# IDENTIFICATION OF SALINE TOLERANT RICE HYBRIDS FOR POKKALI TRACT

**By**

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**(2015-11-028)**

## THESIS

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**COLLEGE OF HORTICULTURE**

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**2018**

# DECLARATION

I hereby declare that the thesis entitled **"Identification of saline tolerant rice hybrids for Pokkali tract"** is a bonafide record of research work done by me during the course of research and that the thesis has not previously formed the basis for the award to me of any degree, diploma, associateship, fellowship or other similar title, of any other university or society.

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# CERTIFICATE

Certified that the thesis entitled **"Identification of saline tolerant rice hybrids for Pokkali tract"** is a record of research work done independently by **Mr. Nikhil Narayanan** under my guidance and supervision and that it has not previously formed the basis for the award of any degree, diploma, fellowship or associateship to him.

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## CONTENTS

## LIST OF TABLES

## LIST OF FIGURES

## LIST OF PLATES



## LIST OF APPENDICES

# INTRODUCTION

# 1. INTRODUCTION

Rice (*Oryza sativa* L.) is one among the most widely consumed cereal grain in the world, belonging to the family Poaceae. It meets the calorie requirements of more than 40 per cent of world's population. It is an important staple food for greater part of the total populace largely in developing nations (Grover *et al.*, 2003). It is thus critical crop for ensuring food security, alleviating poverty and improving livelihood of people.

Owing to its global importance, an increase of at least 25 per cent in the current rice production is demanded by 2030 in order to cope up with escalating population growth. This has to be done with a reduced land, water and under more harsh stresses, owing to climate change and disease pressures (Li,2014). The various constraints causing decline in global rice production are insect pests, weeds, pathogens, drought, salinity and chillness.

Salinity is one of the main abiotic stresses that affects crop productivity and quality and has been identified as a grave threat to agriculture (Chinnusamy *et al.*, 2005). When growing on saline soils, salts in the soil make the growth of the plants difficult. The plants have to cope up with lack of nutrition and degraded soil physical conditions to endure, therefore, their productivity was reduced. Greater than before, salinisation of arable land is likely to have overwhelming worldwide effects, ensuing in a 30 per cent land loss within the coming 25 years and up to 50 per cent by the year 2050.

For mitigating salinity, two techniques can be adopted, one is by developing management options (Shannon, 1997) and the second is by improving the salinity tolerance in the present genotypes by use of genetic tools (Epstein *et al.*,1980). Good quality water resources is often a limiting factor in the carrying out of management options. Therefore, the use of genetic tools for improving the current genotypes for better tolerance towards salinity is anticipated to increase drastically in the future.

In Kerala, saline soils are usually seen within the coastal tracts of the districts of Ernakulam, Alappuzha, Thrissur and Kannur. Rice is the major crop which can be cultivated in these areas. Most of the varieties grown in these area are either traditional varieties or their selections with less yield potential. Under saline situations of Ernakulam and Alappuzha there is a unique traditional system of rice cultivation called as Pokkali. It is an ancient farming practice wherein, one season of rice farming is alternated with another season of prawn culture (Vijayan, 2016). The traditional rice variety's grown under this area show remarkable tolerance to salinity and floods makes it unique. However, the yield potential of these varieties are low.

Hybrids are the first generation crosses of diverse parents with high yield potential compared to varieties and land races. From 1994 to 2017 a total of ninety three hybrid rice varieties have been developed in India (Directorate of rice development 2017). Out of these few viz. DRRH 28, PSD 3, KRH 4 etc. were reported to have tolerance to salinity. In accordance with the facts about the salinity and in light of the current startling scenario of saline water intrusion as well as yield potentials of hybrids, identification and development of salt tolerant hybrids suitable for Pokkali tract of Kerala is certainly an earnest need of great importance. Hence, this study was designed to explore the adaptability of promising saline tolerant rice hybrids to unique tract of Pokkali and evaluation of traits associated with saline tolerance.

# REVIEW OF LITERATURE

# 2.REVIEW OF LITERATURE

## 1. Rice-Cereal of global prominence.

Rice (*Oryza sativa* L.) is one of the major food crops in the world, it is also tremendously salt-sensitive (Maas & Hoffman, 1977). It belongs to the family Poaceae, with a basic chromosome number of n=12. Rice can be either diploid or tetraploid. In this respect, *Oryza sativa* L. and *Oryza glaberrima* L. both are diploid species (2n= 24) (Brar *et al.,* 2003). Rice provides about one-third of the total carbohydrate source and is considered a major cereal crop of the world. It is used as a staple food by around 3 Billion people and accounts for 50-80 per cent of their daily calorie intake. Rice also provides a considerable amount of recommended Zinc and Niacin (Gopalan *et al.,* 2007). Rice protein has very high digestibility (88%). Rice is used in wide variety of ways viz. snacks, beverages, flour, and rice bran oil as well as in religious events and also for medicinal purposes.

## 2. Production Scenario

Rice has been cultivated for more than 7000 years as a major cereal food crop and supports around 50 per cent of the world population (Karthikeyan, 2011).

India has been a rice cultivating nation traditionally, and rice cultivation has been practised in India for a very long time. An area of 170 million hectares is covered by rice globally, which yields a total of 760 million tons. (FAO, 2017).

India has largest area under rice cultivation while it ranks second in production following China. However, with the escalating population, the boost in production of the crop is an earnest need of great importance in order to sustain the national food and livelihood security system.

India is one of the top exporters of rice. In India, an area of 43.9 million Ha land was cultivated with paddy with a production of 157 million tonnes during the year 2014-15. (Directorate of Economics and Statistics, 2016).

## 3. Abiotic stresses

In the natural environment, plants often grow under unfavourable conditions, such as drought, salinity, chilling, freezing, high temperature, flooding which are collectively known as abiotic stresses, and these can hinder plant growth and development, as well as can be fatal in extreme cases.

Almost 900 million Ha of land globally has been affected by salinity which accounts for 20 per cent of the cultivated land worldwide (Munns, 2002 and FAO, 2007). About 1 billion ha of land globally (Fageria *et al.,* 2012) and about 8.4 million ha land in India is salinity affected (Tyagi and Minta, 1998).

## 4. Salinity- a growing concern

Rice is a salt-sensitive monocot crop (Darwish *et al.,* 2009; Maas and Hoffman, 1997; Shereen *et al.,* 2005) and in many cases salinity becomes a limiting factor for plant production and is becoming more widespread as the intensity of agriculture increases. On a global basis, 5 per cent of arable land is being adversely affected by high saline conditions which challenges the agricultural production from those regions (Ghassemi *et al.,* 1995; Gunes *et al.,* 2007).

Salinity acts as one of the major hurdles in improving global crop production. The use of poor quality water for irrigation increases the problems due to salinity and it invariably diminishes the quality and quantity of crop production.

Crop production is severely limited by salinity among the abiotic stresses (Shannon, 1998). A saline soil is generally the pool of a number of soluble salts



16

such as $Ca^{2+}$, $Mg^{2+}$, $Na^{+}$ and anions $SO_4^{2-}$, $Cl^{-}$, $HCO_3^{-}$ with good quantity of $K^{+}$, $CO_3^{2-}$, and $NO_3^{-}$. Saline soil has electrical conductivity of 4 dS $m^{-1}$ or more (USDA-ARS, 2008), which is corresponding to about 40 mM NaCl having about 0.2 MPa of osmotic pressure.

When a significant reduction in yield takes place in most crops due to a certain level of EC, that condition is salinity. The pH of saline soils generally ranges from 7-8.5 (Mengel *et al.,* 2001).

The accumulation of salts over ages accounts for the occurence of salinity prone tracts present in the arid and semiarid zones. Additionally, the process has been accelerated to a great extent due to weathering of the parental rocks (Szabolcs, 1989 and Rengasamy, 2002). Salinity can also be consider ed as a natural occurrence taking place near sea shores due to seawater flooding.

### *4.1 Salinity – Physiological overview in plants.*

Many physiological aspects of plant growth are affected by salinity. Salinity stress affects a major part of the plant's physiology and biochemistry (Darwish *et al.,* 2009). Generally water stress, nutritional imbalance and salt stress have adverse effect on the growth of plants, (Ashraf and Harris 2004; Marschner, 1995). All these factors imparts pleiotropic effects on crop growth and development physiologically and biochemically (Munns, 2002; Tester and Davenport 2003 and Winicov, 1998).

Based on the level of resistance to salinity, plants are classified as halophytes or glycophytes. Halophytes have tolerance to high salt concentrations *i.e.*, upto 400 mM NaCl, meanwhile, glycophytes have tolerance to low concentrations of salt (Maas and Nieman, 1978). Most of the cultivated crops are glycophytes and their growth is diminished during salinity stress. Rye (*Secale cereale)* is the most tolerant crop among the cereals with a threshold of 11 $dSm^{-1}$ and rice is the most sensitive crop plant with a threshold of 3 $dSm^{-1}$ for most cultivated varieties (USDA, 2016). It has been reported that the tolerance of rice to salinity stress was relatively high during germination, active tillering and towards maturity, whereas it was found to be most susceptible during early seedling and reproductive stages (Heenan *et al*., 1988 and Zeng *et al*., 2001).

High $Na^+$ concentration causes undesirable alterations in enzymatic activities of plants (Maathuis and Amtmann, 1999). Salt tolerance is affected by exclusion of $Na^+$ ion and its circulation in all leaves homogeneously (Ashraf and O'Leary, 1995 and Haq *et al.,* 2009).

Usually, osmotic and ionic stresses are caused by salinity. An increase in the amount of salts in the root zone further than a threshold point leads to osmotic stress while an increase in amount of $Na^+$ ions in vacuole and cytoplasm of older leaves causes interruption of metabolic activities and death of the cell, it is known as ionic stress (Munns and Tester, 2008).

Salinity is found to have a delaying effect on seed germination (Akbar and Yabuno, 1974). Kapoor (2011) reported that, higher seed germination and vigour index was observed in control in comparison to salinity stress.

Energy for plant growth and development is produced by photosynthesis, which is an essential physiological process and it also helps the plants to get adapted to environmental and biotic stresses. For the duration of high salt stress, tolerant rice cultivars were found to have higher net photosynthesis along with the relative water content than the sensitive rice cultivars (Dionisio-Sese and Tobita, 2000; Moradi and Ismail, 2007 and Cha-Um *et al.,* 2009).

Maas and Grattan (1999) and Hanson *et al*., (1999) indicated that rice yields decrease by 12 per cent for every unit ($dsm^{-1}$) increase in EC (average root-zone EC of saturated soil extract) over 3.0 $dsm^{-1}$.

Salinity guidelines were originally prepared by Maas and Hoffman, (1977). The major inhibitory effect of salinity on plant growth and yield has been attributed to: i) ion toxicity ii) osmotic effect iii) nutritional imbalance leading to a reduction in photosynthetic efficiency and other physiological disorders. Most of the present rice cultivars are severely injured in flooded soil cultured on EC of 8-10 $dSm^{-1}$ at 25 °C; however, the susceptible ones are injured even at 2 $dSm^{-1}$ (Mass and Hoffman, 1977).

Water relations and ionic relations are found affected due to salinity. Initially, leaf excpansion is reduced due to water stress. After a long term exposure premature senescence of adult leaves is caused. Mineral deficiencies (Zn, P) and toxicities (Fe, Al, and organic acids) along with submergence and drought add to the problem (Gregorio *et al.*, 2002).

Uptake of potassium ($K^+$) and calcium ($Ca^{2+}$) is inhibited by excess of $Na^+$ ions under salt stress conditions, this leads to nutritional disorders (Grieve and Fujiyama, 1987; Dobermann and Fairhurst, 2000). Asik *et al.* (2009) reported that availability of soil water decreased with increase in salt content which led to reduced osmotic potential of soil water.

Rice is a species native to wetlands, with susceptibility for salinity stress, and being one of the world's most important food crops. The osmotic pressure caused due to salinity, causes the stomata to close, which in turn reduces the availability of carbon dioxide and leads to permanent damage at cellular level (Darwish *et al.*, 2009). Asch and Wopereis (2001) studied about the factors affecting the salt stress of rice and they are; (i) the strength of the stress, (ii) the resistance intensity of the genotype (iii) the climatic situation (Asch and Wopereis, 2001).

Ionic imbalance occurs due to disproportionate build up of Sodium ion (Na+) and Chlorine ($Cl^-$) ion in the cells, it leads ionic imbalance which results in reduction in uptake of other mineral nutrients, such as Manganese, Calcium, and Potassium (Karimi *et al.,* 2005). Munns and Tester (2008) recognized that in older leaves of many plant species compartmentalization and accumulation of $Na^+$ and $Cl^-$ takes place. In insensitive species or at high salinity environment, $Na^+$ transport or compartmentalization of the ions does not take place and the ionic effect overshadows the osmotic effect (Munns and Tester, 2008).

Sodium concentration and sodium uptake is amplified at elevated saline conditions. During an extended period in salinity, the sodium toxicity leads to a decrease in the yield (Castillo *et al.*, 2003). Chauhan *et al.*, (1997) attributed the salinity tolerance in rice callus to the capacity of the cells to preserve superior concentrations of $K^+$ and lesser levels of $Na^+$ and $Cl^-$ along with the elevated strengths of sterols and polyamines. Rice genotypes were screened by breeders in salt affected areas based on qualities like spikelet sterility, $Na^+$: $K^+$ ratio. spikelet sterility was found to have negative relation with level of salinity tolerance and can be used for screening rice lines. (Mishra *et al.*, 1997).

Zeng *et al.*, 2000, reported growth inhibition , reduction in seedling survival , number of tillers per plant and spikelet number per panicle when rice plants are grown under salinity condition .

Hariadi *et al.*, 2015 observed symptoms of saline stress as chlorosis, drying of leaves and shoot. They also observed that the salt stress hinders growth of rice and productivity by reducing photosynthetic capacity.

Kranto *et al.*, 2016, screened six varieties of rice under hydroponics culture condition. At 8 $dSm^{-1}$ of NaCl, variety Pokkali recorded to be most salt tolerant with a visual score of 4.38. While the susceptible variety IR 29 was found to be highly susceptible with a score of 9.00.

### *4.2 Proline.*

Ashraf and Foolad, (2007) reported that improved amassing of proline in plants was correlated with improved tolerance to salt stress. A reduction in chlorophyll content was observed in rice cultivars induced by salinity nevertheless, the presence exogenous proline was found to mitigate the deleterious effects of salinity stress by the mechanism of escalating the chlorophyll content and the photosynthetic activity (Sobahan *et al.,* 2012; Hasanuzzaman *et al.*, 2014). It was concluded from the above facts that the presence of proline helped in increasing the growth of rice cultivars during salinity stress by enhancing the photosynthetic activity.

Proline content was found to be in higher concentration in IR-28, which is a salt susceptible variety than in Pokkali, which is a salt tolerant cultivar (Demiral and Türkan, 2005), Suggesting that high levels of proline is required by salt sensitive cultivars for mitigating the stress created under saline conditions. Although, the concentration of proline was not enough to mitigate salt stress, it was compensated by amplified antioxidant defence system in those plant systems. Proline was found to have antioxidant properties as it protected cells against abiotic stresses by scavenging the free radicals and suppressing the accretion of reactive oxygen species. (Hasegawa *et al.,* 2000; Okuma *et al.,* 2004 and Banu *et al.,* 2009, 2010).

Proline furthermore plays a part as an osmoprotectant to regulate osmotic constancy, no significant correlation was found between the physiological parameters and proline content, contrary to the expectation of its association with water content (Luttus *et al.*, 1996 and Khedr *et al.*, 2003).

## 6. Effect of salinity on rice plants

At seedling stage, salt tolerant cultivars were found to have a higher root and shoot ratio under saline stress conditions (Yousaf *et al.,* 2004). In salt stressed condition, ions such as $Na^+$ and $Cl^-$and to some extent $Cl^-$ and $SO_4^{2-}$ of $Mg^{2+}$ reach upto toxic levels and this in turn affects plant growth and development. Salinity stress response is multigenic, as a number of processes are involved in the tolerance mechanism such as antioxidant defence mechanism, ion transport and compartmentalization of injurious ions (Sairam and Tyagi, 2004).

Yield components of rice such as number of panicles, tillers and spikelets per plant; floret sterility; individual grain size and heading are often affected by salinity . The decrease in a number of spikelets per panicle is one of the major factors of reduction in rice yield due to salinity (Scardaci *et al.,* 1996 and Shannon, *et al.,* 1998).

IRRI in (1978) reported that during the reproductive stage, salts adversely affect the number of spikelet per panicle. The number of tillers reduecd gradually with rise in salinity levels (Desai *et al.,* 1975 and Sexena and Pandey, 1981).

Ling *et al.,*(2000) and Young *et al.,*(2003) also stated that the number of tillers hill$^{-1}$ reduced with increasing salinity levels in rice. Khatun *et al.,* (1995) and Lutts *et al.,* (1995) reported that Salinity's effect on rice lead to a reduction in the number of productive tillers and fertile florets per panicle and a reduction in individual grain mass.

Abdullah *et al.,* (2001), reported that decreased translocation of soluble carbohydrates to primary and secondary spikelet, accretion of supplementary sodium and fewer potassium in all floral parts and inhibition of the precise activity of starch production in initial rice grains resulted in sterility and reduction in seed set.

Photosynthetic decline and with metabolic damages and sequential death of leaves has been related with the salt build up in the growing leaves (Yeo and Flowers, 1986), and survival competence of various varieties determine the growth vigour (Yeo *et al.,* 1990). So, leaf characters and physiological growth attributes could be significant criteria for a tolerant variety.

Roy *et al.*, (2002) observed decrease of root length, shoot length, dry weight of root and dry weight of shoot with increase in salinity and further reported that the rice cultivar Annada was least affected by induced salinity. Govinda Raju and Balakrishnan (2002) observed that effect of salinity was higher in susceptible varieties than tolerant varieties. Most of the seedling parameters *viz.*, germination, root length, shoot length, vigour index and dry matter accumulation were reduced by NaCl solution (Djanaguiraman *et al.,* 2003).

Soil salinity suppresses shoot growth more than the root growth (Maas and Hoffman 1977 and Ramoliya *et al.,* 2004). Islam *et al.,* (2007) also recorded the differences in plant height of rice varieties with various salinity levels. Javed and Khan (1975), Sexena and Sagi *et al.,* (1997) also found the unfavourable effects of salinity stress on the shoot and root development.

Too much accretion of NaCl in chloroplasts of plant can adversely affect the growth rate as well as reduce the electron transport activities of photosynthesis which ultimately leads to a decrease in plant biomass (Kirst, 1989) and hinderence of PSII activity (Kao *et al.,* 2003).

In general, salinity reduces leaf length, leaf width, shoot and root dry mass leading to low yields (Hamdy *et al.,* 1993; Essa, 2002; Li *et al.,* 2006 and Sharifi *et al.,* 2007). Pandey (1981) also reported that with increase in salinity levels plant height gradually decreased, because the high strength of soluble salts in the soil and osmotic stress creates trouble in the uptake of water and other nutrients.

Ali *et al.,* (2004b) observed a significant reduction of yield in many rice genotypes at a salinity level of 8.5 dS m-1 besides the reduction of many yields contributing parameters viz., chlorophyll content, productive tillers per plant, panicle length and fertility percentage.

Uddin *et al.*, (2007) stated that salinity reduced the number of effective tillers per plant, number of grains per panicle, 100-grain weight and yield plant$^{-1}$. Hosamuzzaman *et al.*, (2009) reported that 1000 grain weight and grain yield decreased with increase in levels of salinity. Similarly, Mohammadi-Nejad *et al.*, (2010) found that salinity stress caused a reduction in overall vigour especially in the number of filled grain per panicle and yield.

Salt stress delayed flowering, decreased the productive tillers plant, fertile florets per panicle, seed set (weight grain$^{-1}$), 1000-seed weight and overall grain yield (Khatun *et al.,* 1995). Further, it was noted that tolerant cultivars had a smaller decrease in floret fertility than sensitive cultivars. Tiller production progressively decreased with increased levels of salinity. In case of variety BR11, more than 30 per cent drop of effective tillers was observed at 150 mM NaCl treatment compared to control (Zeng and Shannon, 2000).

It was observed that the number of productive tillers per hill decreased with increase in salinity levels (Sajjad (1984b), Heeman *et al.*, (1998) and Hasamuzzaman *et al.*, (2009). Filled spikelets per panicle also decreased significantly with increase in the level of salinity. The lowest filled grains per panicle was observed at 150 mM NaCl level (Hasamuzzaman *et al.,* (2009). Ali *et al.,* (2004b) screened different rice genotypes under salinity condition (12 dS m$^{-1}$) and the genotypes IR-552182, IR-59418, IR-65195, IR-71657, NR-1 and IR-9 were graded as tolerant by scoring them visually.

Kranto *et al.,* 2016 reported that plant height, panicles per hill, proline content, Na +, K+, Na +/ K+, seeds per panicle, panicle length , filled grains weight and unfilled grain weight were the traits that responded to salinity levels in all rice cultivars

**7. Screening for salinity.**

Rice plants are much more susceptible to salinity during early seedling stage (2-3 leaves) than during germination and found to have a delaying effect on seed germination (Akbar and Yabuno, 1974). They suggested that effective ways for salinity tolerance screening are significant for the triumph of a breeding program.

According to Maghsoudi Moud and Maghsoudi,2008, shoot growth was reduced by salinity. Early flowering, reduced dry matter, increased root: shoot ratio and reduced leaf size may be considered as possible ways of decreasing yield in plants under salt stress condition.

Ghazizade *et al.,* (2012) opined that growth of plants when exposed to salt stress is linked to the potential of seed germination under stress environment. Hence, there is a requirement of assessment of salt tolerance in genotypes at the primary growth stage. Detection of the sensitivity and tolerance level of a variety at early seedling is a must for crop production in saline condition successfully (Hakim *et al.*, 2010).

Rapid screening techniques for salinity tolerance in rice were developed by (Gregorio *et al.,* 1997) at International Rice Research Institute (IRRI). In rice, a large number of genotypes have been screened for salt tolerance. Some seedling evaluation methods have been used for mass screening of seedlings at the International Rice Research Institute (Akbar, 1985; IRRI, 1996 and Gregorio *et al.,* 1997). These methods were designed to screen for salinity tolerance based on plant vigour (i.e., plant growth at early growth stages) or visual damage on vegetative tissues.

**Visual scoring for salinity symptoms (IRRI, 2002)**

Salinity symptoms on the plants are observed and scored in one to nine scale as given by IRRI 2002

| Score | Observation | Tolerance |
|---|---|---|
| 1 | Normal growth, no leaf symptoms | Highly tolerant |
| 3 | Nearly normal growth, but leaf tips or a few leaves whitish and rolled | Tolerant |
| 5 | Growth severely retarded; most leaves rolled; only a few are elongating | Moderately tolerant |
| 7 | Complete cessation of growth; most leaves dry; some plants dying | Susceptible |
| 9 | Almost all plants dead or dying | Highly susceptible |

This rapid, easy and reliable screening procedure was developed to screen rice varieties tolerant to salinity, as screening based on soil salinity are much expensive and time-consuming and give very low reproducible results (Sirisena *et al.*, 2005). However, the use of visual damage as evaluation for salt tolerance is not always applicable because the symptoms such as chlorosis and leaf rolling are not always easily observed in rice at low or moderate salinity.

Physiological parameters give dependable information, which can be used as a selection parameter for the screening of cultivars for salinity tolerance as opined by Ashraf, (2004); Munns et al., (2006), and El-Hendawy *et al.*, 2009).

**8. Management of salinity stress.**

The salt stress related problems in production of crops can be tackled by managing the field (Shannon, 1997) as well as improving the current genotypes genetically to have a better tolerance to stress (Epstein *et al.,*1980). Effects of salinity on rice have been under study for more than 50 years (Pearson, 1959) and attempt to improve the salt tolerance in rice through breeding date from the early 1970s (Akbar *et al.,* 1972).

The introduction of salt-tolerant varieties in the affected areas can be employed as a better management method of salinity. Unfortunately, on a large scale the enhanced irrigation management methods were found to be too costly and practically difficult to put into practice. Thus, genetic improvement of salt tolerance of major cereal crops like rice (*Oryza sativa*), wheat (*Triticum aestivum*), maize (*Zea mays*), and barley (*Hordeum vulgare*) seems to be the most economic and practicable strategy for maintaining steady worldwide food production (Munns, 2002).

Exhaustive mechanisms to bring about physiological and morphological alterations have been developed by plants to adapt , and to make the survival possible in extreme environmental conditions. A multifarious interaction of signalling cascades at molecular levels is required for the activation of defence responses arising from the extracellular stimuli (Xiong and Yang, 2003).

Zhu (2002) recognized and studied a variety of components of salinity stress signal transduction pathway. The perception of salt stress, which occurs due to the excess of $Na^+$ ions can take place with the help of transmembrane protein, membrane protein or $Na^+$ sensitive enzymes at the external surface of the plasma membrane and within the cell respectively (Urao *et al.,* 1999; Zhu, 2003 and Pareek *et al.,* 2006).

Salt stress signal transduction pathways are divided into three key signalling types: (i) osmotic/oxidative stress signalling that uses mitogen-activated protein (MAP) kinase modules this involves the synthesis of reactive oxygen species scavenging enzymes and antioxidant compounds as well as osmolytes; (ii) $Ca^{2+}$ dependent signalling that leads to the commencement of late embryogenesis abundant (LEA) type genes, which involves the making of stress-responsive proteins mostly of undefined functions and (iii) $Ca^{2+}$ dependent salt overly sensitive (SOS) signalling that regulate ion homeostasis. It involves the SOS pathway, which is specific to ionic stress (Rodriguez *et al.*, 2005). Probable roles of these signalling pathway components in abiotic stress tolerance have been demonstrated using a range of plant species.

The genetic improvement of crop cultivars is the promising method for improving the current productivity of the crop plants as it is not limited by availability of the good quality inputs or cost factors which is the case in using of management options

**9. Breeding approaches to salinity tolerance**

Being a major food crop in Asian countries, developing new cultivars to combat abiotic stresses (specifically drought and salinity) have a significant effect on food production. Rice has been engineered to withstand different abiotic stress conditions, such as drought, salinity, heat, cold and mineral deficiency. Of these, tolerance to drought/salt is the most studied abiotic stress conditions using transgenic rice. Many efforts have been made to advance abiotic stress tolerance traits of rice at national and international level.

In conventional breeding, i.e., the approaches based on genetic variation existing for the character in the gene pool, screening for genetic diversity in agronomic characters within extant genotypes is the first step toward the genetic improvement of crops.

The growth of plants under high saline condition is possible because of the salinity tolerance of the plants which is controlled by multiple genes in an individual, this also helps the plants to have an economic yield (Herkman, 1992).

Alternatively, screening for genetic diversity in physiological characters can be an effective approach in salt tolerance breeding (Yeo and Flowers, 1986



28

and Yeo *et al.,* 1990). This approach has proved successful in an international cooperative project which has developed a salt tolerant cultivar, CSR10, in India (IRRI, 1997). However, the utilization of physiological characters in salt tolerance breeding in no way reduces the significance of agronomic characters in such a program. Instead, the methods for evaluating agronomic characters in salt tolerance screening should be improved since these characters, especially seed yield, is always the primary target in plant breeding.

In conventional methods, genotypes are usually scored and ranked on single characters. An appropriate statistical method will be helpful to analyze multiple agronomic parameters simultaneously in the evaluation of genotypes and facilitate the scores and rankings for salt tolerance among genotypes. The application of cluster analysis in multivariate observations has been suggested for comparisons of cultivar means (Jolliffe *et al.,* 1989). However, only one application has been reported using multivariate analysis in the screening of *in vitro* cultures for salt tolerance in potato (Khrais *et al.,* 1998).

Salinity tolerance screening based on agronomic characters such as growth, yield and yield components is most favoured technique used by breeders all around the world as improvement of yield is the most prominent objective when breeding crops for salt tolerance (El-Hendawy *et al.,* 2009).

Salinity tolerance tactics have used three key ways: (i) conventional breeding, (ii) marker-assisted selection and (iii) genetic engineering. The desirable gene can be inserted into an already existing genotype without affecting any other characters of that individual by using the tools of genetic engineering, hence it is a very promising tool used in plant breeding (Bhatnagar-Mathur *et al.,* 2008).

Genes that encode compatible organic solutes, antioxidants [detoxification of reactive oxygen species (ROS)], ion transport, heat- shock and late embryogenesis abundant proteins have been the focus in the by the use of genetic engineering for salinity tolerance. Transgenic approach for the development of saline resistant genotypes is yet to be explored, even though there have some hopeful reports. The currently developed genetically engineered crops unable to come up under the field conditions as they fail to cope up with complex stress conditions involving salinity along with drought and temperature stress whereas these genotypes show promising growth under protected cultivation

At salt strength of less than 100Mm, germination of rice seeds was not altered. However, at higher salinity levels (100mM and 200 mM NaCl), a delay of 3 to 6 days in germination was recorded (Shereen *et al.,* 2011). Many released rice hybrids were tested by Directorate of Rice Research to find out the suitability under saline conditions. Rice hybrids like DRRH- 28, PSD-3, KRH- 2 etc. were found to be promising (Viraktamath, 2012).

Introgression of the saline tolerant gene (SalTol) into Jyothi, a popular rice variety was achieved throughMarker Assisted Backcross Breeding technique at Rice Research Station, KAU, Vytilla (Nandakumar, 2015).

Crops get exposed to multiple stress factors at the same time under field conditions, thus agricultural sustainability in soils with manifold unfavourable soil factors can be ensured by genes that can confer tolerance to compound abiotic stresses. Improvement of rice for salinity stress tolerance should engage stacking of diverse genes. This can be done by combining multiple genes involved in various protective pathways and stress-regulated promoters to drive the expression of the transgenes for inducing tolerance and resistance.

# MATERIALS AND METHODS

# 3. MATERIAL AND METHODS

The present study on identification of saline tolerant rice hybrids for Pokkali tract was conducted in the Department of Plant Breeding and Genetics, College of Horticulture, Vellanikkara, Kerala Agricultural University. The field trials were carried out in saline-prone areas of Pokkali tract of Kadamakudy Grama Panchayath of Ernakulam district during the season Kharif 2016. The materials used for the study and the methods followed are presented in this chapter.

## 3.1. MATERIALS

Eight rice hybrids were used for the study along with three check varieties as presented in Table 1

The objective of the experiment was identification of rice hybrids suitable for Pokkali tract as well as the evaluation of traits associated with salinity tolerance in rice hybrids. The experiment was divided into two parts. The first experiment was to identify the traits associated with salinity tolerance and the second experiment was to identify the rice hybrids suitable for Pokkali tract.

**Table 1. Rice genotypes used for the investigation**

| Sl. No. | Genotype | Source |
|---|---|---|
| 1 | CORH-3 | TNAU |
| 2 | TNAU RH-4 | TNAU |
| 3 | KRH-4 | UAS, Bangalore |
| 4 | Sahayadri-1 | RARS, Karjat |
| 5 | Sahayadri-2 | RARS, Karjat |
| 6 | Sahayadri-3 | RARS, Karjat |
| 7 | Sahayadri-4 | RARS, Karjat |
| 8 | MRP-5401 | MAHYCO |
| 9 | IR-29 | IRR1, Philipines |
| 10 | Ezhome-2 | KAU, Kerala |
| 11 | Vytilla-6 | RRS, Vyttilla, KAU |

### 3.3.1. Experiment 1: Laboratory screening for salinity tolerance

The experiment was conducted to evaluate traits associated with salinity tolerance in rice hybrids. Sterilized seeds were positioned in Petri dishes with dampened filter paper and kept at 30 °C for 48 hours to germinate. Two pre-germinated seeds were introduced per hole on a Styrofoam seedling float as illustrated by Gregorio *et al.*,(1997), suspended on culture solution (Yoshida *et al.*, 1976) in 10 L plastic trays for 14 days (Plate 1) . The nutrient solution consisted of macronutrients and micronutrients as follows.

| Macronutrients | Concentration ($mgl^{-1}$) | Micronutrients | Concentration ($mgl^{-1}$) |
|---|---|---|---|
| $NH_4NO_3$ , | 40.00 | $(MnC1_3.4H_20$ | 0.50 |
| $NaH_2PO_4.2H_2O$ | 10.00 | $(NH_4)6Mo_70_{24}.4H_20$ | 0.05 |
| $K_2SO_4$(), | 40.00 | $ZnS04.7H_20$ | 0.01 |
| $CaCl_2$ () | 40.00 | $H_3B0_3$ | 0.20 |
| $MgSO_4.7H_2O$ | 40.00 | $CuS04.5H_20$ | 0.01 |
| | | $FeC1_3.6H_20$ | 2.00 |

At 14 days after sowing, NaCl was added to the culture solution to bring its electrical conductivity to 12 dS $m^{-1}$. Silicon in the form of Sodium Metasilicate 9 hydrate (16·9 mM) was added to avoid lodging. The pH of the culture solution was adjusted daily to 5 by adding either NaOH or HCl to avoid Fe deficiency (Yoshida *et al.*, 1976) and the solution was changed every 7 days.

All entries were monitored and scored based on visual symptoms of salt stress injury as described by Gregorio *et al.,* (1997) using modified Standard Evaluation System for rice (SES; IRRI, 2014) at 7 and 21 days after salinisation as the initial and final evaluation, respectively. Final scoring and sampling were accomplished when the sensitive check IR29 scored 7 (SES 1, normal growth; 9, plants are dead). At final scoring, the number of surviving plants of each line was counted to calculate percentage survival.

Observations were recorded from 10 plants per replication in each treatment as given below.

*3.3.1.1. Shoot length* (cm)

Measured in centimetres from the base of culm to the tip of the shoots at 7 and 21 days after salinisation and mean was worked out.

*3.3.1.2. Root length* (cm)

Measured in centimetres from the base of culm to the tip of the roots at 7 and 21 days after salinisation and mean was worked out.

*3.3.1.3. Root-shoot ratio*

The dry weight of root and culm of each plant was measured in grams at 21 days after salinisation. The root shoot ratio was worked out by dividing root weight and shoot weight.

*3.3.1.4. Total number of roots*

Number of roots was counted at 21 days after salinisation for 10 randomly selected plants and mean was worked out.

*3.3.1.5. Vigour index*

Vigour index was calculated at 21 days after salinisation and mean was worked out as suggested by Abdul-Baki and Anderson (1973)

Vigour index = Germination (%) x Mean seedling length (cm)

*3.3.1.6. Root CEC* (meq/100g dry weight)

Root Cation Exchange Capacity (CEC) was estimated by hydrochloric treatment of living roots of seedling (Mitsui and Ueda, 1963) at 21 days after salinisation and mean value was worked out.

*3.3.1.7. Proline content in root, shoot and leaf* (mg/g)

Free proline content was determined according to Gilmour *et al*., (2000). Plant samples from each variety were homogenized in one ml of three per cent (w/v) Sulphosalicylic acid at 21 days after salinisation at room temperature and then stored at 4°C overnight. The supernatant was added with acid ninhydrin and glacial acetic acid. The mixture was heated at 100° C for 45 min in a water bath. The reaction was then stopped by using an ice bath. The mixtures were extracted with toluene and measured using a UV-visible spectrophotometer at wavelength 519 nm. Proline concentration was determined using the calibration curve and expressed as mg proline $g^{-1}$.

*3.3.1.8. $Ca^{+}$, $Na^{+}$, $K^{+}$, Chloride and Sulphate content in root, shoot and leaf* (%)

Plant samples were collected from the seedlings at 21 days after salinisation of the crop and analyzed for $Ca^{2+}$, $Na^{+}$, $K^{+}$, Chloride and Sulphate status in it using standard procedures.

Calcium content in the plant was estimated by Atomic absorption spectroscopy (AAS) given by Issac and Kerber, 1971 and expressed in percentage.

Sodium and potassium content in the plants were estimated by flame photometry method and expressed in percentage (Jackson, 1958).

Chloride content in the plant was estimated by Volhard's method (Volhard *et al.,* 1874).

Sulphate content in the plant was estimated by the Turbidometric method and expressed in percentage (Bhargava and Raghupathy, 1995).

*3.3.1.9. Survival per cent* (%)

At 21 days after salinisation, the number of surviving plants of each treatment were counted to calculate survival percentage.

$$\text{Survival \%} = \frac{\text{Number of seedlings survived}}{\text{Total number of seedlings planted}} \times 100$$

*3.3.1.10. Relative water content* (%)

Relative water content (RWC) of the leaf was measured in percentage at 21 days after salinisation stage of the crop using the formula.

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

FW= Fresh weight

DW= Dry weight

TW= Turgid weight

*3.3.1.11. SPAD chlorophyll meter reading (SCMR)*

SCMR was recorded at 21 days after salinisation by SPAD (*Soil Plant AnalyticalDevelopment)* chlorophyll meter - 502 and mean was worked out.

**3.3.2. Experiment 2: Field evaluation of rice hybrids in Pokkali tract**

The experiment was conducted to identify the rice hybrids suitable for Pokkali tract. It was conducted in the field of farmer Mr Thomas at Pokkali tract of Kadamakudy Grama Panchayath of Ernakulam district. Experiment was conducted in plots of $4m^2$ as randomised block design with 11 genotypes including eight hybrids and three check varieties with three replication.The following observations were recorded from 25 plants per replication in each treatment as given below

*3.3.2.1. Plant height* (cm)

Measured in centimetres (cm) from the base of the culm to the tip of the tallest leaf blade at flowering stage of the crop and mean was worked out.

*3.3.2.2. Uppermost internodal length* (cm)

Uppermost internodal length in each plant was measured in centimetres (cm) from the node of uppermost internode to the point of panicle at flowering stage of the crop.

*3.3.2.3. Days to 50 per cent flowering*

Number of days from the sowing of seeds to 50 per cent flowering was counted.

*3.3.2.4. Days to maturity*

Number of days from the sowing of seeds to harvest (when 85% of grains on the panicle have matured) was counted.

*3.3.2.5. Number of productive tillers per plant*

Number of panicles bearing tillers per plant was counted at harvest stage of the crop for 10 randomly selected plants and mean was worked out.

*3.3.2.6. Number of spikelets per panicle*

All spikelets including fertile and sterile ones in each panicle after harvest were counted for 10 randomly selected plants and mean was worked out.

*3.3.2.7. Seed setting percentage* (%)

Seed setting percentage of randomly selected 10 plants after harvest was calculated by using the formula given below and mean was worked out.

$$\text{Seed setting \%} = \frac{\text{Number of filled grains}}{\text{Total number of spikelets}} \times 100$$

*3.3.2.8. Length of panicle* (cm)

The length of panicle was measured from base to tip of the topmost spikelet (awns included) on panicle at harvest stage of the crop for randomly selected 10 plants. The mean was worked out and expressed in centimetres.

*3.3.2.9. Sterility percentage* (%)

Sterility percentage of randomly selected 10 plants after harvest was calculated using the formula given below and mean was worked out.

$$\text{Sterility \%} = \frac{\text{number of sterile spikelets}}{\text{Total number of spikelets}} \times 100$$

*3.3.2.10. 1000 grain weight* (g)

The weight of randomly selected 1000 numbers of grains after harvest was recorded in grams and mean was worked out.

*3.3.2.11. Grain yield per plant* (g)

The weight of total grains from each plant after harvest was recorded in grams and mean was worked out.

### 3.3.3. Visual scoring for salinity symptoms (IRRI, 2002)

Salinity symptoms on the plants were observed and scored in one to nine scale as given by IRRI 2002

| Score | Observation | Tolerance |
|---|---|---|
| 1 | Normal growth, no leaf symptoms | Highly tolerant |
| 3 | Nearly normal growth, but leaf tips or a few leaves whitish and rolled | Tolerant |
| 5 | Growth severely retarded; most leaves rolled; only a few are elongating | Moderately tolerant |
| 7 | Complete cessation of growth; most leaves dry; some plants dying | Susceptible |
| 9 | Almost all plants dead or dying | Highly susceptible |

## 3.4. Statistical analysis

The data on various parameters studied during the course of the investigation were subjected to statistical analysis. Analysis of variance was performed using the online software 'Wasp 2.0' developed by ICAR Research Complex for Goa. The critical differences for treatments showing significant differences were worked out at 5 per cent probability level. Correlation coefficients between the traits were estimated using the software OPSTAT

# RESULTS AND DISCUSSION

# 4. RESULTS AND DISCUSSION

Salinity, drought, heat and cold, are the key abiotic stresses causing major loss in yield in huge areas and threatens crop production (Pareek *et al.,* 2010; Mantri *et al.,* 2012). Among these, soil salinity is the major hindrance in crop production and is likely to increase due to worldwide climate changes and as an outcome of numerous irrigation methods. An abundance of sodium chloride from natural build up or irrigation and can be called as severe salinity (Flowers and Flowers, 2005). According to Reddy *et al.,*(2017), an average of 2000 $hm^2$ irrigated land has been reported to be rendered unfit for cultivation due to the problem of salt intrusion yearly.

Many researchers have suggested that the dissimilarity in response to the levels of salinity is seen among species as well as with cultivars within species (Arzani, 2008; Ashraf and Foolad, 2013). According to Arzani, 2008, response of plant to salinity is observed to be affected by phases of growth, soil salt level and environmental setting. Assessment of the phenotypes under field setting is not easy as the salt tolerance in rice is a compound trait. The salt tolerance in rice can be improved by finding adequate variation and establishment of reliable and easy screening methods to recognize salt tolerant cultivars.

The present investigation on identification of saline tolerant rice hybrids for Pokkali tract was done as two experiments

## 4.1. Experiment 1: Laboratory screening for salinity tolerance

It is necessary to identify the sensitivity and tolerance level of a variety at early seedling stages for successful crop production in a saline environment (Hakim *et al.*, 2010).Seedling screening offers the possibility of pre-selection of breeding lines and progeny and cultivars before large-scale field evaluation.

Results of screening of eight hybrids and three check varieties under laboratory conditions are presented and discussed below.

### 4.1.1. Shoot length (cm)

Shoot length of 11 genotypes was recorded and presented in Table 2. The shoot length of different treatments was measured at 7 DAS and 21 DAS. The shoot length of different treatments ranged from 6.15 cm to 7.65 cm at 7 DAS and from 16.2 cm to 18.85 cm at 21 DAS. Highest shoot length was recorded in ' KRH-4' and 'Vytilla 6' at 7 DAS and 21 DAS respectively.Minimum shoot length of 6.15 cm was recorded in genotype ' CORH3' which was on par with that of 'MRP-5401' at 7 DAS and 16.2 cm in 'Sahyadri 1' at 21 DAS.

**Table 2. Mean performances of rice genotypes for shoot and root characters under screening for salinity tolerance**

| Genotypes | Shoot Length 7 DAS | Shoot Length 21 DAS | Root Length 7 DAS | Root Length 21 DAS | Total number of roots 21 DAS | Root:shoot Ratio |
|---|---|---|---|---|---|---|
| CORH 3 | 6.15 $^{e}$ | 17.70 $^{b}$ | 2.05 $^{e}$ | 6.05 $^{de}$ | 6.00$^{bcd}$ | 1.20$^{c}$ |
| TNAU RH-4 | 7.20$^{ab}$ | 17.60$^{bc}$ | 4.10 $^{a}$ | 6.70$^{bc}$ | 6.20$^{abc}$ | 0.99$^{d}$ |
| KRH-4 | 7.65 $^{a}$ | 17.00 $^{de}$ | 3.70$^{ab}$ | 6.25$^{cd}$ | 6.45$^{ab}$ | 1.08$^{cd}$ |
| Sahyadri 1 | 6.50 $^{de}$ | 16.20 $^{f}$ | 2.60$^{cde}$ | 6.00$^{de}$ | 5.20$^{ef}$ | 0.65$^{e}$ |
| Sahyadri 2 | 6.75$^{bcd}$ | 17.20 $^{cd}$ | 3.20$^{bc}$ | 6.30$^{cd}$ | 5.15$^{f}$ | 0.68$^{e}$ |
| Sahyadri 3 | 6.40 $^{de}$ | 16.65$^{ef}$ | 2.60$^{cde}$ | 6.20$^{de}$ | 5.60$^{cdef}$ | 0.68$^{e}$ |
| Sahyadri 4 | 7.50 $^{a}$ | 16.35 $^{f}$ | 4.10 $^{a}$ | 5.95$^{de}$ | 5.30$^{def}$ | 0.67$^{e}$ |
| MRP-5401 | 6.15 $^{e}$ | 17.20 $^{cd}$ | 2.15 $^{de}$ | 5.95$^{de}$ | 5.05$^{f}$ | 0.65$^{e}$ |
| IR-29 | 7.10$^{abc}$ | 17.95 $^{b}$ | 3.90 $^{a}$ | 5.75$^{e}$ | 5.95$^{bcde}$ | 0.65$^{e}$ |
| Ezhome 2 | 6.25 $^{de}$ | 17.95 $^{b}$ | 2.60$^{cde}$ | 6.85$^{ab}$ | 6.30$^{abc}$ | 2.70$^{b}$ |
| Vytilla 6 | 6.55$^{cde}$ | 18.85 $^{a}$ | 2.70 $^{cd}$ | 7.25$^{a}$ | 6.95$^{a}$ | **3.28$^{a}$** |
| **CV (%)** | **3.81** | **1.31** | **9.18** | **3.09** | **5.99** | **5.54** |
| **CD (0.05)** | **0.56** | **0.49** | **0.61** | **0.43** | **0.77** | **0.14** |

**Fig 1. Mean performances of rice genotypes for shoot and root characters under screening for salinity tolerance**

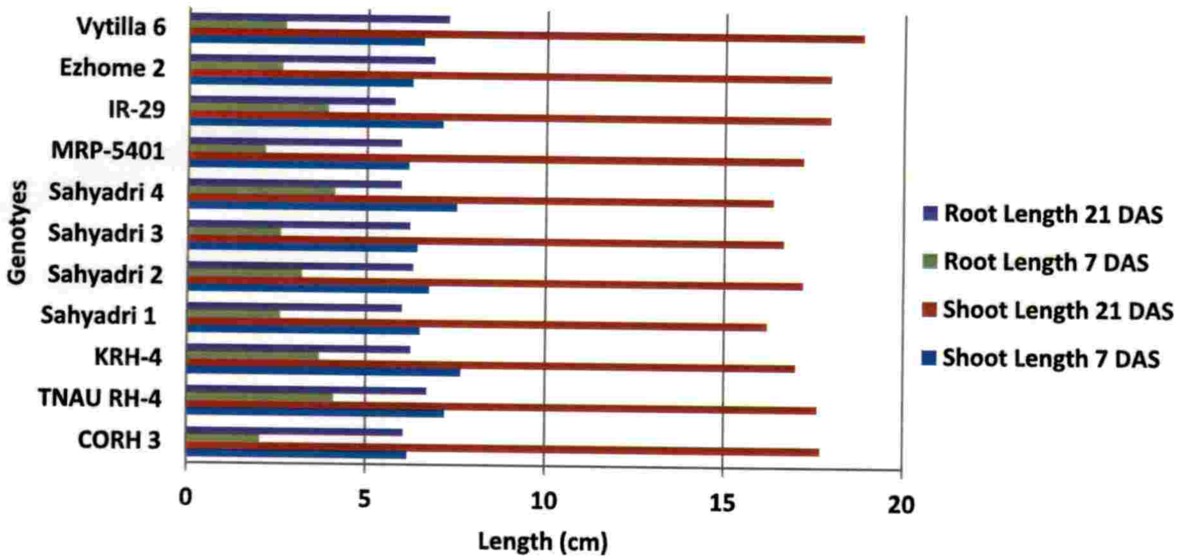



**Fig 2. Mean performances of rice genotypes for root and shoot proline content**

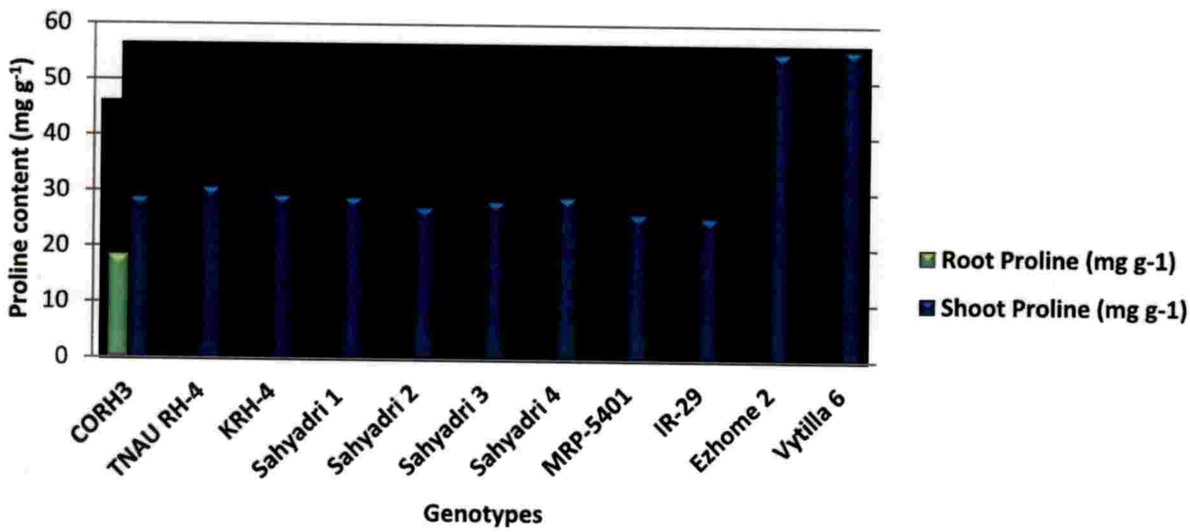


**Plate 1. Variation of germination among different genotypes**

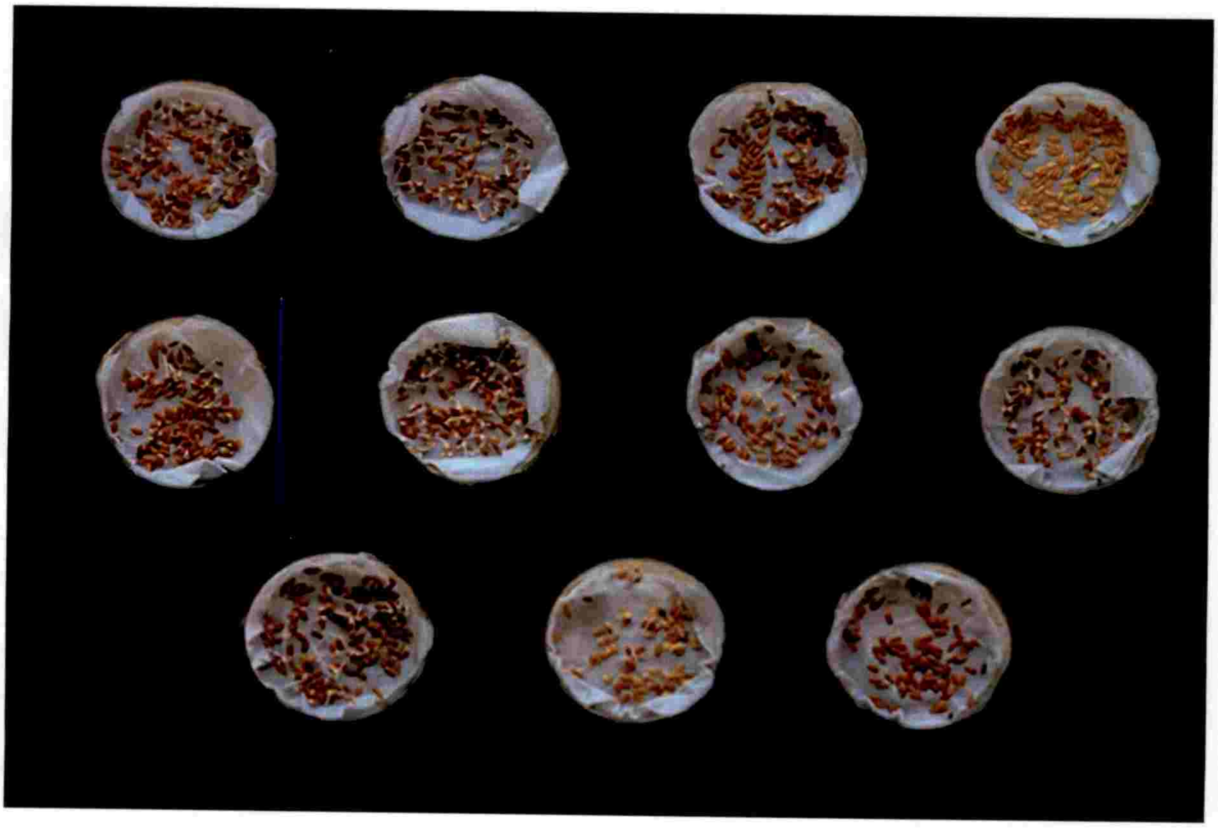


**Plate 2. Laboratory screening of genotypes for salinity**

At seven days after salinisation KRH 4, IR 29 and Sahyadri were taller compared to other varieties. However, after 21 days of salinisation Vytilla 6 showed highest growth followed by CORH 3, Ezhome 2, TNAU RH 4 and IR 29 indicating the salt tolerant capacity of these genotypes. Hybrids , KRH 4, and Sahyadri which were having high shoot growth at early stages was affected by extended exposure to salinity leading to less growth rate. Many workers have reported consequence of salt stress on seedling development and shoot growth. Seed germination, seedling development, leaf size, shoot expansion, shoot and root length, shoot dry weight, shoot fresh weight, number of tillers per plant, flowering stage, spikelet number, percent of sterile florets and productivity are the characters affected by salt stress (Zeng and Shannon, 2000; Lauchli and Grattan, 2007; Moradi and Ismail, 2007; Munns and Tester, 2008; Ashraf and Akram, f2009; Hakim *et al.*, 2010; Gupta and Huang, 2014).

**4.1.2.Root length(cm)**

Root length of 11 genotypes was recorded and presented in Table 2. At 7 DAS highest root length of 4.1 cm was observed in 'Sahyadri 4' which was on par with 'TNAU RH-4', and IR 29. Minimum root length of 2.05 cm was seen in 'CORH3'. At 21 DAS high root length of 7.25 cm was observed in saline tolerant check 'Vytilla 6' which was on par with root length in Ezhome 2. This clearly indicate that the traditional varieties had high tolerance to salinity and other genoytpes were with different levels of salinity tolerance. IR 29 and Sahyathri 4, TNAU RH 4 which had longer roots in early stages did not have longer roots at the 21DAS indicating that high salt concentration reduces the root length in the case susceptible genotype. The hybrids which exhibited an intermediate value for root length at 21 DAS can be considered to have salinity tolerance at varying levels. According to Saha *et al.*, 2010 salinity stress causes a drastic effect on roots causing a reduction in root length

### 4.1.3. Total number of roots

The total number of roots recorded for 11 rice genotypes are presented in Table 2. The total number of root varied from 5.05 to 6.95. 'Vytilla 6' recorded the high total number of roots indicating its tolerance to salinity which was ion par with Ezhome 2 , TNAURH 1 and KRH 4. Two hybdris were having high number of roots on par with the traditional varieties indicate that these two hybrids has salinity tolerance capacity. Salinity tolerance is a multifaceted quantitative trait which is controlled by compound genes (Chinnusamy *et al.*, 2005). Rice has been grouped as the salt susceptible cereal, especially, at its young stage (Lutts *et al.*, 1995) and salinity limits the competence of production at the older stage (Todaka *et al.*, 2012). Salt stress reduces growth of rice and productivity by reduction in photosynthetic capability (Munns .2005). Salinity caused significant reduction in germination, root, and shoot lengths, and fresh root and shoot weight (Jamil *et al.,* 2006). The increase of osmotic pressure of the root mediumcan lead to reduction in growth of rice from germination to maturity (Mudgal *et al.,* 2010). Saha *et al.*, (2010) reported that salinity stress causes a drastic effect on roots causing a reduction in root length, number of root hairs and branches, and also roots become tubby, fragile and brown in colour.

**Table 3. Mean performances of rice genotypes for root CEC and root and shoot proline content**

| **Genotypes** | **Root CEC** (meq/100g dry weight) | **Root Proline** (mg $g^{-1}$) | **Shoot Proline** (mg $g^{-1}$) |
|---|---|---|---|
| CORH3 | $2.95^{bc}$ | $18.45^{c}$ | $29.00^{c}$ |
| TNAU RH-4 | $2.75^{cde}$ | $16.63^{de}$ | $30.85^{b}$ |
| KRH-4 | $2.90^{bcd}$ | $18.155^{c}$ | $29.38^{bc}$ |
| Sahyadri 1 | $2.40^{ef}$ | $16.43^{de}$ | $29.09^{c}$ |
| Sahyadri 2 | $2.30^{f}$ | $16.69^{de}$ | $27.27^{e}$ |



46

| | | | |
|---|---|---|---|
| Sahyadri 3 | $2.40^{ef}$ | $16.27^{de}$ | $28.46^{cd}$ |
| Sahyadri 4 | $2.30^{f}$ | $16.42^{de}$ | $29.30^{bc}$ |
| MRP-5401 | $2.50^{def}$ | $16.95^{d}$ | $26.30^{e}$ |
| IR-29 | $3.10^{abc}$ | $16.02^{e}$ | $25.71^{e}$ |
| Ezhome 2 | $3.25^{ab}$ | $45.56^{a}$ | $55.38^{a}$ |
| Vytilla 6 | $3.50^{a}$ | $36.12^{b}$ | $55.92^{a}$ |
| **CV (%)** | **6.868** | **1.948** | **2.192** |
| **CD (0.05)** | **0.417** | **0.92** | **1.621** |

### 4.1.4. Root CEC

Root CEC of 11 treatments were presented in Table 3. Root CEC of different treatments ranged from 2.3 to 3.5. Out of 11 treatments, saline tolerant check variety 'Vytilla 6' ranked first with a root CEC of 3.5 which was followed by 'Ezhome 2' indicating the ability of these genotypes to accumulate more cations even from saline soil to impart tolerance to salinity. Minimum value of root CEC (2.3) was observed in 'Sahyadri 4' and 'Sahyadri 2'. IR 29 is considered to be susceptible to salinity. However, the values of CEC were observed to be high. This indicate that the root CEC alone may not be contributing to salinity tolerance in plants. High CEC will help in uptake of cations and improve the growth of the plant. The cation exchange capacity of roots had significant impact on dry-matter accumulation of rice as reported by Srivasthava and Srivasthava 1991.

### 4.1.5. Proline content in root and shoot

Proline is an osmo-protectant which accumulates in the cytosol of the cell. High proline content is a mechanism of tolerance to abiotic stress. Results of proline content in root and shoot of 11 treatments were recorded and presented in Table 3. Highest proline content in root, as well as shoot, was recorded in saline tolerant checks 'Vytilla 6' followed by 'Ezhome 2'. Lowest root and shoot proline content was recorded in the saline susceptible check variety 'IR-29' confirming it's susceptible nature for salinity.

According to Lehmann *et al.*, 2010 proline is an indispensable amino acid for the key metabolism in plants. Yoshiba *et al.*, 1997 suggested that proline is synthesized from Glutamic Acid *via* 1-Pyrroline-5-Caroxylate (P5C) by two enzymes, P5C synthetase (P5CS) and P5C reductase and then degraded to Glutamic Acid via P5C by two enzymes, Proline dehydrogenase and P5C dehydrogenase . Many researchers observed that proline is required to sustain pH of cytosolic redox of cell and as antioxidant or singlet oxygen quencher (Greenway and Munns, 1980; Matysik *et al.*, 2002). High accumulation of proline in salt tolerant transgenic rice plants with expression of P5CS was observed by Karthikeyan *et al.,* 2011. Ashraf and Foolad, (2007) reported that enhanced salt tolerance was linked with amplified accretion of proline in plants.

**Table 4. Mean performances of rice genotypes for, vigour index, survival , visual scoring, Spad chlorophyll meter reading (SCMR), and Relative water content (RWC)**

| **Genotypes** | **Vigour index** | **Survival (%)** | **Visual scoring** | **SCMR** | **RWC (%)** |
|---|---|---|---|---|---|
| CORH3 | $466.35^{i}$ | $80.00^{b}$ | $4.95^{d}$ | $34.33^{cde}$ | $62.60^{b}$ |
| TNAU RH-4 | $766.02^{c}$ | $80.00^{b}$ | $6.75^{c}$ | $34.88^{cd}$ | $60.27^{c}$ |
| KRH-4 | $778.18^{b}$ | $80.00^{b}$ | $6.80^{c}$ | $33.96^{de}$ | $62.00^{b}$ |
| Sahyadri 1 | $555.00^{f}$ | $75.00^{b}$ | $9.20^{a}$ | $32.74^{e}$ | $55.92^{de}$ |
| Sahyadri 2 | $634.75^{e}$ | $60.00^{c}$ | $7.25^{bc}$ | $32.83^{e}$ | $55.20^{e}$ |
| Sahyadri 3 | $540.27^{g}$ | $72.50^{b}$ | $7.05^{c}$ | $33.19^{de}$ | $56.90^{d}$ |
| Sahyadri 4 | $802.20^{a}$ | $72.50^{b}$ | $7.70^{b}$ | $32.52^{e}$ | $55.29^{e}$ |
| MRP-5401 | $466.29^{i}$ | $62.50^{c}$ | $5.45^{d}$ | $32.93^{de}$ | $54.96^{e}$ |
| IR-29 | $729.10^{d}$ | $60.10^{c}$ | $9.25^{a}$ | $38.35^{b}$ | $59.51^{c}$ |
| Ezhome 2 | $519.70^{h}$ | $97.50^{a}$ | $3.35^{e}$ | $36.035^{c}$ | $62.50^{b}$ |
| Vytilla 6 | $558.48^{f}$ | $97.50^{a}$ | $3.05^{e}$ | $42.07^{a}$ | $81.05^{a}$ |
| **CV (%)** | **0.292** | **5.573** | **3.63** | **2.65** | **1.007** |
| **CD (0.05)** | **3.978** | **9.674** | **0.514** | **2.035** | **1.33** |

#### 4.1.6. Vigour index

Vigour index is based on germination percentage of seeds. One with highest vigour index is having highest germination percentage of seeds. Maximum vigour index was noticed in 'Sahyadri 4' and minimum was recorded in 'MRP-5401'. Other treatments recorded vigour indexes ranging from 466.29-802.20 (Table 4). High vigour index observed in 'Sahyadri 4' can be due to the high germination percentage rather than the tolerance to salinity . Hence, this trait can only be considered along with other traits to indicate salinity tolerance. According to Yeo *et al.,* 1990, survival efficiency of various varieties can be associated with the growth vitality. Most of the seedling parameters viz., germination, root length, shoot length, vigour index and dry matter accumulation were reduced by NaCl solution (Djanaguiraman*et al.,* 2003).

#### 4.1.7. Survival percentage

Survival percentage of 11 treatments during seedling stage were presented in Table 4. Survival percentage of different treatments ranged from 60 to 97.5. Saline resistant check genotypes 'Vytilla-6' and 'Ezhome-2' both showed the highest survival per cent of 97.5 indicating the ability to tolerate high saline condition.

Minimum survival percentage was noticed in 'Sahyadri 2' which was on par with that of 'MRP-5401'. Zeng *et al.*, 2000, observed growth inhibition , reduction in seedling survival , number of tillers per plant and spikelet number per panicle.

In a high-saline condition even if the yield component parameters of a genotype are good but if survival per cent is bad it will affect the total yield. Hence, survival per cent is a very important criterion which determines the economic yield in saline stress condition.

**Fig 3.Mean performances of rice genotypes for survival and Relative water content (RWC)**

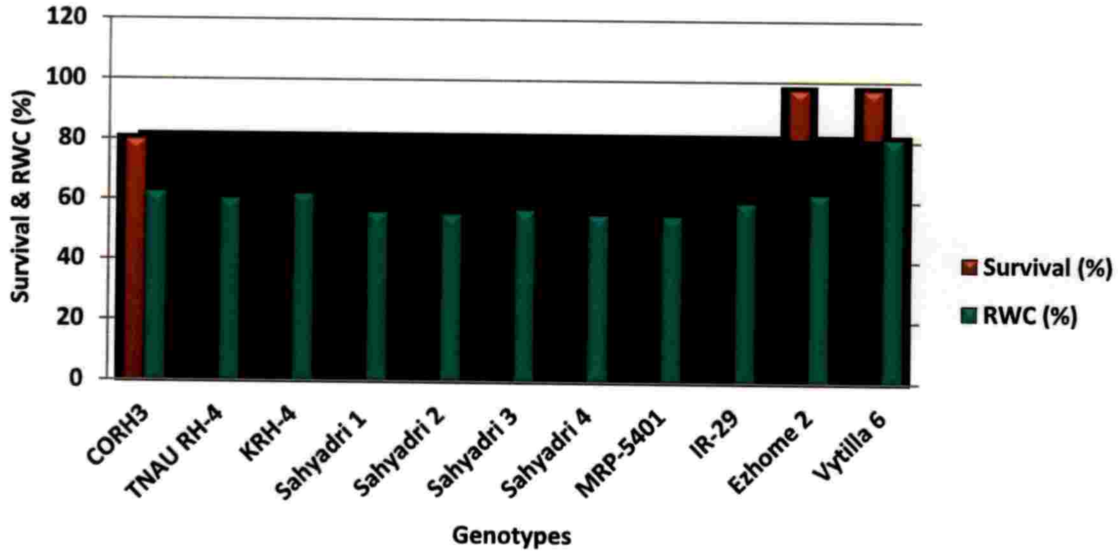
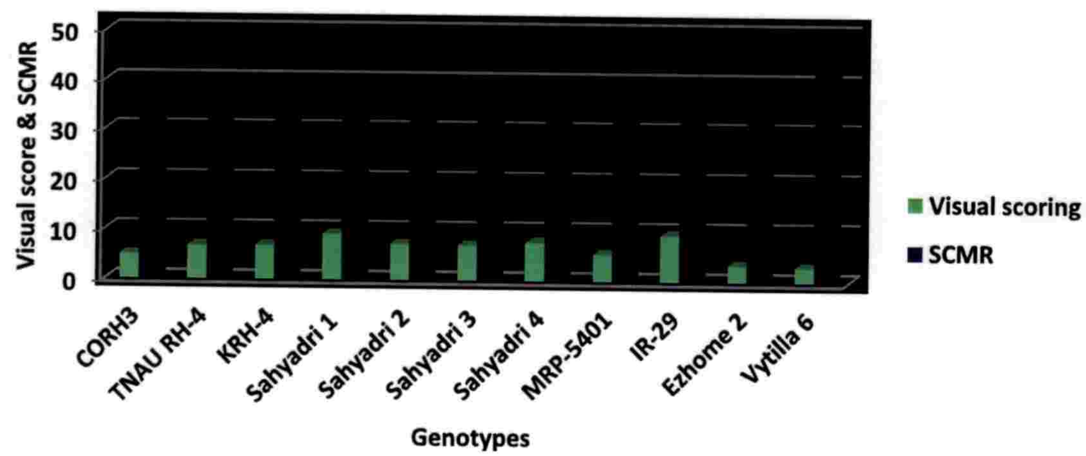



**Fig 4. Mean performances of rice genotypes for visual scoring and Spad chlorophyll meter reading (SCMR)**



### 4.1.8. Spad chlorophyll meter reading (SCMR)

Chlorophyll meter measures the green colour intensity and is associated with chlorophyll density (Songgri *et al.*, 2009). The result showed that 'Vytilla 6' the saline tolerant genotype recorded high chlorophyll content indicating its tolerance capacity to salinity. Hariadi *et al.*, 2015 observed symptoms of saline stress as chlorosis, drying of leaves and shoot. Proline was found to alleviate the deleterious consequences of salinity stress on rice by enhancing photosynthetic activity and chlorophyll contents. A decline in the content of chlorophyll was also reported in the plants undergoing salinity stress. (Sobahan *et al.,* 2012; Hasanuzzaman *et al.*, 2014). Ali *et al.,* (2004) observed a significant reduction of yield in many rice genotypes at a salinity level of 8.5 $dSm^{-1}$ besides the reduction of many yields contributing parameters viz., chlorophyll content, productive tillers per plant, panicle length and fertility percentage. According to Kranto *et al.*,2016, SPAD showed more stability than other traits in all salt concentrations. It can be inferred that salinity stress does not affect the green colour of the rice.

### 4.1.9.Visual scoring for salinity symptoms

The system for salinity screening is based on the ability of seedlings to grow in salinized nutrient solution. Scoring is relative and carried out according to the standard evaluation system of IRRI with a score of 1 for tolerant and 9 for sensitive. Scoring is carried out at 21 days of salt treatment. At this stage, sensitive seedlings begin to die, whereas intermediate genotypes show varying degrees of tolerance.

Visual scoring of 11 treatments was presented in Table 4. Saline resistant checks recorded to have the lowest score based on the score chart proposed by IRR1,2002. Score 3 was recorded for genotypes 'Vytilla 6' and 'Ezhome 2'; score of 5 was recorded for genotypes 'CORH3', 'MRP-5401', 'TNAU RH-4' and

'KRH-4'; genotypes 'Sahyadri 2', 'Sahyadri 3' and 'Sahyadri 4' observed to have score more than seven. Highest score of 9 was noticed in the genotypes 'Sahyadri-1' 'IR-29', indicating that these genotypes are more susceptible to salinity.

According to Krant *et al.,* 2016 , the salt injury scores for all 6 varieties they have tested under hydroponic conditions, showed a significant variation at 8 dS $m^{-1}$ of NaCl,. Genotype 'Pokkali' showed the maximum tolerance to salinity with a score of 4.38 and SRN1 was grouped as moderate tolerant, while IR62266-RDG was susceptible. The salt injury score at 8 and 12 dS $m^{-1}$ showed identical responses for the Pokkali variety, demonstrating that the variety has moderate salt tolerance, while other varieties were grouped as susceptible, especially IR29 which recorded the maximum susceptibility with a score of 9.00.

### *4.1.10. Relative water content*

The mean Relative Water Content (RWC) was recorded among 11 rice genotypes and presented in Table 4. The RWC varied from 81.05 per cent to 54.96 per cent . The genotype 'Vytilla 6' exhibited the highest RWC . Genotype 'MRP-5401' recorded low RWC of 54.96 per cent which was found to be on par with that of 'Sahyadri 2' and 'Sahyadri 4'' having a RWC of 55.2 per cent and 55.29 per cent, respectively.

In high-saline areas high salt deposition in the soil causes low water potential zone in the soil making it very complicated for the plant to acquire both water and nutrients (Mahajan and Tuteja, 2005). Therefore, salt stress basically leads to a form of a physiological drought because of the water deficit condition in the plant.

The result showed that the tolerant genotypes exhibited more RWC than sensitive genotypes indicating the negative influence of high salinity on the



52

**Plate 3. Determination of RWC**

**Plate 4. General view of experimental field**

sensitive genotypes. Soil water potential and availability of water to plant shoot and root was reduced by the high salt concentration in rhizosphere which further influences cellular physiology and metabolic pathways (Misra and Dwivedi, 2004). This causes the reduction of relative water content in crop plants.

Photosynthesis supplies the vital energy required for plant development and facilitates adaptation to environmental and biotic stresses. net photosynthesis and RWC were found to be higher in the salt tolerant lines compared to the salinity susceptible lines\(Dionisio-Sese and Tobita, 2000; Moradi and Ismail, 2007 and Cha-Um *et al.,* 2009).

### *4.1.11Calcium, Sodium, Potassium, Chloride and Sulphate content in root and shoot at 21 DAS*

Calcium content in root was significantly higher for 'IR-29' followed by 'Sahyadri 4' and 'Sahyadri 1', these genotypes recorded Calcium content of 1.28 per cent , 0.70 per cent and 0.69 per cent, respectively. The saline tolerant check 'Vytilla 6' recorded the lowest calcium content of 0.18 per cent among all the 11 rice genotypes under study (Table 5).

Highest shoot calcium content of 0.80 per cent was recorded in the saline susceptible genotype 'IR-29' followed by 'Sahyadri 2' which was found to be on par with 'Sahyadri 4' and'Sahyadri 1'. The lowest shoot calcium content of 0.18 per cent was observed in 'Vytilla 6' as represented in the Table 5.

**Table 5. Mean root and shoot Calcium, Sodium, Potassium, Chloride and Sulphate content of rice genotypes**

| Genotypes | Root Calcium (%) | Shoot Calcium (%) | Root Sodium (%) | Shoot Sodium (%) | Root Potassium (%) | Shoot Potassium (%) | Root Chloride (%) | Shoot Chloride (%) | Root Sulphate (%) | Shoot Sulphate (%) |
|---|---|---|---|---|---|---|---|---|---|---|
| CORH3 | $0.34^{d}$ | $0.47^{c}$ | $0.71^{fg}$ | $0.88^{cd}$ | $0.91^{fg}$ | $1.27^{cd}$ | $1.11^{b}$ | $1.80^{de}$ | $0.17^{cd}$ | $0.30^{f}$ |
| TNAU RH-4 | $0.28^{ef}$ | $0.42^{d}$ | $0.69^{gh}$ | $0.86^{cd}$ | $1.08^{d}$ | $1.31^{c}$ | $1.10^{b}$ | $1.92^{d}$ | $0.25^{ab}$ | $0.48^{c}$ |
| KRH-4 | $0.25^{fg}$ | $0.36^{ef}$ | $0.74^{f}$ | $0.88^{cd}$ | $0.92^{ef}$ | $1.30^{cd}$ | $1.10^{b}$ | $1.63^{e}$ | $0.20^{bc}$ | $0.29^{f}$ |
| Sahyadri 1 | $0.69^{b}$ | $0.61^{b}$ | $0.94^{bc}$ | $1.07^{a}$ | $1.23^{a}$ | $1.36^{b}$ | $1.24^{a}$ | $2.78^{b}$ | $0.25^{a}$ | $0.60^{b}$ |
| Sahyadri 2 | $0.63^{c}$ | $0.62^{b}$ | $0.92^{cd}$ | $0.98^{b}$ | $1.19^{b}$ | $1.35^{b}$ | $1.22^{a}$ | $2.75^{b}$ | $0.25^{a}$ | $0.41^{d}$ |
| Sahyadri 3 | $0.61^{c}$ | $0.39^{de}$ | $0.98^{b}$ | $1.06^{a}$ | $1.18^{b}$ | $1.39^{b}$ | $1.26^{a}$ | $2.94^{b}$ | $0.27^{a}$ | $0.58^{b}$ |
| Sahyadri 4 | $0.70^{b}$ | $0.60^{b}$ | $1.03^{a}$ | $0.99^{b}$ | $1.23^{a}$ | $1.35^{b}$ | $1.23^{a}$ | $3.52^{a}$ | $0.26^{a}$ | $0.59^{b}$ |
| MRP-5401 | $0.31^{de}$ | $0.48^{c}$ | $0.82^{e}$ | $0.92^{bc}$ | $0.96^{e}$ | $1.29^{cd}$ | $1.01^{c}$ | $1.94^{d}$ | $0.14^{de}$ | $0.37^{e}$ |
| IR-29 | $1.28^{a}$ | $0.80^{a}$ | $0.88^{d}$ | $1.08^{a}$ | $1.14^{c}$ | $1.49^{a}$ | $1.22^{a}$ | $2.25^{c}$ | $0.28^{a}$ | $2.45^{a}$ |
| Ezhome 2 | $0.22^{g}$ | $0.33^{f}$ | $0.67^{gh}$ | $0.82^{d}$ | $0.87^{gh}$ | $1.26^{d}$ | $1.04^{c}$ | $3.55^{a}$ | $0.01^{f}$ | $0.02^{h}$ |
| Vytilla 6 | $0.18^{h}$ | $0.18^{g}$ | $0.66^{h}$ | $0.72^{e}$ | $0.84^{h}$ | $1.08^{e}$ | $0.09^{d}$ | $0.96^{f}$ | $0.12^{e}$ | $0.19^{g}$ |
| **CV (%)** | **4.519** | **3.538** | **2.266** | **3.21** | **1.729** | **1.476** | **1.746** | **4.795** | **10.558** | **2.404** |
| **CD (0.05)** | **0.044** | **0.039** | **0.049** | **0.068** | **0.038** | **0.044** | **0.043** | **0.247** | **0.049** | **0.03** |

Fig 5. Mean root and shoot Sodium and Potassium content of rice genotypes

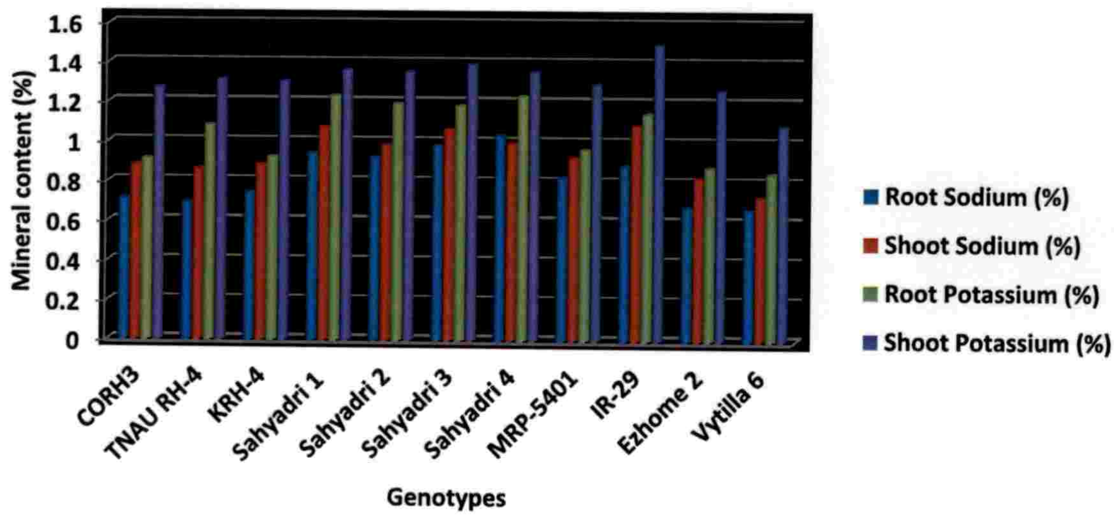
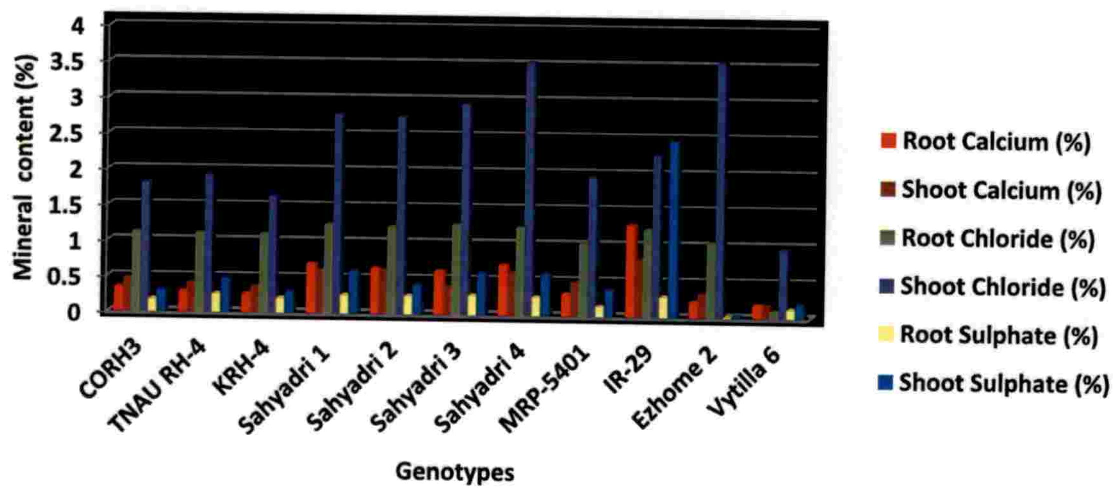



Fig 6. Mean root and shoot Calcium, Chloride and Sulphate content of rice genotypes



The root sodium content observed in the 11 rice genotypes varied from 1.03 per cent to 0.66 per cent as presented in Table 5. The highest amount of sodium content in the root was seen in the genotype 'Sahyadri 4' followed by 'Sahyadri 3' while the lowest amount of sodium content was recorded in the rice genotype used a saline tolerant check 'Vytilla 6' with 0.66 per cent sodium content in the roots.

The highest value for sodium content in the shoot was recorded in the saline susceptible genotype 'IR-29' with a value of 1.08 percent which was found to be on par with 'Sahyadri 1' which recorded a value of 1.07(Table 5).

According to Maathuis and Amtmann, 1999, high Na + strength adversely affect many enzymatic activities of plants. Salinity tolerance is linked to barring of $Na^+$ ion and allocation of almost homogeneous amount of this ion in all leaves (Ashraf and O'Leary, 1995 and Haq *et al.,* 2009). Hence, retention of high quantity of Na in the plants indicate their susceptibility to salinity. Incursion of large amounts of Na+ into the plant leads to cell death by disruption of metabolic activities due to heightened amount of salt in old leaves (Munns and Tester, 2008). According to Grieve and Fujiyama, (1987); and Dobermann and Fairhurst, (2000), Uptake of calcium ions is hindered by increase of sodium ion concentration. Castillo *et al.*, 2003 reported that high salinity increases sodium concentration and sodium uptake. During a long time in salinity, therefore, the sodium toxicity causes a reduction in the yield. Sahyadri 4 and Sahyadri-3 , the genotypes accumulating sodium can be considered to be susceptible to salinity leading to tissue damage and non availability of other nutrients.

The mean potassium content recorded in the root of the 11 rice genotypes ranged from 1.23 per cent to 0.84 per cent as presented in Table 5. The rice genotypes 'Sahyadri 4' and 'Sahyadri 1' both recorded the high root potassium content of 1.23 per cent , while the lowest root potassium content was seen in saline tolerant check ‘Vytilla 6’ which was 0.84 per cent .

The mean potassium content observed in the shoot of the 11 rice genotypes varied from 1.49per cent to 1.08 per cent as seen in Table 5. While the highest potassuim content was observed in saline susceptible genotype ‘IR-29’, lowest content of shoot potassium was recorded in saline tolerant check variety Vytilla 6.

Potassium is a major nutrient essential for normal growth and development of plants. Accumulation of potassium in tissues will help the plants to grow well and tolerate salinity, .however, in the present study 'Sahyadri 4' and 1 accumulated more potassium in shoots and IR 29 the susceptible check variety accumulated more potassium in roots. This indicate that accumulation of potassium alone will not make the plant tolerant to salinity. Several other factors and their interactions can result in salinity tolerance.

The mean amount of root chloride recorded in the 11 rice genotypes under study ranged from 1.26 per cent to 0.09 per cent . The highest amount of root chloride was recorded in the genotype‘Sahyadri 3’ which was found to be on par with genotypes ‘Sahyadri 1’, ‘Sahyadri 4’, ‘IR-29’ and ‘Sahyadri 2’ while the lowest amount of root chloride recorded was in the saline tolerant genotype ‘Vytilla 6’(Table 5).

The shoot chloride content in the 11 rice genotypes under studyvaried from 0.96 per cent to3.55 per cent as shown in Table 5. High amount of shoot chloride was seen in the genotype ‘Ezhome 2’ which was found to be on par with genotype ‘IR-29’ with values 3.55 per cent and 2.25 per cent respectively. The lowest amount of shoot chloride content of 0.96 per cent was observed in the saline tolerant genotype ‘Vytilla 6’.

Chloride is a mineral compound accumulation of which will result in toxicity in plants. In saline condition, among the genotypes tested low root chloride is seen in the genotypes, 'Vytilla-6' and'MRP-5401' indicating that in these genotypes the salinity tolerance mechanism is the exclusion of toxic chloride. At the same time high shoot chloride is seen in the genotypes 'Ezhome-2' and 'Sahyadri 4' indicating that in these genotypes the salinity tolerance mechanism is not exclusion but absorption and depositing in cytosol which will not affect the plant

The mean root and shoot sulphate content recorded in the 11 rice genotypes is presented in Table 5. The root sulphate content in the genotypes under observation varied from 0.006 per cent to 0.28 per cent . The highest amount of root sulphate content was seen in the genotype 'IR-29', which was seen to be on par with 'Sahyadri 3', 'Sahyadri 4', 'Sahyadri 2' and 'Sahyadri 1' with values of 0.28, 0.27, 0.26, 0.25, and 0.25 per cent respectively. The lowest root sulphate content was recorded in the saline tolerant rice genotype 'Ezhome 2', followed by 'Vytilla 6'.

The mean shoot sulphate content ranged from 0.015 per cent to 2.45 per cent . The saline susceptible rice genotype 'IR-29' recorded the highest amount of shoot sulphate content, followed by 'Sahyadri 1', 'Sahyadri 4', 'Sahyadri 3'. The lowest amount of shoot sulphate content was observed in the saline tolerant rice genotype 'Ezhome 2', followed by 'Vytilla 6' with values of 0.015 per cent and 0.19 per cent , respectively.

Sulphate is another compound which also toxic to plant. In saline condition, among the genotypes low root sulphate is seen in the genotypes 'Ezhome-2' and 'Vytilla-6'. The low shoot sulphate in the genotypes 'Ezhome-2', 'Vytilla-6', 'KRH-4' and 'CORH3' indicating that in these genotypes the salinity tolerance mechanism is the exclusion of toxic sulphate. At the same time high root sulphate is seen in the genotypes 'Sahyadri 3', 'Sahyadri 4', 'Sahyadri 2' and 'Sahyadri 1' indicating that in these genotypes the sulphates are not excluded but it is absorbed and deposited in cytosol which may not affect the plant. High root sulphate is seen in the saline susceptible genotype 'IR-29'

Influx of sodium ions along with the exclusion of potassium ions leads to the increase in the $Na^+ / K^+$ ratio to reach a hazardous level, it leads to the deficit of other nutrient minerals although the degree of damage caused due to these factors is limited by the genotype along with environment. (Ranamunns, 2002).

The result of sodium and potassium content in plant can be expressed as Na+ / K+ ratio. Lee *et al.*, (2003) observed that the cultivar with low Na +/ K+ ratio was highly tolerant and the susceptible one had high Na+/ K+ ratio. However, in the present study there was no such trend observed. The genotypes which accumulated high sodium in the tissue were accumulating more potassium also. Hence, the susceptibility of the genotypes could be due to interaction of several factors rather than accumulation of sodium or potassium in the tissues.

According to Chauhan *et al.*, 1997 Salinity tolerance in the rice callus can be attributed to the capacity of the cells to keep high amount of $K^+$ high and low strengths of $Na^+$ and $Cl^-$ along with increased strength of sterols and polyamines. Mishra *et al.*, 1997 opined that an increased percentage of spikelet sterility was found to be related to a decreased level of salinity tolerance and can be taken into deliberation as a looked-for characteristic while screening rice lines.

According to Sairam and Tyagi, 2004, salinity stress response is multigenic, as many components are involved in the tolerance apparatus such as antioxidant defence mechanism, ion transport and compartmentalization of injurious ions. Accumulation of, Sodium, Chloride and Sulphate in different parts of the plant are injurious to the plant. Hence the genotypes with low value of these compounds can tolerate salinity effectively.

**Table 6. Correlation among 21 characters recorded for laboratory experiment**

| | V 1 | V- 2 | V- 3 | V- 4 | V- 5 | V- 6 | V- 7 | V- 8 | V- 9 | V- 10 | V- 11 | V- 12 | V- 13 | V- 14 | V- 15 | V- 16 | V- 17 | V- 18 | V- 19 | V- 20 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **V- 1** | | | | | | | | | | | | | | | | | | | | |
| **V- 2** | $0.64^{*}$ | | | | | | | | | | | | | | | | | | | |
| **V- 3** | $0.74^{**}$ | $0.71^{**}$ | | | | | | | | | | | | | | | | | | |
| **V- 4** | $-0.19^{NS}$ | $-0.12^{NS}$ | $0.12^{NS}$ | | | | | | | | | | | | | | | | | |
| **V- 5** | $0.88^{**}$ | $0.59^{*}$ | $0.89^{**}$ | $-0.12^{NS}$ | | | | | | | | | | | | | | | | |
| **V- 6** | $0.62^{*}$ | $0.76^{**}$ | $0.59^{*}$ | $-0.33^{NS}$ | $0.71^{**}$ | | | | | | | | | | | | | | | |
| **V- 7** | $0.64^{*}$ | $0.86^{**}$ | $0.66^{*}$ | $-0.27^{NS}$ | $0.72^{**}$ | $0.96^{**}$ | | | | | | | | | | | | | | |
| **V- 8** | $0.68^{**}$ | $0.56^{*}$ | $0.84^{**}$ | $0.02^{NS}$ | $0.90^{**}$ | $0.72^{**}$ | $0.75^{**}$ | | | | | | | | | | | | | |
| **V- 9** | $0.87^{**}$ | $0.59^{*}$ | $0.77^{**}$ | $-0.03^{NS}$ | $0.88^{**}$ | $0.57^{*}$ | $0.67^{*}$ | $0.81^{**}$ | | | | | | | | | | | | |
| **V- 10** | $0.79^{**}$ | $0.76^{**}$ | $0.85^{**}$ | $-0.13^{NS}$ | $0.83^{**}$ | $0.62^{*}$ | $0.76^{**}$ | $0.73^{**}$ | $0.88^{**}$ | | | | | | | | | | | |
| **V- 11** | $-0.26^{NS}$ | $-0.66^{*}$ | $-0.42^{NS}$ | $0.31^{NS}$ | $-0.28^{NS}$ | $-0.48^{NS}$ | $-0.51^{NS}$ | $-0.13^{NS}$ | $-0.06^{NS}$ | $-0.43^{NS}$ | | | | | | | | | | |
| **V- 12** | $-0.41^{NS}$ | $-0.80^{**}$ | $-0.64^{*}$ | $0.29^{NS}$ | $-0.47^{NS}$ | $-0.61^{*}$ | $-0.69^{**}$ | $-0.39^{NS}$ | $-0.35^{NS}$ | $-0.67^{*}$ | $0.87^{**}$ | | | | | | | | | |
| **V- 13** | $-0.76^{**}$ | $-0.67^{*}$ | $-0.77^{**}$ | $0.20^{NS}$ | $-0.79^{**}$ | $-0.60^{*}$ | $-0.60^{*}$ | $-0.60^{*}$ | $-0.55^{NS}$ | $-0.66^{*}$ | $0.68^{**}$ | $0.64^{*}$ | | | | | | | | |
| **V- 14** | $-0.69^{**}$ | $-0.82^{**}$ | $-0.71^{**}$ | $0.17^{NS}$ | $-0.67^{*}$ | $-0.68^{**}$ | $-0.74^{**}$ | $-0.49^{NS}$ | $-0.52^{NS}$ | $-0.75^{**}$ | $0.83^{**}$ | $0.81^{**}$ | $0.85^{**}$ | | | | | | | |
| **V- 15** | $-0.72^{**}$ | $-0.75^{**}$ | $-0.65^{*}$ | $0.22^{NS}$ | $-0.68^{*}$ | $-0.58^{*}$ | $-0.73^{**}$ | $-0.53^{NS}$ | $-0.80^{**}$ | $-0.93^{**}$ | $0.49^{NS}$ | $0.68^{*}$ | $0.57^{*}$ | $0.77^{**}$ | | | | | | |
| **V- 16** | $-0.55^{*}$ | $-0.28^{NS}$ | $-0.53^{NS}$ | $0.06^{NS}$ | $-0.49^{NS}$ | $0.04^{NS}$ | $-0.07^{NS}$ | $-0.20^{NS}$ | $-0.53^{NS}$ | $-0.63^{*}$ | $0.34^{NS}$ | $0.37^{NS}$ | $0.57^{*}$ | $0.49^{NS}$ | $0.63^{*}$ | | | | | |
| **V- 17** | $-0.53^{NS}$ | $-0.58^{*}$ | $-0.43^{NS}$ | $0.53^{NS}$ | $-0.60^{*}$ | $-0.87^{**}$ | $-0.78^{**}$ | $-0.49^{NS}$ | $-0.35^{NS}$ | $-0.47^{NS}$ | $0.67^{*}$ | $0.63^{*}$ | $0.69^{**}$ | $0.74^{**}$ | $0.51^{NS}$ | $0.07^{NS}$ | | | | |
| **V- 18** | $0.04^{NS}$ | $-0.54^{NS}$ | $-0.12^{NS}$ | $0.35^{NS}$ | $0.03^{NS}$ | $-0.39^{NS}$ | $-0.42^{NS}$ | $0.10^{NS}$ | $0.21^{NS}$ | $-0.21^{NS}$ | $0.89^{**}$ | $0.74^{**}$ | $0.36^{NS}$ | $0.62^{*}$ | $0.30^{NS}$ | $0.02^{NS}$ | $0.55^{NS}$ | | | |
| **V- 19** | $-0.72^{**}$ | $-0.56^{*}$ | $-0.70^{**}$ | $0.37^{NS}$ | $-0.78^{**}$ | $-0.65^{*}$ | $-0.63^{*}$ | $-0.54^{NS}$ | $-0.52^{NS}$ | $-0.68^{**}$ | $0.71^{**}$ | $0.71^{**}$ | $0.88^{**}$ | $0.86^{**}$ | $0.65^{*}$ | $0.55^{*}$ | $0.82^{**}$ | $0.43^{NS}$ | | |
| **V- 20** | $-0.55^{*}$ | $-0.79^{**}$ | $-0.57^{*}$ | $0.33^{NS}$ | $-0.53^{NS}$ | $-0.63^{*}$ | $-0.74^{**}$ | $-0.37^{NS}$ | $-0.48^{NS}$ | $-0.79^{**}$ | $0.82^{**}$ | $0.84^{**}$ | $0.67^{*}$ | $0.91^{**}$ | $0.87^{**}$ | $0.50^{NS}$ | $0.67^{*}$ | $0.71^{**}$ | $0.74^{**}$ | |
| **V- 21** | $-0.66^{*}$ | $-0.74^{**}$ | $-0.55^{*}$ | $0.50^{NS}$ | $-0.61^{*}$ | $-0.78^{**}$ | $-0.78^{**}$ | $-0.43^{NS}$ | $-0.44^{NS}$ | $-0.66^{*}$ | $0.79^{**}$ | $0.82^{**}$ | $0.73^{**}$ | $0.89^{**}$ | $0.69^{**}$ | $0.29^{NS}$ | $0.87^{**}$ | $0.65^{*}$ | $0.85^{**}$ | $0.85^{**}$ |

**V-1**-Shoot length 21DAS;**V-2**-Root length 21DAS; **V-3**-Total roots;**V-4**-Vigour index ; **V-5**-Root CEC; **V-6**-Root Proline; **V-7**-Shoot Proline; **V-8**-Survival(%);**V-9**-SCMR; **V-10**-RWC; **V-11**-Root Ca; **V-12**-Shoot Ca; **V-13**-Root Na; **V-14**-Shoot Na; **V-15**-Root Cl; **V-16**-Shoot Cl; **V-17**-Root $SO_4$; **V-18**-Shoot $SO_4$; **V-19**-Root K;**V-20**- Shoot K; **V-21**- Visual Score

Correlation among 21 characteristics recorded in the laboratory experiment presented in table 6 are discussed below.

Among the correlation coefficients of 21 characteristics, visual score showed highly significant positive correlation with root Ca, shoot Ca, root Na, shoot Na, root Cl, root $SO_4^{2-}$, root K, and shoot K. It showed significant positive correlation with shoot $SO_4^{2-}$ visual score exhibited highly significant negative correlation with root length, root proline and shoot proline along with significant negative correlation with shoot length, total number of roots, root CEC and RWC

The character total number of roots showed highly significant positive correlation with shoot length, root length, root CEC, survival per cent, SCMR and RWC. It showed significant positive correlation with root proline and shoot proline. Highly significant negative correlation of total number of roots under present study was seen with root Na, shoot Na and root K however, and shoot Ca, root Cl, shoot K and visual score it showed significant negative correlation .

Survival per cent was found to have highly significant positive correlation with shoot length, total number of roots, root CEC, root proline, shoot proline, SCMR and RWC while it showed highly significant negative correlation with root Na.

RWC which is an important character known to affect the saline tolerance of the crop was observed to have highly significant positive correlation with shoot length, root length, total number of roots, root CEC, shoot proline, sterility per cent and SCMR while, it was observed to have highly significant negative correlation with shoot Na, root Cl, root K, shoot K and significant negative correlation with shoot Ca, root Na, shoot Cl and visual score.

Correlation results suggest that lower visual score which corresponds to better salinity tolerance could be achieved by exercising indirect selection simultaneously for decreased values of dependent traits namely, root Ca, shoot Ca, root Na, shoot Na, root Cl, root $SO_4^{2-}$, root K, and shoot K and shoot $SO_4^{2-}$.



6

Improvement in value of root proline, shoot proline, shoot length, root length, total number of roots, root CEC and RWC can also result in lower visual score indicating sterilty tolerance

## 4.2. Experiment 2: Field evaluation of rice hybrids in Pokkali tract

The saline tolerant rice hybrids as presented in Table 1 were raised in the field of Mr.K.A. Thomas, Kalluveetil(H) at Pokkali tract of Kadamakudy Grama Panchayath of Ernakulam district during the Kharif season of 2016-17, following a randomised block design. Recommended agronomic practices were followed during the crop growth period as per the package of practices reccomendatios. Observations on biometrical characters and visual scoring for symptoms of salt toxicity was done. Visual scoring was done using a scale of 1 - 9 based on Standard Evaluation System for Rice (IRRI, 2002). The results of the study were detailed and discussed below.

According to Ashraf and Harris 2004 and Marschner, 1995, the differential response of the plants to salinity depends on the concentration and composition of ions in the solution and the genotype of the plant. Many physiological processes in the plants are affected by salinity. The deleterious effects of salinity in plants are associated with low osmotic potential of soil solution which is equal to water stress, nutritional imbalance, specific ion effects and combination of all these. Munns, 2002 , Tester and Davenport 2003 and Winicov, 1998 suggested that all of these leads to unfavorable pleiotropic effects on plant growth at physiologically , biochemically and at the molecular level.

### *4.2.1. Plant height*

Plant height of 11 genotypes was recorded and presented in Table 7. The plant height of different treatments ranged from 87.5 cm to 117.35 cm at flowering stage. Highest plant height was recorded in saline tolerant check 'Vytilla 6', followed by 'Ezhome 2'. Minimum plant height of 87.5 cm was recorded in saline susceptible check variety 'IR-29' which was on par with that of 'Sahyadri 2'. Roy *et al.*, 2002 , observed that with increase of salinity, reduction of root length, shoot length, dry weight of root and dry weight of shoot occurs according to Maas and Hoffman 1977 and Ramoliya *et al.,* 2004 soil salinity suppresses shoot growth more than the root growth . Islam *et al.,* (2007) also observed differences in plant height of rice genotypes with different salinity levels. Adverse effects of salinity stress on the shoot and root growth was observed by Javed and Khan (1975) and Sagi *et al.,* (1997) . As per the reports of Pandey (1981), plant height gradually declined with rise in salinity levels, because the high concentration of soluble salts in the soil and osmotic pressure creates disorder in the uptake of water and other nutrients leading to reduction in growth of plants. Rajendran *et al.*, 2009 and Sirault *et al.*, 2009 reported that shoot elongation is hindered by the rise in temperature of the plant leaf which happens due to the closing of the stomata brought about by the increased amount of salts. Hence, it can be assumed that the plant height reduces under salinity for susceptible genotypes and they may produce taller plants if they are grown under non saline condition.

**Table 7. Mean performances of rice genotypes for biometrical traits under field evaluation**

| Genotypes | Plant height (cm) | Uppermost internodal length (cm) | Days to 50 per cent flowering | Days to maturity | Productive tillers per plant | Visual scoring |
|---|---|---|---|---|---|---|
| CORH 3 | $97.95^{c}$ | $11.03^{de}$ | $82.00^{bc}$ | $112.22^{bc}$ | $9.30^{a}$ | $5.35^{cde}$ |
| TNAU RH-4 | $94.97^{d}$ | $11.00^{de}$ | $83.29^{bc}$ | $112.78^{bc}$ | $4.60^{de}$ | $5.10^{de}$ |
| KRH-4 | $96.96^{cd}$ | $11.40^{c}$ | $84.76^{abc}$ | $117.64^{a}$ | $5.10^{cd}$ | $6.00^{cd}$ |
| Sahyadri 1 | $90.66^{e}$ | $10.67^{f}$ | $83.43^{bc}$ | $106.45^{de}$ | $4.40^{e}$ | $7.60^{b}$ |
| Sahyadri 2 | $87.88^{f}$ | $10.41^{g}$ | $81.33^{bc}$ | $108.15^{cde}$ | $3.80^{f}$ | $7.60^{b}$ |
| Sahyadri 3 | $91.36^{e}$ | $10.83^{ef}$ | $80.02^{c}$ | $108.52^{cde}$ | $4.70^{de}$ | $7.40^{b}$ |

| | | | | | | |
|---|---|---|---|---|---|---|
| Sahyadri 4 | 90.48$^{e}$ | 10.68$^{f}$ | 80.70$^{c}$ | 108.65$^{cde}$ | 3.70$^{f}$ | 8.75$^{a}$ |
| MRP-5401 | 96.27$^{cd}$ | 11.15$^{d}$ | 80.04$^{c}$ | 110.40$^{cd}$ | 5.10$^{cd}$ | 4.95$^{e}$ |
| IR-29 | 87.5$^{f}$ | 10.39$^{g}$ | 88.17$^{a}$ | 105.27$^{e}$ | 5.50$^{c}$ | 8.95$^{a}$ |
| Ezhome 2 | 101.29$^{b}$ | 14.92$^{b}$ | 85.69$^{ab}$ | 115.40$^{ab}$ | 4.70$^{de}$ | 3.10$^{f}$ |
| Vytilla 6 | 117.35$^{a}$ | 15.45$^{a}$ | 88.66$^{a}$ | 117.78$^{a}$ | 6.20$^{b}$ | 1.80$^{f}$ |
| **CV (%)** | **1.14** | **0.87** | **2.21** | **1.86** | **4.41** | **7.72** |
| **CD (0.05)** | **2.45** | **0.22** | **4.07** | **4.61** | **0.51** | **1.02** |

**Table 8. Mean performances of rice genotypes for biometrical traits under field evaluation**

| Genotypes | Number of Spikelets per panicle | Seed setting percentage | Length of panicle (cm) | Sterility percentage | 1000 grain weight (g) | Grain yield per plant (g) |
|---|---|---|---|---|---|---|
| CORH 3 | 150.50$^{c}$ | 47.97$^{cd}$ | 20.70$^{cd}$ | 12.09$^{d}$ | 19.82$^{c}$ | 15.19$^{a}$ |
| TNAU RH-4 | 148.20$^{cd}$ | 48.38$^{c}$ | 20.28$^{d}$ | 13.45$^{c}$ | 19.62$^{c}$ | 10.62$^{c}$ |
| KRH-4 | 150.10$^{c}$ | 47.53$^{cde}$ | 20.29$^{d}$ | 13.07$^{c}$ | 19.65$^{c}$ | 13.34$^{b}$ |
| Sahyadri 1 | 145.40$^{ef}$ | 46.84$^{cde}$ | 19.29$^{ef}$ | 14.51$^{b}$ | 19.27$^{c}$ | 8.57$^{f}$ |
| Sahyadri 2 | 141.60$^{g}$ | 42.94$^{gh}$ | 18.70$^{g}$ | 14.97$^{a}$ | 19.13$^{c}$ | 8.48$^{f}$ |
| Sahyadri 3 | 145.50$^{def}$ | 45.57$^{def}$ | 19.52$^{e}$ | 14.43$^{b}$ | 19.25$^{c}$ | 8.72$^{f}$ |
| Sahyadri 4 | 144.20$^{fg}$ | 43.70$^{fgh}$ | 18.98 | 14.67$^{ab}$ | 19.16$^{c}$ | 8.78$^{f}$ |
| MRP-5401 | 148.00$^{cde}$ | 45.07$^{efg}$ | 18.92$^{fg}$ | 14.66$^{ab}$ | 19.40$^{c}$ | 8.63$^{f}$ |
| IR-29 | 196.25$^{a}$ | 42.45$^{h}$ | 21.08$^{c}$ | 11.48$^{e}$ | 19.10$^{c}$ | 9.58$^{e}$ |
| Ezhome 2 | 196.30$^{a}$ | 72.69$^{a}$ | 27.15$^{a}$ | 7.89$^{g}$ | 34.25$^{a}$ | 10.29$^{d}$ |
| Vytilla 6 | 158.00$^{b}$ | 68.73$^{b}$ | 22.25$^{b}$ | 8.79$^{f}$ | 33.46$^{b}$ | 10.47$^{cd}$ |
| **CV (%)** | **0.78** | **2.30** | **1.04** | **1.37** | **1.54** | **1.34** |
| **CD (0.05)** | **2.72** | **2.56** | **0.48** | **0.39** | **0.82** | **0.31** |

#### *4.2.2. Uppermost internodal length*

Mean of uppermost internodal length at flowering stage recorded for 11 rice genotypes are presented in Table 7. The uppermost internodal length varied from 10.39-15.45 cm. 'Vytilla 6' recorded the highest uppermost internodal length and Sahyadri had the lowest. Uppermost internodal length is having a direct contribution towards plant height. When the genotype is having low value for uppermost intermodal length it will have a low plant height.

#### *4.2.3. Days to 50 per cent flowering*

Number of days from the sowing of seeds to 50 per cent flowering was counted for the 11 rice genotypes and presented in Table 7. Days to 50 per cent flowering varied from 80-88 days .MRP 5401 ,Sahyadri 3 and 4 were early to flower while IR 29 was the late flowering genotype among the tested entries. Khatun *et al.,* 1995 reported that salinity resulted in delayed flowering. The study by Maghsoudi Moud and Maghsoudi 2008 , showed that shoot growth was reduced by salinity and plants were early to flower. The CORH 3 is reported to be a medium duration variety with 120-140 days duration. In the present study its fifty per cent flowering occurs at 82 days making its duration to 112 days which is earlier than its normal duration. TNAU RH 4 also reduced its duration from 130-145 (tnau.ac.in/cpbg/rice) days to 113 days. Hence, it can be concluded that the salinity make the varieties to enter into reproductive phase early compared to non saline condition.

#### *4.2.4. Days to maturity*

Days to maturity counted as number of days from sowing to harvest (when 85 % of grains on the panicle have matured) is presented in Table 7. Six rice genotypes 'Sahyadri 1', 'Sahyadri 2', 'Sahyadri 3', 'Sahyadri 4', 'MRP-5401' and 'IR-29' recorded a duration of 105 - 110 days, two rice genotypes 'CORH3', and 'TNAU RH-4' recorded a duration of 112 days, two rice genotypes 'Vytilla 6'

Fig 7. Mean performances of rice genotypes for biometric traits under field evaluation

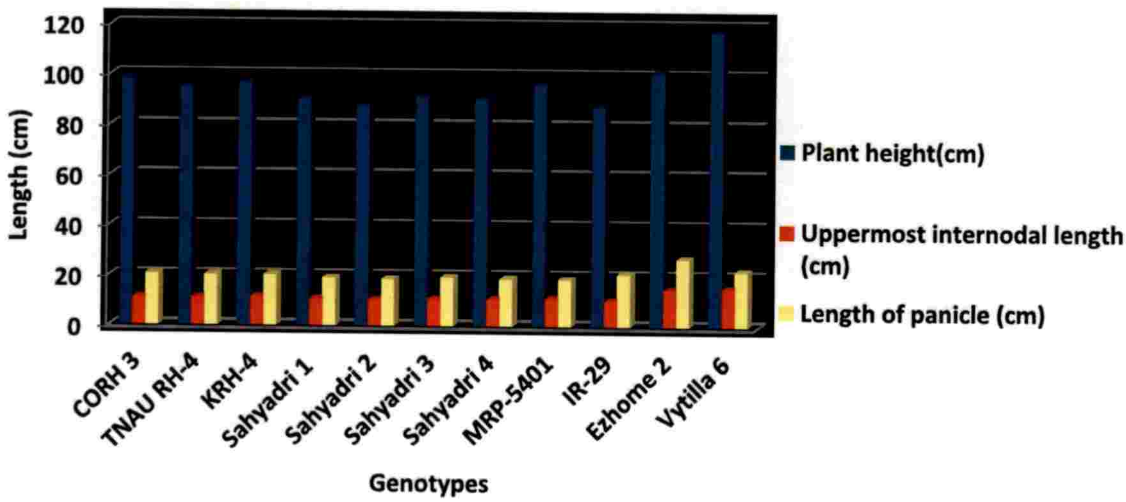
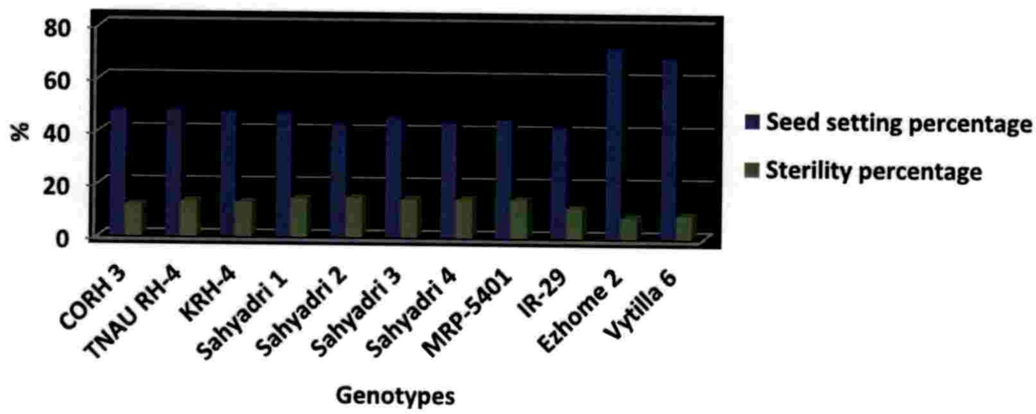



Fig 8. Mean performances of rice genotypes for seed setting and sterility under field evaluation



and 'KRH-4' recorded a duration of 117 days, and rice genotype 'Ezhome 2' recorded a duration of 115 days. As seen in the case of days to fifty per cent flowering the genotypes were early to flower and mature under saline condition. Ezhome 2 which had a total duration of 125-130 days under Kaipad condition reached maturity in 115 days . Hence it can be suggested that salinity induces early flowering and maturity in the tested genotypes. This will reduce the vegetative phase of the plant to accumulate photosynthates to produce its potential yield leading to reduction in grain yield under saline condition along with other factors.

#### *4.2.5. Number of productive tillers per plant*

The average figure of productive tillers per plant recorded amongst 11 rice genotypes at the flowering stage is presented in Table 7. The numbers of tillers per plant varied from 9.3 to 3.7. 'CORH3' exhibited the highest number of tillers per plant at flowering stages and 'Sahyadri 4' recorded the lowest number of tillers per plant. Many researchers have reported that number of productive tillers per plant is a significant trait contributing to productivity in rice under all the situations of cultivation (Parimala, 2016, Thippani *et al.*, 2017 and Sadimantara *et al.*, 2018). According to Ali *et al.*,(2004b) no of productive tillers per plant were considerably further in NR-2 than all other cultivars under saline conditions. Many workers has reported reduction in number of tillers with increasing salinity (Ling *et al.*,2000., Young *et al.*, 2003., Khatun *et al.*, 1995 and Lutts *et al.*, 1995 ). Kranto *et al.*, 2016, reported reduction in number of tillers per plant and greatest decline in tillers and panicles were observed in susceptible genotype IR 29 and tolerant variety RD6 showed lesser reductions in the number of productive tillers. This indicates that the saline tolerant varieties produce enough number of tillers and panicles to maintain an adequate level of production under saline condition.

### 4.2.6. Visual scoring for salinity symptoms

The technique for salinity screening is based on the ability of seedlings to grow in salinised nutrient solution. Scoring is relative and carried out according to the standard evaluation system of IRRI with a score of 1 for tolerant and 9 for sensitive.

Visual scoring of 11 treatments was presented in Table 7. Saline resistant checks recorded to have the lowest score based on the score chart proposed by IRR1,2002. Score 1 was recorded for genotype 'Vytilla 6' while 'Ezhome 2' recorded a score of 3; score of 5 was recorded for genotypes 'CORH3', 'MRP-5401', 'TNAU RH-4' and 'KRH-4'; genotypes 'Sahyadri 1', 'Sahyadri 2', 'Sahyadri 3' and 'Sahyadri 4' and 'IR-29' observed to have score more than seven indicating that these genotypes are susceptible to salinity.

### *4.2.7. Number of spikelets per panicle`*

Mean values of spikelets per panicle of rice genotypes recorded after harvest are depicted in Table 8 and it varied from 141.60-196.30. The highest number of spikelets per panicle was recorded in 'Ezhome 2' which was on par with that of 'IR-29' followed by 'Vytilla 6' and the lowest spikelets per panicle was recorded for 'Sahyadri 2'. Scardaci *et al.,* 1996 and Shannon, *et al.,* 1998 reported that salinity has a negative impact on a number of yield components of rice. The decrease in a number of spikelets per panicle is one of the chief factors of reduction in rice yield due to salinity. During the reproductive stage, salts adversely affect the number of spikelet per panicle (IRRI,1978).

**Plate 5. Growth of Vytilla- 6 at Pokkali field**

**Plate 6. Growth of IR-29 at Pokkali field**

### *4.2.8. Seed setting percentage*

Seed setting per cent of rice genotypes was recorded after harvest and it varied from 42.45-72.69 per cent (Table 8). 'Ezhome 2' recorded maximum seed setting percentage The saline susceptible check variety 'IR-29' recorded the minimum seed setting per cent which indicates that salinity of soil decreases the seed setting per cent. This was also reported by Ali *et al.*, (2004). According to Abdullah *et al.,* (2001), declined translocation of soluble carbohydrates to primary and secondary spikelet along with the build up of increased sodium and decreased potassium in all floral parts lead to the sterility and drop in seed set by restraining the specific activity of starch production in young rice grains

### *4.2.9. Length of panicle*

Mean length of the panicle of rice genotypes recorded varied from 18.69 - 27.15 cm (Table 8).`Ezhome 2' recorded the highest panicle length followed by 'Vytilla 6' and 'IR-29', respectively. Acording to Krant *et al.*, 2016, in the soil culture technique, injury score was associated to plant height, proline content and panicle length. Pokkali and tolerant genotypes with a low salt injury score were related with increased plant height as well as panicle length.

### *4.2.10. Sterility percentage*

Sterility per cent of rice genotypes grown is recorded after harvest is presented in Table 8. It varied from 7.89- 14.97 per cent. 'Sahyadri 2' recorded maximum sterility per cent followed by 'Sahyadri 4', and 'MRP-5401'. 'Ezhome-2' showed minimum sterility per cent. Hasamuzzaman *et al.*, (2009) reported that a radical decrease in spikelet fertility was seen with increase in salt level. According to their study the least influence was observed on NR-2 then by NR-3. Under the saline situation high panicle fertility per cent was observed in NR-2 while highest panicle fertility affected was in Basmati-370 (Ali *et al.*, 2004).

According to Mohammadi-Nejad *et al.*, (2010) salinity stress caused a reduction in the number of filled grain per panicle and yield.

### *4.2.11. 1000 grain weight*

1000 grain weight of the rice genotypes grown were recorded after harvest and it varied from 19.1-34.25 g (Table 8). 'Ezhome-2' recorded maximum 1000 grain weight followed by 'Vytilla 6'. 'IR-29' recorded the minimum 1000 grain weight which was on par with CORH-3, Sahyadri 2, MRP-5401, TNAU RH-4, Sahyadri 3, KRH-4, Sahyadri 1 and Sahyadri 4. In saline condition the saline susceptible check 'IR-29' recorded minimum 1000 grain weight indicating that high-salinity level reduces the weight of grains. This was also reported by Hasamuzzaman *et al.*,in 2009. Khatun *et al.*, 1995 observed reduction in 1000-seed weight under salinity.

### *4.2.12. Grain yield per plant*

Grain yield per plant of the rice genotypes grown are recorded after harvest and it varied from 9.58-15.19 g (Table 8). Rice genotype 'CORH-3' recorded maximum yield per plant. 'Sahyadri 2' recorded the lowest yield per plant which was on par with that of 'MRP-5401', 'Sahyadri 3', 'Sahyadri 1' and 'Sahyadri 4'.

Chinnusamy *et al.*, 2005 suggested that multiple genes control the salinity tolerance. According to Lutts *et al.*, 1995, rice is known to be salinity susceptible cereal, particularly, at its young stage. Todaka *et al.*, 2012 reported that the productivity at the mature stage is limited by salinity. Singh *et al.*, 2004 reported that By following certain management practices the effect of salinity on the rice cultivars can mitigated at the young stage by planting of aged seedlings but the stress at flowering stages cannot be avoided because it is a very sensitive growth phase . Many workers reported reduction in grain yield in rice under salinity (Uddin *et al.,* 2007, Maghsoudi Moud and Maghsoudi 2008, Hasamuzzaman *et* *al*.,2009.,and Mohammadi-Nejad *et al*., 2010). Yield is a complex character directly and indirectly, affected by many factors .Under saline condition all the growth stages and characters of the plant are negatively affected by salinity resulting in reduction in yield of susceptible varieties

**Table 9. Correlation among 12 characters recorded for field experiment**

| | Variable 1 | Variable 2 | Variable 3 | Variable 4 | Variable 5 | Variable 6 | Variable 7 | Variable 8 | Variable 9 | Variable 10 | Variable 11 | Variable 12 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Variable 1** | | | | | | | | | | | | |
| **Variable 2** | $0.67^{*}$ | | | | | | | | | | | |
| **Variable 3** | $-0.81^{**}$ | $-0.89^{**}$ | | | | | | | | | | |
| **Variable 4** | $-0.86^{**}$ | $-0.71^{**}$ | $0.81^{**}$ | | | | | | | | | |
| **Variable 5** | $-0.85^{**}$ | $-0.87^{**}$ | $0.98^{**}$ | $0.88^{**}$ | | | | | | | | |
| **Variable 6** | $-0.31^{NS}$ | $-0.78^{**}$ | $0.53^{NS}$ | $0.43^{NS}$ | $0.52^{NS}$ | | | | | | | |
| **Variable 7** | $-0.82^{**}$ | $-0.59^{*}$ | $0.64^{*}$ | $0.81^{**}$ | $0.73^{**}$ | $0.32^{NS}$ | | | | | | |
| **Variable 8** | $-0.29^{NS}$ | $-0.35^{NS}$ | $0.10^{NS}$ | $0.39^{NS}$ | $0.14^{NS}$ | $0.23^{NS}$ | $0.29^{NS}$ | | | | | |
| **Variable 9** | $-0.15^{NS}$ | $-0.74^{**}$ | $0.51^{NS}$ | $0.11^{NS}$ | $0.42^{NS}$ | $0.74^{**}$ | $0.06^{NS}$ | $0.09^{NS}$ | | | | |
| **Variable 10** | $-0.84^{**}$ | $-0.88^{**}$ | $0.98^{**}$ | $0.81^{**}$ | $0.98^{**}$ | $0.50^{NS}$ | $0.69^{**}$ | $0.14^{NS}$ | $0.47^{NS}$ | | | |
| **Variable 11** | $-0.61^{*}$ | $-0.92^{**}$ | $0.85^{**}$ | $0.50^{NS}$ | $0.79^{**}$ | $0.59^{*}$ | $0.52^{NS}$ | $0.16^{NS}$ | $0.77^{**}$ | $0.87^{**}$ | | |
| **Variable 12** | $-0.28^{NS}$ | $-0.76^{**}$ | $0.06^{NS}$ | $0.33^{NS}$ | $0.13^{NS}$ | $0.24^{NS}$ | $0.58^{*}$ | $0.79^{**}$ | $0.03^{NS}$ | $0.72^{**}$ | $0.23^{NS}$ | |

1-Visual score; 2-Sterility %; 3-1000 Grain wt; 4-Plant height; 5-Internodal length; 6-DFF; 7-DM; 8-Productive tillers/panicle; 9-Spiklets/panicle; 10-Seed Setting %; 11-Panicle length; 12-Grain yield/ plant



74

Correlation among 12 characteristics recorded in the field experiment presented in table 9 are discussed below.

Among the correlation coefficients of 12 characteristics, grain yield showed highly significant positive correlation with productive tillers/ plant and seed setting per cent along with significant positive correlation days to maturity whereas grain yield showed highly significant negative correlation with sterility per cent.

Panicle length showed highly significant positive correlation with 1000 grain weight, internodal length, spikelet/ panicle and seed setting per cent; and significant positive correlation with days to 50 per cent flowering. Highly significant negative correlation was seen with sterility per cent whereas significant negative correlation was seen with visual score.

Similarly high significant negative correlation of sterility per cent, which is another indicator of salinity tolerance was observed with the characters 1000 grain weight, plant height, internodal length, days to fifty per cent flowering, spikelets/ panicle, seed setting per cent, panicle length and grain yield points out the fact that improvement in sterility per cent could be achieved by exercising selection simultaneously for decreased value of these traits. The above results are in agreement with the reports of Vanaja *et al*., (1998), Ramakrishnan *et al*. (2006), Chandra *et al*. (2009), Akhtar *et al*. (2011), Idris *et al*. (2012), Nagaraju *et al*. (2013); Ramakrishnan *et al*. (2006), Kumar and Nilanjaya, (2014) for seed setting per cent; Reddy *et al*. (2013), Allam *et al*. (2015) for number of spikelets per panicle.

Correlation results suggest that higher grain yield could be achieved by exercising indirect selection simultaneously for increased values of dependent biometric traits namely, productive tillers/ plant and seed setting per cent along with days to maturity whereas for decreased value of sterility per cent.

# SUMMARY

# 5.SUMMARY

The present study on identification of saline tolerant rice hybrids for Pokkali tract was conducted in the Department of Plant Breeding and Genetics, College of Horticulture, Vellanikkara, Kerala Agricultural University. The study comprised of two experiments, the first experiment was Laboratory screening for salinity tolerance and the second experiment was field evaluation of rice hybrids in Pokkali tract. The laboratory screening was done at the Department of Plant Breeding and Genetics, College of Horticulture, Vellanikkara, Kerala Agricultural University. The field evaluation was carried out in saline-prone areas of Pokkali tract of Kadamakudy Grama Panchayath of Ernakulam district during the season Kharif 2016.

The investigation was conducted for identification of rice hybrids suitable for Pokkali tract as well as evaluation of traits associated with salinity tolerance in rice hybrids

The materials comprised of 11 rice genotypes which include eight rice hybrids along with three check varieties which include, improved saline tolerant variety of Kaipad (Ezhome-2), improved saline tolerant Pokkali variety (Vytilla-6) and international saline susceptible variety (IR-29); and rice hybrids from Regional Agricultural Research Station, Karjat: Sahyadri-1, Sahyadri-2, Sahyadri-3, Sahyadri-4; TNAU-RH-4, CORH-3 hybrids from Tamil Nadu Agricultural University; KRH-4 a hybrid developed by University of Agricultural Sciences, Bengaluru; and MRP-5401 a rice hybrid developed by Mahyco.

The eleven rice genotypes were screened for salinity tolerance under laboratory conditions. The laboratory screening was done following a completely randomised design with three replications and the genotypes were grown in Yoshida's solution and evaluated for various seedling characters. Observations on various seedling characters were recorded on 10 randomly selected plants in each replication for each treatment. Observations were taken on shoot length, root length, root-shoot ratio, total number of roots, vigour index, root CEC, proline content in root and shoot, $Ca^{+}$, $Na^{+}$, $K^{+}$, Chloride and Sulphate content in root and shoot, survival per cent, relative water content, SPAD chlorophyll meter reading (SCMR) and visual scoring for salinity symptoms at 21 days after salinization.

Field evaluation for the eleven rice genotypes was carried out in saline-prone areas of Pokkali tract of Kadamakudy Grama Panchayath of Ernakulam district during the season Kharif 2016 in a randomized block design with three replications. Observations on various biometric parameters were recorded on 10 randomly selected plants in each replication for each treatment leaving the border rows. Observations were taken as per the 'Standard Evaluation System for Rice' (IRRI, 1996) on plant height, uppermost internodal length at flowering stage; days to 50 per cent flowering, days to maturity, number of productive tillers per plant, number of spikelets per panicle, seed setting per cent, length of panicle, sterility per cent, 1000 grain weight and grain yield per plant at harvesting. The data on plant observations were subjected to statistical analyses of variance and correlation.

Low root and shoot proline content were observed in IR-29 confirming its susceptibility to salinity. Among the hybrids, a high value for shoot length, root length, total number of roots, root CEC, root proline, shoot proline and survival per cent was observed in the hybrids CORH-3 and KRH-4.

Vigour index was high in Sahyadri 4 followed by KRH-4 and low in MRP-5401. Vytilla-6 and Ezhome-2 showed the high survival per cent while low survival per cent was noticed in Sahyadri 2 and MRP-5401. Vytilla-6 exhibited high chlorophyll content and RWC while low RWC was recorded in MRP-5401, Sahyadri-2 and Sahyadri-4.

Ca in root and shoot along with Na content in shoot were high in IR-29 while Vytilla-6 had low Ca and Na content. High Na in root was seen in Sahyadri 4 followed by Sahyadri 3. High amount of root $Cl_2$ was recorded in Sahyadri-3, Sahyadri-1, Sahyadri-4, IR-29 and Sahyadri-2 while, the lowest amount of root and shoot $Cl_2$ was in Vytilla-6. High amount of shoot $Cl_2$ was seen in Ezhome-2 and IR-29. High amount of root and shoot $SO_4$ content was seen in IR-29, Sahyadri-3, Sahyadri-4, Sahyadri-2 and Sahyadri-1. The lowest root and shoot $SO_4$ content was recorded in Ezhome-2, followed by Vytilla-6.

Low visual score of 3 was recorded in Vytilla-6 and Ezhome-2; a score of 5 was recorded for CORH-3, MRP-5401, TNAU RH-4 and KRH-4. Sahyadri-2, Sahyadri-3 and Sahyadri-4 were observed to have scored more than seven. Score 9 was noticed in Sahyadri-1 and IR-29, indicating that these genotypes are more susceptible to salinity. Visual score under salinity was found to be negatively correlated with shoot and root length, number of roots, vigour, proline content and RWC, while it was positively correlated with content of Ca, Na, $Cl_2$, $SO_4$ and K in the plant tissue.

Field evaluation of rice hybrids in Pokkali tract was done during Kharif season of 2016-17, following a randomised block design. Days to fifty per cent flowering and maturity showed that all hybrids became early under salinity. Tall plants were observed in Vyttila-6 and Ezhome-2 and short plants in IR-29. High number of productive tillers was observed in CORH-3 and low in Sahyadri-2. Ezhome-2, IR-29 and Vyttila-6 had high number of spikelets per panicle while seed setting percentage and long panicles were observed in Ezhome-2. Spikelet sterility was high in Sahyadri-2 and low Ezhome-2. High 1000 grain weight was observed in Ezhome-2 and low in IR-29. Based on visual scoring Vyttila-6 was classified as highly tolerant and IR-29 as highly susceptible.

Correlation studies indicated that grain yield per plant was positively correlated with productive tillers per plant and seed setting per cent, while it was found to be negatively correlated with sterility per cent. Visual scoring was negatively correlated with plant height, uppermost internodal length, days to maturity and seed setting per cent. The hybrid CORH-3 was found to be moderately tolerant based on visual scoring and it produced highest yield per plant indicating that this hybrid is better than saline tolerant traditional varieties.

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86

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87

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# Identification of saline tolerant rice hybrids for Pokkali tract

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**ABSTRACT OF THE THESIS**

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ABSTRACT

Various abiotic stresses causing a decline in global rice production are drought, salinity and chillness. Among these, salinity is the major factor that affects crop productivity. The traditional rice varieties grown under Pokkali area show remarkable tolerance to salinity and floods making it unique. However, the yield potential of these varieties is low.

In India, out of ninety three rice hybrids developed, a few viz. DRRH 28, KRH 4, PSD 3, etc. were reported to have tolerance to salinity. Considering the potentials of hybrids, identification of salt tolerant hybrids suitable for Pokkali tract of Kerala is an urgent need of the hour. Hence, the study was designed to explore the adaptability of eight rice hybrids to the unique tract of Pokkali and evaluation of traits associated with salinity tolerance.

The study comprised of two experiments, the first experiment was Laboratory screening for salinity tolerance and the second experiment was Field evaluation of rice hybrids in Pokkali tract.

The laboratory screening was done following a completely randomised design and the genotypes were grown in Yoshida's solution and evaluated for various seedling characters. High shoot length, root length, high root CEC and high root and shoot proline content were seen in Vytilla-6 followed by Ezhome-2. Low root and shoot proline content were observed in IR-29 confirming its susceptibility to salinity. Among the hybrids, a high value for shoot length, root length, total number of roots, root CEC, root proline, shoot proline and survival per cent was observed in the hybrids CORH-3 and KRH-4.

Vigour index was high in Sahyadri 4 followed by KRH-4 and low in MRP-5401. Vytilla-6 and Ezhome-2 showed the high survival per cent while low survival per cent was noticed in Sahyadri 2 and MRP-5401. Vytilla-6 exhibited high

chlorophyll content and RWC while low RWC was recorded in MRP-5401, Sahyadri-2 and Sahyadri-4.

Ca in root and shoot along with Na content in shoot were high in IR-29 while Vytilla-6 had low Ca and Na content. High Na in root was seen in Sahyadri 4 followed by Sahyadri 3. High amount of root $Cl_2$ was recorded in Sahyadri-3, Sahyadri-1, Sahyadri-4, IR-29 and Sahyadri-2 while, the lowest amount of root and shoot $Cl_2$ was in Vytilla-6. High amount of shoot $Cl_2$ was seen in Ezhome-2 and IR-29. High amount of root and shoot $SO_4$ content was seen in IR-29, Sahyadri-3, Sahyadri-4, Sahyadri-2 and Sahyadri-1. The lowest root and shoot $SO_4$ content was recorded in Ezhome-2, followed by Vytilla-6.

Low visual score of 3 was recorded in Vytilla-6 and Ezhome-2; a score of 5 was recorded for CORH-3, MRP-5401, TNAU RH-4 and KRH-4. Sahyadri-2, Sahyadri-3 and Sahyadri-4 were observed to have scored more than seven. Score 9 was noticed in Sahyadri-1 and IR-29, indicating that these genotypes are more susceptible to salinity. Visual score under salinity was found to be negatively correlated with shoot and root length, number of roots, vigour, proline content and RWC, while it was positively correlated with content of Ca, Na, $Cl_2$, $SO_4$ and K in the plant tissue.

Field evaluation of rice hybrids in Pokkali tract was done during Kharif season of 2016-17, following a randomised block design. Days to fifty per cent flowering and maturity showed that all hybrids became early under salinity. Tall plants were observed in Vyttila-6 and Ezhome-2 and short plants in IR-29. High number of productive tillers was observed in CORH-3 and low in Sahyadri-2. Ezhome-2, IR-29 and Vyttila-6 had high number of spikelets per panicle while seed setting percentage and long panicles were observed in Ezhome-2. Spikelet sterility was high in Sahyadri-2 and low Ezhome-2. High 1000 grain weight was observed in Ezhome-2 and low in IR-29. Based on visual scoring Vyttila-6 was classified as highly tolerant and IR-29 as highly susceptible.

Correlation studies indicated that grain yield per plant was positively correlated with productive tillers per plant and seed setting per cent, while it was found to be negatively correlated with sterility per cent. Visual scoring was negatively correlated with plant height, uppermost internodal length, days to maturity and seed setting per cent. The hybrid CORH-3 was found to be moderately tolerant based on visual scoring and it produced highest yield per plant indicating that this hybrid is better than saline tolerant traditional varieties.

# APPENDIX

Composition of Yoshida's nutrient solution

| **Macronutrients** | **Concentration (mg $l^{-1}$)** |
|---|---|
| $NH_4NO_3$ , | 40.00 |
| $NaH_2PO_4.2H_2O$ | 10.00 |
| $K_2SO_4$(), | 40.00 |
| $CaCl_2$ () | 40.00 |
| $MgSO_4.7H_2O$ | 40.00 |
| | |
| **Micronutrients** | **Concentration (mg $l^{-1}$)** |
| $(MnC1_3.4H_20$ | 0.50 |
| $(NH_4)6Mo_70_{24}.4H_20$ | 0.05 |
| $ZnS04.7H_20$ | 0.01 |
| $H_3B0_3$ | 0.20 |
| $CuS04.5H_20$ | 0.01 |
| $FeC1_3.6H_20$ | 2.00 |