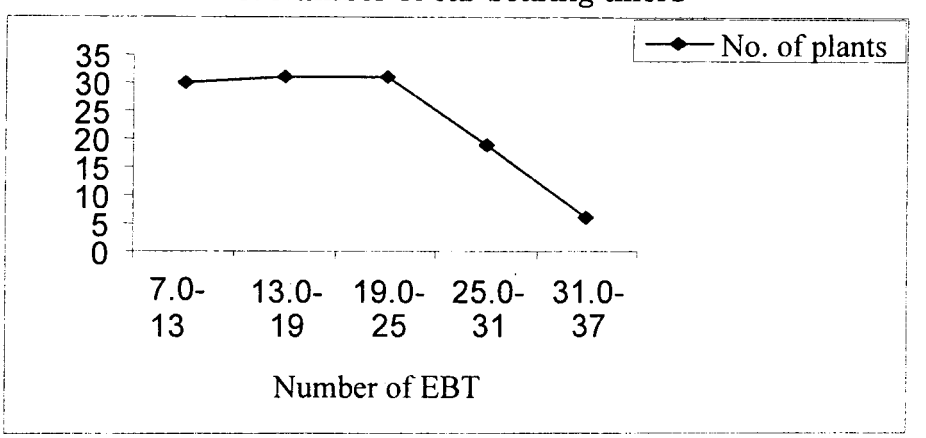
4. Number of tillers at flowering



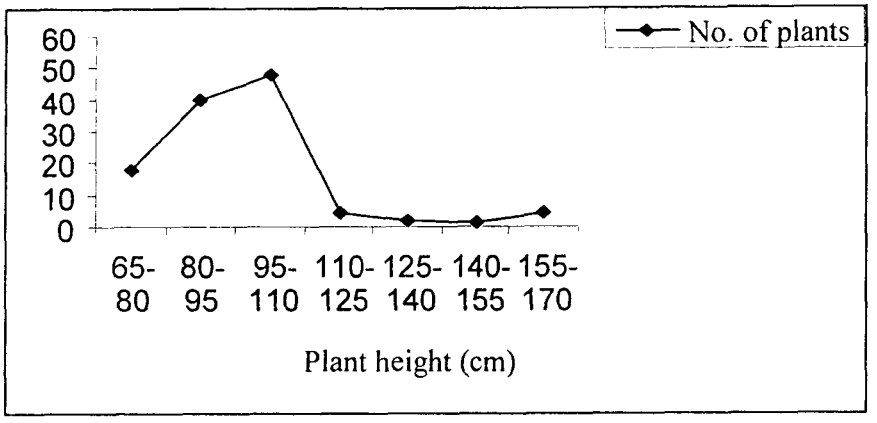
5. Tiller number at harvest



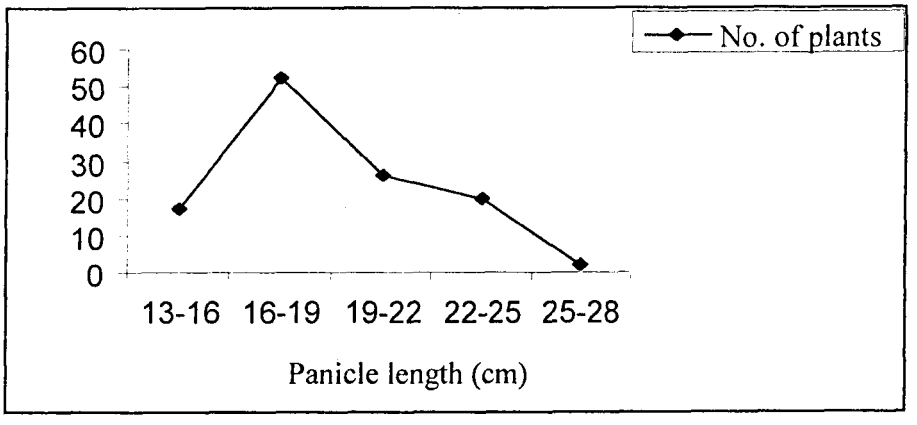
6. Number of ear bearing tillers



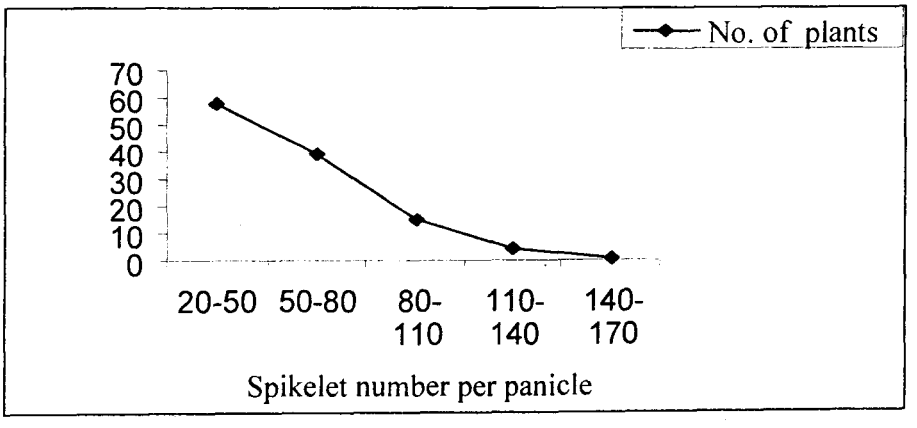
7. Plant height (cm)



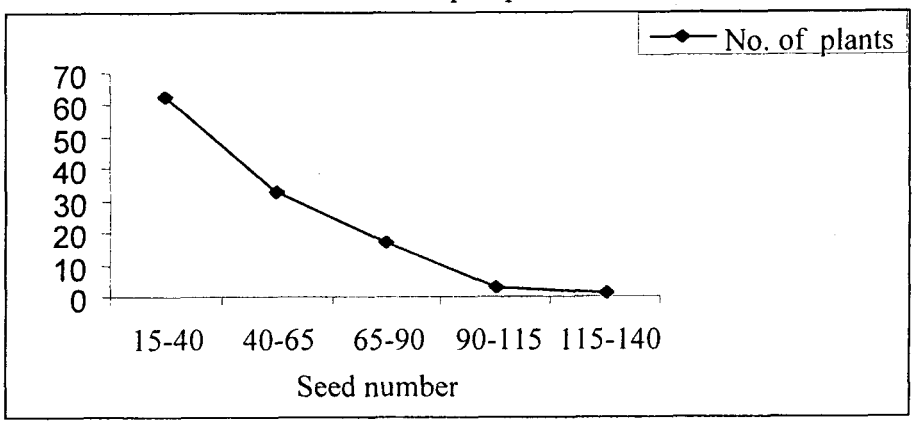
8. Panicle length (cm)



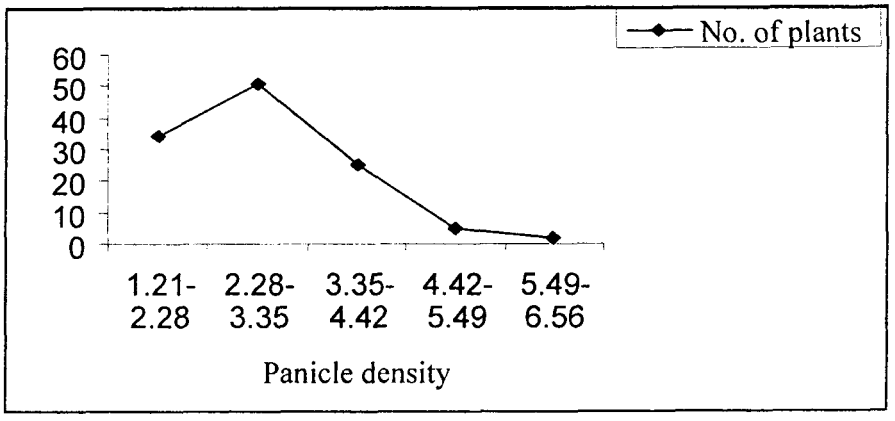
9. Spikelet number per panicle



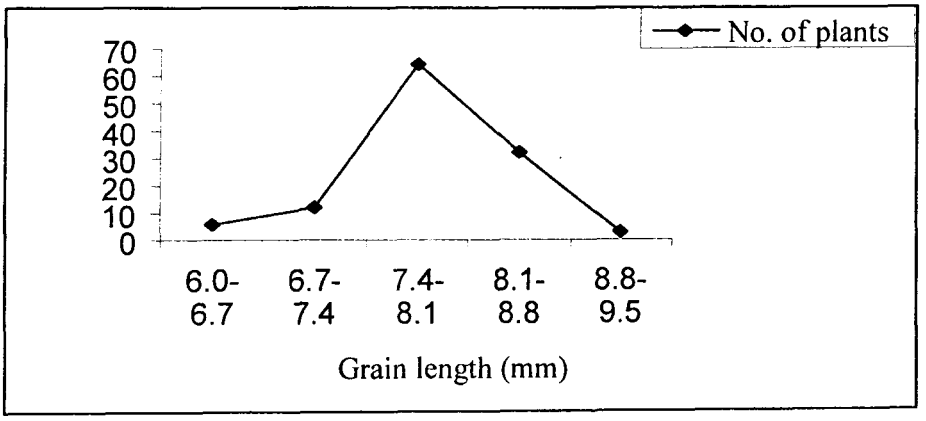
10. Seeds per panicle



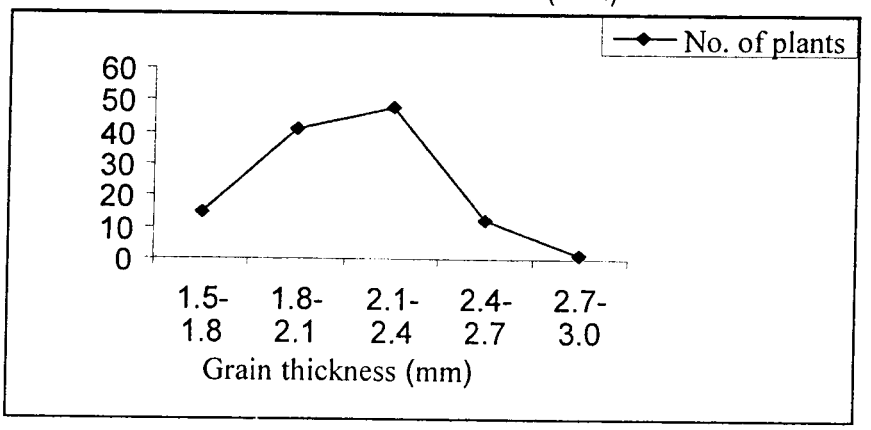
11. Panicle density



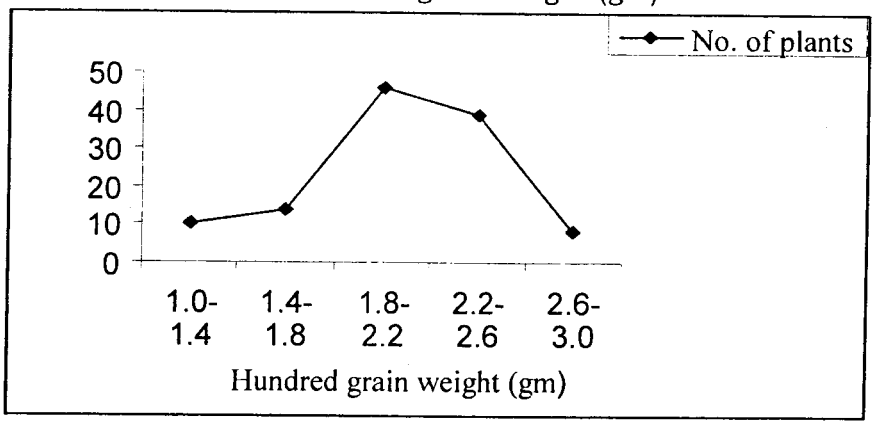
12. Grain length (mm)



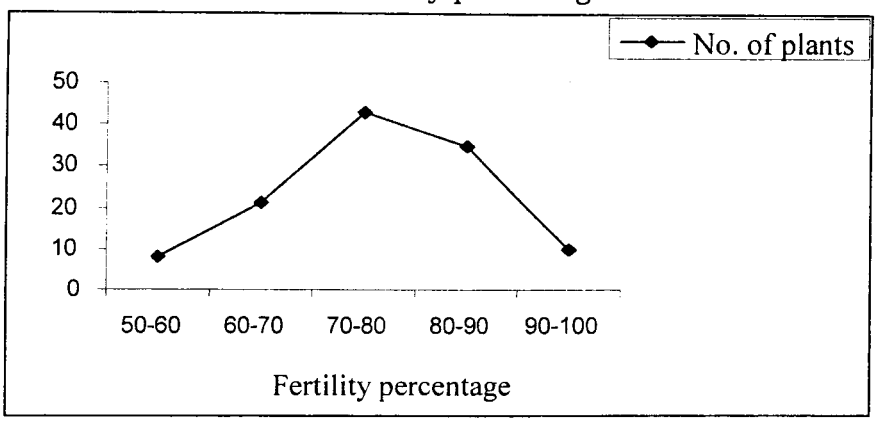
13. Grain thickness (mm)



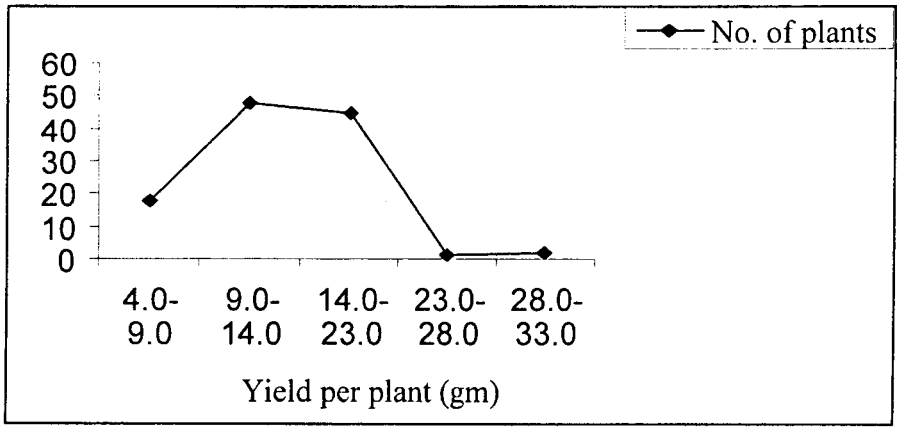
14. Hundred grain weight (gm)



15. Fertility percentage



16. Yield per plant (gm)



Tillers number at flowering ranged from 9.67 to 39.33 and tiller number at harvest ranged from 9.89 to 39.33 among the different cultivars under study (Table 4.7). Frequency distribution analysis revealed normal distribution of the characters with extreme plants in lower number and average plants in higher numbers. This phenomenon indicates the ample scope for selection among the genotypes based on these characters. However, EBT number showed a distribution with higher frequency towards lower EBT number indicating the necessity of additional care to be exercised while selecting for high tillering plants. The native rice cultivars of Kerala under study were found to be medium to tall in nature (Table 4.2). However, frequency distribution analysis showed that medium type of genotypes were higher in number when compared to tall ones (Table 4.12 & Fig. 4.2).

The present study showed that in the case of panicle length, spikelet number per panicle, seed number per panicle and panicle density higher frequency of plants was towards the lower side of the

distribution and only a few number of plants showed higher values. This shows the scope for intensive selection for these characters. However, parameters like grain length, grain thickness and 100 grain weight showed higher frequency towards the middle part of the distribution. Fertility percentage also showed a similar trend (Table 4.12 & Fig. 4.2). Yield per plant varied from 4.70 gm to 24.53 gm (Table 4.5) Frequency distribution analysis shows the accumulation of higher frequency of plants towards lower yield values and the representation of higher yielding plants in lower numbers only.

The above observations on the morphometric characters of rice indicating their polygenic control, continuous distribution and different levels of skewness in the distribution of genotypes are in conformity with the concept of polygenic control of agronomic characters as reported earlier by different workers. The quantitative nature of ear bearing tillers has been reported by Sukanya Subramanian and Rathinam (1984), Nadarajan and Kumaravelu (1994), Verma and Thakur (1994), Chakraborthy and Hazarika (1994b) and Mohanan (1996). Polygenic control of days to flower and duration has been reported by Chakraborthy and Hazarika (1994a), Chakraborthy *et al.* (1994) and Mohanan (1996). Polygenic control of plant height in rice has been reported by Majumdar *et al.* (1990), Anandkumar and Sreerangasamy (1986), Panwar *et al.* (1989), Paramasivan and Sreerangasamy (1988), Chakraborthy and Hazarika (1994b) and Mohanan

(1996). Polygenic control of panicle length has been reported by Chakraborthy and Hazarika (1994b) and Mohanan (1996). Polygenic control of grain related characters has been reported by Nadarajan and Kumaravelu (1994) and Mohanan (1996). Different systems of genetic control have been reported for sterility percentage by earlier workers (Pavithran and Mohandas, 1976; Shyla, 1984; Sharma, 1985; Shobha, 1993; Chakraborthy and Hazarika, 1994a and Mohanan, 1996).

4.2. Characterisation and conservation of native rices of Kerala

Thirty nine cultivars of native rices of Kerala (Table 3.1 & Fig.4.3) were collected, grown in the net house of the Genetics and Plant Breeding Division of the Department of Botany, Calicut University and characterised based on sixteen characters (Table 4.13).

Table 4.13. Characters of the 39 rice cultivars studied.

	1. Chitteni	**2.Thekkan chitteni**	**3. Ponni**	**4. Chemm-een**
Age at tiller initiation (days)	19.22±1.79	21.00±1.00	18.89±0.60	19.22±0.83
Age at flowering (days)	195.33±4.36	190.22±12.37	165.00±3.16	175.44±19.49
Total duration (days)	225.33±4.36	220.22±12.37	195.00±3.16	205.44±19.49
Number of tillers at flowering	30.22±3.60	33.11±3.89	30.56±3.36	19.78±4.89
Number of tillers at harvest	31.33±4.18	34.74±3.90	31.33±3.74	20.56±5.77

EBT number	23.78±1.71	24.00±7.30	22.11±4.31	15.67±6.24
Plant height (cm)	98.54±5.10	82.80±11.24	87.24±4.48	87.52±8.20
Panicle length (cm)	17.48±1.62	16.72±2.26	18.24±2.07	20.97±2.88
Spikelets per panicle	42.67±6.87	39.00±18.75	58.22±12.13	59.67±18.84
Seeds per panicle	41.44±8.40	30.78±14.09	44.33±10.69	54.89±13.72
Panicle density	2.44±0.31	2.25±0.70	3.19±0.59	2.84±0.34
Grain length (mm)	7.85±0.32	7.83±0.45	7.15±0.37	7.85±0.72
Grain thickness (mm)	2.33±0.37	2.39±0.32	1.84±0.27	2.34±0.42
Hundred grain weight (gm)	1.96±0.11	2.04±0.16	1.52±0.08	1.72±0.16
Fertility percentage	84.91±1.94	79.62±11.26	75.97±9.98	74.70±13.35
Yield per plant (gm)	17.11±3.65	14.27±7.32	14.10±4.48	11.69±5.41
	5. Cheru vellari	**6. Vellari vembala**	**7. Chettadi**	**8. Ponmani**
Age at tiller initiation (days)	18.33±0.71	18.33±0.50	19.89±0.93	16.22±0.66
Age at flowering (days)	195.11±4.14	189.78±7.65	130.56±4.50	182.89±8.88
Total duration (days)	225.11±4.14	219.78±7.65	160.56±4.50	212.89±8.88
Number of tillers at flowering	23.00±10.16	26.89±3.62	24.11±4.17	31.89±8.89
Number of tillers at harvest	24.00±10.33	27.33±3.46	25.11±4.20	32.56±8.85
EBT number	19.78±10.13	18.44±3.32	18.33±4.00	25.44±8.83

Plant height (cm)	86.56±6.69	103.28±12.45	98.53±9.22	75.19±7.59
Panicle length (cm)	16.47±1.82	17.42±1.67	21.33±1.99	16.89±1.39
Spikelets per panicle	36.78±9.35	44.33±7.98	79.44±13.30	44.44±12.25
Seeds per panicle	30.44±11.06	37.33±7.16	71.00±14.93	36.33±10.42
Panicle density	2.21±0.37	2.43±0.32	3.71±0.47	2.61±0.57
Grain length (mm)	7.83±0.33	8.18±0.49	7.88±0.90	7.67±0.59
Grain thickness (mm)	2.04±0.19	2.19±0.25	1.76±0.16	2.14±0.24
Hundred grain weight (gm)	2.12±0.19	2.12±0.12	1.31±0.30	1.84±0.25
Fertility percentage	80.74±12.19	84.27±6.75	88.82±5.00	83.52±10.15
Yield per plant (gm)	11.86±6.16	14.54±3.45	16.87±5.26	16.04±2.77
	9.Gandha-kasala	**10. Veliyan**	**11.Chuva-nna chitteni**	**12.Puncha kaima**
Age at tiller initiation (days)	18.00±0.01	19.22±0.44	18.11±0.33	19.33±0.50
Age at flowering (days)	129.56±4.07	179.22±5.21	157.00±5.79	203.11±2.37
Total duration (days)	159.56±4.07	209.22±5.21	187.00±5.79	233.11±2.37
Number of tillers at flowering	11.44±2.88	31.44±6.80	27.67±8.85	25.56±2.60
Number of tillers at harvest	11.78±2.95	32.33±6.65	28.67±8.97	26.33±1.87
EBT number	11.00±2.92	25.44±6.06	21.00±5.12	22.67±3.54
Plant height (cm)	97.10±5.22	101.61±7.20	82.16±8.20	98.89±5.06

Panicle length (cm)	19.67±2.60	16.16±2.68	16.96±1.57	16.51±2.01
Spikelets per panicle	58.67±16.20	40.33±9.11	34.22±7.08	37.67±13.82
Seeds per panicle	42.22±11.95	30.33±7.48	27.67±6.58	31.22±12.80
Panicle density	2.95±0.28	2.48±0.26	2.00±0.33	2.22±0.57
Grain length (mm)	6.53±0.14	7.64±0.31	8.55±0.48	7.86±0.18
Grain thickness (mm)	1.73±0.13	2.18±0.12	2.07±0.15	2.14±0.10
Hundred grain weight (gm)	1.03±0.11	2.00±0.18	2.30±0.23	2.07±0.12
Fertility percentage	70.23±10.82	76.27±8.22	80.79±7.66	82.24±6.81
Yield per plant (gm)	4.70±1.43	14.98±3.07	13.17±2.18	11.05±3.30
	13. Kaima	**14. Ponna-riyan**	**15. Vithan-dan**	**16. Chomala**
Age at tiller initiation (days)	19.56±0.88	18.56±0.53	19.33±0.50	33.56±1.66
Age at flowering (days)	134.00±2.69	101.11±2.47	211.11±3.06	167.00±6.65
Total duration (days)	164.00±2.69	131.11±2.47	241.11±3.06	197.00±6.65
Number of tillers at flowering	28.67±2.96	16.22±2.82	35.22±3.87	20.89±3.86
Number of tillers at harvest	26.33±3.35	15.33±3.08	37.78±5.67	21.67±4.39
EBT number	16.11±2.26	12.78±2.33	26.11±3.62	16.22±3.35
Plant height (cm)	90.59±5.15	105.44±5.95	81.37±4.95	92.79±3.96
Panicle length (cm)	20.34±1.48	23.88±1.64	16.63±1.39	16.98±1.99

Spikelets per panicle	78.00±13.44	107.33±13.84	31.44±5.08	40.67±8.99
Seeds per panicle	58.00±14.53	97.44±13.05	24.00±3.00	32.78±10.21
Panicle density	3.84±0.62	4.49±0.45	1.86±0.25	2.37±0.31
Grain length (mm)	7.50±0.19	8.50±0.19	8.16±0.64	7.70±0.48
Grain thickness (mm)	1.85±0.24	1.85±0.18	2.28±0.20	2.08±0.14
Hundred grain weight (gm)	1.43±0.40	1.77±0.31	2.30±0.27	1.94±0.11
Fertility Percentage	75.21±13.72	90.74±1.63	75.46±7.57	77.01±9.90
Yield per plant (gm)	12.94±3.43.	21.19±5.34	13.24±3.36	10.81±4.31
	17. Kottarakkara	**18. Arikkinai**	**19. Athian**	**20. Muttuppatta**
Age at tiller initiation (days)	24.44±0.88	20.56±0.52	20.44±0.52	19.56±0.52
Age at flowering (days)	201.89±0.93	196.00±1.00	197.33±5.45	128.22±1.09
Total duration (days)	231.89±0.93	226.00±1.00	227.33±5.45	158.22±1.09
Number of tillers at flowering	24.89±4.65	30.33±2.29	32.33±4.15	31.89±6.73
Number of tillers at Harvest	25.00±4.44	31.89±1.67	32.89±4.14	30.89±6.41
EBT number	17.00±4.33	18.22±3.11	24.89±6.47	24.33±4.56
Plant height (cm)	86.78±3.73	98.07±7.40	95.72±7.73	82.27±5.97
Panicle length (cm)	16.84±1.15	17.57±0.57	15.51±1.86	19.91±1.03
Spikelets per panicle	41.89±9.41	49.67±6.44	38.33±5.48	87.33±15.24

Seeds per panicle	29.82±13.12	43.56±6.58	30.89±7.03	69.33±11.62
Panicle density	2.37±0.34	2.88±0.32	2.29±0.54	4.37±0.61
Grain length (mm)	7.36±0.24	7.53±0.18	7.88±0.13	7.64±0.29
Grain thickness (mm)	2.05±0.16	2.21±0.27	2.37±0.24	1.64±0.17
Hundred grain weight (gm)	1.87±0.07	1.89±0.08	2.08±0.12	1.21±0.19
Fertility percentage	81.33±2.83	90.40±5.49	78.38±14.96	76.36±8.19
Yield per plant (gm)	9.98±0.34	15.34±2.74	16.16±5.87	21.39±5.70
	21. Palakkadan	**22. Kunhu kunhu**	**23. Orkazhama**	**24. Navara**
Age at tiller initiation (days)	19.22±0.44	21.33±0.50	22.00±0.50	22.00±0.71
Age at flowering (days)	208.00±4.03	88.22±2.54	102.67±0.71	71.11±4.54
Total duration (days)	238.00±4.03	118.22±2.54	132.67±0.71	101.11±4.54
Number of tillers at flowering	37.11±5.75	10.56±1.40	14.00±2.87	9.67±2.82
Number of tillers at harvest	38.00±5.59	9.89±1.36	14.33±2.87	23.89±4.83
EBT number	27.78±3.46	8.78±0.97	9.56±2.07	21.11±3.98
Plant height (cm)	106.10±8.46	66.61±2.43	119.68±7.39	96.73±11.00
Panicle length (cm)	15.74±0.88	20.28±1.44	23.73±1.08	18.44±2.62
Spikelets per panicle	35.56±6.77	107.89±19.90	87.33±13.71	67.89±21.55
Seeds per panicle	31.00±5.70	95.33±16.37	57.56±11.17	64.00±22.30
Panicle density	2.24±0.31	5.29±0.65	3.67±0.47	3.64±0.75

Grain length (mm)	8.35±0.10	8.15±0.46	8.83±0.26	7.57±0.30
Grain thickness (mm)	2.23±0.20	1.77±0.20	2.17±0.19	1.93±0.18
Hundred grain weight (gm)	2.06±0.20	1.55±0.34	2.42±0.25	1.76±0.26
Fertility percentage	82.95±9.12	88.77±2.20	66.46±10.21	90.23±9.10
Yield per plant (gm)	16.08±3.06	13.83±3.80	13.76±4.30	24.53±12.71
	25. Kuttadan	**26. Mundakan**	**27. Kuthiru**	**28. Aruvakkari**
Age at tiller initiation (days)	20.56±0.52	20.22±1.09	19.78±0.44	20.00±0.01
Age at flowering (days)	216.67±2.24	209.33±5.70	132.67±4.74	199.44±11.98
Total duration (days)	246.67±2.24	239.33±5.70	162.67±4.94	229.44±11.98
Number of tillers at flowering	36.78±6.57	34.56±9.02	17.33±3.67	39.33±6.75
Number of tillers at harvest	37.89±6.81	37.78±11.00	16.78±3.60	39.11±7.49
EBT number	25.89±3.76	25.89±7.90	9.22±0.83	27.56±7.36
Plant height (cm)	77.00±6.80	87.76±8.37	101.54±9.47	79.97±5.81
Panicle length (cm)	16.77±1.02	17.62±0.77	23.24±3.00	16.01±1.32
Spikelets per panicle	31.67±6.82	41.56±6.35	83.89±17.75	33.89±5.51
Seeds per panicle	21.67±4.58	32.67±6.73	64.78±14.78	25.67±4.61
Panicle density	1.87±0.30	2.36±0.36	3.59±0.41	2.13±0.37
Grain length (mm)	8.08±0.43	7.79±0.35	8.85±0.30	7.57±0.37
Grain	2.16±0.25	2.02±0.12	2.29±0.13	1.97±0.10

thickness (mm)				
Hundred grain weight (gm)	1.92±0.26	2.03±0.28	2.44±0.23	1.85±0.17
Fertility percentage	69.52±11.18	75.80±9.28	79.27±14.70	76.92±5.56
Yield per plant (gm)	10.88±1.91	14.88±2.60	15.22±3.47	13.47±3.24
	29. Vellarian	**30. Kuruva**	**31. Thondi**	**32. Punnadan thondi**
Age at tiller initiation (days)	18.44±0.52	22.33±0.50	18.33±0.50	22.00±0.01
Age at flowering (days)	183.33±2.55	140.33±3.20	126.44±5.36	120.11±4.62
Total duration (days)	213.33±2.55	170.33±3.20	156.44±5.37	150.11±4.62
Number of tillers at flowering	26.44±3.97	25.44±7.13	17.89±4.68	19.33±4.58
Number of tillers at harvest	27.56±3.78	26.00±7.07	20.33±4.03	19.33±3.64
EBT number	20.44±2.74	20.22±4.12	14.11±2.15	14.78±3.87
Plant height (cm)	88.40±5.62	77.26±1.66	101.20±10.35	104.42±9.07
Panicle length (cm)	14.72±1.07	16.51±1.33	23.19±2.59	18.83±2.03
Spikelets per panicle	36.44±4.85	47.67±9.03	66.00±15.96	50.00±15.19
Seeds per panicle	27.44±5.86	40.22±8.07	45.22±8.73	30.78±14.05
Panicle density	2.47±0.20	2.87±0.38	2.84±0.56	2.62±0.57
Grain length (mm)	7.63±0.42	6.19±0.22	7.60±0.16	7.81±0.12
Grain thickness (mm)	2.14±0.26	2.24±0.44	2.03±0.06	2.25±0.13
Hundred grain	1.83±0.01	1.20±0.15	2.13±0.10	2.00±0.25

weight (gm)				
Fertility percentage	76.87±12.10	82.12±9.82	61.86±5.56	59.94±12.89
Yield per plant (gm)	10.81±1.89	12.22±3.42	14.53±3.69	8.47±5.37
	33. Mara thondi	**34. Adukkan**	**35. Alli kkannan**	**36. Kururai**
Age at tiller initiation (days)	21.00±0.01	18.33±0.50	18.22±0.44	23.44±0.52
Age at flowering (days)	111.11±4.65	116.33±3.67	107.00±4.58	106.89±2.67
Total duration (days)	141.11±4.65	146.33±3.67	137.00±4.58	136.89±2.67
Number of tillers at flowering	16.33±5.27	24.67±6.95	9.78±1.99	12.89±2.71
Number of tillers at harvest	17.11±5.28	22.44±6.52	10.00±2.00	11.67±2.78
EBT number	12.22±3.87	12.33±2.35	8.11±1.62	8.78±3.27
Plant height (cm)	97.01±10.23	98.83±7.15	139.84±22.42	162.58±27.25
Panicle length (cm)	21.98±1.03	18.11±0.37	23.76±4.29	23.14±2.18
Spikelets per panicle	74.78±6.52	55.00±7.09	113.56±53.98	94.44±25.15
Seeds per panicle	47.78±6.02	38.00±6.56	80.33±46.63	62.56±20.92
Panicle density	3.40±0.24	3.03±0.34	4.56±1.55	4.05±0.92
Grain length (mm)	7.90±0.20	8.02±0.24	8.47±0.19	8.43±0.22
Grain thickness (mm)	2.09±0.08	2.42±0.08	2.28±0.24	2.31±0.10
Hundred grain weight (gm)	2.22±0.18	2.02±0.06	2.39±0.19	2.31±0.11
Fertility percentage	64.28±8.68	67.99±3.60	63.79±13.29	65.76±9.94

Yield per plant (gm)	13.08±2.45	12.25±2.10	14.06±6.81	13.39±6.61
	37. Vrischi kappandi	**38. Kutti veliyan**	**39. Jeerakasala**	
Age at tiller initiation (days)	21.00±0.01	21.22±0.44	30.00±0.87	
Age at flowering (days)	144.67±1.80	135.00±1.32	140.44±2.92	
Total duration (days)	174.67±1.80	165.00±1.32	170.44±2.92	
Number of tillers at flowering	24.89±6.45	17.22±3.80	18.44±4.33	
Number of tillers at harvest	25.22±6.38	18.00±4.12	21.33±4.39	
EBT number	19.78±4.92	13.22±2.17	13.44±2.70	
Plant height (cm)	94.09±7.20	105.91±11.44	101.58±4.80	
Panicle length (cm)	17.19±1.82	20.00±1.82	22.20±2.41	
Spikelets per panicle	42.78±6.85	68.11±17.14	63.78±15.38	
Seeds per panicle	30.33±5.59	42.89±15.76	50.78±14.06	
Panicle density	2.48±0.27	3.38±0.65	2.85±0.48	
Grain length (mm)	7.73±0.49	7.54±0.30	7.52±0.29	
Grain thickness (mm)	2.24±0.36	2.25±0.17	1.80±0.06	
Hundred grain weight (gm)	1.91±0.28	2.18±0.32	1.49±0.06	
Fertility percentage	70.58±8.01	64.49±9.52	78.17±5.48	
Yield per plant (gm)	11.42±3.74	12.62±5.07	10.32±2.22	

Fig. 4.3. Thirty nine accessions of native rices of Kerala studied.

CHITTENI
Age at tiller initiation:19 days
Age at flowering:195 days
Total duration:225 days
Number of tillers at flowering:31
Tiller number at harvest:32
EBT Number:24
Plant height:99 cm
Panicle length:18 cm
Spikelet number per panicle:43
Seed number per panicle:43
Panicle density: 2.44
Hundred grain weight:1.96 gm
Grain length:7.85 mm
Grain thickness:2.32 mm
Yield per plant:20.18 gm

THEKKAN CHITTENI
Age at tiller initiation: 21 days
Age at flowering: 190 days
Total duration: 220 days
Number of tillers at flowering: 33
Tiller number at harvest: 35
EBT Number: 24
Plant height: 82.80 cm
Panicle length: 16.72 cm
Spikelet number per panicle: 39
Seed number per panicle: 32
Panicle density: 2.25
Hundred grain weight: 2.04 gm
Grain length: 7.83 mm
Grain thickness: 2.39 mm
Yield per plant:14.27 gm

PONNI
Age at tiller initiation: 19 days
Age at flowering: 165 days
Total duration: 195 days
Number of tillers at flowering: 31
Tiller number at harvest: 31
EBT Number: 22
Plant height: 87.24 cm
Panicle length: 18.24 cm
Spikelet number per panicle: 58
Seed number per panicle: 44
Panicle density: 3.19
Hundred grain weight: 1.52 gm
Grain length: 7.15 mm
Grain thickness: 1.84 mm
Yield per plant:14.10 gm

CHEMMEEN
Age at tiller initiation: 19 days
Age at flowering: 175 days
Total duration:2.05 days
Number of tillers at flowering: 20
Tiller number at harvest: 21
EBT Number: 15
Plant height: 87.52 cm
Panicle length: 20.97 cm.
Spikelet number per panicle: 60
Seed number per panicle: 55
Panicle density: 2.84
Hundred grain weight: 1.72 gm
Grain length: 7.85 mm
Grain thickness: 2.34 mm
Yield per plant:11./69 gm

CHERUVELLARI
Age at tiller initiation: 18 days
Age at flowering: 195 days
Total duration: 225 days
Number of tillers at flowering: 23
Tiller number at harvest: 24
EBT Number:20
Plant height: 86.56 cm
Panicle length: 16.47 cm.
Spikelet number per panicle:37
Seed number per panicle: 30
Panicle density: 2.21
Hundred grain weight: 2.12 gm
Grain length: 7.83 mm
Grain thickness: 2.04 mm
Yield per plant:11.86 gm

VELLARIVEMBALA
Age at tiller initiation: 18 days
Age at flowering: 190 days
Total duration: 220 days
Number of tillers at flowering: 27
Tiller number at harvest: 27
EBT Number: 18
Plant height: 103.28 cm
Panicle length:17.42 cm.
Spikelet number per panicle: 44
Seed number per panicle: 37
Panicle density: 2.43
Hundred grain weight: 2.12 gm
Grain length: 8.18 mm
Grain thickness: 2.19 mm
Yield per plant: 14.54 gm

CHETTADI

Age at tiller initiation: 20 days
Age at flowering: 131 days
Total duration: 159 days
Number of tillers at flowering: 24
Tiller number at harvest: 25
EBT Number: 18
Plant height: 98.53 cm
Panicle length: 21.33 cm
Spikelet number per panicle: 79
Seed number per panicle: 71
Panicle density: 3.71
Hundred grain weight: 1.31 gm
Grain length: 7.88 mm
Grain thickness: 1.76 mm
Yield per plant:16.87 gm

PONMANI

Age at tiller initiation: 16 days
Age at flowering: 183 days
Total duration: 213 days
Number of tillers at flowering: 32
Tiller number at harvest:33
EBT Number: 25
Plant height:75.19 cm
Panicle length: 16.89 cm
Spikelet number per panicle: 44
Seed number per panicle: 36
Panicle density: 2.61
Hundred grain weight:1.84 gm
Grain length: 7.67 mm
Grain thickness: 2.14 mm
Yield per plant: 16.04 gm

GANDHAKASALA

Age at tiller initiation: 18 days
Age at flowering: 130 days
Total duration: 160 days
Number of tillers at flowering: 11
Tiller number at harvest: 12
EBT Number: 11.
Plant height: 97.10 cm
Panicle length: 20 cm
Spikelet number per panicle: 59
Seed number per panicle: 42
Panicle density: 2.95
Hundred grain weight: 1.03 gm
Grain length: 6.53 mm
Grain thickness: 1.73 mm
Yield per plant: 4.7 gm

VELIYAN

Age at tiller initiation: 19 days
Age at flowering: 179 days
Total duration: 209 days
Number of tillers at flowering: 31
Tiller number at harvest: 32
EBT Number: 25
Plant height: 101.61 cm
Panicle length:16.16 cm
Spikelet number per panicle: 40
Seed number per panicle: 30
Panicle density: 2.48
Hundred grain weight: 2.0 gm
Grain length: 7.64 mm
Grain thickness:2.18 mm
Yield per plant:14.98 gm

CHUVANNA CHITTENI

Age at tiller initiation: 18 days
Age at flowering: 157 days
Total duration: 187 days
Number of tillers at flowering: 28
Tiller number at harvest: 29
EBT Number: 21
Plant height: 82.16 cm
Panicle length: 16.96 cm
Spikelet number per panicle: 34
Seed number per panicle: 28
Panicle density: 2.00
Hundred grain weight: 2.3 gm
Grain length: 8.55 mm
Grain thickness: 2.07 mm
Yield per plant: 13.17 gm

PUNJAKAIMA

Age at tiller initiation: 19 days
Age at flowering: 203 days
Total duration: 233 days
Number of tillers at flowering: 26
Tiller number at harvest: 26
EBT Number: 23
Plant height: 98.89 cm
Panicle length: 16.51 cm
Spikelet number per panicle: 38
Seed number per panicle: 31
Panicle density: 2.22
Hundred grain weight: 2.07 gm
Grain length: 7.86 mm
Grain thickness: 2.14 mm
Yield per plant:11.05 gm

KAIMA

Age at tiller initiation: 20 days
Age at flowering: 134 days
Total duration: 164 days
Number of tillers at flowering: 29
Tiller number at harvest: 26
EBT Number: 16
Plant height: 90.59 cm
Panicle length: 20.34 cm
Spikelet number per panicle:78
Seed number per panicle: 58
Panicle density: 3.84
Hundred grain weight: 1.43 gm
Grain length: 7.50 mm
Grain thickness: 1.85 mm
Yield per plant: 12.94 gm

PONNARIYAN

Age at tiller initiation: 19 days
Age at flowering: 101 days
Total duration: 131 days
Number of tillers at flowering: 16
Tiller number at harvest: 15
EBT Number: 13
Plant height: 105.44 cm
Panicle length: 23.88 cm
Spikelet number per panicle: 107
Seed number per panicle: 97
Panicle density: 4.49
Hundred grain weight: 1.77 gm
Grain length: 8.0 mm
Grain thickness: 1.85 mm
Yield per plant: 21.19 gm

VITHANDAN

Age at tiller initiation: 19 days
Age at flowering: 211 days
Total duration: 241 days
Number of tillers at flowering: 35
Tiller number at harvest: 38
EBT Number: 26
Plant height: 81 cm
Panicle length: 16.63 cm
Spikelet number per panicle: 31
Seed number per panicle: 24
Panicle density: 1.86
Hundred grain weight: 2.30 gm
Grain length: 8.16 mm
Grain thickness: 2.28 mm
Yield per plant: 13.24 gm

CHOMALA

Age at tiller initiation: 34 days
Age at flowering: 167 days
Total duration: 197 days
Number of tillers at flowering: 21
Tiller number at harvest: 22
EBT Number: 16
Plant height: 93 cm
Panicle length: 16.98 cm
Spikelet number per panicle: 41
Seed number per panicle: 33
Panicle density: 2.37
Hundred grain weight: 1.94 gm
Grain length: 7.70 mm
Grain thickness: 2.08 mm
Yield per plant: 10.81 gm

KOTTARAKKARA

Age at tiller initiation: 24 days
Age at flowering: 202 days
Total duration: 232 days
Number of tillers at flowering: 25
Tiller number at harvest: 25
EBT Number: 17
Plant height: 86.78 cm
Panicle length: 16.84 cm
Spikelet number per panicle: 42
Seed number per panicle:30
Panicle density: 2.37
Hundred grain weight: 1.87 gm
Grain length: 7.36 mm
Grain thickness: 2.05 mm
Yield per plant: 9.98 gm

ARIKKINAI

Age at tiller initiation: 21 days
Age at flowering: 196 days
Total duration: 226 days
Number of tillers at flowering: 30
Tiller number at harvest: 32
EBT Number: 18
Plant height: 98.07 cm
Panicle length:17.57 cm
Spikelet number per panicle: 50
Seed number per panicle: 44
Panicle density: 2.88
Hundred grain weight: 1.87 gm
Grain length: 7.53 mm
Grain thickness: 2.21 mm
Yield per plant: 15.34 gm

ATHIAN

Age at tiller initiation: 20 days
Age at flowering: 197 days
Total duration: 227 days
Number of tillers at flowering: 32
Tiller number at harvest: 33
EBT Number: 25
Plant height: 95.72 cm
Panicle length: 15.51 cm
Spikelet number per panicle: 38
Seed number per panicle: 31
Panicle density: 2.29
Hundred grain weight: 2.08 gm
Grain length: 7.88 mm
Grain thickness: 2.37 mm
Yield per plant:16.16 gm

MUTTUPPATTA

Age at tiller initiation: 20 days
Age at flowering: 128 days
Total duration: 158 days
Number of tillers at flowering: 32
Tiller number at harvest: 31
EBT Number: 24
Plant height: 82.27 cm
Panicle length: 19.91 cm
Spikelet number per panicle: 87
Seed number per panicle: 69
Panicle density: 4.37
Hundred grain weight: 1.21 gm
Grain length: 7.64 mm
Grain thickness: 1.64 mm
Yield per plant: 21.39 gm

PALAKKADAN

Age at tiller initiation: 19 days
Age at flowering: 208 days
Total duration: 238 days
Number of tillers at flowering: 37
Tiller number at harvest: 38
EBT Number: 28
Plant height: 106.1 cm
Panicle length: 15.74 cm
Spikelet number per panicle: 36
Seed number per panicle: 31
Panicle density: 2.24
Hundred grain weight: 2.06 gm
Grain length: 8.35 mm
Grain thickness: 2.23 mm
Yield per plant:16.08 gm

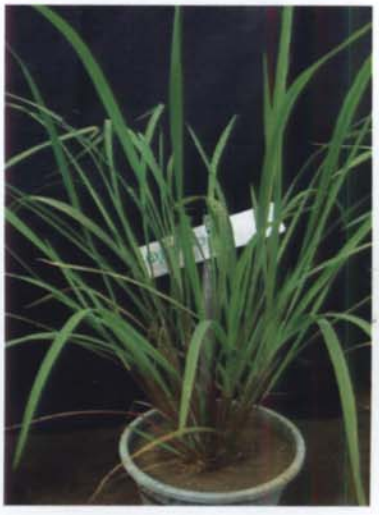
KUNHUKUNHU
Age at tiller initiation: 21 days
Age at flowering: 88 days
Total duration: 118 days
Number of tillers at flowering: 10
Tiller number at harvest: 10
EBT Number: 9
Plant height: 66.61 cm
Panicle length: 20.28 cm
Spikelet number per panicle:108
Seed number per panicle: 95
Panicle denbsity; 5.29
Hundred grain weight: 1.55 gm
Grain length: 8.15 mm
Grain thickness: 1.77 mm
Yield per plant:13.83 gm

ORKAZHAMA
Age at tiller initiation: 22 days
Age at flowering: 103 days
Total duration: 133 days
Number of tiller at flowering: 14
Tiller number at harvest: 14
EBT Number:10
Plant height: 119.68 cm
Panicle length: 23.73 cm
Spikelet number per panicle: 87
Seed number per panicle: 58
Panicle density: 3.67
Hundred grain weight: 2.42 gm
Grain length: 8.83 mm
Grain thickness: 2.17 mm
Yield per plant: 13.76 gm

NAVARA
Age at tiller initiation: 22 days
Age at flowering: 71 days
Total duration: 101 days
Number of tillers at flowering: 9
Tiller number at harvest: 24
EBT Number: 21
Plant height: 96.73 cm
Panicle length: 18.44 cm
Spikelet number per panicle: 68
Seed number per panicle: 64
Panicle density: 3.64
Hundred grain weight: 1.76 gm
Grain length: 7.57 mm
Grain thickness: 1.93 mm
Yield per plant: 24.53 gm

KUTTADAN

Age at tiller initiation: 21 days
Age at flowering: 217 days
Total duration: 247 days
Number of tillers at flowering: 37
Tiller number at harvest: 38
EBT Number: 26
Plant height: 77 cm
Panicle length: 16.77 cm
Spikelet number per panicle:32
Seed number per panicle: 22
Panicle density: 1.87
Hundred grain weight: 1.92 gm
Grain length: 8.1 mm
Grain thickness: 2.16 mm
Yield per plant:10.88 gm



MUNDAKAN

Age at tiller initiation: 20 days
Age at flowering: 209 days
Total duration: 239 days
Number of tillers at flowering: 35
Tiller number at harvest: 38
EBT Number: 26
Plant height: 87.76 cm
Panicle length: 17.62 cm
Spikelet number per panicle: 42
Seed number per panicle: 33
Panicle density: 2.36
Hundred grain weight: 2.03 gm
Grain length: 7.79 mm
Grain thickness: 2.02 mm
Yield per plant:14.88 gm

KUTHIRU

Age at tiller initiation: 20 days
Age at flowering: 133 days
Total duration:163 days
Number of tillers at flowering: 17
Tiller number at harvest: 17
EBT Number: 9
Plant height: 101.54 cm
Panicle length: 23.24 cm
Spikelet number per panicle: 84
Seed number per panicle: 65
Panicle density: 3.59
Hundred grain weight: 2.44 gm
Grain length: 8.85 mm
Grain thickness: 2.29 mm
Yield per plant:15.22 gm

ARUVAKKARI
Age at tiller initiation: 20 days
Age at flowering: 199 days
Total duration: 229 days
Number of tillers at flowering: 39
Tiller number at harvest: 39
EBT Number: 28
Plant height: 80cm
Panicle length: 16.01cm
Spikelet number per panicle:34
Seed number per panicle: 26
Panicle density: 2.13
Hundred grain weight: 1.85 gm
Grain length: 7.57 mm
Grain thickness: 1.97 mm
Yield per plant:13.47 gm

VELLARIAN
Age at tiller initiation:18 days
Age at flowering: 183 days
Total duration: 213 days
Number of tillers at flowering: 26
Tiller number at harvest: 28
EBT Number: 20
Plant height: 88.40 cm
Panicle length: 14.72 cm
Spikelet number per panicle: 36
Seed number per panicle: 27
Panicle density: 2.47
Hundred grain weight: 1.83 gm
Grain length:7.63 mm
Grain thickness:2.14 mm
Yield per plant: 10.81 gm

KURUVA
Age at tiller initiation: 22 days
Age at flowering: 140 days
Total duration: 170 days
Number of tillers at flowering: 25
Tiller number at harvest: 26
EBT Number: 20
Plant height: 77.26 cm
Panicle length: 16.51 cm
Spikelet number per panicle: 48
Seed number per panicle: 40
Panicle density: 2.87
Hundred grain weight: 1.2 gm
Grain length: 6.19 mm
Grain thickness: 2.24 mm
Yield per plant:12.22 gm

THONDI
Age at tiller initiation:18 days
Age at flowering: 126 days
Total duration: 156 days
Number of tillers at flowering: 18
Tiller number at harvest: 20
EBT Number: 14
Plant height: 101.20 cm
Panicle length: 23.19 cm
Spikelet number per panicle: 66
Seed number per panicle: 45
Panicle density: 2.84
Hundred grain weight: 2.13 gm
Grain length: 7.60 mm
Grain thickness: 2.03 mm
Yield per plant:14.53 gm

PUNNADAN THONDI
Age at tiller initiation: 22 days
Age at flowering: 120 days
Total duration: 150 days
Number of tillers at flowering: 19
Tiller number at harvest: 19
EBT Number: 15
Plant height: 104.42 cm
Panicle length: 18.83 cm
Spikelet number per panicle: 50
Seed number per panicle: 31
Panicle density: 2.62
Hundred grain weight: 2.0 gm
Grain length: 7.81 mm
Grain thickness: 2.25 mm
Yield per plant:8.47 gm

MARATHONDI
Age at tiller initiation: 21 days
Age at flowering: 111 days
Total duration: 141 days
Number of tillers at flowering: 16
Tiller number at harvest: 17
EBT Number: 12
Plant height: 97 cm
Panilcle length: 21.98 cm.
Spikelet number per panicle: 75
Seed number per panicle: 48
Panicle density: 3.40
Hundred grain weight: 2.22 gm
Grain length: 7.9 mm
Grain thickness: 2.09 mm
Yield per plant:13.08 gm

ADUKKAN
Age at tiller initiation: 18 days
Age at flowering: 116days
Total duration: 146 days
Number of tillers at flowering: 25
Tiller number at harvest: 22
EBT Number: 12
Plant height: 98.83 cm
Panicle length:18.11 cm
Spikelet number per panicle: 55
Seed number per panicle: 38
Panicle density: 3.03
Hundred grain weight: 2.02 gm
Grain length: 8.02 mm
Grain thickness: 2.42 mm
Yield per plant: 12.25 gm

ALLIKKANNAN
Age at tiller initiation: 18 days
Age at flowering: 107 days
Total duration: 137 days
Number of tillers at flowering: 10
Tiller number at harvest: 10
EBT Number: 8
Plant height: 139.84 cm
Panicle length: 23.76 cm
Spikelet number per panicle: 114
Seed number per panicle: 80
Panicle density: 4.56
Hundred grain weight: 2.39 gm
Grain length: 8.47 mm
Grain thickness: 2.28 mm
Yield per plant: 14.06 gm

KURURAI
Age at tiller initiation: 23 days
Age at flowering: 106 days
Total duration: 136 days
Number of tillers at flowering: 13
Tiller number at harvest: 12
EBT Number: 9
Plant height: 162.58 cm
Panicle length: 23.14 cm
Spikelet number per panicle: 94
Seed number per panicle: 63
Panicle density: 4.05
Hundred grain weight: 2.31 gm
Grain length: 8.43 mm
Grain thickness: 2.31 mm
Yield per plant:13.39 gm

VRISCHIKAPPANDI
Age at tiller initiation: 21days
Age at flowering: 145 days
Total duration: 175 days
Number of tillers at flowering: 25
Tiller number at harvest: 25
EBT Number: 20
Plant height: 94.09 cm
Panicle length: 17.19 cm
Spikelet number per panicle: 43
Seed number per panicle: 30
Panicle density: 2.48
Hundred grain weight: 1.91 gm
Grain length: 7.73 mm
Grain thickness: 2.24 mm
Yield per plant: 11.42 gm

KUTTIVELIAN
Age at tiller initiation:21 days
Age at flowering: 135 days
Total duration: 165 days
Number of tillers at flowering: 17
Tiller number at harvest: 18
EBT Number: 13
Plant height: 105.91 cm
Panicle length: 20 cm
Spikelet number per panicle: 68
Seed number per panicle:43
Panicle density: 3.38
Hundred grain weight: 2.18 gm
Grain length: 7.54 mm
Grain thickness: 2.25 mm
Yield per plant: 12.62 gm

JEERAKASALA
Age at tiller initiation: 30 days
Age at flowering: 140 days
Total duration: 170 days
Number of tillers at flowering: 18
Tiller number at harvest: 21
EBT Number: 13
Plant height: 101.58 cm
Panicle length: 22.20 cm
Spikelet number per panicle: 64
Seed number per panicle: 51
Panicle density: 2.85
Hundred grain weight: 1.49 gm
Grain length: 7.52 mm
Grain thickness: 1.80 mm
Yield per plant:10.32 gm

The highest age at tiller initiation was shown by Chomala (33.56 days) and the lowest by Ponmani (16.22 days). The highest age at flowering was shown by Kuttadan (216.67 days) and the lowest age by Navara (71.11 days). The highest duration also was shown by Kuttadan (246.67 days) and the lowest by Navara (101.11 days). The highest tiller number at flowering was shown by Aruvakkari (39.33) and the lowest by Navara (9.67). The highest tiller number at harvest was also shown by Aruvakari (39.33) and the lowest by Kunhukunhu (9.89). The highest EBT number was shown by Palakkadan (27.78) and the lowest by Allikkannan (8.11). The highest plant height was shown by Kururai (162.58 cm) and the lowest by Kunhukunhu (66.61 cm). Panicle length was found to be the highest in Ponnariyan (23.88 cm) and the lowest panicle length was shown by Vellarian (14.72 cm).The highest spikelet number per panicle was showen by Allikkannan (113.56) and the lowest by Vithandan (31.44). The highest seed number per panicle was shown by Ponnariyan (97.44) and the lowest by Kuttadan (21.67). Kunhukunhu showed the highest panicle density (5.29) and Vithandan showed the lowest (1.86). Kuthiru showed the highest grain length (8.85 cm) and Kuruva showed the lowest grain length (6.19 cm). Thekkan chitteni showed the highest (2.39 mm) and Muttuppatta showed the lowest grain thickness (1.64 mm). Hundred grain weight was the maximum (2.24 gm) in the case of Kuthiru and the minimum (1.03 gm)

in the case of Gandhakasala. Fertility percentage was the highest in Ponnariyan (90.74%) and the lowest in Punnadanthondi (59.94%). Yield per plant was the highest in Navara (24.53 gm) and the lowest in Gandhakasala (4.70 gm).

Characterisation and conservation of native rice varieties is very important in the present senario of green revolution and it's after effects. Many of the native rice varieties have become very rare or even extinct due to the wide popularisation of advanced varieties. However, the present study has shown that some of such varieties are even now available with the farmers. The conservation of such varieties is the need of the time, since most of them are getting disappeared very quickly. Moreover many such varieties have been found to be moderate to high tillering and giving fairly good yield.

Several efforts have been carried out for the characterisation and conservation of native rice germoplasm in different parts of the world. Hancock (2004) has opined that the conservation of native germplasm sources is absolutely critical to our future breeding success and perhaps the continuous survival of rice. Lu (1996) has pointed out that modern plant breeding practices and changes in crop management have accelerated the loss of biodiversity in rice. Nanda and Sharma (2003) have discussed the importance of both *ex situ* and *in situ* conservation of rice. Jackson (1995, 1997) has

stressed the importance of conserved germplasm in rice research.

Many of the countries in Asia, Africa and Latin America have maintained large collections of rice germplasm in which land races and local varieties have been conserved. Four centres of the Consultative Group on International Agricultural Research (CGIAR) are also maintaining rice germplasm (FAO, 2006). The international Rice Gene Bank of International Rice Research Institute maintains one of the largest collections of rice germplasm (IRRI, 2006b).

However, on farm conservation has been recommended as a very important method for rice (Bellon *et al.*, 1997). In such situations it is very important to list, characterize and conserve natively available rice germplasm in all conventional rice tracts so that further gene erosion does not take place. Moreover, on farm conservation and popularisation of selected rice varieties for cultivation are also important.

4.3. Tillering potential and tiller behaviour in rice.

Pre-green revolution rice varieties were tall and leafy with weak stems, profused tillering and lodging habit. These varieties show a harvest index of 0.3. To increase the yield potential of tropical rice, it was necessary to improve the harvest index as well as biomass production. This was accomplished by the reduction of plant height through the

incorporation of the recessive gene *(sd-1)* for short stature from a Chinese variety "Deo-Geo-Woo-Gen". The IR series developed at IRRI resulted in a gradual increase of harvest index from 0.3 to 0.5 thus changing the maximum yield per hectare from 4 T to 10 T under proper management. These varieties were subsequently used widely under green revolution (Khush, 2000).

Yield is a function of total dry matter and the harvest index. Therefore further increase in the yield potential is possible through the increase of biomass production or harvest index or both. Harvest index can be increased by increasing the proportion of energy stored in the grain or by increasing the sink size. The sink size can be increased by increasing the number of spikelets per panicle, increased spikelet filling, slow leaf senescence, maintenance of healthy root system and increased lodging resistance. Biomass can be increased by both genetic manipulations as well as by better management practices (Khush, 2000).

Khush (1994) has conceptualised a new plant type in rice for the purpose, with lower tillering capacity, absence of unproductive tillers, higher number of grains per panicle, medium height, sturdy stems, dark green, thick and erect leaves, thickened, deepened roots, multiple disease and insect resistance and acceptable grain quality. Under this circumstance an effort has been made presently to study the performance of different types of rice tillers

so as to assess their relative contribution towards yield.

Rice germinates as a single culm known as mother tiller. Subsequently it gives rise to primary, secondary and tertiary tillers. As a general rule primary tillers develop first, followed by secondary and tertiary tillers. In the case of ten rice varieties studied for the purpose, seven produced primary, secondary, and tertiary tillers where as three, produced only primary and secondary tillers. In all the cases tertiary tillers emerged significantly late indicating the possibility of their inability to contribute mature grains at the time of harvest (Table 4.14). Tertiary tillers flowered in the case of three varieties and they flowered 14-29 days after the first flowering of the plants, thus further indicating their probable unripe condition at the time of harvest. Tertiary tiller height was significantly low in the case of all the four varieties which developed healthy tertiary tillers. Seeds per panicle and panicle density were found to be low in the case of tertiary tillers. Panicle length, spikelets per panicle and seeds per panicle were also significantly low in tertiary tillers in most of the cases. The above study indicates the relative non contributing nature of tertiary tillers thus emphasizing the need for developing rice varieties with optimum numbers of primary and secondary tillers and with out tertiary tillers so that uniform ripening, harvest and maximum yield is possible.

Table 4.14. Tiller related analysis of plant and yield characters in rice.

1. Days taken for tiller emergence.

Sl. No	Variety	Primary tillers	Secondary tillers	Tertiary tillers	Plant value
1	Chuvanna chitteni	53.57±14.48	67.47±6.54 **	87.50±13.23 **	34
2	Chuvanna vattan	40.79±13.94	55.17±6.02 **	58.88±5.07 **	21
3	Thekkan cheera	43.96±11.13	55.30±8.62 **	57.80±2.77 **	27
4	Thekkan chitteni	54.07±13.98	64.32±9.97 **	70.50±2.65 **	38
5	Thondi	34.75±11.24	58.08±2.01 **	-	26
6	Chemmeen	46.79±8.49	49.77±5.81	-	33
7	Kuruva	44.43±9.36	52.04±4.78 **	52.25±1.71 **	32
8	Chitteni	47.44±15.73	59.50±10.66 **	72.00±5.00 **	28
9	Vellarian	49.64±17.37	60.73±7.24 **	68.00±0.82 **	29
10	Kunhu kunhu	39.25±7.56	51.95±11.37 **	-	30

2. Days taken for flowering

Sl. No	Variety	Mother tiller	Primary tillers	Secondary tillers	Tertiary tillers	Plant mean
1	Chuvanna chitteni	84	86.71±4.39	97.25±7.51 **	109.67±3.21 **	81
2	Chuvanna vattan	100	98.21±3.56	95.36±3.81 **	108.50±0.71 **	95
3	Thekkan cheera	82	86.09±3.27 **	93.74±9.62 **	103.30±18.90 **	82
4	Thekkan chitteni	90	99.60±5.47 **	108.40±9.42 **	-	90
5	Thondi	96	100.08±2.97 **	106.08±2.91 **	-	96
6	Chemmeen	95	98.57±4.24 *	102.9±3.79 **	-	95
7	Kuruva	84	84.5±0.71	88.75±6.88 *	-	84
8	Chitteni	76	84±5.56 **	90.54±6.34 **	98.67±3.21 **	76
9	Vellarian	101	102.41±3.24	104.38±1.43 **	-	101
10	Kunhu kunhu	75	75.65±3.06	74.67±4.22	-	73

3. Number of leaves

Sl. No	Variety	Mother tiller	Primary tillers	Secondary tillers	Tertiary tillers	Plant total
1	Chuvanna	4	4.00±0	4.24±0.44	3.00±0	106

	chitteni			*		
2	Chuvanna vattan	6	5.75±0.46	5.67±0.49 **	4.33±0.58 **	150
3	Thekkan cheera	5	5.11±0.33	4.83±0.38 *	4.00±0	145
4	Thekkan chitteni	6	5.50±0.55 *	5.50±0.53 **	-	78
5	Thondi	7	6.67±0.52	5.60±0.55	-	75
6	Chemmeen	7	6.71±0.49	6.30±0.67 **	-	117
7	Kuruva	6	5.67±0.52	5.00±0.87	-	85
8	Chitteni	5	4.88±0.64	4.33±0.65 **	3.50±0.71 **	103
9	Vellarian	6	6.00±0	5.56±0.53	-	92
10	Kunhu kunhu	7	6.00±0	6.40±0.42 **	-	69

4. Tiller height (cm)

Sl. No	Variety	Mother tiller	Primary tillers	Secondary tillers	Tertiary tillers	Plant height
1	Chuvanna chitteni	72.40	71.27±5.42	61.66±4.74 **	49.50±4.53 **	77.30
2	Chuvanna vattan	93.00	88.33±5.41 *	80.33±5.42 **	74.42±9.14 **	98.25
3	Thekkan cheera	92.80	85.36±3.88 **	73.96±3.26 **	65.70±8.21 **	92.80
4	Thekkan chitteni	98.20	88.81±7.50 *	77.81±2.90 **	-	98.20
5	Thondi	110.30	104.44±7.35	106.08±2.91	-	112.90
6	Chemmeen	109.00	93.17±10.69 **	84.84±5.39 **	-	109.00
7	Kuruva	93.00	84.88±9.70 *	71.01±4.96 **	-	97.50
8	Chitteni	91.40	77.73±8.14 **	64.67±11.26 **	58.25±0.35 **	91.40
9	Vellarian	113.30	102.26±10.05 **	99.07±2.67 **	-	113.30
10	Kunhu kunhu	65.20	57.52±5.76 **	48.20±2.67	-	65.20

5. Panicle length (cm)

Sl. No	Variety	Mother tiller	Primary tillers	Secondary tillers	Tertiary tillers	Plant mean
1	Chuvanna chitteni	16.80	14.42±0.82 **	12.73±0.98 **	10.35±0.49 **	13.14
2	Chuvanna vattan	19.00	18.28±1.13	16.56±1.80 **	15.60±1.81 **	17.34
3	Thekkan cheera	17.70	17.90±1.28	16.46±2.51 *	16.50±0 *	16.99
4	Thekkan chitteni	21.20	19.43±0.78 **	16.10±3.32 **	-	17.57

5	Thondi	24.50	22.52±1.57 *	17.99±2.50 **	-	20.80
6	Chemmeen	21.60	18.39±1.97 **	17.24±1.36 **	-	18.09
7	Kuruva	20.40	18.25±1.36 **	14.28±1.31 **	-	16.42
8	Chitteni	15.75	15.77±1.64	15.36±2.39	15.25±1.77	15.49
9	Vellarian	22.30	21.43±0.36 **	17.62±3.28 **	-	19.24
10	Kunhu kunhu	19.06	16.80±1.85 **	14.28±2.99 **	-	15.86

6. Spikelets per panicle

Sl. No	Variety	Mother tiller	Primary tillers	Secondary tillers	Tertiary tillers	Plant mean
1	Chuvanna chitteni	43	32.41±1.90 **	28.17±4.26 **	17.00±7.07 **	20.99
2	Chuvanna vattan	39	33.94±10.55	32.70±6.88 **	25.83±7.01 **	33.00
3	Thekkan cheera	52	37.88±14.46 *	33.91±8.94 **	31.00±0 **	35.88
4	Thekkan chitteni	74	56.99±6.54 **	38.92±7.60 **	-	46.88
5	Thondi	127	99.90±27.81 *	43.50±11.82 **	-	78.67
6	Chemmeen	75	59.36±18.96 *	48.90±7.71 **	-	54.42
7	Kuruva	93	66.92±10.73 **	40.25±9.02 **	-	55.61
8	Chitteni	49	41.21±8.67	34.00±4.05 **	22.00±0 **	36.52
9	Vellarian	89	63.08±9.86 **	41.33±6.32 **	-	52.44
10	Kunhu kunhu	96	72.75±15.06	59.70±20.24 **	-	68.89

7. Seeds per panicle

Sl. No	Variety	Mother tiller	Primary tillers	Secondary tillers	Tertiary tillers	Plant mean
1	Chuvanna chitteni	39	29.47±2.87 **	25.08±3.64 **	14.00±7.07 **	25.91
2	Chuvanna vattan	35	36.13±8.08	30.20±6.79 **	22.50±6.06 **	32.42
3	Thekkan cheera	48	38.76±5.48 **	28.79±7.75 **	25.00±0 **	32.76
4	Thekkan chitteni	70	54.25±6.18 **	36.55±7.66 **	-	44.32
5	Thondi	122	94.90±26.64 *	39.70±13.25 **	-	74.17
6	Chemmeen	74	56.07±17.62 *	46.75±8.91 **	-	51.86
7	Kuruva	89	63.17±9.89 **	38.50±8.56 **	-	52.64
8	Chitteni	46	36.07±9.10 *	27.88±4.52 **	17.00±0 **	30.93

9	Vellarian	85	59.58±10.53 **	37.50±6.94 **	-	48.72
10	Kunhu kunhu	88	65.20±15.87 **	51.90±19.70 **	-	61.24

8. Panicle density

Sl. No	Variety	Mother tiller	Primary tillers	Secondary tillers	Tertiary tillers	Plant mean
1	Chuvanna chitteni	2.58	2.22±0.16 **	2.20±0.23 **	1.66±0.76 **	2.18
2	Chuvanna vattan	2.08	2.03±0.28	1.89±0.28 *	1.65±0.26 *	1.99
3	Thekkan cheera	2.83	2.31±0.27 **	2.06±0.34 **	1.88±0 **	2.16
4	Thekkan chitteni	4.19	4.23±1.27	2.32±0.36 **	-	3.06
5	Thondi	5.15	4.37±0.99	2.73±0.76 **	-	3.75
6	Chemmeen	3.47	3.13±0.75	2.62±0.49 **	-	2.86
7	Kuruva	4.55	3.53±0.36 **	2.79±0.42 **	-	3.23
8	Chitteni	3.10	2.57±0.36 **	2.18±0.30 **	1.60±0 **	2.32
9	Vellarian	3.90	2.93±0.38 **	2.46±0.69 **	-	2.73
10	Kunhu kunhu	4.90	4.28±0.51 **	3.76±0.99 **	-	4.10

9. Fertility percentage

Sl. No	Variety	Mother tiller	Primary tillers	Secondary tillers	Tertiary tillers	Plant mean
1	Chuvanna chitteni	90	88.83±4.08	85.91±7.35 **	80.68±8.03 **	86.44
2	Chuvanna vattan	91	93.98±3.69 *	93.03±5.22 **	87.07±4.42 **	92.51
3	Thekkan cheera	92	91.09±4.46	84.71±3.35 **	80.64±0 **	86.96
4	Thekkan chitteni	96	95.69±1.99	94.11±3.02 **	-	94.72
5	Thondi	96	94.95±2.56	90.78±6.53	-	93.32
6	Chemmeen	98	93.69±2.32 **	94.77±4.35 *	-	94.53
7	Kuruva	95	94.26±1.32	95.05±2.85	-	94.72
8	Chitteni	94	86.95±5.89 *	80.77±6.59 **	77.27±0 **	83.28
9	Vellarian	95	92.33±3.42 *	90.16±4.31 **	-	91.29
10	Kunhu kunhu	90	91.26±1.65	85.43±5.85	-	91.20

**: significant at 1% level; *: significant at 5% level (t test)

Increasing the number of primary tillers and reducing the number of secondaries should also be considered as a breeding priority in rice for better synchronized flowering and maturity of tillers. As mentioned earlier Khush (1994; 2000) has indicated the importance of optimum or even reduced tillering so as to improve the yield potential of rice. Reduced tillering facilitates synchronized flowering and maturity, uniform panicle size and heavier grains. According to Padmaja Rao (1987), number of grains produced per unit area determines the grain yield in cereal crops (Takeda, 1984). However, the modern high yielding varieties that have replaced the traditional varieties have got higher tiller and panicle numbers, the additional tillers becoming unproductive as opined by Khush (2000). Hence the approach should be to increase the number of grains per panicle rather than number of panicles per plant. In other cereals like maize and jowar, yield potential has been increased by increasing the ear size (Khush, 1993).

4.4. *In vivo* clonal propagation of rice by tillers

Tiller splitting and transplantation has been recommended by workers like Richharia (1987), Mohanan (1993), and Mohanan and Pavithran (2001) to multiply, conserve and propagate rice plants especially under critical conditions. The technique helps to maintain the unique genetic identity of rare and endangered materials since the sexual cycle is bypassed. Moreover, the technique is practicable at farmer level and hence can be used as

a system adoptable by farming communities especially under threat and stress conditions.

Tillers of rice plants emerge on a chronological basis. The primary tillers emerge first, alternatively from subsequent nodes of the mother tiller pushing the first emerged ones to the external sides. The secondaries emerge in similar manner at right angles to the plane of emergence of the primaries from the nodes of the primary tillers and the tertiaries emerge at right angles to the plane of emergence of secondaries from the nodes of the corresponding secondaries. This type of origin of tillers is described as peripetal (Ramesh, 1989; Mohanan, 1996).

If these tillers are separated from the mother plant at appropriate intervals and planted separately they become autotrophic plants and produce tillers in the same chronological order (Mohanan and Pavithran, 2001). However, response to this type of *in vivo* clonal propagation is a varietal phenomenon to some extent. Hence nine rice varieties as listed in Table 3.6 have been subjected to *in vivo* clonal propagation and analysed based on six plant characters and seven yield characters in comparison with seed plants grown simultaneously.

Usually rice plants start to tiller fifteen days after germination and by the 30th day become three tillered. The three tillers were separated and planted on the 30th day and three tiller plants were obtained (Table 4.15). Within a period of fifteen days the

plants again become three tillered which can be further separated into three tillers each and planted separately on the 45th day. Again by fifteen days the plants get retillered and can be tiller separated and planted on the 60th day. This can be further repeated in the case of long duration varieties. However, in short and medium duration varieties the process of tiller splitting is to be stopped by the 60th day since such varieties usually start flowering with in a few days. As a result a total of 27 plants are obtained from a single mother plant within sixty days through three subsequent splitting cycles (Tables 4.15 & 4.16 and Fig. 4.4). Out of the 27, one plant will be mother tiller derived, six plants primary tiller derived, twelve plants secondary tiller derived and eight plants tertiary tiller derived.

Table 4.15. Pattern of tiller splitting and transplanting in *in vivo* cloning of rice.

Day of tiller splitting	Status of plants split	Status of tiller plants obtained	Total number of tiller plants obtained
30th day	Mother plant	Mother plant, P1 plant, P2 plant	3
45th day	Mother plant	Mother plant, P3 plant, P4 plant	9
	P1 plant	P1 plant, P1S1 plant, P1S2 plant	
	P2 plant	P2 plant, P2S1 plant, P2S2 plant	
60th day	Mother plant	Mother plant, P5 plant, P6 plant	27

	P1 plant	P1 plant, P1S3 plant, P1S4 plant	
	P2 plant	P2 plant, P2S3 plant, P2S4 plant	
	P3 plant	P3 plant, P3S1 plant, P3S2 plant	
	P4 plant	P4 plant, P4S1 plant, P4S2 plant	
	P1S1 plant	P1S1plant, P1S1T1 plant, P1S1T2 plant	
	P1S2 plant	P1S2 plant, P1S2T1 plant, P1S2T2 plant	
	P2S1 plant	P2S1 plant, P2S1T1 plant, P2S1T2 plant	
	P2S2 plant	P2S2 plant, P2S2T1 plant, P2S2T2 plant	

Table 4.16. Status of tiller derived plants obtained by *in vivo* cloning in rice through three consecutive splittings.

Status of the tillers giving rise to the plant	Details	Number of plants
Mother tiller	MT derived plant	1
Primary tillers	P1, P2, P3, P4, P5 and P6 derived plants	6
Secondary tillers	P1S1, P2S1, P1S2, P2S2, P3S1, P3S2, P4S1, P4S2, P1S3, P2S3, P1S4 and P2S4 derived plants	12
Tertiary tillers	P1S1T1, P2S1T1, P1S1T2, P2S1T2, P1S2T1, P2S2T1, P1S2T2 and P2S2T2 derived plants	8
Total number of plants produced		27

Nine rice varieties were subjected to *in vivo* clonal propagation as described above and the clonal plants were compared with seed developed plants based on thirteen agronomic parameters. The clonal plants derived presently through *in vivo* cloning have been compared with seed plants in relation to thirteen agronomic characters (Table 4.17). The observation shows that days to flower and total duration are significantly increased in clonal plant in all the cases. This is due to the fact that plants maintained their juvenile status for a longer time due to repeated tiller separation. Number of tillers at flowering has got significantly reduced in all the varieties except Chuvanna vattan in the case of clonal plants and tiller number at harvest has got reduced significantly in Chuvanna

vattan, Vellarian, Chettadi, Chuvanna chitteni, Chitteni, Palakkadan and Kuruva. EBT number got reduced significantly in all the varities except Chuvanna vattan. Even though reduction in tiller number may *prima face* seem to be an undesirable change, since the concept of high tillering varieties in rice is being displaced with high density planting of medium to low tillering plants, this cannot be considered undesirable. Plant height shows significant reduction in the clonal plants of Thekkan cheera and significant increase in the clonal plants of Chettadi, Poojyam pathu and Palakkadan.

Table 4.17. Comparative analysis of agronomic and other morphometric characters of seed plants and clonal plants in the case of the nine varieties of rice used for *in vivo* clonal propagation.

1. Days to flower			
Sl. No.	Variety	Seed plant	Clonal plant
1	Chuvanna vattan**	91.33±2.08	94.52±3.08
2	Thekkan cheera**	79.33±0.58	82.67±1.96
3	Vellarian**	95.67±1.53	110.48±5.38
4	Chettadi**	125.00±3.00	139.22±16.70
5	Chuvanna chitteni**	80.00±1.00	87.26±5.47
6	Chitteni**	80.67±0.58	86.52±5.57
7	Poojyam pathu**	83.30±1.53	95.93±3.57
8	Palakkadan**	122.67±7.51	89.59±4.78
9	Kuruva**	111.00±1.00	116.63±1.55
2. Duration (days)			
1	Chuvanna vattan**	121.33±2.08	124.52±3.08
2	Thekkan cheera**	109.33±0.58	112.67±1.96
3	Vellarian**	125.67±1.53	140.48±5.38

4	Chettadi**	155.00±3.00	169.22±16.70
5	Chuvanna citteni**	110.00±1.00	117.26±5.47
6	Chitteni**	110.67±0.58	116.52±5.57
7	Poojyam pathu**	113.30±1.53	125.93±3.57
8	Palakkadan**	152.67±7.51	119.59±4.78
9	Kuruva**	141.00±1.00	146.63±1.55
3. Number of tillers at flowering			
1	Chuvanna vattan	19.67±1.15	19.70±8.49
2	Thekkan cheera**	16.33±5.86	7.37±3.15
3	Vellarian**	19.00±3.61	6.44±2.47
4	Chettadi**	12.67±4.04	28.81±5.18
5	Chuvanna chitteni**	23.61±5.51	2.70±1.81
6	Chitteni**	15.67±2.52	2.81±1.30
7	Poojyam pathu**	5.67±1.53	2.33±1.44
8	Palakkadan**	9.67±0.58	3.26±2.03
9	Kuruva**	14.00±3.00	2.93±1.04
4. Tiller number at harvest			
1	Chuvanna vattan**	26.33±4.51	24.56±8.89
2	Thekkan cheera	21.00±7.94	20.00±4.37
3	Vellarian**	20.33±4.16	17.15±5.36
4	Chettadi**	23.67±5.03	30.26±6.96
5	Chuvanna chitteni**	29.33±6.81	15.93±5.32
6	Chitteni**	30.33±3.51	17.07±5.73
7	Poojyam pathu	8.33±2.08	9.04±3.94
8	Palakkadan**	30.67±3.52	13.67±5.88
9	Kuruva**	18.67±5.51	10.67±2.92
5. Ear Bearing Tiller (EBT) number			
1	Chuvanna vattan	22.00±5.00	20.00±8.11
2	Thekkan cheera**	19.33±7.77	15.78±4.65
3	Vellarian	12.33±2.08	12.78±4.53
4	Chettadi**	15.00±2.65	8.07±5.98
5	Chuvanna chitteni**	21.00±4.58	10.74±3.81
6	Chitteni**	26.33±2.08	11.67±4.79

7	Poojyam pathu**	5.00±1.00	7.48±3.94
8	Palakkadan**	18.67±0.58	10.96±5.45
9	Kuruva**	16.67±7.51	9.33±3.04
6. Plant height (cm)			
1	Chuvanna vattan	97.33±4.73	98.88±8.94
2	Thekkan cheera**	90.20±3.15	86.39±6.72
3	Vellarian	110.50±8.67	113.22±8.91
4	Chettadi**	105.33±6.81	112.65±9.31
5	Chuvanna chitteni	85.00±5.07	82.41±9.98
6	Chitteni	86.67±4.51	87.09±7.49
7	Poojyam pathu**	62.83±2.08	73.52±8.70
8	Palakkadan*	80.67±0.58	88.44±17.94
9	Kuruva	103.67±4.51	97.37±21.55
7. Panicle length (cm)			
1	Chuvanna vattan**	19.13±1.16	17.63±1.57
2	Thekkan cheera**	13.82±1.15	17.21±1.74
3	Vellarian	21.80±0.88	21.51±1.42
4	Chettadi	21.97±1.72	22.32±2.06
5	Chuvanna chitteni	16.27±0.32	16.50±1.88
6	Chitteni**	16.23±1.82	17.25±1.84
7	Poojyam pathu**	18.37±0.45	21.21±2.83
8	Palakkadan**	14.20±0.70	18.25±1.93
9	Kuruva**	17.07±0.65	18.69±2.40
8. Spikelets per panicle			
1	Chuvanna vattan**	37.67±3.51	43.00±7.72
2	Thekkan cheera**	35.33±0.34	53.37±15.98
3	Vellarian	73.00±15.52	74.37±13.25
4	Chettadi*	65.33±4.93	59.63±16.23
5	Chuvanna chitteni**	47.33±2.08	54.15±10.29
6	Chitteni*	44.33±11.93	50.28±12.85
7	Poojyam pathu**	87.33±4.51	77.59±14.10
8	Palakkadan**	37.00±3.00	53.88±14.70
9	Kuruva**	54.00±4.00	84.15±25.28

9. Seeds per panicle			
1	Chuvanna vattan**	35.33±3.21	41.07±7.72
2	Thekkan cheera**	30.33±2.65	46.56±9.29
3	Vellarian	65.17±14.75	62.67±12.09
4	Chettadi**	55.67±6.11	41.11±13.97
5	Chuvanna chitteni**	44.33±3.51	49.41±9.66
6	Chitteni**	38.67±8.74	46.67±11.02
7	Poojyam pathu**	83.67±0.06	70.85±13.32
8	Palakkadan**	34.00±5.00	51.06±13.77
9	Kuruva**	47.67±4.51	74.11±22.86
10. Panicle density			
1	Chuvanna vattan*	1.97±0.10	2.80±2.02
2	Thekkan cheera**	2.54±0.34	3.24±0.54
3	Vellarian	3.35±0.76	3.44±0.49
4	Chettadi**	2.98±0.32	2.65±0.55
5	Chuvanna chitteni**	2.91±0.15	3.61±1.06
6	Chitteni*	2.70±0.52	2.91±0.50
7	Poojyam pathu**	4.57±2.89	3.71±0.45
8	Palakkadan**	2.61±0.09	3.00±0.42
9	Kuruva**	3.17±0.12	4.47±0.92
11. Hundred grain weight (gm)			
1	Chuvanna vattan	2.25±0.08	2.23±0.26
2	Thekkan cheera	2.09±0.14	2.08±0.25
3	Vellarian**	2.45±0.30	2.60±0.21
4	Chettadi**	2.78±0.17	2.62±0.22
5	Chuvanna chitteni	2.43±0.11	3.53±4.79
6	Chitteni	2.23±0.16	2.42±0.22
7	Poojyam pathu*	2.37±2.69	2.44±0.21
8	Palakkadan**	2.48±0.05	2.63±0.21
9	Kuruva**	1.54±0.13	1.01±0.18
12. Fertility percentage			
1	Chuvanna vattan	93.90±3.96	95.39±2.53

2	Thekkan cheera	86.34±9.92	85.88±7.13
3	Vellarian**	89.33±1.32	84.11±7.23
4	Chettadi**	85.12±5.78	68.32±12.73
5	Chuvanna chitteni**	93.64±5.55	91.19±3.87
6	Chitteni**	80.06±4.76	92.39±4.86
7	Poojyam pathu**	95.79±1.73	91.36±5.75
8	Palakkadan**	92.02±5.47	95.33±2.17
9	Kuruva	87.83±1.83	87.16±5.49
13. Yield per plant (gm)			
1	Chuvanna vattan	17.82±6.21	17.75±7.69
2	Thekkan cheera**	12.18±4.62	16.18±4.81
3	Vellarian	19.53±4.56	20.54±9.01
4	Chettadi**	25.01±6.49	10.02±11.04
5	Chuvanna chitteni**	22.38±3.57	13.97±6.18
6	Chitteni**	23.53±4.44	14.04±7.75
7	Poojyam pathu*	10.00±1.79	13.69±8.65
8	Palakkadan	15.68±2.99	15.86±9.28
9	Kuruva**	13.49±4.75	7.28±3.78

*: Significant at 5% level (t test); **: Significant at 1 % level (t test)

Panicle length got significantly reduced in Chuvanna vattan and significantly increased in Thekkan cheera, Chitteni, Poojyam pathu, Palakkadan and Kuruva. Increase in panicle length is highly desirable since it may provide more space to accommodate higher number of grains. Spikelet number per panicle and seed number per panicle are significantly reduced in the case of Chettadi, Poojyam pathu and significantly increased in Chuvanna vattan, Thekkan cheera, Chuvanna chitteni, Chitteni, Palakkadan and Kuruva. Seed number per panicle showed significant reduction in the clonal plants of Chettadi and Poojyam pathu and

significant increase in the clonal plants of Chuvanna vattan, Thekkan cheera, Chuvanna chitteni, Chitteni, Palakkadan and Kuruva. Increase in spikelet number and seed number per panicle of the clonal plants in majority of the varieties studied indicates the usability of clonal propagation as a farming technique besides a technique of conservation. Panicle density showed significant reduction in the clonal plants of Chettadi and Poojyam pathu and significant increase in the clonal plants of Chuvanna vattan, Chettadi, Chuvanna chitteni, Chitteni, Palakkadan and Kuruva. Hundred grain weight showed significant increase in Vellarian, Poojyam pathu and Palakkadan and significant decrease in Chettadi and Kuruva. Fertility percentage showed significant decrease in the clonal plants of Vellarian, Chettadi, Chuvanna chitteni and Poojyam pathu and significant increase in the case of the clonal plants of Chitteni and Palakkadan. Yield per plant decreased significantly in the clonal plants of Chettadi, Chuvanna chitteni, Chitteni and Kuruva and increased significantly in the case of Thekkan cheera and in others there was no significant variation.

The above analysis of the agronomic characters of clonal plants in relation to seed plants has revealed mixed response of the varieties towards *in vivo* cloning in relation to agronomic characters. This shows that clonal plants show differential behaviour in relation to agronomic characters and it stresses the need for screening of varieties suitable

for clonal propagation on a large scale. Earlier workers like Richharia (1960; 1962; 1987), Pavithran (1975), Richharia and Pavithran (1987), Mohanan (1992), Mohanan and Pavithran (2001) have described the utility of *in vivo* clonal propagation of rice as a method of rice propagation adaptable under rapid environmental and climatic changes, stress and unforeseen instances of seedling and seed loss including natural calamities, wars and repatriation.

Clonal propagation of any kind, in rice or other crops will result in large scale production of genetically uniform planting materials. Clonal propagation starting from single mother plants results in the production of uniparental progenies that are genetically uniform and this technique is being utilitized world wide as a method of conservation of valuable unique genotypic systems but most of these efforts are carried out utilizing *in vitro* cloning technology and as such the technique is skill, capital and technology intensive and inaccessible to the rural and marginalized farming communities of the south. Hence, *in vivo* cloning technology stands unique since it is ecofriendly and farmer friendly. The present study shows that twenty seven clonal plants can be raised starting from a single seed through tiller separation and *in vivo* clonal propagation of tillers repeatedly at the three tiller stage for three times. Mohanan (1992) has developed a system of producing 27 plants in short duration varieties of rice through three splits,

eighty one plants through four splits in medium duration varieties and 243 plants through five splits in the case of long duration varieties and the present study provides additional information on the comparative behaviour of clonal plants and varietal differences in the performance of clonal plants.

STUDIES ON VARIABILITY AND CONSERVATION OF SOME NATIVE RICES OF KERALA

Thesis submitted in part fulfilment of requirements for the Degree of Doctor of Philosophy in Botany of the University of Calicut

by

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Chapter 5

SUMMARY AND CONCLUSION

The present study on genetic variability and conservation of some native rices of Kerala has been carried out to analyze the genetic variability of the native rice cultivars of Kerala State of India, to study the interrelationship of characters in them and to find out their affinities to each other so that effective steps could be taken for their conservation.

In spite of the success of the high tillering dwarf and semi dwarf varieties of rice, certain adverse comments have been raised by some experts on the relative potential of rice tillers of different status in yield contribution. It is argued that tillers of tertiary status usually emerge late and as a result they cannot contribute mature grains at the time of harvest. An effort has been made presently to assess the relative potential of rice tillers of different status in effective yield contribution.

Even though rice is seed propagated, clonal propagation techniques of *in vivo* and *in vitro* nature have also been recommended in rice at least under certain special circumstances. Clonal propagation is a very effective method of conservation since the material produced will be genetically uniform. An experiment has been carried out presently to study the effectiveness of *in vivo* clonal propagation of rice as a measure of conservation.

The experiment was carried out in the experimental net house of the Genetics and Plant Breeding Division of the Department of Botany of University of Calicut, Kerala, India during 2002-2005.

Even though Kerala State of India is a traditional rice cultivating area with diversity of native cultivars, green revolution and post green revolution developments and changes in cropping patterns from annual to perennial crops and from subsistence crops to cash crops has resulted in considerable loss of the diversity of its rice genetic resources.

Intra specific variability of a crop depends upon the peculiarities and diversity of its habitat. Due to the diversity of rice habitats, several rice cultivars suited for different environmental conditions are available in Kerala. The variability of 39 native rice cultivars of Kerala has been studied presently based on seven growth characters and nine yield characters.

The rice plant germinates as single culm but after a few days it produces accessory branches known as tillers of primary, secondary and tertiary status. Tillering is a varietal character and the general observation is that native rices of Kerala are medium to low tillering. The seven growth characters studied presently were age at tiller initiation, age at flowering, total duration, number of tillers at

flowering, number of tillers at harvest, number of ear bearing tillers and plant height.

Tiller initiation started in the earliest tillering variety on 16th day after keeping for germination and in the latest tillering variety on the 34th day indicating the varietal variation in the expression of this character. Among the 39 cultivars studied, the earliest flowering cultivar was Navara which is a famous medicinal variety and the latest flowering was Kuttadan which is photosensitive. Total duration was also the minimum in Navara and the maximum in Kuttadan. Number of tillers at flowering ranged from 10 to 39 and EBT number ranged from 8 to 28. Plant height of the native cultivars studied ranged from 66.01 cm to 162.60 cm showing that most of them are medium to tall in nature.

The study of variability among the 39 cultivars in relation to nine yield characters showed that panicle length of the cultivars ranged from 14 .7 cm to 29.9 cm, spikelets per panicle varied from 31.44 to 113.56 and seeds per panicle varied from 21.67 to 97.44. Panicle density varied from 1.86 to 5.29, grain length varied from 6.19 mm to 8.85 mm, 100 grain weight from 1.03 gm to 2.44 gm and yield per plant from 4.70 gm to 24.53 gm, thus showing high level of variability in the case of these characters among the cultivars of native rices of Kerala studied.

The extent of genetic variability among the cultivars was analyzed using ANOVA, genotypic and

phenotypic coefficients of variation, heritability (broad sense) and genetic advance under selection.

All the thirteen characters studied namely age at tiller initiation, age at flowering, total duration, number of tillers at flowering, number tiller at harvest, ear bearing tiller number, plant height, panicle length spikelets per panicle, seeds per panicle, panicle density, grain length, grain thickness, 100 grain weight, fertility percentage and yield per plant showed statistically significant variations between the cultivars studied indicating definite morphological and genetic differences between them.

In the case of all the characters studied, phenotypic variance was higher than genotypic variance indicating the polygenic nature of the characters under study and also the involvement of additive genes in the control of the characters. Genotypic coefficients of variation were also lower in all the cases when compared to phenotypic coefficients of variation showing the differential levels of influence of environmental factors on the expression of the characters under study. Among the growth characters, the highest GCV and PCV were shown by number of tillers at flowering followed by number of tillers at harvest and number of ear bearing tillers, showing the wide variability of these characters among the cultivars studied and suggesting the feasibility of selecting high tillering native rice cultivars. Among the yield characters seeds per panicle showed the highest variation

followed by spikelets per panicle indicating the scope for selection using these characters so as to improve the yield of native rices cultivated in Kerala.

Among the thirteen characters studied the highest heritability was shown by age at flowering and total duration followed by age at tiller initiation and plant height in the case of the growth characters. Among the yield characters 100 grain weight showed the highest heritability indicating the varietal nature of the character. It was closely followed by panicle density, spikelets per panicle, grain length, seeds per panicle and panicle length.

Among the growth characters genetic advance was found to be the highest in the case characters associated with tiller number followed by characters like age at flowering and total duration. This shows that these characters can be effectively used for selecting superior genotypes. Among the yield characters seeds per panicle showed the highest genetic advance followed by spikelets per panicle. These are the characters to be considered first when selection is practiced for yield.

The present study has indicated positive and significant correlation between many characters and negative correlation between some others. The study has further revealed that tillering parameters and panicle characters are interrelated. Characters that show strong positive correlation usually show covariation and selection of such characters can be done considering them as single units.

Study of character association by means of factor analysis has shown that the characters under study could be grouped into three groups. The first group consists of spikelet number per panicle, panicle density, panicle length, seed number per panicle, plant height and age at tiller initiation. The second group consists of fertility percentage and the third group consists of yield per plant, grain length, 100 grain weight, number of tillers at harvest, number of ear bearing tillers, number of tillers at flowering, grain thickness, total duration and age at flowering. Spikelet number per panicle showed the highest factor loading in the first group and yield per plant showed the highest factor loading in the second group. The third group consists of a single character, fertility percentage. Characters with highest factor loading can be considered as lead variables that can be used for selection.

The 39 genotypes of plants studied presently could be grouped into sixteen clusters showing their genetic diversity. Genotypes belonging to distant clusters can be used for hybridization programmes to bring their dominant alleles together.

A preliminary analysis of the genetic control of sixteen agronomic characters of rice based on the present study using frequency distribution analysis proved the polygenic nature of the characters. However, differential distribution patterns of alleles were evident from the different levels of skewness shown by the frequency curves of different characters.

Characterization of 39 native rice cultivars of Kerala has been attempted presently as a prerequisite for their effective conservation. Characterization and conservation of native rice cultivars is very important in the present scenario of green revolution and its after effects. Many of the native rice cultivars have become very rare due to the wide popularization of advanced rice varieties. However, at least some of such varieties are even now available with the farmers.

Pre green revolution rice varieties were tall with weak stems and lodging habit. They showed a harvest index of about 0.3. However, the use of green revolution varieties resulted in the gradual increase of harvest index to 0.5. Further increase in yield potential is possible through the increase of per unit biomass production or harvest index or both. The high tillering green revolution rice varieties produce numerous tillers but many of them emerge late and as a result they are not fully efficient to contribute mature grains at the time of harvest. Recently a new plant type has been conceptualized in rice with low tillering capacity, absence of unproductive tillers, higher number of grains per panicle, medium height, sturdy stem, dark green, thick and erect leaves, thickened, deepened roots, multiple disease and insect resistance and acceptable grain quality. Under these circumstances an effort has been made presently to study the performance of different types of rice tillers in relation to their yield contribution.

Rice germinates as a single culm known as mother tiller and subsequently it gives rise to primary, secondary and tertiary tillers. The study showed that tertiary tillers emerged significantly late indicating their inability to contribute mature grains at the time of harvest. Tertiary tillers flowered late and they showed lesser tiller height. Their panicle length, seed number and panicle density were also low indicating their relatively non contributing nature to effective yield.

Even though rice is seed propagated, clonal propagation both at *in vivo* and *in vitro* levels has been proposed to multiply, conserve and propagate rice plants especially under critical situations. *In vivo* clonal propagation has been standardized in nine native rice cultivars of Kerala presently starting from the three tillers stage by way of separating the tillers and planting them to given rise to new plants and repeating the process subsequently at three tiller stage till flower initiation. As a result, a total of 27 plants could be obtained starting from a single mother plant within sixty days through three subsequent splitting cycles. Clonal propagation starting from single mother plants results in the production of uniparental progenies that are genetically uniform. The present technique of *in vivo* clonal propagation is ecofriendly and farmer practicable and can be used as a conservation method under critical situations.

The above study has generated additional information on genetic variability of native rices of

Kerala and the need of their conservation. It has further indicated the relatively non contributing nature of the late emerging tillers of high tillering rice varieties and stressed the importance of developing low to medium tillering rice verieties which on high density planting may give better results. *In vivo* clonal propagation technology has been found to be useful as a farmer practicable conservation technique for genetically superior rice genotypes especially under conditions of threat and stress.

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