TRAITS FOR SALINITY TOLERANCE, NON-LODGING AND HIGH YIELD OF RICE IN KAIPAD SOIL OF KERALA

by

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(2014-11-192)

THESIS

Submitted in partial fulfilment of the

requirements for the degree of

MASTERS SCIENCE IN AGRICULTURE

Faculty of Agriculture

Kerala Agricultural University

DEPARTMENT OF PLANT BREEDING AND GENETICS

COLLEGE OF AGRICULTURE

PADANNAKKAD, KASARGOD – 671 314

KERALA, INDIA

2016

<u>**DECLARATION**</u>

I, hereby declare that this thesis entitled **"Traits for salinity tolerance, non-lodging and high yield of rice in Kaipad soil of Kerala'** is a bonafide record of research work done by me during the course of research and the thesis has not previously formed the basis for the award to me of any degree, diploma, associateship, fellowship or other similar title, of any other University or Society.

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CERTIFICATE

Certified that this thesis entitled " **Traits for salinity tolerance, non-lodging and high yield of rice in Kaipad soil of Kerala"** is a record of research work done independently by Ms. Sowmya, N.R. under my guidance and supervision and that it has not previously formed the basis for the award of any degree, diploma, fellowship or associateship to her.

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ACKNOWLEDGEMENT

It is a matter of pleasure to glance back and recall the path one traverses during the days of hard work and pre-perseverance. It has still great at this juncture to recall all the faces and spirit in the form of teachers, friends, near and dear ones.

My diction would be inadequate to express my deepest sense of gratitude and heartfelt thanks to ***Dr. Vanaja, T.*** *Associate Professor, Department of Plant Breeding and Genetics and Chairman of Advisory Committee, for her valued guidance, scholarly counsel, sustained support, untiring encouragement, meticulous care and friendly approach during the entire course of study period. This work would not have been possible without her valuable help and support.*

I wish to express my sincere gratitude to ***Dr. Jayaprakash Naik, B.*** *Professor and Head, Department of Plant Breeding and Genetics, Member of Advisory Committee, for his meticulous personal care, technical guidance rendered at every stage of work, periodical review of the progress and valuable suggestions in bringing out this thesis to a presentable form.*

I express my heartfelt gratitude to ***Dr. G.V. Sudarshana rao.*** *Professor, Department of Plant Physiology and Member of Advisory Committee, for his constant encouragement, support, critical suggestions and timely help throughout the research work and course of study.*

I wish to express my heartfelt thanks to ***Dr. Namboodiri Raji Vasudevan,*** *Assistant Professor, Department of Plant Breeding and Genetics and Member of Advisory Committee, for her moral support, valuable suggestion in processing and interpreting the data.*

I am grateful to ***Dr. M. Govindan,*** *Associate Dean, College of Agriculture, Padannakkad, for his critical suggestions and instructions throughout the post graduate programme.*

I take this opportunity to express sincere thanks to teachers ***Dr. K. Abdul, Dr. P.R. Suresh, Dr. A.S. Anilkumar, Dr. Sujatha, R. Dr. K.P. Chandran, Dr. N.K. Binitha, Mr. Ashique and Ms. Neethu Prabhakar*** *who have always given encouragement and support. Their personal involvement at times of need was highly valuable.*

I whoud like to convey my inmost respect to ***Dr. Jayaramaiah, Dr. Nagaraj, Dr. Shiva kumar, M. S. and Dr. G. G. Kadalli*** *Assistant Professors, Agriculture College, Hassan, for their moral support and constant encouragement throughout my study.*

Above all, my success would have remained an illusion without the ambitious encouragement, unquantifiable love, continued calm endurance, constant support and affection showered on me throughout the educational endeavour from my beloved parents ***Sri. Rajanna, G.*** *and* ***Smt. Parameshwari.*** *I have been highly fortunate and lucky to express my heartfelt respect to my loving sister and brother* ***Sahana*** *and* ***Samyukth*** *who have always been so proud of me and my relatives for their kind blessings and well wishes showed on me.*

I thank my friends ***Kokila, Nimisha, Anjana, Abhimanue, Saravanan, Arun, Alok, Yusuf Abbas, Premalatha, Chethana, Shruthi, Manjunath and my juniors Sherin, Ashwathy, Vineetha, Ebimol, Shanthi, Vishnupriya, Sunayana, Ashibha, Chanchala*** *and all my friends for their everlasting source of inspiration and love.*

I sincerely acknowledge the Kerala Agricultural University for financial support in the form of KAU Junior Research Fellowship during my studies.

Finally, I thank God for bestowing me with divine spirit, essential strength and necessary support to find my way towards a glorious career amidst several hurdles and struggles.

Sowmya. N.R.

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LIST OF ABBREVATIONS

%	-	Per cent
CD	-	Critical difference
cm	-	Centimetre
et al	-	And others
Fig.	-	Figure
g	-	Gram
kg	-	Kilogram
m	-	metre
m^2	-	Square metre
l^3	-	Cubic litre
ml	-	Millilitre
NS	-	Not significant
RARS	-	Regional Agricultural Research Station
SE	-	Standard error

INTRODUCTION

1. INTRODUCTION

Rice is one of the most important food crops in the world and it is the staple food for over 2.7 billion people. Rice cultivation began in eastern India or western China sometime between 4,000 and 10,000 B.C. In India, area under rice cultivation is 36.95 m ha with total production of 80.41 million tonnes (paddy) with an average yield of 2177 Kg/ha (http://www.airea.net/). It is grown in almost all the states in India namely, West Bengal, Uttar Pradesh, Madhya Pradesh, Bihar, Orissa, Andhra Pradesh, Assam, Tamil Nadu, Kerala, Punjab, Maharashtra and Karnataka are major rice growing states and contribute to total 92% of crop area and production.

Kerala is one of the major rice growing states in India. Area under rice cultivation is 2.34 lakh ha with the production of 6.25 lakh tones and productivity of 2,671 Kg (Directorate of economics and statistics Government of Kerala, 2010). In Kerala, Kaipad is a unique coastal wetland rice production tract which is saline prone and naturally organic production tract. Kaipad system is a traditional integrated rice-shrimp farming adopted in the brackish water areas that are subjected to tidal action and in monsoon, flooded by water brought in by rivers and drainage from the adjoining hills. Kaipad tract is seen in the North Malabar districts of Kerala, ie., Kannur and Kasargod

'Kuthiru', 'Orkayama' are the traditional land races widely grown in Kaipad rice tracts. 'Mundon', 'Kandorkutty', 'Orpandy', 'Odiyan', 'Orissa', 'Punchakayama' and 'Kuttadan'/ 'Kuttoosan' are the other land races cultivated in some pockets of Kaipad. These land races are tolerant to low and medium salinity (Vanaja, 2013). In recent years, Kerala Agricultural University developed saline tolerant high yielding rice varieties for Kaipad ecosystem viz., 'Ezhome-1', 'Ezhome-2', 'Ezhome-3' and 'Ezhome-4'.

The rice plant is a member of Poaceae (old Gramineae) family. The common cultivated rice plant is an annual which usually grows to a height of a half meter to two meters but there are certain varieties that grow much taller (6-9 metres). The two major rice varieties grown worldwide today are *Oryza sativa* var *indica* and *Oryza sativa* var *japonica*. Although rice is considered as a sensitive crop to salinity, it is one of the most widely grown crops in coastal areas. Salinity is the second most widespread soil problem in rice growing countries, next to drought and considered as a serious constraint to increase rice production worldwide. Investigations of the effects of salinity on rice have been underway for more than 50 years (Pearson, 1959) and attempts to enhance the salt tolerance in rice through breeding date from the early 1970s (Akbar *et al.*, 1972). In spite of considerable efforts, through both international and national breeding programmes, progress in enhancing salinity tolerance has been slow, with few new cultivars released.

Salinity reduces the growth of plant through osmotic effects, reduces the ability of plants to take up water and this causes reduction in growth. There may be salt specific effects. Na^+ and Cl^- are the principal ions in majority of salt affected soils, which mainly affect plants growth. The roots of rice plants readily absorb Na^+ which is distributed in all plant organs to pose ion damage, osmotic stress and imbalance nutrition (Siringam *et al.*, 2011). Excess amount of salt in plant rise a toxic level in older transpiring leaves causes premature senescence and reduces the photosynthetic leaf area (Shereen *et al.*, 2005). Salinity affects plant in two processes, water relations and ionic relations. And also salinity having three potential effects on plants (1) lowering of water potential, (2) direct toxicity of Na^+ and Cl^- ions absorbed and, (3) interference with nutrient uptake (Flowers and Flowers, 2005).

Rice is differentially affected by salinity at different growth stages. The effect of salinity on rice plant growth were related to stage of plant development, salt concentration, type of salt, duration of exposure to salt, soil pH, water regime, temperature, humidity and solar radiation. Rice is relatively tolerant during germination, sensitive at seedling stage and becomes tolerant at maturity (Rao *et al.*, 2008).

Evolutionary adaptation to salinity involves a complex set of parameters, many of which, especially physiology of plant presumably have still not been uncovered. The present day saline tolerant rice varieties are tolerant to low-medium salinity only. Use of physiological traits in breeding programmes is an avenue to be exploited and may be the way forward for crop improvement and developing rice varieties tolerant to high salinity. An approach to enhancing resistance through selection of parents on the basis of physiological criteria and the subsequent combining of these traits, in a process termed pyramiding, has been advocated by Yeo *et al.*, (1990).

Besides salinity, lodging has been one of the important constraints on rice production for a long time. When, lodging occurs, the canopy structure will destroy and reduces the capacity of photosynthetic rate and dry matter production. In severe cases, it causes breaking of stem (or) pulls the root out, blocks the transportation of water, minerals and photosynthates, leading to substantial decline of yield and quality.

Growth of world population and increasing area of land being abandoned due to salinization, necessitate that future rice varieties not only produce more grains under normal growth conditions, but also minimize yield loss under various stressed growth conditions. Further, in order to reduce the laborious process of harvest, lodging tolerance is another trait preferred by farmers for easy mechanization. Identification of trait(s) for high yield, tolerance to salinity and lodging will help the breeders in future, to identify and select suitable parents for hybridization and development of high yielding rice varieties tolerant to salinity and lodging.

Development of tolerance for salinity in plants remains elusive, due to multi-genic nature of the traits and its complexity. Developing/Identifying the tolerant trait(s) is an important sound progress to improve rice production especially for crop improvement aspect. Considering this prospect, the present study intends to address some of these problems.

Objectives:

Identification of most correlated physiological/morphological/biochemical trait(s) associated with salinity tolerance, high yield and non-lodging at seedling and reproductive stages in Kaipad soil.

REVIEW OF LITERATURE

2. REVIEW OF LITERATURE

Present study on "Traits for salinity tolerance, non-lodging and high yield of rice in Kaipad soil of Kerala" was undertaken with the main objective of identification of the most correlated physiological/morphological/biochemical trait(s) associated with salinity tolerance, high yield and non-lodging at seedling and reproductive stages in Kaipad soil. Besides, the study covered correlation studies among yield and growth parameters, bio-chemical parameters and physiological parameters. Path analysis was done keeping yield, survival %, biomass production, non-lodging, spikelet sterility and seed setting % as the dependent variables and other parameters as independent variables. A comprehensive review of these aspects is presented in this chapter.

The available literature on various aspects is presented in this chapter under following subheads:

1. Morphological parameters of plant
2. Physiological parameters of plant
3. Bio-chemical parameters of plant
4. Physico-chemical parameters of soil
5. Yield parameters of plant
6. Saline tolerant rice varieties
7. Tolerant genes for salinity

2.1. Morphological parameters of plant

Karim and Haque (1986) reported that plant height, root length, number of tillers per plant, straw yield and dry weight of root was affected by salinity during vegetative stage. Generally, salinity affects the growth of rice plant at all stages of its life cycle. But it is more pronounced on reproductive stage than on vegetative stage consequently decreased the grain yield (Afridi *et al.,* 1988).

Studies conducted at IRRI in 1997, indicated that rice (*Oryza sativa* L.) is tolerant during germination, becomes very sensitive during early seedling stage (2-3 leaf stage), gains tolerance during vegetative growth stage, becomes sensitive during pollination and fertilization and then becomes increasingly more tolerant at maturity. Further it was also reported by Rao *et al.* (2008).

Pareek *et al.* (1998) observed delayed germination, reduction in germination per cent, reduced growth of primary root and culm axis and arrest of root branching at higher salinity levels. Severe effects of salinity on germination and seedling growth were reported by Chakrabarty and Chattopadhyay (2000).

Twelve rice genotypes have been evaluated for salt tolerance based on various agronomic parameters. Wide genotypic differences were observed for relative salt tolerance in terms of spikelet number per panicle and tiller number per plant. Spikelet and tiller number per panicle contributed the most of the variations to seed yield under salinity among parameters investigated when data were analysed across all genotypes (Zeng *et al.*, 2002). Lee *et al.* (2003) observed significantly lower reduction of all growth parameters of salt tolerant *indica* varieties than *japonica* varieties.

The study on effect of salinity on morphological characters of salt tolerant genotypes indicated that plant height, total tillers, root, culm and total dry matter per panicle were significantly decreased by the application of salinity. Similarly sharp decrease in measurement of those characters is seen in susceptible genotypes (Razzaque *et al.*, 2009). Reduction in emergence and seedling growth both in hybrids and parents of rice with increasing salinity levels was reported by Maiti *et al.* (2009).

Effects of planting density on agronomical traits and morphological characteristics that related to lodging were studied by Mobasser *et al.* (2009). Results showed that the least spikelet's number and sterile spikelet's number in spike were obtained in Langrodi Tarom and the least tiller number per hill and panicle number per m^2 was produced in Mahalli Tarom and Sang Tarom, respectively. The shortest length of first, second and third internode and the biggest third internode diameter and also the least plant height favours resistant to lodging.

Response of morphological traits related to lodging of rice (*Oryza sativa* L.) to Chlormequat Chloride application time and nitrogen rates in the North of Iran was studied by Ghanbari-Malidarreh *et al.* (2012). The results indicated that nitrogen rates had significantly increased all morphological traits and only third and fourth internodal diameter had significantly decreased. Nitrogen application does not increases the number of internodes but significantly it increases the internodal length, this favours lodging.

Salinity significantly reduces plant height, dry biomass, tiller number, membrane stability and relative water content in rice varieties in all growth stages. Tolerant rice varieties Pokkali and Narendra usher dhan 3 showed less reduction about traits but, the sensitive genotypes IR-28 and IR-29 exhibits higher reduction (Gautam *et al.,* 2015).

Drastic decrease of seed germination and seedling growth of rice varieties (Kharaganja, shua-92, IR-9 and FL-478) with increasing salt concentration and temperature was observed by Shakeela *et al.* (2015). Germination and seedling growth of Kharaganja and Fl-478 is higher compare to Shua-92 and IR-9 at higher salt concentration and temperature.

2.2. Physiological parameters of plant

Dubey and Sharma (1989) reported that delayed differentiation of root and culm and reduction in seedling vigour index with increase in salt concentration. The culm growth was found to be more inhibited than root growth. Physiological studies of rice suggest that a range of characteristics such as low culm sodium concentration, compartmentation of salt in older leaves rather than younger leaves, tolerance to salt within leaves and plant vigour would increase the ability of the plant to cope up with salinity (Yeo *et al.,* 1990). Roy *et al.* (1992) observed that salt stress tended to reduce the root and culm growth of germinating seeds. The reduction was more prominent in salt sensitive variety Ratna than resistant cultivar CSR-4.

Peris and Rana Singhe (1993) reported that, irrespective of the varietal tolerance, the dry weight of the seedlings was reduced in the saline treatment. Salt sensitive entry, IR-5931-110-1 exhibited greater (65 % over control) reduction in total dry weight than salt tolerant variety Nonabokra (33 % reduction over control). Mandal and Pramanik (1995) studied the response of 35 cultivars to different levels of salt stress (8, 12 and 16 dS m^{-1}) and inferred that *japonica* and *javonica* cultivars are more tolerant at higher salinity level than *indica* cultivars.

Asch *et al.* (1997) selected five lines I Kang Pao, IR 64, IR 4630-22-2, CSR 10 and Aiwu to be salt tolerant based on the traits of grain yield decline, spikelet sterility, sodium and potassium distribution in top three leaves, stem, stem base and root. They reported that potassium sodium ratio in the three leaves from the top was high in these genotypes and this could be used as a reliable index for salt tolerance.

Zeng and Shannon (2000) observed significant reduction in root dry weight of rice genotypes at 1.9 and 3.4 dS m^{-1} of salinity. The gradual decrease in root length with the increase in salinity as observed might be due to more inhibitory effect of NaCl salt to root growth compared to that of culm growth (Rahman *et al.,* 2001). Gregorio *et al.* (2002) attempted pooling physiological traits in rice for generating salt-tolerant lines. With increase of salinity, reduction of root length, culm length, dry weight of root and dry weight of culm was observed by Roy *et al.* (2002) and further reported that the rice cultivar Annada was the least effected by induced salinity.

In a study performed by Ansari *et al.* (2003) cultivars Ganga White, Nona Bokra, IR 6 and Shua-92 had better seedling survival, whereas IR 28 and Basmati had the lowest seedling survival. These cultivars had a more or less similar ranking in straw or grain weight.

Abeysiriwardena and De (2004) also reported the reduction in germination per cent with increasing salinity and observed that tolerant cultivars recorded higher germination per cent than the sensitive cultivars. Salt tolerant lines had higher root culm ratio at seedling stage thus, providing a clue about salt tolerance potential of a genotype (Yousaf *et al.*, 2004).

Growth reduction immediately after the application of 12.5 dS m^{-1} of EC was observed by Alam *et al.* (2004) in rice, but no significant variation was seen at lower levels (8.5 and 4.5 dS m^{-1}). They observed severe effects on leaf area, culm and root fresh weight besides effect on all plant parts.

Ten advanced rice lines (NR-2, NR-3, NR-4, NR-5, Basmati-385 x NIAB-IRRI-9, Basmati-320, DM-51-24, NIAB-IRRI-9 x DM25, Jhona-349 and Pokkali) were screened by Ali *et al.* (2004a) and found that tolerant lines had higher root and culm ratio thus provided a clue about salt tolerance parameter of a genotype.

Sharma and Brar (2005) stated that seedling stage was observed to be the most sensitive to salinity. They stated that chlorophyll and protein content decreased while soluble sugars and catalase activity increased and attributed to the reduction in dry matter at higher salinity to the toxic effect of added salts and physiological scarcity of water or altered carbon and nitrogen metabolism.

Islam and Mia (2007) reported that root growth was less affected than culm growth due to salinity based on dry weight basis. Rahmanzadeh *et al.* (2008) evaluated four rice cultivars both in pots and under *in vitro* conditions at various levels of salinity and found Tichung-65 as the most sensitive cultivar, based on reduction in seedling dry weight, wet weight, culm length and root length. Subasinghe *et al.* (2007) studied several traditional, old improved, new improved and hybrid rice cultivars at different levels of salinity and categorized Pokkali, AA 354, Nona Bokra and AT- 401 as salt tolerant, where Pokkali recorded the highest germination under the highest salinity level.

Latif *et al.* (2009) reported that root and culm weight of KS-282, BG-402 and IR-28 rice varieties were decreased when subjected to saline environment.

Among them KS-282, BG-402-4 rated as tolerant to semi-tolerant and IR-28 as sensitive to salinity. Haq *et al.* (2009) screened seven rice cultivars at 100 mM of salt concentration and reported that with increase in salinity significant reduction were observed in culm dry weight, culm fresh weight and number of tillers plant^{-1} after 42 days of salt stress. Saha *et al.* (2010) reported that salinity stress causes drastic effect on roots causing reduction in root length, number of root hairs and branches, and also roots become stout, brittle and brown in colour.

Hakim *et al.* (2010) studied the response of twelve rice varieties against six salinity levels (0, 4, 8, 12, 16 and 20 dS m^{-1}) at germination and early seedling stages and found that salinity decreased the final germination per cent and led to reduction in culm and root length and dry weight in all varieties. Awala *et al.* (2010) screened 54 genotypes of *Oryza glaberrima*, NERICA (21) and *Oryza sativa* (41) and grown in pots by irrigating with NaCl (80 mM) solution. They observed that relative root biomass was significantly lower in *Oryza glaberrima* than others.

Germination of rice seeds was not affected by NaCl concentration less than 100mM. At higher salinity levels (100 and 200 mM NaCl), a delay of 3 to 6 days in germination was observed (Shereen *et al.,* 2011). Ismail *et al.* (2013) reported that the means by which different physiological tolerance mechanisms addressed varies widely, and no single mechanism appears to be effective in conferring a high level of tolerance in any single genetic background.

Reproductive stage salinity tolerance has been difficult to study due to the complexity of the trait and lack of reliable stage specific phenotyping techniques. In this study, growing the genotypes in real saline field condition, the evaluation at reproductive stage was done. In order to standardize rice screening for reproductive stage of salinity tolerance, a leaf-cutting technique was developed with the minimum numbers of leaves needed by the rice plant that will not significantly affect grain yield and yield components (Palao *et al.,* 2013).

Salt stress causes increased chlorophyll b concentration in leaves of a tolerant FL-485 rice genotype, but significantly decreased chlorophyll a content in FL-485 and salt sensitive IR-29 cultivars. Reduced chlorophyll a and chlorophyll b ratio in susceptible variety is one of the reasons for higher tolerance of FL-485 (Sacdipour, 2014).

Physiological traits associated with tolerance of salinity at seedling stage were studied by Barua *et al.* (2015) with six rice genotypes (BRRI dhan 47, BINA dhan 8, and BINA dhan 10, FL 478, IR 64 and IR 29). These were evaluated for morpho-physiological traits that contribute to salinity tolerance. The results showed that among six genotypes, BRRI dhan 47 and FL 478 found the most salt tolerant cultivar while IR-29 was the least tolerant cultivar had higher culm sodium concentration and higher Na^+/ K^+ ratio. The cultivar BINA dhan 8 found to be susceptible and cultivars BINA dhan 10 and IR-64 found mid-tolerant to salinity.

Gautam et al. (2015) reported that salinity causes reduction in chlorophyll content and increases the carbohydrates and activity of antioxidant catalase in salt susceptible genotypes than tolerant genotypes.

2.3. Biochemical parameters of plant

The Na^+ uptake of the salt tolerant land race 'Pokkali' is not less than the salt sensitive dwarf IR-28 but the low Na^+ concentration in Pokkali is attributed to the diluting effect of its rapid vegetative growth (Yeo and Flowers, 1984).

The Na^+/ K^+ ratio shows relative decrease in K^+ content compared to Na^+ content in the genotypes along with salinity gradient (Mass and Poss, 1989) and higher salinity disturbs Na^+/ K^+ ratio in the plant which impairs the protein metabolism of the plants.

Gill (1990) studied the differential Na^+ accumulation in different plant parts of cultivar Jaya and wild rice when subjected to salt stress and the salt injury in Jaya is higher due to greater translocation of Na^+ ion to the culm system.

Generally, the salt tolerant varieties of rice maintain low concentration of Na^+ in their leaves than those of salt sensitive lines, when exposed to salt stress (Lutts and Guerrir, 1995). Therefore, Na^+/K^+ in the leaves of crop plants can be used as an important indicator of salinity tolerance and breeding for low ion accumulation could be a simple way to improve salt tolerance.

Lutts, *et al.* (1996) reported salt resistant rice cultivars Nona Bokra and IR 4630 exposed at the seedling stage during one (or) two weeks to 0, 20, 30, 40, (or) 50 mM NaCl. These varieties accumulated less Na, Cl, Zn and proline and more K at root and culm levels than salt sensitive I Kong Pao and IR 31785.

Lutts *et al.* (1996) found that the resistant cultivars accumulated less Na, Cl, Zn and proline and more K in roots and culms than salt sensitive cultivar. Accumulation of Na and decrease in K content in culms were restricted to the oldest leaves in salt resistant cultivars.

Screening of rice genotypes based on Na^+: K^+ ratio is being followed by breeders in salt affected soils. Low Na^+/K^+ ratio of ion uptake is positively correlated with a high level of salt tolerance and can be taken into consideration as a desired characteristic while screening rice lines (Mishra *et al.,* 1997).

Lee *et al.* (2003) observed that salt tolerant *indica* cultivars were good Na^+ excluders with high K^+ absorption and maintained a low Na^+/K^+ ratio in culm this indicates that tolerance level of *indica* was higher than that of *japonica.* And also they observed that the cultivar with low Na^+/K^+ ratio was highly tolerant and the susceptible one had high Na^+/K^+ ratio.

Soil salinity affects plant growth and development by way of osmotic stress, injurious effects of toxic Na^+ and Cl^- ions and some extent of Cl^- and SO_4^{2-} of Mg^{2+} and nutrient imbalance caused by excess of Na^+ and Cl^- ions. Salinity stress response is multigenic, as a number of processes are involved in the tolerance mechanism such as various compatible solutes/osmolytes, polyamines, reactive oxygen species, antioxidant defence mechanism, ion transport and compartmentalization of injurious ions (Sairam and Tyagi, 2004).

Suriya–Arunroj *et al.* (2005) screened and categorized rice cultures in three groups based on response to different levels of salinity. The tolerant group consisted of Pokkali, FL-496 and FL-530; moderately tolerant group had FL-358, FL-367, FL-411 and KDMC-105 and RD- 6 are susceptible.

Roy *et al.* (2005) stated that culm Na^+/K^+ ratio is considered as a reliable parameter to evaluate salt tolerant genotypes in rice. The typical mechanism of salt tolerance in rice is the Na^+ exclusion or reduced uptake of Na^+ and increased absorption of potassium to maintain a good Na^+/ K^+ balance in the culm.

Characteristics of a salt-tolerant variety include Na^+ exclusion, K^+/Na^+ discrimination, retention of ions in the leaf sheath, tissue tolerance, ion partitioning into different-aged leaves, osmotic adjustment, transpiration efficiency, early vigour and early flowering leading to a shorter growing season and the later increasing water use efficiency (Colmer *et al.,* 2005).

Salinity affects plant growth and development generally through osmotic stress limiting water uptake and the excessive uptake of ions, particularly Na^+ and Cl^- that ultimately interfere with various metabolic processes (Munns and Tester, 2008).

Sexcion *et al.* (2009) observed the morpho-physiological traits associated with salinity tolerance in rice cultivars and classified Pokkali, Cheriviruppu, FL-478 and IR-651 as salt tolerant due to consistent expression of high vigour, low standard evaluation score (SES), high culm root biomass, lower culm Na^+ accumulation and lower culm Na^+ / K^+ ratio compared to sensitive genotypes.

Haq *et al.* (2009) reported significant variation in leaf Na^+ under salt stress but not in control. The tolerant variety (CO-34) accumulated lower Na^+ (14.9 mol m^{-3}) while susceptible variety (Monoberekan) accumulated 52.9 mol m^{-3} in the leaf sap. They further reported larger reduction in K^+/Na^+ ratio due to salt stress and they revealed that the key feature of plant salt tolerance was the ability of plant cells to maintain optimum K^+/Na^+ ratio. Latif *et al.* (2009) stated tolerant genotypes KS-282 and BG-402 maintained low Na^+ and Cl^- level and higher K: Na ratio than susceptible IR-28.

Rice varieties Nona Bokra and Pokkali were evaluated for their response to salinity in terms of some physiological and biochemical attributes. A significant increase in sodium was recorded which was also con-committing with the changes of other metabolic profiles like proline, phenol, polyamine etc. when the varieties exposed to the salinity level of 200 mM concentration of sodium chloride for 24, 48 and 72 hours (Ghosh *et al.,* 2011).

Islam and Gregorio (2013) reported that BR 23, BRRI dhan 40, BRRI dhan 41, BRRI dhan 53 and BRRI dhan 54 possess salinity tolerance up to EC 8 dSm^{-1} in addition to high yield potential (> 4.0 t/ha), lodging tolerance and 10-38 days shorter growth duration over traditional rice varieties for the wet season.

Pokkali, PTT 1 and the Thai indigenous rice cultivars ULR 198 and KKU-ULR 076 were identified as salt-tolerant. These salt tolerant varieties exhibited low Na content but accumulated high K resulting in a lower Na / K ratio, a higher survival rate and a lower salt injury score than the other varieties (Ninsuwan *et al.,* 2013).

The tolerant rice genotypes have a capacity of compensating mechanism to Na^+ exclusion and K^+ absorption which neutralizes to excessive salt stress. But, the susceptible genotypes respond very quickly to the salinity and leads to death of plant (Senguttuvel *et al.,* 2013). They also stated identification of tolerant genotypes at early seedling stage can be done with an potential indicators of reduced level of CO_2 assimilation, Stomatal closure, transpiration rate, exclusion of Na^+ ion and K^+ absorption and increased level of antioxidant enzymes.

Tolerant cultivar FL-485 had less accumulation of Na^+ compared to sensitive IR-29. Avoiding excess accumulation of Na^+ facilitates salinity tolerance in rice (Sacdipour, 2014). Significant increase of sodium content in leaves causes concomitant decrease of K and Ca in saline soil. The tolerant genotypes Pokkali and Narendra usher dhan 3 accumulate comparatively less sodium than susceptible varieties (Gautam *et al.*, 2015).

2.4. Physico-chemical properties of soil

Certain rice varieties have been reported as being salt sensitive in their seedling and reproductive stages leading to a reduction in crop productivity of more than 50% when exposed to 6.65 dS m^{-1} electrical conductivity (EC) and soil salinity (Zeng and Shannon, 2000). Ansari *et al.* (2003) have reported that sodium uptake increased and potassium decreased with increasing salinity.

Salt salinity of the kaipad soil in summer varied from 10.9 m mhos/cm to 19.9 m mhos/cm and water salinity in summer varied from 35.9 m mhos/cm to 49.9 m mhos/cm and in the month of July in middle of the south west monsoon varies from 1.6 m mhos/cm to 4.7 m mhos/cm. Soil pH during April ranged from 4.9 to 6.6. Water pH ranged between 6.71 and 7.47 in April and in June ranged from 6.15 to 6.71, this was reported by Chandramohanan and Mohanan (2012) and also they reported that the major rice varieties cultivated in the saline wetland are the native cultivars Kuthiru, Orkayama, Kutturan, Orthadiyan and Chovverian among which Kuthiru is the most popular and the best performing.

2.5. Yield parameters of plant

Salinity delays flowering, reduces the productive tillers $plant^{-1}$, fertile florets $panicle^{-1}$, seed set (weight $grain^{-1}$), 1000-seed weight and overall grain yield (Khatun *et al.*, 1995). Screening of rice genotypes based on Spikelet sterility by the breeders in salt affected soils was reported by (Mishra *et al.*, 1997). They stated high percentage of spikelet sterility relates to a high level of salt tolerance in rice. Further it was noted that tolerant genotypes had lesser reduction in floret fertility than sensitive genotypes.

Zeng and Shannon (2000) stated tiller production gradually decreased with increased levels of salinity and also they observed variety BR11 having more than 30 percent reduction of effective tillers at 150 mM NaCl treatment compared to control. Zeng *et al.* (2000) reported that the reduction in spikelet number per panicle was a major cause of yield loss under salinity. Total number of tillers, grain weight per panicle, 1000-seed weight and quantity of grains decreased progressively with increase in salinity levels (Abdullah *et al.,* 2001).

Govindaraju and Balakrishnan (2002) indicated that plant height, number of productive tillers hill^{-1}, 1000-grain weight, grain yield, straw yield, chlorophyll content and photosynthetic ability decreased with increase of salinity. Mishra *et al.* (2003) have identified stable salt tolerant genotypes for yield and its components on the basis of stability parameters under multiple stress environments. The most stable and adaptable genotypes identified are CSR 10, CSR 11, CSR 13, CSR 27, CSR 1, Pokkali, CSR 18 and CSR 21 for grain yield , filled grains per panicle, low spikelet fertility(%), Na / K ratio and K absorption.

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

Natarajan *et al.* (2005) observed that high yielding and tolerant genotype IR 60494-2B-18-3-2-3 significantly recorded more number of productive tillers hill^{-1} and number of filled grains panicle^{-1}. Uddin *et al.* (2007) stated that salinity reduced the number of effective tillers plant-1, number of grains panicle^{-1}, 100 grain weight and yield plant^{-1}.

Sankar *et al.,* (2008) have reported the presence of heterosis for grain yield per plant in normal and salt affected environments. The thermo-sensitive genetic male sterility (TGMS) based rice hybrid GD 98179/CSSRI 60 recorded the highest standard heterosis per cent for the trait grain yield per plant in all the environments followed by GD 98168/Vytilla-3, GD 98029/CSSRI 60, GD

98029/CSR 23 and GD 98028/ Nona Bokra. In salt affected environments the hybrids GD 98028/CSR 23 and GD 98021/CO 43 recorded high heterosis at both Na^+: K^+ ratio and grain yield per plant.

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 reduction in overall vigour especially in the number of filled grains panicle^{-1} and yield plant^{-1}. Grain yield and 1000 grain weight of IR-29 and FL-485 was decreased with the application of NaCl (Saedipour, 2014). Gautam *et al.*, (2015) reported decrease of number of panicles per plant and grain yield per plant in all varieties is higher in saline soil than normal soil.

2.6. Saline tolerant rice varieties

The first systemic attempt to breed salt-tolerant varieties in the early 1980's initiated by CSSRI, Karnal, India, resulted in the development of the first high yielding, salt-tolerant and early maturing rice variety CSR10. It was released in 1989 by the Central Varietal Release Committee (CVRC) for sodic and inland saline soils of India. This variety can withstand highly deteriorated sodic (pH 9.8-10.2) and inland saline soil (EC 6-10 dSm^{-1}) conditions under a transplanted irrigated management system (Mishra *et al.*, 1992).

Shylaraj and Sasidharan (2005) reported that VTL 5 is having multiple tolerances to abiotic stress such as salinity, acidity and submergence. It is tall, medium duration, high yielding and white kernelled rice variety with good cooking quality and average yield of 3500 Kg ha^{-1}.

VTL 6, the first saline tolerant, semi-tall, non-lodging and high yielding rice variety of Kerala. This variety has multiple tolerance to abiotic stresses like salinity, acidity, submergence and is a medium duration, red kernelled variety with good cooking quality and average yield about 4500 Kg ha^{-1} (Shylaraj *et al.*, 2006).

In Bangladesh, six rice varieties were recently released for salt tolerance named BRRI dhan 47, BRRI dhan 53, BRRI dhan 54, BRRI dhan 55, BINA dhan 8 and BINA dhan 10 within the last five years. Among them BRRI dhan 54 is suitable for wet season and all of the others are suitable for both wet and dry seasons (Islam *et al.,* 2008).

Vanaja *et al.* (2009) have developed two high yielding and non-lodging organic red rice varieties meant for the saline prone rice fields of Kaipad, namely Ezhome 1 and Ezhome 2 having awn less, non shattering and better cooking qualities.

Islam and Gregorio (2013) reported that development of BRRI dhan 47, BINA dhan 8, BRRI dhan 53 and BRRI dhan 55 for dry season was a major breakthrough for breeding salt tolerant rice in Bangladesh. BRRI dhan 47 can tolerate EC 12 to 14 dS m^{-1} salt stress. The potential yield of the varieties ranged from 5.4 to 8.3 t ha^{-1} in different saline prone areas.

Traditional cultivars are the most tolerant to abiotic stresses. Cultivars namely Pokkali, Cheriviruppu, Nonabokra, SR26B, Damodar and Getu are tolerant to salinity but possess poor agronomic characters (Reddy *et al.,* 2014).

Two Malaysia varieties, MR 211 and MR 232 performed better in terms of vegetative growth namely plant height, leaf area per plant, number of tillers per plant, dry matter accumulation per plant, photosynthetic rate, transpiration rate, yield components, grain yield and injury symptoms. While the varieties MR 33, MR 52 and MR 219 are having the capacity of withstand salinity stress than salt-sensitive control varieties BRRIdhan 29 and IR 20 (Hakim *et al.*, 2014).

Vanaja, *et al.* (2015) developed the first saline tolerant, non-lodging, high yielding rice variety suitable to kaipad ecosystem, Ezhome-1, with the favourable traits demanded by farmers by adopting combined strategy of conventional plant breeding linked with novel strategies of organic plant breeding and participatory plant breeding.

2.7. Tolerant genes for salinity

Gregorio (1997) described *SalTol* locus that confers salinity tolerance at vegetative stage and is associated with Na-K ratios. *SKC 1* is a sodium transporter from the HKT family isolated from 'Nona Bokra' rice using map-based cloning. Advances in molecular transformation using complementation analysis and electo-physiological tests showed *SKC's* role in maintaining K^+ homeostasis during vegetative growth (Ren *et al.,* 2005).

Walia *et al.* (2005) validated SKC expression levels to be higher for tolerant 'Agami' under salt-stressed conditions as compared to the intolerant genotype during rice panicle initiation stages. *SKC 1* gene confers salinity tolerance throughout rice growth. The *SalTol* locus affected Na-K ratios more than any other traits and may be related with *SKC1* (Thomson *et al.,* 2010).

To identify and develop useful markers for selective breeding at IRRI, several other QTLs for salinity tolerance at vegetative stage were identified from IR29/Pokkali recombinant inbred line (RIL) population and validation of some QTL markers was done on salt tolerant 'Pokkali' accessions. Results revealed allelic variation existed for 'Pokkali' alleles identified in the *SalTol* region and therefore, breeding requires careful strategy in choosing donors and markers to transfer salt tolerance to intolerant lines (Thomson *et al.*, 2010).

The HKT family of genes is important for Na^+ transport. Plett *et al.*, (2010) used *Arabidopsis* HKT and expressed this in the root cortex of rice. Expression of AtHKT1:1 in rice increased salinity tolerance and decreased Na^+ accumulation.

Salt tolerance in rice is a complex trait may involve many quantitative trait loci (QTLs). Some of the identified genes in these QTLs (*SKC 1, SalT, Nax 2, SOS 1, SOS 2, ERA 1, PP 2C*) are mentioned in a review by Roy *et al.* (2011) and a few are involved in maintaining Na-K homeostasis.

Major QTLs on rice chromosome 1 in the region of the *SalTol* locus and new QTLs in chromosome 8 and 12, were also identified from a F_2 population of BRRI dhan 40 / IR 61920-3 B-22-2-1 (NSICRc106) using simple sequence repeats (SSRs) and expressed tags (ESTs) (Islam *et al.*, 2011).

Recent studies showed variations in the *SKC1* sequence, which may result in changes in protein function affecting or enhancing its Na^+ total accumulation (Negro *et al.*, 2011).

Negrao and colleagues (2012) used EcoTILLING to also evaluate five key genes (*OsCPK, OsNHX1, OsRMC, OsHKT1-5* and *SalT*) related to salt tolerance enhancement and identified several single nucleotide polymorphosis (SNPs) with in each of those genes that are relevant by association studies. And their studies showed that different rice genotypes have different mechanisms to cope up with salt stress and that no accession carries all favourable alleles of the target loci.

The validation of one SSR marker, RM8094, in 115 rice accessions showed strong linkage for salt tolerance and was useful for discriminating between tolerant and intolerant genotypes and therefore may be useful for marker-assisted selection (Islam *et al.*, 2012).

Gene expression was up regulated in salt-stressed lines containing the gene while in knock-out mutants and artificial micro RNA lines, osmotic and salt tolerance decreased, inferring that *hsfc1b* may be a positive regulator for root and culm growth (Schmidt *et al.*, 2012).

MATERIAL AND METHODS

3. MATERIAL AND METHODS

The present study was conducted in the Department of Plant Breeding and Genetics, College of Agriculture, Padannakkad, Kerala Agriculture University. The field trials were carried out in three locations namely high-saline and low-saline prone areas of Kaipad tract at Ezhome Grama Panchayath of Kannur district and non saline area at Regional Agricultural Research Station, Pilicode during the season kharif 2015. The materials used for the study and the methods followed are presented in this chapter.

3.1. MATERIALS

Eighteen rice genotypes were used for the study which include, saline tolerant traditional land races of Kaipad tract (Kuthiru and Orkayama), improved saline tolerant varieties of Kaipad (Ezhome-1, Ezhome-2 and Ezhome-3), improved saline tolerant breeding lines of Kaipad (JO532-1, JK 15, JK 59 and JO 583), saline tolerant traditional land races of Pokkali tract (Chettivirippu and Cherivirippu), improved saline tolerant Pokkali varieties (Vytilla-1 and Vytilla-6), international saline tolerant varieties (Pokkali, FL-478 and Nona Bokra), international saline susceptible variety (IR-29) and saline susceptible popular variety of Kerala (Jyothi).

The objective of the experiment was identification of most correlated physiological/morphological/biochemical trait(s) associated with salinity tolerance, high yield and non-lodging at seedling and reproductive stages in Kaipad soil. The experiment material constituted eighteen rice genotypes in randomized block design with eighteen treatments and two replications.

Table 1. . Rice genotypes used for the investigation

Sl. No.	Genotype	Parentage / Pedigree	Evolved at
1	Kuthiru	Traditional cultivar of Kaipad	Kerala
2	Orkayama	Traditional cultivar of Kaipad	Kerala
3	Ezhome-1	Jaya x Kuthiru	KAU,Kerala
4	Ezhome-2	Jaya x Orkayma	KAU,Kerala
5	Ezhome-3	Mahsuri x Kuthiru	KAU, Kerala
6	JO-532-1 (Ezhome-4)	Jaya x Orkayma	KAU,Kerala
7	JK-15	Jaya x Kuthiru	PRS, Panniyur, KAU,Kerala
8	JK-59	Jaya x Kuthiru	PRS, Panniyur, KAU,Kerala
9	JO-583	Jaya x Orkayma	PRS, Panniyur, KAU,Kerala
10	Chettivirippu	Traditional cultivar of Pokkali	Kerala
11	Cherivirippu	Traditional cultivar of Pokkali	Kerala
12	Vytilla-1	Pure line selection from Chettivirippu	RRS, Vyttilla, KAU
13	Vytilla-6	(Cherivirippu x IR-5) x Jaya	RRS, Vyttilla, KAU
14	Pokkali	Traditional cultivars	Kerala
15	FL-478	IR 29 x Pokkali B	IRRI, Philippines
16	Nona Bokra	Hamilton (Selection)	West bengal,India
17	IR-29	FB 24 x KH 68	IRR1, Philipines
18	Jyothi	Ptb-10 x IR-8 (Hybrid selection)	KAU, Kerala

3.2. Design of the experiment

Design: RBD

Treatment: 18

Replication: 2

Plot size: 20 m^2

3.3. Observations

The observations were recorded for morphological, physiological, biochemical, physico-chemical and yield parameters of rice crop at seedling and flowering stages during kharif season 2015 and physico-chemical properties of soil for a period of one year at monthly interval. The details of the observations recorded are shown below.

Plate 1. Seed treatment with Beejamrutha

Plate 2. Nursery of 18 rice genotypes raised at RARS, Pilicode

Plate 3: Experimental plot at high-saline Kaipad

Plate 4. Experimental plot at low-saline Kaipad

3.3.1. Morphological parameters

The description of the morphological observations of rice genotypes are given below.

3.3.1.1. Plant height

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

3.3.1.2. Number of tillers per plant

Number of tillers in each plant was counted at seedling and flowering stages of crop and mean was worked out.

3.3.1.3. Number of nodes

Number of nodes in each plant was counted at flowering stage of the crop.

3.3.1.4. Uppermost internodal length

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 crop.

3.3.1.5. Orientation of flag leaf

Orientation of flag leaf was measured as erect, intermediate and descending type given by Descriptors for Rice (*Oryza sativa* L.) from IBPGR-IRRI Rice Advisory Committee.

3.3.1.6. Lodging/Non-lodging

Lodging and non-lodging characteristics of plants was measured by visual observations.

3.3.1.7. Duration of crop

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

3.3.2. Physiological parameters

3.3.2.1. Survival %

Survival percentage was recorded at seedling and flowering stage of crop and mean was worked out.

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

3.3.2.2. Specific leaf area (SLA)

Leaf area from the selected plants were measured at seedling and flowering stages using portable leaf area meter, Model LI-3000A and specific leaf area was calculated and expressed as square centimetre per gram.

$$\text{SLA} = \frac{\text{Leaf area}}{\text{Leaf dry weight}}$$

3.3.2.3. Relative water content

Relative water content (RWC) of leaf was measured in percentage at seedling and flowering stage of 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

Plate 5. Recording stomatal conductance at field using Porometer

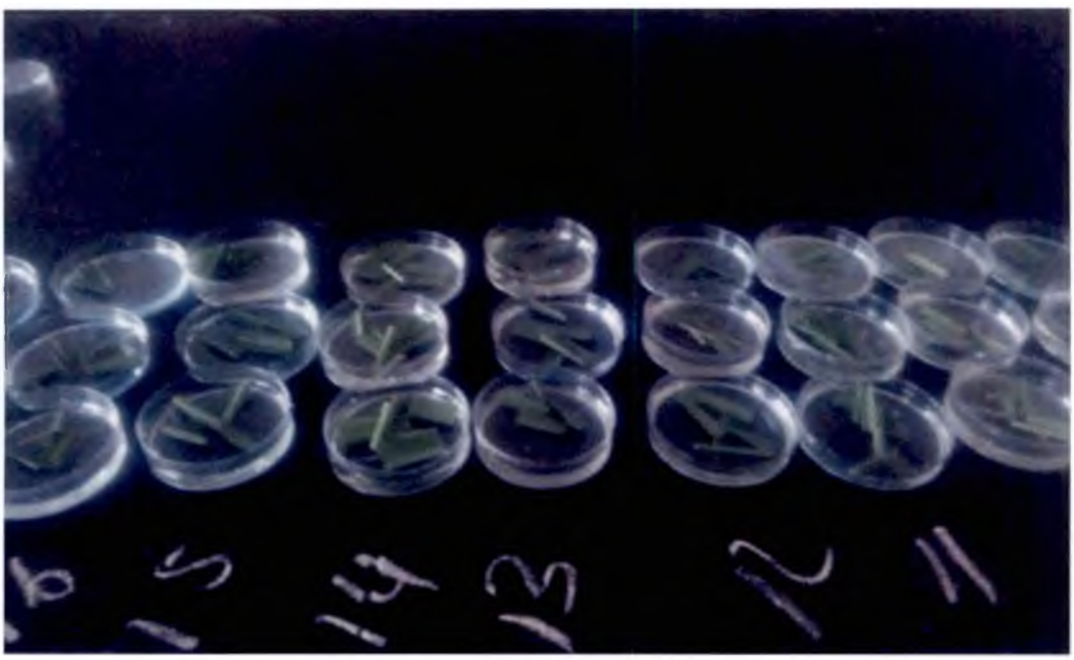

Plate 6. Determination of RWC

3.3.2.4. SPAD chlorophyll meter reading (SCMR)

SCMR were recorded at seedling and flowering stages and mean was worked out by SPAD (*Soil Plant Analytical Development)* chlorophyll meter - 502).

3.3.2.5. Stomatal conductance and resistance

Stomatal conductance (usually measured by steady state porometer in m mol m^{-2} s^{-1}) is the measure of the rate of passage of carbon dioxide (CO_2) entering, or water vapour exiting through the stomata of a leaf. Stomatal resistance is the reciprocal of Stomatal conductance. The readings taken at seedling and flowering stages and means were worked out.

3.3.2.6. Biomass

Measured in grams by taking dry weight of whole plant including both root and culm and means were worked out.

3.3.2.7. Root length

It is the measurement of length in centimetres between base of culm and tip of the roots at seedling and flowering stage of the crop and mean was worked out.

3.3.2.8. Root volume

Root volume was measured by using volume displacement method at seedling and flowering stage of crop and expressed in mL^3.

3.3.2.9. Root culm ratio

Dry weight of root and culm of each plant was measured in grams at seedling and flowering stage of crop. The root culm ratio was worked out by dividing root weight and culm weight.

3.3.3. Biochemical parameters

3.3.3.1. Proline content in root, culm and leaf

Free proline content was determined according to Gilmour *et al.* (2000). Plant samples from each variety was homogenized in 3% (w/v) Sulphosalicylic acid one mL at room temperature and then stored at 4°C over night. 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. Reaction was then stopped by using an ice bath. The mixtures were extracted with toluene and measured using a UV-visible spectrophotometer (Thermo Electron, Model Bio Mate 3, Massachusetts, USA) at wavelength 519 nm. Proline concentration was determined using calibration curve and expressed as mg proline g^{-1}.

3.3.3.2. Ca^{+}, Na^{+}, K^{+}, Chloride and Sulphate content in root, culm and leaf

Plant samples were collected from the seedling and flowering stage of the crop and analyzed for Ca^{2+}, Na^{+}, K^{+}, Chloride and Sulphate status in it using standard procedures.

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

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

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

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

3.3.3.3. Root CEC

Root Cation Exchange Capacity (CEC) was estimated by hydrochloric treatment of living roots (Mitsui and ueda, 1963) at seedling and flowering stages of crop and mean was worked out.

3.3.4. Physico-chemical parameters of soil

Soil samples for laboratory analysis were collected from Kaipad low-saline and high-saline tracts at monthly interval from July 2014 to June 2015. The samples were air dried, ground, sieved with 2mm sieve and stored in air tight container. They were analyzed for pH, Electrical Conductivity (EC), Cation Exchange Capacity (CEC), Exchangeable Cations, Exchangeable sodium percentage (ESP), Sodium absorption ratio (SAR), Chloride and Sulphate as per the standard procedures.

pH in soil was estimated by using pH meter (Jackson, 1958).

EC (Electrical conductivity) of soil was estimated by using Conductivity meter and expressed in mmhos/cm (Jackson, 1958).

CEC (Cation Exchange Capacity) of soil is a measure of the quantity of readily exchangeable cations neutralizing the negative charge in the soil and expressed in milli equivalent per 100 gram of soil.

Exchangeable cations of soil were estimated by Atomic absorption spectroscopy given by Department of Sustainable Natural Resources.

Exchangeable sodium percentage (ESP) of soil was estimated by using the formula

$$\text{ESP (\%)} = \frac{\text{Exchangeable sodium}}{\text{CEC}} \times 100$$

Sodium absorption method (SAR) was estimated by the formula

$$\text{SAR} = \frac{Na^{2+}}{\sqrt{1/2(Ca^{2+}+Mg^{2+})}} \times 100$$

Chloride content in soil was estimated by mhor method using $AgNO_3$ and expressed in mg / L.

Sulphate content in soil was estimated by using photoelectric colorimetry (Massouni and Comfield, 1963).

3.3.4. Yield parameters

3.3.4.1. Number of productive tillers per plant

Number of panicles bearing tillers per plant was counted for randomly selected 10 plants and mean was worked out.

3.3.4.2. Number of spikelets per panicle

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

3.3.4.3. Number of filled grains per panicle

Filled grains in each panicle of randomly selected 10 plants were counted and mean was worked out.

3.3.4.4. Seed setting percentage

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

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

3.3.4.5. Sterility percentage

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

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

3.3.4.6. Length of panicle

The length of panicle was measured from base to tip of the top most spikelet (awns included) on panicle for randomly selected 10 plants. The mean was worked out and expressed in centi meters.

3.3.4.7. 1000 grain weight

Weight of randomly selected 1000 numbers of grains was recorded in grams and mean was worked out.

3.3.4.8. Grain yield per plot

Weight of total grains from each plot was recorded in kilograms and mean was worked out.

3.3.4.9. Straw yield per plot

The dry weight of paddy straw from each plot was recorded and means was worked out and expressed in kilograms.

3.4. Statistical analysis

The data on various parameters studied during the course of investigation were subjected to statistical analysis. Analysis of variance was performed using the ICAR Research Complex for Goa developed online software 'Wasp 2.0'. The critical differences for treatments showing significant differences were worked out at 5 % probability level. Two factor analysis using 'OPSTAT' were worked out for finding the interaction effect of genotypes in different soil conditions. The significance of genotypic and phenotypic correlation coefficients among the characteristics observed in high-saline soil was assessed at 5 % and 1 % levels from the table value at (n-2) degrees of freedom using 'SPSS'. Genotypic and phenotypic path coefficients among the characteristics observed in high-saline soil were assessed using 'INDOSTAT'.

RESULTS

4. RESULTS

An investigation was conducted for identification of most correlated physiological/morphological/biochemical trait(s) associated with salinity tolerance, high yield and non-lodging at seedling and reproductive stages in naturally organic saline prone Kaipad soil of North Kerala, India.

Evaluation was done in low-saline Kaipad, high-saline Kaipad and in non-saline paddy field. The physico-chemical parameters of these three types of soils are described below

4.1. Physico-chemical parameters of soil

4.1.1. Physico-chemical parameters of soil of low-saline Kaipad

Physico-chemical parameters such as pH, electrical conductivity (EC), cation exchange capacity (CEC), exchangeable cations, exchangeable sodium percentage (ESP), sodium absorption ratio (SAR), chloride and sulphate content of low-saline Kaipad soil was analysed and are presented in Table 2. The result showed that the particular soil is saline soil.

Table 2. Soil analysis result of low-saline soil Kaipad

Sl. No.	pH	EC (mmhos/cm)	CEC (meq/100g soil)	E. cations	ESP (%)	SAR (%)	Chloride (mg / Kg soil)	Sulphate (mg / Kg soil)
July	5.63	4.48	15.3	2.53	4.9	13.2	1.38	0.195
August	5.13	4.84	15.7	2.66	2.9	12.6	1.26	0.175
September	5.53	3.51	16.6	2.96	3.5	15.1	1.21	0.18
October	4.93	2.47	14.8	2.40	4.4	14.2	1.28	0.19
November	4.75	5.85	12.3	2.79	4.6	13.7	1.31	0.187
December	4.37	4.72	13.6	2.44	4.5	13.9	1.76	0.21
January	4.61	3.54	13.9	2.75	4	13.3	1.18	0.24
February	4.60	4.74	14.7	2.61	4.2	12.8	1.92	0.236
March	5.30	5.60	15.3	2.42	3.7	13.7	1.46	0.248
April	5.35	4.98	14.6	2.1	5.2	13.8	1.39	0.275
May	5.46	4.68	14.8	2.78	2.7	12.9	1.22	0.245
June	5.86	4.39	15.8	3.17	2.9	13.6	1.24	0.23

4.1.2. Physico-chemical parameters of soil of high-saline Kaipad

Physico-chemical parameters such as pH, electrical conductivity (EC), cation exchange capacity (CEC), exchangeable cations, exchangeable sodium percentage (ESP), sodium absorption ratio (SAR), chloride and sulphate content of high-saline Kaipad soil was analysed and are presented in Table 3. The result showed that the particular soil is acid saline soil.

Table 3. Soil analysis result of high-saline soil Kaipad

Sl. No.	pH	EC (mmhos/cm)	CEC (meq/100g soil)	E. cations	ESP (%)	SAR (%)	Chloride (mg / Kg soil)	Sulphate (mg / Kg soil)
July	3.93	14.48	12.6	2.89	6.1	14.6	2.5	0.25
August	4.42	14.98	13.7	2.53	8.1	14.8	2.6	0.27
September	4.79	13.04	13.8	2.59	5.6	14.3	2.36	0.22
October	3.48	14.55	12.9	2.62	6.1	14.6	2.76	0.22
November	3.47	14.47	12.7	2.68	5.7	13.9	2.38	0.26
December	3.50	11.3	12.3	2.34	8.7	13.6	2.79	0.28
January	3.97	13.68	11.9	2.67	6.2	13.7	3.26	0.23
February	3.60	16.03	11.67	2.56	7.8	13.8	3.23	0.29
March	3.60	13.43	12.3	2.14	7.5	14.2	3.67	0.25
April	4.25	13.86	13.7	2.67	7.2	14.7	3.76	0.21
May	3.85	14.86	12.9	2.58	6	14.1	3.18	0.28
June	3.89	13.18	12.8	2.67	6.7	14.8	3.28	0.22

4.1.3. Physico-chemical parameters of soil of non-saline paddy field

In non-saline condition, soil analysis was done before planting the crop for the parameters pH (5.43), EC (0.14 mmhos/cm), CEC (4.3 meq/100 gm soil), Exchangeable cations (1.56), ESP (5.81%), SAR (11.81%), Chloride (1.02 mg/Kg soil) and Sulphate (0.58 mg/Kg soil).

4.2. Variability

In the present investigation 18 rice genotypes including saline tolerant land races of Kaipad tract, improved saline tolerant varieties of Kaipad, improved saline tolerant breeding lines of Kaipad, saline tolerant traditional land races of Pokkali tract, improved saline tolerant Pokkali varieties, international saline tolerant varieties, international saline susceptible variety and saline susceptible popular variety of Kerala were evaluated under high-saline and low-saline soils of Kaipad tract and non-saline soil of RARS (Regional Agricultural Research Station) Pilicode for different morphological, physiological, biochemical and yield parameters. The data on various parameters were statistically analysed separately for three situations and also done pooled analysis. The analysis results are presented here after. There was significant difference among genotypes in each three situations for 43 quantitative parameters studied both at seedling and flowering stages except for survival per cent at seedling and flowering, SLA at seedling and stomatal resistance at seedling in non-saline condition; survival per cent at seedling and flowering, stomatal conductance and resistance at flowering, root culm ratio at seedling and leaf sodium content at seedling in low-saline condition and root culm ratio at seedling, culm calcium content at seedling, root chloride content at seedling and number of productive tillers per plant in high-saline condition. In pooled analysis there was significant interaction effect with respect to 43 quantitative parameters studied both at seedling and flowering stages except for root culm ratio at seedling stage; number of nodes and leaf proline content at flowering stage.

Pooled analysis showed that there is a significant difference between soil conditions with respect to 43 quantitative parameters studied both at seedling and flowering stages except for root culm ratio at seedling stage; number of internodes and leaf proline content at flowering stage.

4.2.1. Morphological parameters

4.2.1.1. Plant height at seedling and flowering stages

The mean plant height of 18 genotypes recorded at seedling and flowering stages are presented in Table 4. Plant height at seedling stage varies from 42.7 cm to 93.9 cm and at flowering stage it varies from 84.75cm to 182cm. In non-saline condition, the highest plant height was exhibited by 'Orkayama', 'Kuthiru' and 'Cheriviripppu' at seedling stage and at flowering stage 'Pokkali' recorded the highest plant height which was found to be on par with Chettiviripppu'. 'Ezhome-1' recorded the lowest plant height at both seedling and flowering stages.

In low-saline condition, at seedling stage 'Cheriviripppu' recorded the highest height which was on par with that of 'Chettiviripppu', 'Orkayama', 'Vytilla-1' and 'Pokkali'. 'Pokkali' recorded significantly the highest height at flowering stage which was on par with that of 'Kuthiru', 'Cheriviripppu', 'Chettivirippu', 'Vytilla-1', 'Nona Bokra', 'JK-15', 'Orkayama' and 'Ezhome-3'. 'Jyothi' and 'IR-29' recorded the lowest plant height at seedling and flowering stages.

Table 4. Mean performances of rice genotypes for plant height (cm)

Genotypes	Seedling stage (cm)			Flowering stage (cm)		
	Non-saline	Low-saline	High-saline	Non-saline	Low-saline	High-saline
Kuthiru	93.90*	70.35	66.60	142.80	167.00	141.00
Orkayama	93.30*	76.54	67.35*	124.00	135.25	112.75
Ezhome-1	51.40	58.40	56.05	85.50	100.50	88.25
Ezhome-2	58.80	53.97	54.31	100.92	101.50	99.75
Ezhome-3	59.82	54.75	65.95	110.50	133.00	121.50
JO 532-1	55.25	60.17	61.95	153.62	118.75	145.75
JK-15	66.77	69.40	65.55	118.57	142.25	144.00
JK-59	71.80	72.60	62.55	133.37	126.45	144.50
JO-583	62.05	66.25	63.40	119.80	123.25	162.25
Chettivirippu	80.10	79.00	65.55	167.50	152.50	165.00
Cheriviripppu	91.12*	84.40*	68.15*	153.25	156.00	154.25
Vytilla-1	76.50	75.00	64.10	112.25	146.25	145.00
Vytilla-6	60.87	49.10	57.65	94.80	100.75	88.50
Pokkali	80.90	73.95	67.05	182.00*	171.00*	174.50*
FL-478	66.00	52.05	53.70	93.85	110.00	88.00
Nona Bokra	77.65	67.25	65.65	153.75	143.00	167.00
IR-29	60.05	44.90	50.75	88.62	88.50	145.50
Jyothi	66.60	42.77	53.90	97.05	98.00	84.75
CV (%)	3.54	8.38	8.55	7.46	15.01	3.27
C.D. (0.05)	5.28	11.31	11.12	19.51	40.92	9.10
C.D.(0.05) G×E			9.34			25.49

(* = Significant)

In high-saline condition, at seedling stage 'Cherivirippu' and 'Orkayama' showed significantly the highest height which was on par with 11 rice genotypes at seedling stage and 'IR-29' and 'Jyothi' recorded the lowest plant height. 'Pokkali' recorded the highest plant height which was on par with 'Nona Bokra' at flowering stage and 'Jyothi', 'FL-478', 'Ezhome-1' and 'Vytilla-6' recorded the lowest plant height.

At both seedling and flowering stages there was significant interaction effect between genotypes and environment. At seedling stage, the genotypes

'Ezhome-1', 'JK-15' and 'JK-59' recorded high plant height in low-saline condition. The highest plant height in high-saline condition was exhibited by 'Ezhome-3', 'JO-532-1' and 'JO-583' and remaining all other genotypes recorded the highest plant height in non-saline condition. At flowering stage, the genotypes 'JO-532-1', 'Chettivirippu' and 'Pokkali' recorded high plant height in non-saline condition. The highest plant height in high-saline condition was exhibited by 'JK-15', 'JK-59', 'JO-583', 'Nona Bokra' and 'IR-29' and remaining all other genotypes recorded the highest plant height in low-saline condition.

4.2.1.2. Number of tillers at seedling and flowering stages

Table 5. Mean performances of rice genotypes for number of tillers

	Seedling stage			Flowering stage		
Genotypes	Non-saline	Low-saline	High-saline	Non-saline	Low-saline	High-saline
Kuthiru	3.15	6.85	4.45	5.50	6.00	4.25
Orkayama	4.35	5.90	3.70	5.00	6.25	7.25
Ezhome-1	3.65	7.30	4.50	3.50	9.25	5.00
Ezhome-2	4.55	6.50	3.50	5.50	7.25	4.75
Ezhome-3	2.95	8.55*	4.65	3.50	6.50	5.75
JO 532-1	3.35	5.40	3.30	3.25	4.25	3.75
JK-15	2.65	5.35	3.80	3.00	10.00*	6.25
JK-59	3.55	7.40	3.85	3.50	5.00	5.50
JO-583	3.70	5.70	3.05	5.00	6.50	6.25
Chettivirippu	5.00	6.65	4.80	5.25	5.75	10.75*
Cheriviruppu	4.80	7.65	6.00*	3.75	5.00	6.25
Vytilla-1	3.20	7.75	5.95	4.00	5.25	5.25
Vytilla-6	5.50	6.55	4.50	5.75	7.25	5.75
Pokkali	3.15	7.65	4.35	4.00	6.50	8.75
FL-478	3.70	5.35	3.35	4.50	5.00	5.75
Nona Bokra	4.85	7.10	3.50	5.75	6.25	10.75*
IR-29	5.45	7.15	3.30	5.75	8.00	5.50
Jyothi	5.90*	7.20	2.30	8.50*	7.50	5.00
CV (%)	**2.74**	**10.40**	**15.68**	**21.49**	**16.64**	**17.27**
C.D. (0.05)	**0.24**	**1.49**	**1.34**	**2.14**	**2.29**	**2.28**
C.D.(0.05) G×E			**1.66**			**2.11**

(* = Significant)

The mean number of tillers recorded among 18 rice genotypes at seedling and flowering stages is presented in Table 5. The numbers of tillers varies from 2.3-8.55 at seedling stage and 3-10.75 at flowering stage. In non-saline condition 'Jyothi' exhibited the highest number of tillers at seedling and flowering stages and 'JK-15' recorded the lowest number of tillers.

In low-saline condition 'Ezhome-3' exhibited high number of tillers and found to be on par with that of eight rice genotypes 'Vytilla-1', 'Cheriviripppu', 'Pokkali', 'JK-59', 'Ezhome-1', 'Jyothi', 'IR-29' and 'Nona Bokra' at seedling stage and 'JK-15' and 'FL-478' recorded minimum number of tillers. At flowering stage 'JK-15' showed the highest tiller number which was on par with that of 'Ezhome-1' and 'IR-29'. 'JO-532-1' recorded the lowest number of tillers at flowering stage.

In high-saline condition 'Cheriviripppu' exhibited significant high number of tillers which was on par with that of 'Vytilla-1'and 'Chettiviripppu' at seedling stage. 'Jyothi' recorded the lowest tiller numbers at seedling stage. At flowering stage 'Chettiviripppu' and 'Nona Bokra' recorded the highest number of tillers and was found to be on par with that of 'Pokkali'. 'JO-532-1' recorded the lowest tiller numbers at flowering stage.

At seedling stage all the genotypes showed the highest number of tillers per plant in low-saline condition than in high-saline and non-saline conditions. At flowering stage the highest number of tillers in non-saline condition was exhibited by 'Jyothi', in high-saline condition by 'Orkayama', 'Chettiviripppu', 'Cheriviripppu', 'Pokkali', 'FL-478' and 'Nona Bokra' and for all the remaining genotypes in low-saline condition.

4.2.1.3. Number of nodes at flowering stage

Mean number of nodes at flowering stage among 18 rice genotypes is presented in Table 6a. In non-saline condition the tillers numbers varies from 3.25-5.25. 'Chettiviripppu' recorded the highest number of nodes in non-saline condition and found to be on par with 6 genotypes. 'Ezhome-3' recorded the lowest number of nodes. In low-saline condition the trait was non-significant. In high-saline condition the nodes numbers varies from 3.00-5.75. 'Chettivirippu', 'IR-29', 'Pokkali' and 'Orkayama' recorded significant number of nodes and was found to be on par with seven rice genotypes and 'Jyothi' recorded the lowest number of nodes.

4.2.1.4. Uppermost internodal length at flowering stage

Table 6a. Mean performances of rice genotypes for number of nodes and uppermost internodal length (cm)

Genotypes	Number of nodes at Flowering stage			Uppermost internodal length at Flowering stage (cm)		
	Non-saline	Low-saline	High-saline	Non-saline	Low-saline	High-saline
Kuthiru	3.50	5.45	5.25	18.25	22.50	20.10
Orkayama	3.75	4.15	5.50*	14.09	22.45	16.50
Ezhome-1	3.00	4.45	3.25	12.25	12.75	15.75
Ezhome-2	3.50	5.15	4.00	13.80	13.30	16.25
Ezhome-3	3.25	4.65	3.75	14.17	19.75	17.75
JO 532-1	4.50	4.65	4.00	20.06	19.75	21.40
JK-15	3.50	5.40	5.25*	14.75	19.75	19.90
JK-59	4.00	4.50	4.50	15.25	14.75	19.30
JO-583	4.25	4.10	4.50	17.25	21.80	18.25
Chettivirippu	5.25*	3.95	5.75*	23.25	22.00	22.90
Cherivirippu	5.00	4.60	4.75	22.75	23.25*	22.50
Vytilla-1	4.50	4.60	4.75	12.75	22.40	18.90
Vytilla-6	3.25	4.25	3.50	15.50	16.27	15.15
Pokkali	4.75	4.65	5.50*	23.75*	23.25*	23.90*
FL-478	3.50	3.50	4.00	19.25	18.75	16.45
Nona Bokra	5.00	4.85	5.00	15.00	22.70	22.90
IR-29	4.00	4.20	5.50	17.25	16.75	22.30
Jyothi	3.50	3.9	3.00	15.25	15.50	15.95
CV (%)	12.50	20.43	14.9	2.77	2.70	1.99
C.D. (0.05)	1.05	NS	1.43	0.99	1.10	0.81
C.D.(0.05) G×E			NS			0.94

(* = Significant)

Mean of uppermost internodal length at flowering stage recorded for 18 rice genotypes are presented in Table 6a. In non-saline condition the uppermost internodal length varies from 12.25-23.75 cm. 'Pokkali' recorded the highest length of uppermost internode which was on par with that of 'Chettivirippu'. 'Ezhome-1' exhibited lowest uppermost internodal length. In low-saline condition the uppermost internodal length varies from 15.5-23.25 cm. 'Pokkali' and 'Cherivirippu' found to have significantly highest uppermost internodal length which was on par with that of eight rice genotypes. 'Jyothi' recorded the lowest length. In high-saline condition the uppermost internodal length varies from 15.15-23.9 cm. 'Pokkali' recorded the highest uppermost internodal length and 'Vytilla-6' recorded the lowest uppermost internodal length.

At flowering stage, the genotypes 'Chettivirippu', 'Vytilla-6', and 'Nona Bokra' showed the highest uppermost internodal length in non-saline condition than in saline condition. The highest uppermost internodal length in low-saline condition was exhibited by 'Kuthiru', 'Orkayama', 'Ezhome-3', 'JK-15', 'JO-583', 'Cherivirippu' and 'Vytilla-1'. Remaining all other genotypes showed the highest uppermost internodal length in high-saline condition.

4.2.1.5. Orientation of flag leaf

Orientation of flag leaf was recorded as erect, intermediate and descending type as per the IBPGR-IRRI Descriptors for Rice (*Oryza sativa* L.) (Table 6b). 'Kuthiru', 'Orkayama', 'Ezhome-2', 'JO-532-1', 'JK-59', 'JO-583', 'Chettivirippu', 'Cherivirippu', 'Vytilla-1', 'Pokkali', 'FL-478', 'Nona Bokra' and 'Jyothi' have descending type of orientation. 'Ezhome-1', 'JK-15' and 'Vytilla-6' have erect type of orientation. 'Ezhome-3' and 'IR-29' have intermediate type of orientation.

4.2.1.6. Lodging/Non-lodging

Lodging and Non-lodging characteristics of plants were measured by visual observations (Table 6b). 'Ezhome-1', 'Ezhome-2', Ezhome-3', 'JO-532-1', 'JO-583', 'Cherivirippu', 'Vytilla-6', 'FL-478', 'IR-29' and 'Jyothi' show non-lodging character. 'Kuthiru', 'Orkayama', 'JK-15', 'JK-59', 'Chettivirippu', 'Vytilla-1' and 'Nona Bokra' show lodging in all three soil conditions. 'Pokkali' was non-lodging in non-saline and low-saline condition where as in high-saline condition it showed slight lodging.

4.2.1.7. Duration of crop

Duration of crop counted as number of days from sowing to harvest (when 85 % of grains on the panicle have matured) is presented in Table 6b. Four rice genotypes 'FL-478', 'IR-29', 'Kuthiru' and 'Jyothi' recorded a duration of 105 - 108 days, six rice genotypes 'Ezhome-2', 'JK-59', 'Chettivirippu', 'Cherivirippu', 'Vytilla-1' and 'Vytilla-6' recorded a duration of 112 days, two rice genotypes 'JK-15' and 'Pokkali' recorded a duration of 116 days, four rice genotypes 'Orkayama', 'Ezhome-1', 'Ezhome-3' and 'JO-583' recorded a duration of 118 days and 2 rice genotypes 'JO-532-1' and 'Nona Bokra' recorded a duration of 122 days.

Table 6b. Visual observation of Orientation of flag leaf, Lodging/ Non-lodging and Duration of crop

Genotypes	Orientation of flag leaf	Lodging/Non-lodging	Duration of crop (days)
Kuthiru	Descending	Lodging	108
Orkayama	Descending	Lodging	118
Ezhome-1	Erect	Non-lodging	118
Ezhome-2	Descending	Non-lodging	112
Ezhome-3	Intermediate	Non-lodging	118
JO 532-1	Descending	Non-lodging	122
JK-15	Erect	Lodging	116
JK-59	Descending	Lodging	112
JO-583	Descending	Non=lodging	118
Chettivirippu	Descending	Lodging	112
Cherivirippu	Descending	Non-lodging	112
Vytilla-1	Descending	Lodging	112
Vytilla-6	Erect	Non-lodging	112
Pokkali	Descending	Non-lodging	116
FL-478	Descending	Non-lodging	105
Nona Bokra	Descending	Lodging	122
IR-29	Intermediate	Non-lodging	105
Jyothi	Descending	Non-lodging	108

4.2.2. Physiological parameters

4.2.2.1. Survival % at seedling and flowering stages

Survival per cent of 18 rice genotypes recorded at seedling and flowering stages in three soil conditions is presented in Table 7. In non-saline and low-saline soils the result was found to be non significant. In high-saline condition survival per cent varies from 82.975 %-98.305 % at seedling stage and 28.055 %-93.010 % at flowering stage. Both at seedling and flowering stages 'Kuthiru', 'Orkayama', 'JO 583', 'Chettivirippu', 'Cherivirippu' and 'Vytilla-6' recorded the highest survival per cent followed by 'Nona Bokra', 'IR-29', 'JO-532-1', 'JK-59', 'Ezhome-3' and 'Pokkali'. 'FL-478' recorded the lowest survival per cent at both seedling and flowering stage and 'Jyothi' recorded the lowest survival per cent at flowering stage.

Table 7. Mean performances of rice genotypes for survival per cent

Genotypes	Seedling stage (%)			Flowering stage (%)		
	Non-saline	Low-saline	High-saline	Non-saline	Low-saline	High-saline
Kuthiru	99.39	96.31	97.74*	99.26	95.59	97.43
Orkayama	99.21	93.14	98.30*	99.07	93.02	98.01*
Ezhome-1	99.09	98.74	89.94	98.77	98.19	89.22
Ezhome-2	99.69	98.97	90.17	99.55	98.82	89.86
Ezhome-3	99.74	98.66	90.53	99.62	98.54	90.39
JO 532-1	99.43	98.38	92.03	99.34	97.99	91.60
JK-15	99.53	97.91	89.12	99.39	97.66	88.64
JK-59	98.87	95.16	91.67	98.50	94.25	91.35
JO-583	99.50	95.92	98.13*	99.38	95.92	97.80
Chettivirippu	99.28	97.49	96.95*	98.57	96.78	96.41
Cherivirippu	99.23	97.63	98.08*	98.80	97.18	97.18
Vytilla-1	99.37	98.64	92.42	99.25	98.25	92.13
Vytilla-6	99.85	99.52	97.09*	99.57	99.28	95.26
Pokkali	99.61	98.61	90.47	99.49	98.45	90.07
FL-478	100.00	97.22	82.97	99.75	96.93	38.34
Nona Bokra	99.58	96.15	93.00	98.81	95.64	92.40
IR-29	99.39	96.69	92.28	99.09	96.52	91.94
Jyothi	99.24	96.48	89.24	98.99	96.20	28.05
CV (%)	0.31	1.88	1.99	0.45	1.84	3.05
C.D. (0.05)	NS	NS	3.89	NS	NS	5.57
C.D.(0.05) G×E			2.97			2.75

(*= Significant)

At seedling and flowering stages all the genotypes showed the highest survival per cent in non-saline condition than in saline condition.

4.2.2.2. Specific leaf area (SLA) at seedling and flowering stages

A significant difference in specific leaf area was observed among the rice genotypes under different saline conditions (Table 8). In non-saline condition, there was no significant difference among the rice genotypes at seedling stage, and at flowering stage SLA varies from 99.92 cm^2/g - 410.70 cm^2/g. 'JK-15' recorded the highest SLA and 'Ezhome-2' recorded the lowest SLA.

Table 8. Mean performances of rice genotypes for specific leaf area (SLA)

Genotypes	Seedling stage (cm^2/g)			Flowering stage (cm^2/g)		
	Non-saline	Low-saline	High-saline	Non-saline	Low-saline	High-saline
Kuthiru	203.97	241.68	226.45	125.29	159.25	138.28
Orkayama	243.99	159.76	176.36	148.13	155.92	318.80
Ezhome-1	197.71	200.73	330.72	100.44	135.61	218.40
Ezhome-2	191.19	120.83	142.88	99.92	101.06	150.46
Ezhome-3	169.02	200.50	360.67	178.96	171.09	112.85
JO 532-1	251.00	233.50	209.17	280.83	283.48*	165.63
JK-15	245.55	271.11	208.20	410.70*	78.37	191.86
JK-59	291.92	195.77	275.54	143.59	110.80	295.49
JO-583	209.25	243.95	296.95	128.99	212.66	227.18
Chettivirippu	200.50	215.94	305.87	174.61	177.94	248.55
Cherivirippu	147.30	184.43	203.27	186.61	111.38	103.29
Vytilla-1	189.37	328.32*	284.91	111.29	87.83	182.48
Vytilla-6	226.56	169.45	889.50*	180.69	122.28	158.21
Pokkali	303.68	204.00	205.03	103.30	189.51	165.57
FL-478	199.68	204.80	178.06	110.68	111.52	91.44
Nona Bokra	264.90	294.07	263.62	176.32	179.95	141.60
IR-29	161.43	188.62	701.08	162.94	132.39	479.17*
Jyothi	185.92	210.12	163.43	139.68	145.45	167.72
CV (%)	**19.86**	**20.68**	**59.33**	**20.26**	**26.65**	**17.33**
C.D. (0.05)	**NS**	**93.75**	**377.05**	**70.37**	**83.29**	**72.26**
C.D. (0.05) G×E			**220.27**			**75.01**

(* = Significant)

In low-saline condition, at seedling stage SLA varies from 120.83cm^2-328.325cm^2. 'Vytilla-1' recorded the highest SLA and was on par with that of 'Nona Bokra', 'JK-15' and 'JO-583' at seedling stage and 'Ezhome-3' recorded the lowest SLA. At flowering stage SLA varies from 78.370 cm^2/g -283.480 cm^2/g. 'Kuthiru' and 'JO-532-1' recorded the highest SLA which was on par with 'JO-583'. 'JK-15' recorded the lowest SLA at flowering.

In high-saline condition at seedling stage SLA varies from 142.885cm^2-889.500cm^2. 'Vytilla-6' recorded the highest SLA followed by 'IR-29' at seedling stage and 'Ezhome-2' recorded the lowest SLA. At flowering stage SLA varies from 91.440 cm^{2m}/g - 479.170 cm^2/g. 'IR-29' recorded the highest SLA at flowering stage and 'FL-478' exhibited the lowest SLA.

At seedling stage the genotypes 'Orkayama', 'Ezhome-2', 'JO-532-1', 'JK-59' and 'Pokkali' showed the highest SLA in non-saline condition than in saline conditions. 'Kuthiru', 'JK-15', 'Vytilla-1', 'FL-478', 'Nona Bokra' and 'Jyothi' showed the highest the SLA in low-saline condition and remaining six genotypes showed the highest SLA in high-saline condition. At flowering stage the genotypes 'Ezhome-3', 'JK-15', 'Cheriviruppu' and 'Vytilla-6' showed the highest SLA in non-saline condition than in saline condition. 'Kuthiru', 'JO-532-1', 'Pokkali', 'FL-478' and 'Nona Bokra' showed the highest SLA in low-saline condition and remaining ten genotypes showed the highest SLA in high-saline condition.

4.2.2.3. Relative water content (RWC) at seedling and flowering stages

The mean RWC in leaves of 18 rice genotypes was measured and values presented in Table 9. In non-saline condition the RWC varies from15.21 %-96.42 % at seedling stage and 15.585 %-85.935 % at flowering stage. 'Jyothi' exhibited high RWC at seedling stage and at flowering stage 'Jyothi' and 'Ezhome-3' exhibited maximum RWC. 'FL-478' recorded the lowest RWC at seedling and flowering stages.

In low-saline condition at seedling stage the RWC varies from 44.190%-90.195%. 'JK-15' recorded high RWC at seedling stage and 'Kuthiru' recorded the lowest RWC. At flowering stage the RWC varies from 37.360%-76.920%. 'FL-478' recorded the highest RWC and was on par with that of 'Jyothi', 'Nona Bokra', 'Orkayama' and 'Chettivirippu'. 'Ezhome-2' recorded the lowest RWC at flowering stage.

Table 9: Mean performances of rice genotypes for relative water content (RWC %)

Genotypes	Seedling stage (%)			Flowering stage (%)		
	Non-saline	Low-saline	High-saline	Non-saline	Low-saline	High-saline
Kuthiru	60.93	44.19	61.39	45.03	41.58	41.39
Orkayama	65.74	66.39	52.18	38.77	69.44	56.57
Ezhome-1	54.48	74.45	46.15	56.37	47.31	38.69
Ezhome-2	55.72	58.83	53.42	53.57	37.36	34.36
Ezhome-3	43.17	55.00	54.31	82.97*	53.69	71.71
JO 532-1	42.56	55.96	62.26	49.99	53.12	74.19
JK-15	45.24	90.19*	76.53	65.38	76.87*	76.78*
JK-59	68.19	74.58	85.19	73.33	53.18	52.06
JO-583	54.27	50.21	88.31	69.36	51.92	51.57
Chettivirippu	53.24	65.47	94.90*	53.07	63.38	56.98
Cheriviríppu	58.93	62.03	84.09	56.91	62.94	51.51
Vytilla-1	58.73	48.29	74.13	60.94	56.34	55.45
Vytilla-6	60.98	48.27	72.87	63.95	52.28	53.75
Pokkali	61.94	49.26	76.14	60.58	47.22	43.51
FL-478	15.21	78.97	67.43	15.58	76.92*	63.03
Nona Bokra	58.75	72.85	85.80	57.47	70.00	49.84
IR-29	53.93	63.64	76.54	58.8	58.33	34.24
Jyothi	96.42*	64.91	75.18	85.93*	74.43	64.44
CV (%)	**14.97**	**7.40**	**3.62**	**5.80**	**11.14**	**16.07**
C.D. (0.05)	**17.69**	**9.75**	**5.47**	**7.13**	**13.67**	**18.27**
C.D. (0.05) G×E			**12.21**			**13.09**

(*= Significant)

In high-saline condition at seedling stage the RWC varies from 46.155%-94.900%. 'Chettivirippu' recorded the highest RWC and 'Ezhome-1' recorded the lowest RWC. At flowering stage the RWC varies from 34.240%-76.780%.

'JK-15' recorded the highest RWC which was on par with that of 'JO-532-1', 'Ezhome-3', 'Jyothi' and 'FL-478'. 'IR-29' at flowering stage recorded the lowest RWC.

At seedling stage the genotype 'Jyothi' shows the highest RWC in non-saline condition than in saline conditions. 'Orkayama', 'Ezhome-1', 'Ezhome-2', 'Ezhome-3', 'JK-15' and 'FL-478' showed the highest RWC in low-saline condition and remaining all other genotypes showed the highest RWC in high-saline condition. At flowering stage the genotypes 'JO-532-1' and 'FL-478' showed the highest RWC in high-saline condition. 'Orkayama', 'JK-15', 'Chettivirippu', 'Cherivirippu' and 'Nona Bokra' showed the highest RWC in low-saline condition and remaining all other genotypes showed the highest RWC in non-saline condition than in saline condition.

4.2.2.4. Spad chlorophyll meter reading (SCMR) at seedling and flowering stages

SCMR of 18 rice genotypes in three soil conditions are presented in Table 10. In non-saline condition at seedling stage the SCMR ranges from 25.37-38.02. 'Jyothi' recorded the highest SCMR and 'Ezhome-3' recorded the lowest SCMR values. At flowering stage the SCMR ranges from 28.620-46.950. 'Orkayama' recorded the highest SCMR and was found to be on par with that of 'JO-532-1'. 'Chettivirippu' recorded the lowest SCMR at flowering stage.

In low-saline condition at seedling stage the SCMR ranges from 29.880-45.160. 'Jyothi' recorded maximum SCMR followed by seven rice genotypes at seedling stage and 'JK-59' recorded the lowest SCMR. At flowering stage SCMR ranges from 24.820-52.835. 'FL-478' recorded the maximum SCMR and 'JK-15' recorded minimum SCMR at flowering stage.

In high-saline condition at seedling stage the SCMR ranges from 32.790-47.240. 'Orkayama' recorded maximum SCMR and was on par with that of 'Vytilla-6' and 'Cherivirippu'. 'Nona Bokra' recorded minimum SCMR values. At flowering stage the SCMR ranges from 33.920-49.035. 'FL-478' recorded the highest SCMR and was on par with 'JO-532-1', 'Orkayama', 'IR-29', 'Vytilla-6' and 'JO583'. 'Vytilla-1'and 'Chettivirippu' recorded minimum SCMR.

Table 10: Mean performances of rice genotypes for Spad chlorophyll meter reading (SCMR in SPAD units)

Genotypes	Seedling stage			Flowering stage		
	Non-saline	Low-saline	High-saline	Non-saline	Low-saline	High-saline
Kuthiru	30.76	38.06	38.19	32.10	31.32	42.62
Orkayama	30.36	43.61	47.24*	46.95*	36.44	46.15
Ezhome-1	28.00	41.62	41.43	32.75	28.25	35.99
Ezhome-2	28.28	39.70	35.07	36.48	27.37	38.30
Ezhome-3	25.37	36.56	37.56	32.35	29.02	35.02
JO 532-1	28.10	43.33	41.07	41.19	36.40	46.24
JK-15	28.94	39.14	36.77	38.68	24.82	36.69
JK-59	26.41	29.88	37.76	31.65	33.60	39.62
JO-583	30.90	41.26	36.35	34.42	37.85	43.14
Chettivirippu	29.01	33.60	34.84	28.62	25.70	33.92
Cheriviripppu	29.65	40.40	42.62	39.54	25.89	41.08
Vytilla-1	27.64	35.18	34.40	37.48	35.80	34.24
Vytilla-6	35.43	37.98	42.74	38.52	29.94	43.75
Pokkali	33.40	34.18	35.92	34.37	29.05	36.28
FL-478	30.37	44.34	41.49	38.72	52.83*	49.03*
Nona Bokra	29.61	37.01	32.79	37.68	30.47	40.70
IR-29	27.97	42.48	39.34	34.37	29.45	43.87
Jyothi	38.02*	45.16*	40.22	35.50	39.17	42.02
CV (%)	**1.97**	6.19	6.11	9.06	**8.22**	**7.48**
C.D. (0.05)	**1.24**	**5.10**	4.99	6.92	**5.62**	6.39
C.D. (0.05) G×E			4.37			**5.73**

(*= Significant)

At seedling stage, the genotypes 'Kuthiru', 'Orkayama', 'Ezhome-3', 'JO-583', 'Chettivirippu', 'Cheriviripppu', 'Vytilla-6' and 'Pokkali' showed the highest SCMR in high-saline condition and remaining all other genotypes showed the highest SCMR in low-saline condition. At flowering stage the genotypes 'Orkayama' and 'JK-15' showed the highest SCMR in non-saline condition than in saline condition. 'FL-478' shows the highest SCMR in low-saline condition and remaining all other genotypes showed the highest SCMR in high-saline condition.

4.2.2.5. Stomatal conductance and resistance at seedling and flowering stages

Stomatal conductance and resistance of rice genotypes are presented in Table 11 and 12. The stomatal conductance in 18 genotypes at different soil condition varies from 114.7-453.8 m mol $m^{-2}s^{-1}$ at seedling stage and 46.5-492.95 m mol $m^{-2}s^{-1}$ at flowering stage and the stomatal resistance varies from 0.002-0.03.

Table 11. Mean performances of rice genotypes for Stomatal conductance (m mol $m^{-2}s^{-1}$)

Genotypes	Seedling stage			Flowering stage		
	Non-saline	Low-saline	High-saline	Non-saline	Low-saline	High-saline
Kuthiru	149.75	253.15	174.35	99.90	323.40	247.80
Orkayama	231.85	266.00	248.95	98.85	372.75	333.65
Ezhome-1	155.35	312.95	343.75	248.15	438.30	132.90
Ezhome-2	165.30	250.00	322.00	207.30	349.75	298.70
Ezhome-3	222.35	149.05	146.20	178.80	200.90	296.35
JO 532-1	453.80*	235.65	293.30	313.95	244.82	295.60
JK-15	181.00	184.45	126.95	230.65	282.50	332.00
JK-59	160.45	334.10*	125.75	355.40*	404.05	306.70
JO-583	177.40	183.10	129.75	146.30	391.40	402.00
Chettivirippu	158.90	293.40	114.70	149.30	143.30	298.45
Cheriviruppu	162.75	181.25	258.60	83.20	230.75	282.90
Vytilla-1	203.45	160.65	238.35	51.80	160.80	302.10
Vytilla-6	185.80	196.45	372.45*	90.55	232.05	385.60
Pokkali	169.85	257.30	186.00	60.10	310.90	271.80
FL-478	144.35	124.25	277.90	62.90	260.60	492.95*
Nona Bokra	176.30	142.35	226.70	58.00	377.05	301.15
IR-29	166.15	194.85	297.10	46.55	370.30	286.95
Jyothi	170.40	301.95	206.55	46.50	376.53	276.45
CV (%)	**17.53**	**20.63**	**28.16**	**13.68**	**27.76**	**17.53**
C.D. (0.05)	**70.59**	**97.23**	**135.00**	**40.55**	**NS**	**113.95**
C.D. (0.05) G×E			**102.84**			**117.32**

(*= Significant)

Table 12. Mean performances of rice genotypes for Stomatal resistance

Genotypes	Seedling stage			Flowering stage		
	Non-saline	Low-saline	High-saline	Non-saline	Low-saline	High-saline
Kuthiru	0.007	0.004	0.006	0.011	0.003	0.004
Orkayama	0.004	0.004	0.004	0.010	0.003	0.003
Ezhome-1	0.007	0.003	0.003	0.004	0.002	0.008*
Ezhome-2	0.006	0.005	0.003	0.005	0.003	0.003
Ezhome-3	0.004	0.007	0.007	0.006	0.006	0.003
JO 532-1	0.002	0.004	0.003	0.003	0.004	0.003
JK-15	0.006	0.006	0.008*	0.004	0.004	0.003
JK-59	0.006	0.003	0.008*	0.003	0.003	0.004
JO-583	0.006	0.005	0.009*	0.007	0.003	0.002
Chettivirippu	0.006	0.003	0.009*	0.007	0.007	0.003
Cheriviripppu	0.006	0.006	0.004	0.012	0.004	0.004
Vytilla-1	0.005	0.006	0.004	0.020	0.006	0.003
Vytilla-6	0.005	0.005	0.003	0.011	0.005	0.003
Pokkali	0.006	0.004	0.003	0.018	0.003	0.004
FL-478	0.007	0.008*	0.004	0.017	0.004	0.002
Nona Bokra	0.006	0.007	0.004	0.017	0.003	0.003
IR-29	0.006	0.005	0.003	0.030*	0.003	0.004
Jyothi	0.006	0.003	0.005	0.023	0.003	0.004
CV (%)	**22.16**	**23.09**	**32.44**	**57.58**	**36.14**	**18.91**
C.D. (0.05)	**NS**	**0.002**	**0.003**	**0.014**	**NS**	**0.001**
C.D. (0.05) G×E			**0.002**			**0.008**

(*= Significant)

In non-saline condition, at seedling and flowering stages 'JO-532-1' and 'JK-59' recorded high Stomatal conductance respectively. The variation among genotypes for stomatal resistance is non-significant at seedling stage but at flowering stage the genotype 'IR-29' showed significant resistance and was on par with that of 'Jyothi', 'Vytilla-1', 'Pokkali', 'FL-478' and 'Nona Bokra'. 'Kuthiru' and 'FL-478' at seedling stage and 'IR-29' and 'Jyothi' at flowering stage recorded minimum stomatal conductance where as JK-59' recorded minimum stomatal resistance at flowering stage.

In low-saline condition 'JK-59' recorded significant the highest conductance at seedling stage and was found to be on par with that of 'Ezhome-1', 'Jyothi', 'Chettivirippu', 'Orkayama', 'Pokkali', 'Kuthiru' and 'Ezhome-2'. 'FL-478' recorded significantly the highest resistance and was on par with 'Nona Bokra' and 'Ezhome-3' at seedling stage and result was non-significant at flowering stage. 'FL-478' recorded minimum conductance and 'JK-59' recorded minimum resistance at seedling stage. Stomatal conductance and resistance was non-significant at flowering stage.

In high-saline condition, at seedling stage 'Vytilla-6' recorded significant the highest conductance and was on par with 'Ezhome-1', 'Ezhome-2', 'IR-29', 'JO-532-1', 'FL-478', 'Cherivirippu', 'Orkayama' and 'Vytilla-1'. At flowering stage 'FL-478' showed significantly the highest conductance and found to be on par with that of 'JO-583' and 'Vytilla-6'. 'Chettivirippu', 'JO-583', 'JK-15' and 'JK-59' recorded significantly high value with respect to the trait stomatal resistance and was on par with that of 'Ezhome-3' and 'Kuthiru' at seedling stage and at flowering stage 'Ezhome-1' exhibited significant the highest stomatal resistance. 'Chettivirippu' and 'Ezhome-1' recorded minimum conductance at seedling and flowering stages where as 'Vytilla-1', 'Orkayama', 'Cherivirippu', 'FL-478', 'IR-29', 'JO-532-1', 'Ezhome-1', 'Ezhome-2', 'Vytilla-6' and 'Pokkali' recorded minimum resistance at seedling stage. 'FL-478' recorded minimum resistance at flowering stage.

At seedling stage, the genotypes 'Ezhome-3', 'JO-532-1' and 'FL-478' showed the highest stomatal conductance in non-saline condition. 'Ezhome-1', 'Ezhome-2', 'Cherivirippu', 'Vytilla-1', 'Vytilla-6', 'Pokkali', 'Nona Bokra' and 'IR-29' showed the highest stomatal conductance in high-saline condition and remaining all other genotypes showed the highest stomatal conductance in low-saline condition. At flowering stage the genotype 'Ezhome-3', 'Jyothi' and 'JO-532-1' showed the highest stomatal conductance in non-saline condition than in saline condition. 'Ezhome-3', 'JK-15', 'JO-583', 'Chettivirippu', 'Cherivirippu', 'Vytilla-1', 'Vytilla-6' and 'FL-478' shows the highest stomatal conductance in high-saline condition and remaining all other genotypes showed the highest stomatal conductance in low-saline condition.

At seedling stage, the genotypes 'Ezhome-3', 'JK-15', 'JK-59', 'JO-583' and 'Chettivirippu' showed the highest stomatal resistance in high-saline condition. 'Ezhome-3', 'JO-532-1', 'Vytilla-1', 'Vytilla-6', 'FL-478' and 'Nona Bokra' showed the highest stomatal resistance in low-saline condition and remaining all other genotypes showed the highest stomatal resistance in non-saline condition than in saline conditions. At flowering stage the genotype 'Ezhome-3', 'JK-15' and 'JO-532-1' showed the highest stomatal resistance in low-saline condition. 'Kuthiru' and 'Ezhome-1' showed the highest stomatal resistance in high-saline condition and remaining all other genotypes showed the highest stomatal resistance in non-saline condition.

4.2.2.6. Biomass at seedling and flowering stages

Biomass of 18 rice genotypes in different soil conditions were recorded and presented in Table 13. The biomass of 18 rice genotypes in different soil conditions varies from 2.00-23.290 gm at seedling stage and 4.485-17.025 gm at flowering stage. In non-saline condition, variety 'Orkayama' and 'Kuthiru' recorded the highest biomass and 'Vytilla-1' and 'FL-478' recorded the lowest biomass at seedling and flowering stages respectively.

In low-saline condition the highest biomass was recorded in 'Cheriviripu' which was on par with that of 'Nona Bokra' at seedling stage. At flowering stage 'Cheriviripu' exhibited significantly the highest biomass at flowering stage. 'JO-583' recorded the lowest biomass at seedling and flowering stages.

In high-saline condition biomass was the highest for 'Orkayama' and 'Pokkali' at both seedling and flowering stages. 'JK-59' and 'Ezhome-1' exhibited the lowest biomass at seedling and flowering stages respectively.

Comparison of performance of each genotype in saline stress conditions and non stress condition showed that at seedling stage in the case of the genotypes

'Vytilla-6' and 'FL-478' highest biomass was in high-saline condition. In the case of 'Ezhome-1', 'JK-15', 'JK-59', 'Cheriviripp u', 'Vytilla-1', 'Pokkali' and 'Nona Bokra' the highest biomass was in low-saline condition. Remaining all other genotypes showed the highest biomass in non-saline condition than in saline conditions. At flowering stage the genotype 'Vytilla-6' showed the highest biomass in high-saline. 'Kuthiru', 'Orkayama', 'Ezhome-2', 'Ezhome-3' and 'Jyothi' showed the highest biomass in non-saline condition and remaining all other genotypes exhibited the highest biomass in low-saline condition.

Table 13. Mean performances of rice genotypes for biomass (g)

Genotypes	Seedling stage (g)			Flowering stage (g)		
	Non-saline	Low-saline	High-saline	Non-saline	Low-saline	High-saline
Kuthiru	9.14	8.50	6.35	13.42*	12.71	6.31
Orkayama	23.29*	4.77	12.67*	7.82	7.17	5.99
Ezhome-1	3.68	5.07	2.34	5.88	10.12	4.48
Ezhome-2	8.46	4.05	3.04	11.11	8.48	5.65
Ezhome-3	7.04	4.04	4.10	9.82	6.48	5.92
JO 532-1	12.05	4.63	3.60	6.60	9.21	6.45
JK-15	6.54	10.84	4.61	9.26	12.15	4.52
JK-59	5.08	5.25	2.00	7.53	9.82	4.62
JO-583	5.35	3.39	2.28	7.81	5.48	5.19
Chettivirippu	8.38	7.37	3.28	10.89	11.26	5.74
Cheriviripp u	8.45	14.99*	4.44	6.01	17.02*	6.54
Vytilla-1	3.19	7.57	4.48	5.50	9.87	6.60
Vytilla-6	3.94	4.63	8.03	7.07	7.15	5.87
Pokkali	3.71	6.82	4.42	5.62	6.88	9.88*
FL-478	3.64	4.27	5.21	5.31	6.85	4.63
Nona Bokra	6.72	13.10	5.69	8.38	14.09	4.77
IR-29	8.09	5.10	2.50	8.73	6.32	7.99
Jyothi	7.22	6.56	3.24	8.88	9.96	5.12
CV (%)	**11.03**	**28.44**	**39.31**	**11.03**	**4.95**	**13.58**
C.D. (0.05)	**1.73**	**4.03**	**3.79**	**0.75**	**0.99**	**1.69**
C.D. (0.05) G×E			**3.30**			**1.17**

(*= Significant)

4.2.2.7. Root length (cm)

Root length of 18 rice genotypes at different soil conditions were presented in Table 14. The root length in different soil conditions varied from 10.70-23.80 cm at seedling stage and 11.750-26.00 cm at flowering stage. In non-saline condition, at seedling stage 'Orkayama' and 'Jyothi' recorded the highest root length and was on par with 'Nona Bokra' and 'Ezhome-3'. The minimum root length was observed for 'JK-59' at seedling stage. At flowering stage, 'Vytilla-6', 'Kuthiru', 'Orkayama' and 'FL-478' exhibited the highest root length at flowering stage 'Ezhome-3' and 'JO-583' recorded minimum root length.

Table 14. Mean performances of rice genotypes for root length (cm)

	Seedling stage (cm)			Flowering stage (cm)		
Genotypes	Non-saline	Low-saline	High-saline	Non-saline	Low-saline	High-saline
Kuthiru	18.20	18.05	21.95	25.07*	22.50	21.50
Orkayama	23.60*	20.60	23.80*	24.75*	19.50	24.00*
Ezhome-1	12.95	21.50	15.10	23.75	16.75	15.50
Ezhome-2	15.40	23.20	20.40	16.87	16.00	15.25
Ezhome-3	11.60	19.95	22.20	13.62	18.75	23.50
JO 532-1	15.50	16.90	23.60*	21.25	13.50	12.25
JK-15	11.80	20.60	21.20	23.75	23.25	15.75
JK-59	10.70	20.40	22.00	22.25	25.25*	11.75
JO-583	14.20	16.80	19.70	13.25	15.25	20.50
Chettivirippu	13.44	24.40	21.00	22.00	22.50	19.75
Cherivirippu	13.00	27.20*	23.00	19.75	14.75	14.25
Vytilla-1	16.50	24.40	19.20	19.75	17.75	12.75
Vytilla-6	15.10	15.25	15.30	26.00*	22.00	12.50
Pokkali	16.00	19.70	23.50*	19.25	24.50	16.50
FL-478	20.90	14.05	17.20	24.75*	16.75	16.0
Nona Bokra	21.65	22.60	22.30	23.25	20.25	22.25
IR-29	15.00	12.30	17.00	16.25	23.75	18.25
Jyothi	22.20*	13.10	16.90	20.87	12.25	12.75
CV (%)	**10.87**	**12.13**	**8.56**	**15.89**	**16.74**	**11.42**
C.D. (0.05)	**5.03**	**4.99**	**3.67**	**7.01**	**6.77**	**4.08**
C.D. (0.05) G×E			**5.02**			**5.80**

(*= Significant)

In low-saline condition, 'Cheriviripру' and 'JK-59' showed maximum root length at seedling and flowering stages. 'IR-29' and 'Jyothi' recorded minimum root length at seedling and flowering stages.

In high-saline condition, at seedling stage 'Orkayama', 'JO-532-1' and 'Pokkali' exhibited maximum root length which was on par with that of eight rice genotypes. 'Vytilla-6' and 'Ezhome-1' recorded the minimum root length at seedling stage. At flowering stage 'Orkayama' recorded the highest root length and was on par with that of 'Ezhome-3' 'Nona Bokra', 'Kuthiru' and 'JO583'. 'JK-59' recorded the minimum root length at flowering stage.

Comparison between three soil conditions revealed that at seedling stage, in the case of genotypes 'JK-59', 'Jyothi' and 'FL-478' the highest root length was in non-saline condition than in saline conditions, at the same time 'Ezhome-1', 'Ezhome-2', 'Chettiviripру', 'Cheriviripру', 'Vytilla-1' and 'Nona Bokra' showed the highest root length in low-saline condition than in non-saline and high-saline conditions. Remaining all other genotypes showed the highest root length in high-saline condition. At flowering stage the genotype 'Ezhome-3', 'JK-59' and 'JO-583' showed the highest root length in high-saline condition than in non-saline and low-saline conditions at the same time 'JK-59', 'Chettiviripру', 'Pokkali' and 'IR-29' showed the highest root length in low-saline condition than in non-saline and high-saline conditions and remaining all other genotypes recorded the highest root length in non-saline condition.

4.2.2.8. Root volume

Root volume of 18 rice genotypes in three soil conditions was presented in Table 15. Root volume in different soil conditions varies from 2.6-9.5 ml^3 at seedling stage and 4-12.5 ml^3 at flowering stage. In non-saline condition, at seedling stage 'Orkayama' recorded maximum root volume and was on par with 'Jyothi' and at flowering stage 'JK-59' exhibited high root volume and was on par with that of seven rice genotypes. 'JK-59' at seedling stage and 'Ezhome-2' at flowering stage recorded minimum root volume.

In low-saline condition, at seedling stage 'Cherivirippu' recorded the maximum root volume and 'JO-583', 'Ezhome-1', 'JK-59' and 'FL-478' recorded the lowest root volume. At flowering stage 'JK-59', 'Chettivirippu' and 'JK-15' recorded the maximum root volume and 'FL-478' recorded the lowest root volume.

In high-saline condition, at seedling stage 'Nona Bokra' recorded the highest root volume and at flowering stage 'IR-29' exhibited the highest root volume and was on par with seven rice genotypes. 'Jyothi' and 'Ezhome-1' recorded the lowest root volume at seedling and flowering stages respectively.

Table 15. Mean performances of rice genotypes for root volume (ml^3)

	Seedling stage (ml^3)			Flowering stage (ml^3)		
Genotypes	Non-saline	Low-saline	High-saline	Non-saline	Low-saline	High-saline
Kuthiru	5.0	7.0	7.3	8.7	9.5	6.5
Orkayama	9.5*	6.5	6.4	7.2	9.0	6.2
Ezhome-1	4.4	5.0	5.6	8.7	9.0	4.0
Ezhome-2	5.0	6.0	7.5	4.0	6.0	6.2
Ezhome-3	5.0	6.5	7.6	8.7	8.7	11.2
JO 532-1	3.9	6.0	6.7	5.0	5.0	6.0
JK-15	5.0	7.0	7.2	7.5	11.5*	8.7
JK-59	2.6	5.0	7.2	11.2*	12.5*	6.2
JO-583	2.6	5.0	7.4	8.7	6.5	11.2
Chettivirippu	4.1	8.0	7.3	7.2	12.5*	10.7
Cherivirippu	4.1	8.5*	8.7	8.7	8.7	4.5
Vytilla-1	4.5	6.0	6.4	7.5	6.2	6.2
Vytilla-6	5.0	5.5	5.4	8.7	9.0	11.2
Pokkali	5.5	5.5	5.9	7.7	8.9	6.5
FL-478	7.0	5.0	6.2	6.3	4.2	7.0
Nona Bokra	7.9	7.5	9.5*	7.5	9.5	10.5
IR-29	6.9	5.5	7.4	6.2	8.7	12.5*
Jyothi	8.0	5.5	4.6	10.0	5.5	8.75
CV (%)	**13.8**	**14.66**	**4.23**	**20.44**	**24.46**	**26.14**
C.D. (0.05)	**1.55**	**1.91**	0.62	3.35	4.33	4.43
C.D. (0.05) G×E			**1.41**			**3.81**

(*= Significant)

At seedling stage in the case of genotypes 'Orkayama', 'FL-478' and 'Jyothi' showed the highest root volume in non-saline condition than in saline conditions. 'Chettivirippu', 'Cherivirippu', 'Vytilla-6' and 'Nona Bokra' showed the highest root volume in low-saline condition and remaining all other genotypes showed the highest root volume in high-saline condition. At flowering stage the genotypes 'Vytilla-1' and 'Jyothi' the highest root volume in non-saline condition. 'Kuthiru', 'Orkayama', 'Ezhome-1', 'JK-15', 'JK-59', 'Chettivirippu', 'Cherivirippu' and 'Pokkali' showed the highest root volume in low-saline condition and remaining all other genotypes showed the highest root volume in high-saline condition.

4.2.2.9. Root shoot ratio at seedling and flowering stages

Root shoot ratio at seedling and flowering stages under different stress conditions are presented in Table 16. Root shoot ratio in different soil conditions for 18 rice genotypes varies from 0.140-3.52 at seedling stage and 0.325-3.511 at flowering stage. In non-saline condition, at seedling stage 'JO-532-1' exhibited the highest root shoot ratio which was on par with 'Kuthiru', 'Ezhome-2' and 'IR-29'. At flowering stage 'Kuthiru' and 'IR-29' showed the highest root shoot ratio. 'Vytilla-1' and 'Cherivirippu' recorded the lowest root culm ratio at seedling and flowering stages respectively.

In low-saline condition, result was non-significant at seedling stage and at flowering stage 'Jyothi' showed the highest root shoot ratio which was on par with that of 'Kuthiru' and 'Cherivirippu'. 'Vytilla-1' showed the lowest root shoot ratio.

In high-saline condition, result was non-significant at seedling stage and at flowering stage 'Pokkali' recorded the highest root shoot ratio which was on par with that of 'Kuthiru'. 'Jyothi' variety recorded the lowest root shoot ratio.

At seedling stage the interaction effect was non-significant. At flowering stage the genotypes 'JO-532-1', 'JK-15', 'JO-583', 'Chettivirippu', 'Cherivirippu', FL-478' and 'Jyothi' showed the highest root shoot ratio in low-saline condition and remaining all other genotypes showed the highest root shoot ratio in high-saline condition.

Table 16. Mean performances of rice genotypes for root shoot ratio

Genotypes	Seedling stage			Flowering stage		
	Non-saline	Low-saline	High-saline	Non-saline	Low-saline	High-saline
Kuthiru	1.40	3.04	2.05	1.28*	2.25	2.84
Orkayama	1.35	1.46	1.62	0.73	1.54	1.77
Ezhome-1	0.82	1.12	2.07	0.51	1.12	1.21
Ezhome-2	1.35	1.01	0.79	0.63	1.03	1.18
Ezhome-3	0.79	1.25	0.59	0.61	0.93	1.76
JO 532-1	2.14*	1.08	3.77	0.36	1.32	0.88
JK-15	0.50	1.11	1.15	0.39	1.18	1.05
JK-59	0.18	1.07	1.47	0.35	0.79	1.25
JO-583	0.52	0.91	0.78	0.57	1.45	1.22
Chettivirippu	0.38	0.66	1.42	0.38	1.12	0.89
Cheriviruppu	0.39	2.18	1.31	0.32	2.19	0.99
Vytilla-1	0.14	0.72	0.95	0.40	0.41	1.34
Vytilla-6	0.21	1.19	3.51	0.44	0.93	1.06
Pokkali	0.41	3.52	1.10	0.41	1.20	3.51*
FL-478	0.41	1.25	1.71	0.39	1.06	1.02
Nona Bokra	0.40	0.83	1.34	0.37	0.82	1.05
IR-29	1.38	2.77	0.95	1.25*	2.03	2.26
Jyothi	0.37	2.39	0.63	0.47	2.31*	0.78
CV (%)	**56.95**	**65.61**	**65.50**	33.42	9.69	**23.45**
C.D. (0.05)	**0.88**	NS	NS	0.39	0.27	0.72
C.D. (0.05) G×E			NS			0.47

(*= Significant)

4.2.3. Biochemical parameters

4.3.3.1. Proline content in root, culm and leaf at seedling and flowering stages

Proline content in root of 18 rice genotypes at seedling and flowering stage was presented in Table 17. In non-saline condition, the genotype 'JO-583' recorded more proline content in root at both seedling and flowering stages. In low-saline condition, the genotype 'JK-59' recorded the highest proline content in root at both seedling and flowering stages. In high-saline condition, the genotype

'Orkayama' recorded the highest proline content in root followed by 'Ezhome-2', 'JK-59', 'JO-583', 'JK-15', 'Kuthiru' and 'Ezhome-1' at both seedling and flowering stages. The genotype 'Jyothi' recorded the lowest proline content in root at both seedling and flowering stages in all three conditions.

Table 17. Root proline content in rice genotypes

Genotypes	Seedling stage (mg g^{-1})			Flowering stage (mg g^{-1})		
	Non-saline	Low-saline	High-saline	Non-saline	Low-saline	High-saline
Kuthiru	41.21	39.58	43.85	42.21	41.08	44.85
Orkayama	42.3	40.59	46.95*	42.81	41.59	47.95*
Ezhome-1	43.42	41.60	43.06	44.42	42.60	43.56
Ezhome-2	42.24	41.84	46.08	43.24	42.84	47.08
Ezhome-3	44.16	42.61	41.16	45.16	43.61	41.66
JO 532-1	42.77	41.69	42.96	43.77	42.69	43.96
JK-15	44.38	43.31	44.13	45.38	44.31	44.63
JK-59	47.49	45.13*	46.31	48.49	46.13*	47.31
JO-583	48.50*	44.16	45.37	49.50*	45.66	46.37
Chettivirippu	37.91	33.21	38.12	38.91	34.21	39.12
Cherivirippu	39.82	37.43	36.34	41.32	38.43	37.34
Vytilla-1	42.73	40.65	39.56	43.73	42.15	40.56
Vytilla-6	39.64	37.87	34.78	40.64	38.87	35.78
Pokkali	38.55	37.09	36.90	39.55	38.09	38.40
FL-478	36.18	36.10	34.01	37.18	36.60	34.51
Nona Bokra	34.72	33.27	38.23	35.72	34.27	38.73
IR-29	18.36	14.54	18.45	19.36	15.54	19.45
Jyothi	16.54	12.76	16.67	17.54	14.26	18.17
CV (%)	**0.42**	**1.81**	**0.21**	**0.73**	**1.93**	**1.14**
C.D. (0.05)	**0.35**	**1.40**	**0.17**	**0.62**	**1.54**	**0.95**
C.D. (0.05) G×E			**0.027**			**1.39**

(*= Significant)

Proline content in culm of 18 rice genotypes was presented in Table 18. In non-saline condition, the genotype 'JK-15' recorded more proline content in culm at both seedling and flowering stages. In low-saline and high-saline conditions, the genotype 'JK-59' recorded the highest proline content in culm at both seedling and flowering stages. In high-saline condition, the genotype 'JO-583' recorded the highest proline content in culm at flowering stage. 'Jyothi' recorded the lowest proline content in culm at both seedling and flowering stages in all three conditions.

Proline content in leaf of 18 rice genotypes was presented in Table 19. The genotype 'JK-59' recorded the highest proline content in leaf at seedling and flowering stages in all three conditions namely non-saline, low-saline and high-saline condition. 'JO-583' recorded significantly the highest proline content in leaf at seedling and flowering stages in non-saline condition. 'Jyothi' recorded the lowest proline content in leaf at both seedling and flowering stages in all three soil conditions.

Table 18. Culm proline content of rice genotypes

Genotypes	Seedling stage (mg g^{-1})			Flowering stage (mg g^{-1})		
	Non-saline	Low-saline	High-saline	Non-saline	Low-saline	High-saline
Kuthiru	59.32	56.34	60.34	60.82	57.34	61.34
Orkayama	59.23	57.46	61.46	60.23	58.46	62.46
Ezhome-1	60.24	58.43	62.43	61.24	59.43	63.43
Ezhome-2	59.84	58.86	62.86	60.84	60.36	63.86
Ezhome-3	62.21	59.10	63.10	63.21	60.60	64.10
JO 532-1	62.32	58.89	62.89	63.32	59.89	63.89
JK-15	63.38*	60.21	64.21	64.38*	61.21	65.21
JK-59	61.48	62.81*	66.31*	62.48	63.81*	67.31*
JO-583	62.63	61.61	65.61	63.63	62.61	67.11*
Chettivirippu	56.73	52.71	56.61	57.73	53.71	57.61
Cherivirippu	56.86	54.61	58.72	57.86	55.61	60.22
Vytilla-1	59.76	57.13	61.32	60.76	58.13	62.32
Vytilla-6	58.86	54.11	58.43	59.86	55.11	59.93
Pokkali	56.72	54.21	58.83	57.72	55.21	59.83
FL-478	53.12	53.31	57.34	54.12	54.31	58.34
Nona Bokra	52.24	50.12	54.64	53.24	51.12	55.64
IR-29	29.32	26.22	30.69	30.82	27.22	31.69
Jyothi	26.14	24.32	28.49	27.64	25.32	27.99
CV (%)	**0.003**	**0.31**	**0.19**	**0.48**	**0.54**	**0.85**
C.D. (0.05)	**0.003**	**0.35**	**0.23**	**0.57**	**0.62**	**1.05**
C.D. (0.05) G×E			**0.05**			**1.37**

(*= Significant).

All the genotypes showed high proline content of root, shoot and leaf in high-saline condition than in low-saline and non-saline conditions at both seedling and flowering stages except for leaf proline content at flowering stage which was non-significance.

Table 19. Leaf proline content in rice genotypes

Genotypes	Seedling stage (mg g^{-1})			Flowering stage (mg g^{-1})		
	Non-saline	Low-saline	High-saline	Non-saline	Low-saline	High-saline
Kuthiru	56.23	54.43	58.43	57.23	56.43	59.94
Orkayama	57.32	55.64	59.64	58.32	56.64	60.65
Ezhome-1	58.42	56.34	60.34	58.92	57.34	61.85
Ezhome-2	57.48	56.68	60.68	58.48	57.68	61.69
Ezhome-3	59.12	57.01	61.01	60.62	58.01	62.02
JO 532-1	57.32	56.98	60.98	58.32	57.98	61.99
JK-15	59.38	58.12	62.12	60.38	59.12	63.13
JK-59	62.484	60.13*	64.13*	63.48*	61.13*	65.64*
JO-583	63.63*	59.16	63.16	64.63*	60.16	64.17
Chettivirippu	52.73	50.17	54.16	53.73	52.17	56.17
Cherivirippu	54.86	52.16	56.17	55.86	53.16	57.18
Vytilla-1	57.76	55.31	59.13	58.76	56.31	60.14
Vytilla-6	56.86	52.11	56.14	57.86	53.1	57.15
Pokkali	53.72	52.12	56.18	54.72	53.62	57.19
FL-478	51.12	51.13	55.13	52.12	52.13	56.14
Nona Bokra	49.24	48.21	52.16	50.74	49.21	53.17
IR-29	27.32	24.22	28.96	28.32	26.22	29.97
Jyothi	24.14	22.23	26.18	25.14	24.23	27.19
CV (%)	**1.25**	**0.004**	**0.003**	**1.36**	**1.15**	**0.72**
C.D. (0.05)	**1.41**	**0.004**	**0.004**	**1.56**	**1.28**	**0.86**
C.D. (0.05) G×E			**0.09**			**NS**

(*= Significant)

4.2.3.2. Calcium, Sodium, Potassium, Chloride and Sulphate content in root, culm and leaf at seedling and flowering stages

In non-saline condition, 'Kuthiru' recorded the highest root calcium content followed by 'Pokkali' and 'Ezhome-3' and the lowest calcium content was recorded for 'Ezhome-1' and 'Ezhome-2' at seedling and flowering stages respectively. In low-saline and high-saline conditions, calcium content in root was significantly higher for 'IR-29' followed by 'Kuthiru' and 'Ezhome-2' at seedling and flowering stages. 'JK-15' and 'Cheriviripppu' recorded the lowest calcium content which was on par with that of 'Vytilla-1', 'FL-478' and 'Orkayama' (Table 20).

The genotypes 'Ezhome-1', 'Ezhome-2' 'JO-532-1', 'Nona Bokra' and 'IR-29' recorded the highest root calcium content in high-saline condition and remaining all other genotypes showed the highest root calcium content in non-saline condition at both seedling and flowering stages.

Table 20. Mean root calcium content of rice genotypes

Genotypes	Seedling stage (%)			Flowering stage (%)		
	Non-saline	Low-saline	High-saline	Non-saline	Low-saline	High-saline
Kuthiru	2.37*	0.72	0.82	2.36*	0.77	0.86
Orkayama	0.61	0.14	0.24	0.68	0.19	0.29
Ezhome-1	0.13	0.17	0.27	0.17	0.22	0.32
Ezhome-2	0.13	0.61	0.71	0.19	0.66	0.76
Ezhome-3	1.08	0.52	0.62	1.12	0.57	0.67
JO 532-1	0.24	0.22	0.32	0.24	0.27	0.37
JK-15	0.88	0.12	0.14	0.75	0.17	0.19
JK-59	0.80	0.28	0.38	0.78	0.34	0.43
JO-583	0.64	0.27	0.27	0.67	0.32	0.32
Chettivirippu	0.56	0.21	0.31	0.58	0.26	0.36
Cheriviripppu	0.69	0.12	0.12	0.67	0.17	0.19
Vytilla-1	0.42	0.13	0.18	0.43	0.18	0.23
Vytilla-6	0.49	0.16	0.21	0.49	0.21	0.26
Pokkali	1.13	0.16	0.17	1.14	0.21	0.22
FL-478	0.21	0.17	0.16	0.43	0.20	0.22
Nona Bokra	0.27	0.36	0.46	0.27	0.41	0.51
IR-29	0.32	1.21*	1.51*	0.35	1.17*	1.57*
Jyothi	0.58	0.41	0.48	0.57	0.46	0.53
CV (%)	13.01	4.71	3.65	6.35	4.19	3.05
C.D. (0.05)	0.17	0.03	0.03	0.09	0.03	0.03
C.D. (0.05) G×E			0.03			0.05

(*= Significant)

In non-saline condition, 'Ezhome-1', 'JK-15' and 'Jyothi' recorded the highest culm calcium and 'Kuthiru' and 'Ezhome-2' recorded the lowest culm calcium at seedling stage and flowering stages. In low-saline condition, 'Orkayama' showed more culm calcium content and 'Chettivirippu' recorded the lowest calcium content and was on par with that of 'Cherivirippu', 'Vytilla-6', 'Pokkali' and 'Ezhome-1' at seedling stage and result was non-significant at flowering stage. In high-saline condition, culm calcium was found to be significantly higher in 'Orkayama'. 'Chettivirippu' and 'Cherivirippu' exhibited the lowest calcium content in culm at both seedling and flowering stages (Table 21).

Table 21. Mean culm calcium content of rice genotypes

Genotypes	Seedling stage (%)			Flowering stage (%)		
	Non-saline	Low-saline	High-saline	Non-saline	Low-saline	High-saline
Kuthiru	0.30	0.23	0.33	0.31	0.28	0.38
Orkayama	0.49	0.41*	0.51*	0.48	0.46	0.57*
Ezhome-1	1.36*	0.12	0.17	1.19	0.17	0.23
Ezhome-2	0.24	0.22	0.32	0.22	0.27	0.37
Ezhome-3	0.86	0.19	0.29	0.87	0.24	0.34
JO 532-1	0.61	0.18	0.23	0.58	0.23	0.28
JK-15	1.30*	0.16	0.21	1.23*	0.21	0.36
JK-59	0.77	0.33	0.43	1.02	0.38	0.48
JO-583	0.83	0.16	0.17	0.97	0.21	0.22
Chettivirippu	0.72	0.11	0.10	0.73	0.15	0.16
Cherivirippu	0.67	0.11	0.11	0.72	0.43	0.16
Vytilla-1	0.64	0.14	0.14	0.72	0.19	0.19
Vytilla-6	0.66	0.12	0.12	0.70	0.17	0.17
Pokkali	0.88	0.12	0.12	0.79	0.15	0.17
FL-478	0.85	0.27	0.37	0.75	0.31	0.42
Nona Bokra	0.74	0.28	0.38	0.75	0.33	0.43
IR-29	0.52	0.14	0.24	0.62	0.18	0.29
Jyothi	1.30*	0.24	0.34	1.25*	0.29	0.39
CV (%)	**8.67**	**6.12**	**4.67**	**14.21**	**35.93**	**3.76**
C.D. (0.05)	**0.14**	**0.03**	**0.03**	**0.23**	**NS**	**0.03**
C.D. (0.05) G×E			**0.08**			**0.13**

(*= Significant)

All the genotypes recorded the highest culm calcium content in non-saline condition than in saline condition except 'Orkayama' and 'Ezhome-2' which recorded the highest culm calcium content in high-saline condition at both seedling and flowering stages.

Table 22. Mean leaf calcium content of rice genotypes

Genotypes	Seedling stage (%)			Flowering stage (%)		
	Non-saline	Low-saline	High-saline	Non-saline	Low-saline	High-saline
Kuthiru	0.35.	0.23	0.28	0.33	0.28	0.29
Orkayama	0.84	0.45	0.49	0.89	0.52	0.48
Ezhome-1	0.67	0.52	0.53	0.64	0.58	0.54
Ezhome-2	0.68	0.51	0.53	0.73	0.56	0.52
Ezhome-3	1.36	0.51	0.50	1.39	0.55	0.50
JO 532-1	0.60	0.25	0.25	0.59	0.31	0.27
JK-15	1.91	0.60	0.27	1.97	0.61	0.25
JK-59	0.93	0.21	0.82*	0.96	0.27	0.83*
JO-583	2.09*	0.23	0.24	2.23*	0.28	0.24
Chettivirippu	1.12	0.32	0.33	1.28	0.38	0.31
Cherivirippu	1.59	0.16	0.19	1.64	0.21	0.16
Vytilla-1	0.71	0.10	0.17	0.76	0.11	0.16
Vytilla-6	0.86	0.21	0.16	0.91	0.27	0.17
Pokkali	1.23	0.28	0.17	1.14	0.33	0.16
FL-478	1.29	0.73*	0.33	1.19	0.76*	0.33
Nona Bokra	1.24	0.54	0.52	1.38	0.56	0.52
IR-29	0.97	0.57	0.64	1.05	0.63	0.61
Jyothi	1.33	0.31	0.36	1.30	0.36	0.36
CV (%)	**4.22**	**3.44**	**2.17**	**3.45**	**3.01**	**2.25**
C.D. (0.05)	**0.09**	**0.03**	**0.02**	**0.08**	**0.02**	**0.01**
C.D. (0.05) G×E			**0.03**			**0.05**

(*= Significant)

In non-saline condition, 'JO-583' recorded the highest leaf calcium content and 'Kuthiru' recorded the lowest leaf calcium content at seedling and flowering stages. In low-saline condition, 'FL-478' followed by 'JK-15' exhibited the highest leaf calcium content and 'Vytilla-1' showed the lowest leaf calcium content at seedling and flowering stages. In high-saline condition, 'JK-59' recorded the highest leaf calcium and 'Vytilla-6', 'Vytilla-1', 'Cherivirippu' and

'Pokkali' recorded the lowest calcium content at seedling and flowering stages (Table 22).

All the genotypes recorded the highest leaf calcium content in non-saline condition than in saline conditions at both seedling and flowering stages.

Table 23. Mean root sodium content of rice genotypes

Genotypes	Seedling stage (%)			Flowering stage (%)		
	Non-saline	Low-saline	High-saline	Non-saline	Low-saline	High-saline
Kuthiru	0.21	0.59	0.75	0.25	0.62	0.77
Orkayama	0.23	0.92*	1.03*	0.26	0.97*	1.12*
Ezhome-1	0.21	0.63	0.85	0.26	0.68	0.77
Ezhome-2	0.18	0.58	0.78	0.20	0.62	0.79
Ezhome-3	0.23	0.56	0.67	0.22	0.61	0.72
JO 532-1	0.32	0.46	0.97*	0.32	0.48	1.07*
JK-15	0.24	0.73	0.67	0.24	0.79	0.74
JK-59	0.26	0.49	0.86	0.27	0.53	0.91
JO-583	0.15	0.62	0.86	0.17	0.68	0.92
Chettivirippu	0.19	0.63	0.99*	0.21	0.66	0.99
Cheriviripp u	0.24	0.77	0.68	0.28	0.71	0.63
Vytilla-1	0.29	0.47	0.77	0.38	0.51	0.77
Vytilla-6	0.25	0.61	0.83	0.26	0.66	0.86
Pokkali	0.23	0.50	0.67	0.22	0.56	0.75
FL-478	0.25	0.38	0.63	0.25	0.43	0.63
Nona Bokra	0.15	0.52	0.77	0.17	0.57	0.82
IR-29	0.22	0.42	0.61	0.24	0.52	0.63
Jyothi	0.41*	0.49	0.62	0.41*	0.54	0.60
CV (%)	**12.09**	**3.39**	**4.05**	**5.78**	**2.03**	**3.66**
C.D. (0.05)	**0.06**	**0.04**	**0.06**	**0.03**	**0.02**	**0.06**
C.D. (0.05) G×E			**0.06**			**0.04**

(*= Significant)

In non-saline condition, 'Jyothi' recorded the highest root sodium content at seedling and flowering stages. 'JO-583' and 'Nona Bokra' recorded the lowest root sodium content at seedling and flowering stages respectively. In low-saline condition, root sodium content was significantly higher in 'Orkayama' at seedling and flowering stages. 'IR-29' and 'FL-478' recorded the lowest sodium content respectively. In high-saline condition root sodium content was the highest in

'Orkayama', 'Chettivirippu' and 'JO-532-1' at seedling and flowering stages. 'Cherivirippu', 'Pokkali', 'Ezhome-3', 'JK-15', 'FL-478', 'Jyothi' and 'IR-29' recorded the lowest root sodium content at seedling and flowering stages (Table 23).

All the genotypes recorded the highest root sodium content in high-saline condition than in non-saline and low-saline condition except 'Cherivirippu' which recorded the highest root sodium content in low-saline condition at both seedling and flowering stages.

Table 24. Mean culm sodium content in of rice genotypes

Genotypes	Seedling stage (%)			Flowering stage (%)		
	Non-saline	Low-saline	High-saline	Non-saline	Low-saline	High-saline
Kuthiru	0.35	0.96	1.07	0.38	1.00	1.12
Orkayama	0.80*	0.61	0.75	0.83*	0.65	0.82
Ezhome-1	0.35	0.92	1.01	0.38	0.96	1.03
Ezhome-2	0.42	0.60	0.78	0.42	0.66	0.74
Ezhome-3	0.61	0.85	0.98	0.59	0.91	0.99
JO 532-1	0.54	1.21*	1.36*	0.57	1.26*	1.38*
JK-15	0.37	0.80	0.97	0.38	0.86	1.02
JK-59	0.35	0.73	0.92	0.37	0.76	0.96
JO-583	0.26	1.11	1.25	0.26	1.12	1.25
Chettivirippu	0.22	1.08	1.22	0.33	1.12	1.30
Cherivirippu	0.41	0.90	1.15	0.41	0.97	1.20
Vytilla-1	0.37	0.62	0.83	0.37	0.68	0.86
Vytilla-6	0.36	0.70	0.82	0.37	0.77	0.83
Pokkali	0.37	1.12	1.27	0.38	1.17	1.30
FL-478	0.56	0.77	0.95	0.60	0.84	0.97
Nona Bokra	0.47	1.07	1.18	0.49	1.11	1.21
IR-29	0.32	0.57	0.83	0.32	0.62	0.85
Jyothi	0.55	0.83	1.02	0.52	0.86	1.02
CV (%)	**8.15**	**2.39**	**6.54**	**3.26**	**1.40**	**5.86**
C.D. (0.05)	**0.07**	**0.04**	**0.14**	**0.03**	**0.02**	**0.13**
C.D. (0.05) G×E			**0.06**			**0.07**

(*= Significant)

In non-saline condition, 'Orkayama' recorded the highest culm sodium content at seedling and flowering stages. 'Chettivirippu' at seedling stage and

'JO-583' at flowering stage recorded the lowest culm sodium content. In low-saline condition, 'JO-532-1' showed the highest culm sodium content at seedling and flowering stages. At seedling stage 'IR-29' recorded the lowest sodium content which was on par with that of 'Orkayama' and 'Ezhome-2' and at flowering stage 'Cherivirippu' recorded the lowest sodium content. In high-saline condition, culm sodium content was the highest in 'JO-532-1' at seedling and flowering stages and was on par with that of 'Chettivirippu', 'Pokkali' and 'JO-583'. At seedling and flowering stages 'Orkayama' recorded the lowest sodium content in culm which was on par with that of 'Ezhome-2', 'Vytilla-6', 'IR-29' and 'Vytilla-1' (Table 24).

Table 25. Mean leaf sodium content of rice genotypes

Genotypes	Seedling stage (%)			Flowering stage (%)		
	Non-saline	Low-saline	High-saline	Non-saline	Low-saline	High-saline
Kuthiru	0.19	0.57	0.67	0.24	0.60	0.75
Orkayama	0.16	0.99	1.09	0.18	1.01	1.16
Ezhome-1	0.17	0.91	1.02	0.18	0.97	1.15
Ezhome-2	0.12	0.71	0.81	0.16	0.79	0.83
Ezhome-3	0.27	0.92	1.05	0.28	0.97	1.12
JO 532-1	0.43*	0.71	0.82	0.49*	0.75	0.92
JK-15	0.25	0.68	0.78	0.28	0.73	0.84
JK-59	0.22	0.62	0.72	0.22	0.66	0.84
JO-583	0.17	1.16*	1.08	0.18	1.24	1.22*
Chettivirippu	0.18	0.56	0.66	0.20	0.63	0.73
Cherivirippu	0.26	0.61	0.75	0.27	0.65	0.82
Vytilla-1	0.16	0.72	0.86	0.20	0.77	0.89
Vytilla-6	0.17	0.71	0.83	0.20	0.75	0.82
Pokkali	0.18	0.67	0.77	0.18	0.71	0.85
FL-478	0.26	1.08	1.22*	0.29	0.60	1.27*
Nona Bokra	0.20	0.77	0.91	0.22	0.84	0.92
IR-29	0.18	0.83	0.97	0.19	0.87	0.99
Jyothi	0.21	0.76	0.91	0.22	0.81	1.05
CV (%)	**6.42**	**2.47**	**4.56**	**3.10**	**22.38**	**2.66**
C.D. (0.05)	**0.02**	**0.04**	**0.08**	**0.01**	**NS**	**0.05**
C.D. (0.05) G×E			**0.04**			**0.04**

(*= Significant)

All the genotypes recorded the highest culm sodium content in high-saline condition except 'Orkayama' which recorded the highest culm sodium content in non-saline condition at both seedling and flowering stages.

In non-saline condition 'JO-532-1' recorded the highest leaf sodium content and 'Ezhome-2' recorded the lowest leaf sodium content at seedling and flowering stages. In low-saline condition, at seedling stage 'JO-583' recorded the highest leaf sodium content and 'Chettivirippu' showed the lowest leaf sodium content which was on par with that of 'Kuthiru' at seedling stage. Result was non-significant at flowering stage. In high-saline condition, 'FL-478' recorded the highest leaf sodium followed by 'Orkayama', 'JO-583', 'Ezhome-3' and 'Ezhome-1' at seedling stage and at flowering stage 'JO-583' and 'FL-478' recorded significantly high in leaf sodium content. 'Chettivirippu' and 'Kuthiru' recorded the lowest sodium content at seedling and flowering stages (Table 25).

All the genotypes recorded the highest leaf sodium content in high-saline condition except 'JO-583' which recorded the highest leaf sodium content in low-saline condition at both seedling and flowering stages.

In non-saline condition, 'FL-478' recorded the highest root potassium content at both seedling and flowering stages. 'Ezhome-2' at seedling stage and 'JO-583' at flowering stage recorded the lowest root potassium content. In low-saline condition, at seedling and flowering stages 'Kuthiru' recorded the highest potassium content and was on par with 'JO-583', 'Orkayama' and 'JO-532-1'. 'Jyothi' recorded the lowest root potassium content at both seedling and flowering stage. In high-saline condition, 'Kuthiru' followed by 'JO-532-1', 'Chettivirippu', 'Orkayama', 'JO-583', 'IR-29' and 'Vytilla-6' recorded the highest root potassium content at seedling stage and at flowering stage 'Kuthiru', 'Chettivirippu', 'Orkayama', 'JO-532-1' and 'JO583' recorded high root potassium content. 'Jyothi' recorded the lowest root potassium content at seedling and flowering stages (Table 26).

Among the three soil conditions, all the genotypes recorded the highest root potassium content in high-saline condition except 'Vytilla-1', 'FL-478' and 'Jyothi' which recorded the highest root potassium content in non-saline condition at both seedling and flowering stages.

Table 26. Mean root potassium content of rice genotypes

Genotypes	Seedling stage (%)			Flowering stage (%)		
	Non-saline	Low-saline	High-saline	Non-saline	Low-saline	High-saline
Kuthiru	0.65	1.17*	1.25*	0.62	1.22*	1.24*
Orkayama	0.57	1.05	1.12	0.61	1.07	1.19*
Ezhome-1	0.55	0.73	0.84	0.5	0.83	0.95
Ezhome-2	0.41	0.74	0.98	0.55	0.74	1.00
Ezhome-3	0.44	0.56	0.78	0.48	0.63	0.84
JO 532-1	0.77	1.02	1.17	0.85	1.10	1.19*
JK-15	0.60	0.66	0.72	0.57	0.71	0.96
JK-59	0.55	0.66	0.81	0.60	0.72	0.88
JO-583	0.45	1.05	1.12	0.35	1.08	1.18*
Chettivirippu	0.53	0.91	1.14	0.53	0.94	1.23*
Cherivirippu	0.55	0.69	0.83	0.60	0.72	0.96
Vytilla-1	0.92	0.66	0.83	0.50	0.69	0.96
Vytilla-6	0.60	0.74	1.03	0.69	0.84	1.05
Pokkali	0.62	0.66	0.83	0.67	0.68	0.78
FL-478	1.23*	0.83	0.93	1.21*	0.81	0.89
Nona Bokra	0.58	0.68	0.91	0.57	0.80	0.92
IR-29	0.56	0.77	1.02	0.58	0.80	1.05
Jyothi	0.73	0.46	0.60	0.76	0.49	0.62
CV (%)	**7.29**	**7.57**	**3.58**	**21.93**	**6.05**	**4.50**
C.D. (0.05)	**0.09**	**0.12**	**0.07**	**0.29**	**0.10**	**0.09**
C.D. (0.05) G×E			**0.09**			**0.10**

(*= Significant)

In non-saline condition, 'Cherivirippu' recorded the highest culm potassium content at seedling and flowering stages and 'JK-59' recorded the lowest potassium content at both seedling and flowering stages. In low-saline condition, at seedling stage 'Nona Bokra', 'Pokkali' and 'Ezhome-1' recorded the highest culm potassium content and at flowering stage 'Nona Bokra' recorded high culm potassium content. At seedling and flowering stages 'JK-59', 'IR-29', 'JK-15' and 'Orkayama' recorded low culm potassium content. In high-saline condition, 'Nona Bokra' exhibited significantly the highest culm potassium content at seedling and flowering stages. At seedling stage 'Orkayama' recorded the lowest potassium content in culm and was on par with 'IR-29', 'JK-15', 'JK-59' and 'Vytilla-1' and at flowering stage also 'Orkayama' recorded the lowest potassium content in culm which was on par with 'Ezhome-2', 'Jyothi' and 'IR-29' (Table 27).

All the genotypes recorded the highest culm potassium content in non-saline condition except 'JO-583' and 'Nona Bokra' which recorded the highest culm potassium content in high-saline condition at both seedling and flowering stages.

Table 27. Mean culm potassium content of rice genotypes

Genotypes	Seedling stage (%)			Flowering stage (%)		
	Non-saline	Low-saline	High-saline	Non-saline	Low-saline	High-saline
Kuthiru	1.95	1.11	1.20	1.95	1.13	1.25
Orkayama	1.35	0.74	0.95	1.35	0.72	0.93
Ezhome-1	1.74	1.62*	1.62	1.76	1.69	1.72
Ezhome-2	1.46	0.77	1.19	1.37	0.89	1.04
Ezhome-3	1.59	1.01	1.16	1.56	1.11	1.19
JO 532-1	1.95	1.27	1.41	1.97	1.30	1.45
JK-15	2.72	0.69	1.02	3.37	0.79	1.15
JK-59	1.17	0.75	1.07	1.22	0.74	1.04
JO-583	1.24	1.33	1.35	1.34	1.31	1.27
Chettivirippu	3.81	1.12	1.36	4.25	1.21	1.29
Cheriviri ppu	4.43*	1.13	1.32	5.62*	1.16	1.38
Vytilla-1	1.97	0.96	1.08	1.87	0.99	1.09
Vytilla-6	1.65	0.92	1.10	1.82	0.94	1.07
Pokkali	1.80	1.63*	1.71	1.90	1.66	1.80
FL-478	1.83	1.35	1.57	1.79	1.39	1.65
Nona Bokra	1.97	1.72*	2.00*	1.90	1.83*	1.97*
IR-29	1.67	0.74	0.99	1.75	0.75	1.02
Jyothi	1.82	1.08	1.28	1.75	1.11	1.33
CV (%)	**13.78**	**6.31**	**5.06**	**6.70**	**4.43**	**4.10**
C.D. (0.05)	**0.58**	**0.14**	**0.13**	**0.30**	**0.10**	**0.11**
C.D. (0.05) G×E			**0.34**			**0.19**

(*= Significant)

Table 28. Mean leaf potassium content of rice genotypes

Genotypes	Seedling stage (%)			Flowering stage (%)		
	Non-saline	Low-saline	High-saline	Non-saline	Low-saline	High-saline
Kuthiru	4.12*	0.57	0.72	3.25	0.62	0.72
Orkayama	1.57	1.07	1.17	1.75	1.10	1.25
Ezhome-1	1.22	1.45*	1.65*	1.32	1.37*	1.85*
Ezhome-2	1.70	1.09	1.25	1.82	1.19	1.24
Ezhome-3	1.82	1.15	1.26	1.92	1.13	1.42
JO 532-1	1.75	1.17	1.36	1.82	1.17	1.24
JK-15	1.66	1.37	1.57*	1.65	1.32	1.62
JK-59	1.74	1.16	1.55	1.87	1.27	1.70
JO-583	1.29	1.31	1.44	1.32	1.25	1.43
Chettivirippu	3.93*	1.14	1.27	4.81*	1.14	1.32
Cherivirippu	3.12	1.19	1.30	4.12	1.14	1.29
Vytilla-1	1.80	1.10	1.29	1.72	1.05	1.29
Vytilla-6	1.67	0.95	1.07	1.92	0.88	1.30
Pokkali	1.27	1.26	1.55	1.25	1.21	1.63
FL-478	1.97	1.36	1.58*	1.95	1.32	1.72
Nona Bokra	1.76	1.22	1.33	1.85	1.22	1.45
IR-29	1.72	1.13	1.21	1.83	1.13	1.28
Jyothi	1.96	0.59	0.67	1.98	0.58	0.75
CV (%)	**7.17**	**6.56**	**4.52**	**20.33**	**4.54**	**5.32**
C.D. (0.05)	**0.30**	**0.15**	**0.12**	**0.91**	**0.10**	**0.15**
C.D. (0.05) G×E			**0.19**			**0.51**

(*= Significant)

In non-saline condition, at seedling stage 'Kuthiru' and 'Chettivirippu' recorded the highest leaf potassium content. At flowering stage 'Chettivirippu' recorded the highest leaf potassium content which was on par with that of 'Cherivirippu'. At seedling stage 'Ezhome-1' recorded the lowest leaf potassium content and at flowering stage all genotypes shows the lowest leaf potassium content except 'Chettivirippu' and 'Cherivirippu'. In low-saline condition, at seedling and flowering stages 'Ezhome-1' recorded the highest leaf potassium and on par with that of 'JK-15', 'FL-478', 'JK-59' and 'JO-583'. 'Kuthiru' and 'Jyothi' recorded the lowest leaf potassium content at seedling and flowering stages. In high-saline condition, at seedling stage'Ezhome-1', 'FL-478' and 'JK-

15' recorded high leaf potassium content and was found to be on par with that of 'JK-59' and 'Pokkali'. At flowering stage 'Ezhome-1'recorded high potassium content in leaf and was found to be on par with that of 'FL-478' and 'JK-59'. 'Kuthiru' and 'Jyothi' recorded low leaf potassium content at both seedling and flowering stages (Table 28).

Among three soil conditions, all the genotypes recorded the highest leaf potassium content in non-saline condition except 'JO-583' and 'Ezhome-1'which recorded the highest leaf potassium content in high-saline condition at both seedling and flowering stages.

Table 29. Mean root chloride content of rice genotypes

	Seedling stage (%)			Flowering stage (%)		
Genotypes	Non-saline	Low-saline	High-saline	Non-saline	Low-saline	High-saline
Kuthiru	0.98	1.02	1.10	1.02	1.22	1.09
Orkayama	0.26	0.29	0.34	0.32	1.39	0.38
Ezhome-1	1.85	1.92	2.55	1.88	2.02	2.65
Ezhome-2	0.98	1.12	1.40	1.01	1.24	1.50
Ezhome-3	2.78*	2.89	3.67	2.87	2.99	3.72*
JO 532-1	0.06	0.07	0.08	0.09	0.86	0.09
JK-15	0.98	1.01	1.37	1.12	1.22	1.47
JK-59	0.86	0.99	1.28	1.01	1.31	1.36
JO-583	0.02	0.04	0.09	0.04	0.08	0.12
Chettivirippu	0.62	0.92	0.95	0.92	1.12	0.98
Cherivirippu	0.36	0.56	0.76	0.46	0.85	0.36
Vytilla-1	0.03	0.04	3.20	0.02	0.06	0.07
Vytilla-6	0.04	0.05	0.08	0.05	0.07	0.07
Pokkali	1.28	1.46	2.36	1.58	1.76	2.38
FL-478	2.68	2.88	3.26	2.72	3.02*	3.23
Nona Bokra	2.72	2.925*	3.76	2.92*	2.96	3.67*
IR-29	0.98	1.08	1.40	1.14	1.18	1.43
Jyothi	2.12	2.32	3.18	2.38	2.52	3.28
CV (%)	**1.49**	**0.20**	**321.03**	**0.20**	**0.14**	**1.49**
C.D. (0.05)	**0.03**	**0.005**	**NS**	**0.005**	**0.004**	**0.05**
C.D. (0.05) G×E			**0.27**			**0.17**

(*= Significant)

In non-saline condition, at seedling stage 'Ezhome-3' recorded significantly high root chloride content and at flowering stage 'Nona Bokra' recorded significantly high root chloride content. At seedling stage 'JO-583' and at flowering stage 'Vytilla-1' recorded the lowest root chloride content. In low-saline condition, 'Nona Bokra' at seedling stage and 'FL-478' at flowering stage exhibited significantly the highest root chloride. 'Vytilla-1' and 'JO-583' recorded the lowest root chloride content at seedling and flowering stages. In high-saline condition, root chloride content was non-significant at seedling stage. At flowering stage 'Nona Bokra' and 'Ezhome-3' recorded the highest root chloride content and 'Vytilla-1' recorded the lowest root chloride content which was on par with that of 'JO-532-1' and 'Vytilla-6' (Table 29).

Table 30. Mean culm chloride content of rice genotypes

Genotypes	Seedling stage (%)			Flowering stage (%)		
	Non-saline	Low-saline	High-saline	Non-saline	Low-saline	High-saline
Kuthiru	0.66	0.863	1.66	0.66	0.96	1.72
Orkayama	0.36	0.635	0.68	0.32	0.73	0.86
Ezhome-1	1.71	1.925	2.17	1.67	2.02	2.37
Ezhome-2	0.97	1.025	1.15	0.88	1.12	1.25
Ezhome-3	0.04	0.083	0.08	0.04	0.09	0.08
JO 532-1	0.04	0.086	0.10	0.04	0.90	0.12
JK-15	1.76	1.789	2.76	1.75	1.79	2.79
JK-59	1.65	1.889	2.65	1.60	1.98	2.63
JO-583	0.04	0.099	0.09	0.04	0.10	0.09
Chettivirippu	0.52	0.925	1.02	0.04	0.99	1.25
Cheriviruppu	0.58	0.985	1.24	0.06	1.09	1.30
Vytilla-1	2.45*	2.885*	3.56	2.34*	2.98*	3.15
Vytilla-6	2.31	2.765	3.67*	2.12	2.96	3.65*
Pokkali	0.99	1.215	1.98	0.12	1.51	1.89
FL-478	0.36	0.585	0.63	0.28	0.69	0.08
Nona Bokra	0.04	0.077	0.10	0.05	0.08	0.09
IR-29	0.04	0.073	0.08	0.05	0.09	0.08
Jyothi	1.32	1.72	2.64	1.38	1.79	2.64
CV (%)	**0.60**	**0.37**	**0.23**	**0.61**	**0.33**	**1.09**
C.D. (0.05)	**0.01**	**0.01**	**0.007**	**0.01**	**0.009**	**0.03**
C.D. (0.05) G×E			**0.17**			**0.05**

(*= Significant)

All the genotypes recorded the highest root chloride content in high-saline condition at seedling stage. At flowering stage, the genotypes 'Kuthiru', 'Orkayama', 'JO-532-1', 'Chettivirippu' and 'Cherivirippu' recorded the highest root chloride content in low-saline condition and remaining all other genotypes showed the high root chloride content in high-saline condition.

In non-saline condition, at seedling and flowering stages 'Vytilla-1' recorded the highest culm chloride content. At seedling stage 'Nona Bokra', 'JO-583', 'JO-532-1', 'Ezhome-3' and 'IR-29' recorded the lowest culm chloride, and at flowering stage 'JO-532-1' and 'JO-583' recorded the lowest culm chloride. In low-saline condition, at seedling stage 'Vytilla-1' recorded the highest chloride content in culm and at flowering stage 'Nona Bokra' recorded the highest culm chloride content which was found to be on par with that of 'IR-29'. In high-saline condition, 'Vytilla-6' recorded the highest culm chloride at seedling and flowering stages. At seedling stage 'IR-29' and 'Ezhome-3' recorded the lowest chloride culm content and at flowering stage 'FL-478', IR-29' and 'Ezhome-3' recorded the lowest culm chloride which was on par with that of 'JO-583' and 'Nona Bokra' (Table 30).

All the genotypes recorded the highest root chloride content in high-saline condition at seedling stage except 'Ezhome-3' which shows the highest result in low-saline condition. At flowering stage the genotypes 'JO-532-1', 'JO-583', 'FL-478' and 'IR-29' recorded the highest root chloride content in low-saline condition and remaining all other genotypes showed high culm chloride in high-saline condition.

In non-saline condition, at seedling and flowering stages 'Ezhome-2' recorded the highest leaf chloride content and 'Orkayama', 'Kuthiru' and 'IR-29' recorded low leaf chloride content. In low-saline condition, 'Ezhome-2' showed the highest leaf chloride content at seedling and flowering stages. At seedling and flowering stages 'IR-29', 'Kuthiru' and 'Orkayama' recorded low chloride content in leaf. In high-saline condition, 'Ezhome-2' recorded significantly highest leaf chloride content at seedling and flowering stages. 'Orkayama', 'IR-29' and 'Kuthiru' at seedling stage and 'IR-29' at flowering stage recorded low chloride content in leaf (Table 31).

All the genotypes recorded the highest leaf chloride content in high-saline condition at both seedling and flowering stages.

Table 31. Mean leaf chloride content of rice genotypes

Genotypes	Seedling stage (%)			Flowering stage (%)		
	Non-saline	Low-saline	High-saline	Non-saline	Low-saline	High-saline
Kuthiru	0.02	0.03	0.04	0.02	0.03	0.06
Orkayama	0.02	0.04	0.04	0.02	0.04	0.64
Ezhome-1	0.66	0.66	0.89	0.66	0.35	0.86
Ezhome-2	2.32*	2.82*	4.60*	2.31*	2.82*	4.30*
Ezhome-3	0.53	0.61	1.51	0.54	0.61	1.25
JO 532-1	0.36	0.46	0.87	0.33	0.49	0.88
JK-15	0.438	0.53	0.63	0.44	0.54	0.73
JK-59	0.44	0.54	0.66	0.45	0.55	0.76
JO-583	1.07	1.17	3.06	1.00	1.17	3.09
Chettivirippu	1.14	1.24	2.34	1.00	1.26	2.43
Cheriviruppu	1.21	1.325	2.14	1.00	1.36	2.11
Vytilla-1	1.00	1.20	2.00	1.00	1.21	2.02
Vytilla-6	1.05	1.85	2.04	1.00	1.84	2.05
Pokkali	0.69	0.89	0.96	0.68	0.86	0.98
FL-478	1.69	1.89	3.86	1.64	1.86	3.68
Nona Bokra	0.79	0.98	1.78	0.74	0.96	1.79
IR-29	0.02	0.03	0.04	0.02	0.03	0.04
Jyothi	1.86	1.99	3.36	1.68	1.88	3.85
CV (%)	**0.37**	**0.38**	**0.19**	**0.39**	9.69	**0.22**
C.D. (0.05)	**0.007**	**0.008**	**0.007**	**0.007**	0.20	**0.008**
C.D. (0.05) G×E			**0.28**			**0.21**

(*= Significant)

In non-saline condition, at seedling stage 'Vytilla-6', 'Pokkali' and 'FL-478' recorded the highest root sulphate content, and at flowering stage 'Vytilla-6' recorded the highest root sulphate content. 'Vytilla-1', 'JO-532-1', 'Chettivirippu', 'JK-59', 'JK-15', and 'JO-583' recorded the lowest root sulphate content at seedling and flowering stages. In low-saline condition, at seedling and flowering stages 'Nona Bokra' recorded significantly high root sulphate content. At seedling stage 'Vytilla-1', 'FL-478' and 'Ezhome-2' recorded the lowest root sulphate content and was on par with 'Pokkali' and 'Vytilla-6'. At flowering stage 'Ezhome-2' recorded the lowest root sulphate content which was on par with that of 'Pokkali', 'Kuthiru', 'Orkayama', 'Vytilla-1' and 'FL-478'. In high-saline condition, 'JO-583' recorded significantly high root sulphate content at seedling and flowering stages. 'Ezhome-2' and 'Ezhome-3' recorded the lowest root sulphate content at seedling and flowering stages (Table 32).

Table 32. Mean root sulphate content of rice genotypes

Genotypes	Seedling stage			Flowering stage		
	Non-saline	Low-saline	High-saline	Non-saline	Low-saline	High-saline
Kuthiru	0.31	0.01	0.15	0.33	0.02	0.19
Orkayama	0.19	0.12	0.26	0.29	0.18	0.31
Ezhome-1	0.20	0.17	0.37	0.22	0.23	0.43
Ezhome-2	0.09	0.005	0.006	0.14	0.005	0.01
Ezhome-3	0.10	0.008	0.006	0.15	0.008	0.01
JO 532-1	0.005	0.25	0.24	0.005	0.32	0.26
JK-15	0.005	0.35	0.23	0.005	0.41	0.27
JK-59	0.02	0.35	0.28	0.01	0.42	0.31
JO-583	0.008	5.56*	3.81*	0.006	5.56*	3.88*
Chettiviripppu	0.005	0.22	0.32	0.005	0.28	0.33
Cheriviripppu	0.15	0.23	0.12	0.16	0.32	0.16
Vytilla-1	0.005	0.15	0.27	0.005	0.10	0.25
Vytilla-6	0.57*	0.05	0.12	4.87*	0.32	0.15
Pokkali	0.52*	0.23	0.26	3.31	0.19	0.31
FL-478	0.52*	0.09	0.40	3.06	0.14	0.43
Nona Bokra	0.14	0.04	0.44	0.15	0.02	0.43
IR-29	0.08	0.35	0.37	0.05	0.46	0.40
Jyothi	0.08	0.26	0.22	0.05	0.33	0.26
CV (%)	**21.87**	**5.05**	**1.94**	7.40	4.75	**4.11**
C.D. (0.05)	**0.08**	**0.05**	**0.02**	**0.11**	0.05	**0.04**
C.D. (0.05) G×E			**0.05**			**0.07**

(*= Significant)

At both seedling and flowering stages, the genotypes 'Kuthiru', 'Ezhome-2', 'Ezhome-3', 'Vytilla-6', 'Pokkali' and 'FL-478' showed the highest root sulphate content in non-saline condition than saline conditions. 'Orkayama', 'Ezhome-1', 'Chettivirippu', 'Vytilla-1', 'Nona Bokra' and 'IR-29' showed the highest root sulphate content in high-saline condition and remaining all other genotypes showed higher root sulphate content in low-saline condition.

Table 33. Mean culm sulphate content of rice genotypes

Genotypes	Seedling stage			Flowering stage		
	Non-saline	Low-saline	High-saline	Non-saline	Low-saline	High-saline
Kuthiru	0.27	0.30	0.04	0.18	0.03	0.05
Orkayama	0.04	0.17	0.39	0.004	0.02	0.41
Ezhome-1	0.14	0.44	0.06	0.19	2.03	0.07
Ezhome-2	0.24	0.008	0.006	0.48	0.006	0.01
Ezhome-3	0.09	0.30	0.04	0.16	0.03	0.05
JO 532-1	0.01	0.35	0.18	0.02	0.36	0.22
JK-15	0.06	0.15	0.17	0.20	0.21	0.20
JK-59	0.01	0.11	0.20	0.005	0.17	0.13
JO-583	0.005	0.30	0.17	0.005	0.35	0.22
Chettivirippu	0.005	0.21	0.23	0.005	0.31	0.26
Cheriviripp u	0.07	0.21	0.27	0.005	0.27	0.31
Vytilla-1	0.02	0.01	0.10	0.02	0.01	0.37
Vytilla-6	0.37	0.05	0.15	0.22	0.12	0.48
Pokkali	0.31	0.03	0.25	0.15	0.03	0.29
FL-478	0.52*	0.008	0.006	4.56*	0.009	0.005
Nona Bokra	0.09	9.30*	11.35*	0.10	9.42*	11.26*
IR-29	0.08	0.17	0.35	0.12	0.22	0.41
Jyothi	0.14	3.62	4.98	0.17	3.77	5.56
CV (%)	**83.55**	**5.55**	**1.61**	**8.00**	**1.54**	**11.23**
C.D. (0.05)	**0.25**	**0.10**	**0.03**	**0.06**	**0.03**	**0.26**
C.D. (0.05) G×E			**0.06**			**0.18**

(*= Significant)

In non-saline condition, at seedling stage 'FL-478' recorded the highest culm sulphate content which was found to be on par with that of 'Vytilla-6' and 'Pokkali'. At flowering stage 'FL-478' recorded the highest culm sulphate content. 'Vytilla-1', 'JO-532-1', 'JK-59', 'JO-583', 'Chettivirippu', 'Cheriviripp u' and 'Orkayama' recorded the lowest culm sulphate content at seedling and flowering stages. In low-saline condition, 'Nona Bokra' recorded the highest culm sulphate content at seedling and flowering stages. At both seedling and flowering stages 'FL-478', 'Vytilla-6' and 'Ezhome-2' recorded the lowest culm sulphate content. In high-saline condition, at seedling and flowering stages 'Nona Bokra' recorded the highest culm sulphate content. At seedling stage 'FL-478', 'Ezhome-2' recorded the lowest culm sulphate content and was on par with that of 'Kuthiru' and 'FL-478'. At flowering stage 'Ezhome-2' recorded the lowest culm sulphate content and was on par with 'Kuthiru', 'Ezhome-3', 'Ezhome-1', 'JK-59', 'JK-15', 'JO-583', 'JO-532-1' and 'Chettivirippu' (Table 33).

At seedling stage, the genotypes 'Ezhome-2', 'Vytilla-6', 'Pokkali' and 'FL-478' showed the highest culm sulphate content in non-saline condition. The highest culm content in low-saline condition was exhibited by 'Kuthiru', 'Ezhome-1', 'Ezhome-3' and 'JO-583'. Remaining all other genotypes recorded the highest culm sulphate content in high-saline condition. At flowering stage, the genotypes 'Kuthiru', 'Ezhome-2', 'Ezhome-3' and 'FL-478' showed the highest culm sulphate content in non-saline condition. The highest culm content in low-saline condition was exhibited by 'Ezhome-1', 'JO-532-1', 'JK-15', 'JK-59', 'Chettivirippu' and 'JO-583'. Remaining all other genotypes recorded the highest culm sulphate content in high-saline condition.

In non-saline condition, 'FL-478' followed by 'IR-29' recorded the highest leaf sulphate content at seedling and flowering stages. 'JK-15', 'Chettivirippu' and 'Cheriviruppu' recorded the lowest sulphate content in leaf at seedling and flowering stages. In low-saline condition, at seedling and flowering stages 'IR-29' recorded the highest leaf sulphate content, and 'Orkayama', 'Ezhome-2', 'Nona Bokra', 'Pokkali', 'Ezhome-3', 'JO-532-1', 'FL-478' and 'Vytilla-1' recorded the lowest leaf sulphate content. In high-saline condition, at seedling and flowering stages 'IR-29' recorded the highest leaf sulphate content. 'Orkayama', 'Nona Bokra', 'Ezhome-2', 'Ezhome-3' and 'JO-532-1' at seedling and flowering stages recorded the lowest leaf sulphate content (Table 34).

At seedling stage, the genotypes 'Ezhome-1', 'JK-59', 'JO-583', 'Chettivirippu', 'Cherivirippu' and 'Vytilla-6' showed the highest leaf sulphate content in low-saline condition. The highest leaf content in high-saline condition was exhibited by 'Kuthiru', 'JK-59' and 'Vytilla-1'. Remaining all other genotypes recorded the highest leaf sulphate content in non-saline condition. At flowering stage, the genotypes 'Kuthiru', 'Ezhome-1', 'JK-15', 'JK-59', 'JO-583', 'Chettivirippu', 'Cherivirippu' and 'Vytilla-6' showed the highest leaf sulphate content in low-saline condition. Remaining all other genotypes recorded the highest leaf sulphate content in non-saline condition.

Table 34. Mean leaf sulphate content of rice genotypes

	Seedling stage			Flowering stage		
Genotypes	Non-saline	Low-saline	High-saline	Non-saline	Low-saline	High-saline
Kuthiru	0.21	0.30	0.41	0.28	0.33	0.04
Orkayama	0.21	0.008	0.005	0.25	0.008	0.01
Ezhome-1	0.27	0.45	0.10	0.10	0.49	0.14
Ezhome-2	0.46	0.01	0.01	0.44	0.02	0.01
Ezhome-3	0.14	0.008	0.005	0.20	0.008	0.01
JO 532-1	0.11	0.008	0.005	0.17	0.01	0.008
JK-15	0.010	0.17	0.31	0.005	0.21	0.03
JK-59	0.06	0.25	0.17	0.12	0.31	0.17
JO-583	0.11	0.30	0.18	0.15	0.30	0.17
Chettivirippu	0.005	0.30	0.22	0.005	0.37	0.24
Cherivirippu	0.005	0.35	0.17	0.005	0.42	0.22
Vytilla-1	0.06	0.02	0.28	0.11	0.03	0.03
Vytilla-6	0.22	0.31	0.18	0.10	0.35	0.19
Pokkali	0.12	0.01	0.12	0.29	0.01	0.10
FL-478	6.06*	0.04	0.05	7.81*	0.04	0.06
Nona Bokra	0.48	0.01	0.02	3.50	0.02	0.03
IR-29	5.43	4.63*	2.45*	7.06	4.67*	3.11*
Jyothi	0.48	0.31	0.30	3.31	0.43	0.31
CV (%)	**10.30**	**2.30**	**23.71**	**3.73**	**5.81**	**2.60**
C.D. (0.05)	**0.17**	**0.02**	**0.14**	**0.10**	**0.05**	**0.01**
C.D. (0.05) G×E			**0.13**			**0.07**

(*= Significant)

Table 35. Mean root Na / K ratio of rice genotypes

Genotypes	Seedling stage			Flowering stage		
	Non-saline	Low-saline	High-saline	Non-saline	Low-saline	High-saline
Kuthiru	0.33	0.51	0.60	0.40	0.51	0.62
Orkayama	0.41	0.88	0.92	0.41	0.90	0.94
Ezhome-1	0.39	0.87	1.01	0.45	0.82	0.81
Ezhome-2	0.45	0.79	0.79	0.37	0.84	0.79
Ezhome-3	0.53	1.00	0.85	0.47	0.96	0.86
JO 532-1	0.41	0.45	0.83	0.38	0.44	0.90
JK-15	0.39	1.11*	0.92	0.42	1.10*	0.77
JK-59	0.49	0.74	1.06*	0.45	0.75	1.03*
JO-583	0.34	0.59	0.76	0.49	0.63	0.78
Chettivirippu	0.37	0.68	0.86	0.40	0.70	0.80
Cherivirippu	0.44	1.12	0.81	0.46	0.99	0.65
Vytilla-1	0.32	0.71	0.93	0.40	0.74	0.81
Vytilla-6	0.42	0.82	0.81	0.38	0.78	0.82
Pokkali	0.36	0.76	0.81	0.33	0.82	0.95
FL-478	0.20	0.48	0.67	0.21	0.53	0.71
Nona Bokra	0.26	0.77	0.84	0.30	0.71	0.89
IR-29	0.39	0.55	0.60	0.42	0.66	0.60
Jyothi	0.56*	1.06*	1.04	0.54*	1.10	0.97
CV (%)	**12.54**	**9.16**	**6.66**	**9.59**	**6.80**	**6.09**
C.D. (0.05)	**0.10**	**0.15**	**0.11**	**0.08**	**0.11**	**0.10**
C.D. (0.05) G×E			**0.11**			**0.09**

(*= Significant)

Mean root Na / K ratio of 18 rice genotypes at seedling and flowering stages were presented in Table 35. In non-saline condition, at seedling and flowering stages 'Jyothi' recorded maximum root Na / K ratio which was on par with that of 'Ezhome-3' and 'JK-59'. 'FL-478' recorded minimum root Na / K ratio which was on par which that of 'Nona Bokra'. In low-saline condition, 'Cherivirippu', 'JK-15' and 'Jyothi' at seedling stage and 'JK-15' followed by 'Jyothi' at flowering stage recorded maximum root Na / K ratio. 'Kuthiru', 'FL-478' and 'JO-532-1' recorded minimum root Na / K ratio at both seedling and flowering stages. In high-saline condition, at seedling and flowering stages 'JK-

59' recorded maximum root Na / K ratio which was on par with that of 'Jyothi' and 'Ezhome-1'. 'IR-29' recorded minimum root Na / K ratio which was on par with that of 'Kuthiru' and 'Cherivirippu'.

The genotypes 'Kuthiru', 'Orkayama', 'Ezhome-1', 'JK-59', 'JO-583', 'Chettivirippu', 'Vytilla-1', 'Pokkali', 'FL-478' and 'Nona Bokra' at both seedling and flowering stages, 'Ezhome-1' and 'IR-29' at seedling stage and 'JO-532-1' and 'Vytilla-6' at flowering stage showed the highest root Na / K ratio in high-saline condition. 'Ezhome-2', 'Ezhome-3', 'JK-15', 'Cherivirippu' and 'Jyothi' at both seedling and flowering stages, 'JO-532-1' and 'Vytilla-6 at seedling stage and 'Ezhome-1' 'IR-29' at flowering stage showed the highest root Na / K ratio in low-saline conditions.

Mean culm Na / K ratio of 18 rice genotypes at seedling and flowering stages were presented in Table 36. In non-saline condition, In at seedling and flowering stages 'Orkayama' recorded maximum culm Na / K ratio followed by 'Ezhome-3', 'JK-59', 'FL-478' and 'Jyothi'. 'Chettivirippu' and 'Cherivirippu' recorded minimum culm Na / K ratio. In low-saline condition, at seedling and flowering stages 'JK-15' recorded maximum culm Na / K ratio followed by 'JK-59' and 'Chettivirippu'. 'Ezhome-1', 'FL-478' and 'Nona Bokra' recorded minimum culm Na / K ratio. In high-saline condition, 'JO-532-1' at seedling stage and 'Chettivirippu' at flowering stage recorded maximum culm Na / K ratio. 'FL-478', 'Nona Bokra' and 'Ezhome-3' recorded minimum culm Na / K ratio.

The genotypes 'Orkayama', 'Ezhome-2', 'JK-15', 'JK-59', 'Vytilla-6' and 'IR-29' at both seedling and flowering stages, 'Chettivirippu', 'Cherivirippu' and 'Nona Bokra' at seedling stage alone and 'JO-532-1', 'FL-478' and 'Jyothi' at flowering stage showed the highest culm Na / K ratio in low-saline condition. 'Kuthiru', 'Ezhome-1', 'Ezhome-3', 'JO-583', 'Vytilla-1' and 'Pokkali' at both seedling and flowering stages, 'JO-532-1', 'FL-478' and 'Jyothi' at seedling stage and 'Cherivirippu', 'Chettivirippu' and 'Nona Bokra' at flowering stage showed the highest culm Na / K ratio in high-saline condition.

Table 36. Mean culm Na / K ratio of rice genotypes

Genotypes	Seedling stage			Flowering stage		
	Non-saline	Low-saline	High-saline	Non-saline	Low-saline	High-saline
Kuthiru	0.18	0.86	0.89	0.19	0.88	0.89
Orkayama	0.59*	0.82	0.78	0.62*	0.91	0.88
Ezhome-1	0.20	0.56	0.62	0.21	0.57	0.59
Ezhome-2	0.28	0.78	0.66	0.30	0.74	0.72
Ezhome-3	0.38	0.84	0.85	0.38	0.82	0.82
JO 532-1	0.27	0.95	0.97*	0.29	0.97	0.95
JK-15	0.14	1.16	0.92	0.11	1.09*	0.89
JK-59	0.30	0.98	0.77	0.30	1.02	0.92
JO-583	0.20	0.84	0.87	0.19	0.85	0.98
Chettivirippu	0.08	0.97	0.86	0.07	0.92	1.00*
Cherivirippu	0.09	0.79	0.79	0.07	0.83	0.86
Vytilla-1	0.19	0.64	0.72	0.19	0.68	0.79
Vytilla-6	0.22	0.76	0.76	0.20	0.82	0.78
Pokkali	0.20	0.68	0.79	0.20	0.70	0.72
FL-478	0.30	0.56	0.60	0.34	0.60	0.59
Nona Bokra	0.24	0.62	0.60	0.26	0.61	0.61
IR-29	0.19	0.76	0.77	0.18	0.83	0.83
Jyothi	0.29	0.77	0.80	0.29	0.78	0.77
CV (%)	**9.03**	**7.65**	**5.88**	**3.37**	**4.66**	**7.31**
C.D. (0.05)	**0.04**	**0.12**	**0.09**	**0.01**	**0.08**	**0.12**
C.D. (0.05) G×E			**0.09**			**0.08**

(*= Significant)

Mean leaf Na / K ratio of 18 rice genotypes at seedling and flowering stages were presented in Table 37. In non-saline condition, at seedling and flowering stages 'JO-532-1' recorded maximum Na / K ratio followed by 'JK-15', 'FL-478', 'Ezhome-3' and 'Pokkali'. 'Chettivirippu' followed by 'Cherivirippu' recorded minimum leaf Na / K ratio. In low-saline condition, at seedling and flowering stages 'Jyothi' followed by 'Kuthiru', 'Orkayama' and 'JO-583' recorded maximum leaf Na / K ratio. 'JK-59' recorded minimum leaf Na / K ratio which was on par with that of 'JK-15', 'Chettivirippu' and 'Cherivirippu'. In high-saline condition, at seedling and flowering stages 'Jyothi' followed by

'Kuthiru' and 'Orkayama' recorded maximum leaf Na / K ratio. 'JK-59', 'Pokkali' and 'Chettivirippu' recorded minimum leaf Na / K ratio.

The genotypes 'Ezhome-1', 'JK-15', 'JK-59', 'JO-583', 'Pokkali' and 'FL-478' at both seedling and flowering stages, 'Kuthiru', 'Ezhome-2', 'JO-532-1' and 'Jyothi' at seedling stage alone and 'Ezhome-3', 'Chettivirippu', 'Vytilla-1', 'Vytilla-6' and 'Nona Bokra' at flowering stage showed the highest leaf Na / K ratio in low-saline condition. 'Orkayama', 'Cherivirippu' and 'IR-29' at both seedling and flowering stages, 'Ezhome-3', 'Chettivirippu', 'Vytilla-1', 'Vytilla-6' and 'Nona Bokra' at seedling stage and 'Kuthiru', 'Ezhome-2', 'JO-532-1', 'IR-29' and 'Jyothi' at flowering stage showed the highest leaf Na / K ratio in high-saline condition.

Table 37. Mean leaf Na / K ratio of rice genotypes

	Seedling stage			Flowering stage		
Genotypes	Non-saline	Low-saline	High-saline	Non-saline	Low-saline	High-saline
Kuthiru	0.04	0.99	0.93	0.08	0.96	1.03
Orkayama	0.10	0.92	0.93	0.10	0.92	0.93
Ezhome-1	0.14	0.63	0.62	0.14	0.70	0.62
Ezhome-2	0.07	0.65	0.65	0.08	0.66	0.66
Ezhome-3	0.15	0.80	0.83	0.14	0.86	0.79
JO 532-1	0.25	0.61	0.60	0.26*	0.64	0.74
JK-15	0.15	0.49	0.49	0.17	0.55	0.51
JK-59	0.13	0.47	0.46	0.11	0.52	0.49
JO-583	0.13	0.88	0.74	0.13	0.98	0.85
Chettivirippu	0.04	0.52	0.52	0.04	0.55	0.55
Cherivirippu	0.08	0.51	0.57	0.06	0.57	0.64
Vytilla-1	0.09	0.66	0.66	0.11	0.74	0.68
Vytilla-6	0.10	0.74	0.77	0.10	0.85	0.64
Pokkali	0.14	0.53	0.50	0.14	0.58	0.50
FL-478	0.13	0.79	0.77	0.15	0.83	0.74
Nona Bokra	0.11	0.63	0.68	0.11	0.69	0.64
IR-29	0.10	0.73	0.80	0.10	0.76	0.77
Jyothi	0.11	1.28*	1.23*	0.11	1.39*	1.41*
CV (%)	**9.81**	**4.22**	**6.89**	**10.01**	**6.62**	**9.41**
C.D. (0.05)	**0.02**	**0.06**	**0.10**	**0.02**	**0.10**	**0.14**
C.D. (0.05) G×E			**0.07**			**0.10**

(*= Significant)

4.2.3.3. Root CEC

Root CEC of 18 rice genotypes in three soil conditions is given in Table 38. In non-saline and low-saline conditions, 'FL-478', 'Jyothi' and 'Vytilla-6' recorded the highest root CEC and 'Pokkali' recorded the lowest root CEC at seedling and flowering stages. In high-saline Kaipad, at seedling stage 'JO-532-1' followed by 'JO-583' recorded the highest CEC and 'FL-478' recorded the lowest CEC. At flowering stage, 'JO-532-1' and 'Jyothi' recorded the highest CEC and 'Ezhome-1' and 'Nona Bokra' recorded the lowest CEC.

Table 38. Mean root CEC of rice genotypes

Genotypes	Seedling stage			Flowering stage		
	Non-saline	Low-saline	High-saline	Non-saline	Low-saline	High-saline
Kuthiru	3.3	3.5	3.1	3.4	3.6	3.2
Orkayama	3.1	3.3	2.8	3.2	3.4	2.9
Ezhome-1	3.2	3.5	2.6	3.4	3.6	2.7
Ezhome-2	3.3	3.5	3.3	3.4	3.6	3.4
Ezhome-3	3.2	3.4	3.6	3.3	3.5	3.7
JO 532-1	3.2	3.4	3.8*	3.3	3.5	3.9*
JK-15	3.3	3.5	3.6	3.4	3.6	3.7
JK-59	3.4	3.6	3.7	3.5	3.8	3.8
JO-583	3.5	3.7	2.9	3.6	3.8	3.2
Chettivirippu	3.0	3.2	3.2	3.1	3.4	3.3
Cherivirippu	2.8	3.0	3.6	2.9	3.1	3.7
Vytilla-1	2.6	2.8	3.5	2.6	2.9	3.6
Vytilla-6	3.6*	3.8*	2.8	3.6	3.9*	2.9
Pokkali	2.3	2.5	3.2	2.4	2.6	3.3
FL-478	3.6*	3.8*	1.5	3.7*	3.9*	2.9
Nona Bokra	2.8	3.0	2.6	2.9	3.1	2.7
IR-29	2.5	2.7	3.2	2.6	2.8	3.3
Jyothi	3.6*	3.8*	1.8	3.7*	3.9*	3.9*
CV (%)	**0.47**	**0.62**	**0.19**	**0.46**	**0.0001**	**0.17**
C.D. (0.05)	**0.03**	**0.04**	**0.01**	**0.03**	**0.0001**	**0.01**
C.D. (0.05) G×E			**0.05**			**0.05**

(*= Significant)

The genotypes 'Kuthiru', 'Orkayama', 'Ezhome-1', 'Ezhome-2', 'JO-583', 'Chettivirippu', 'Vytilla-6', 'FL-478', 'Nona Bokra' and 'Jyothi' recorded the highest root CEC in low-saline condition and remaining all other genotypes showed high root CEC in high-saline condition at both seedling and flowering stages.

4.2.4. Yield parameters

Out of 18 rice genotypes evaluated in high-saline soil Kaipad, 'FL-478' and 'Jyothi' survived till flowering stage but collapsed and decayed at the time of harvest. Hence in the case of high-saline condition only 16 genotypes were subjected to stat analysis for yield parameters.

4.2.4.1. Number of productive tillers per plant

Mean number of productive tillers per plant of rice genotypes recorded at harvest stage in three soil conditions is presented in (Table 39). It varied from 2.8-9.8. In non-saline condition, the highest number of productive tillers plant^{-1} was recorded in 'Pokkali' followed by 'Nona Bokra' and 'JK-15'. 'Orkayama' recorded the minimum number of productive tillers. In low-saline condition, 'Ezhome-1' and 'JK-15' followed by 'IR-29', 'Pokkali' and 'Ezhome-2' recorded high number of productive tillers plant^{-1} and 'Vytilla-6' and 'Jyothi' recorded less productive tillers. The result was non-significant at high-saline condition.

Significant interaction effect showed that in the case of genotypes 'Kuthiru', 'Ezhome-1', 'Ezhome-2', 'Ezhome-3', 'JK-15' and 'IR-29' the highest number of productive tillers was observed in low-saline condition than in other two soils . 'JO-532-1', 'JK-59', 'FL-478', 'Jyothi' and 'JO-583' showed uniform result in all three conditions and in case of 'Orkayama', 'Chettivirippu', 'Cheriviripp u', 'Vytilla-1', 'Vytilla-6', 'the Pokkali' and 'Nona Bokra' the highest number of productive tillers was seen in high-saline Kaipad.

4.2.4.2. Number of spikelets per panicle

Mean values of spikelets per panicle of rice genotypes recorded in three soil conditions after harvest is depicted in Table 39 and it varied from 103.05-243.85 . In non-saline condition, the highest number of spikelets per panicle was recorded in 'Pokkali' followed by 'JO-532-1' and the lowest for 'Kuthiru'. In low-saline condition, 'Ezhome-1' recorded the maximum number of spikelets per panicle which was found to be on par with that of 'Nona Bokra', 'Pokkali', 'IR-29' and 'Ezhome-3'. 'Kuthiru' recorded the minimum number of spikelets per panicle and was on par with 'Vytilla-1', 'Jyothi' and 'Orkayama'. In high-saline Kaipad 'Pokkali' and 'Nona Bokra' recorded the maximum number of spikelets which were on par with that of 'Ezhome-1'. 'Kuthiru' recorded the minimum spikelets per panicle in high-saline condition.

Table 39. Mean performance of rice genotypes for number of productive tillers per plant and number of spikelets per panicle

Genotypes	Productive tillers plant^{-1}			Spikelets panicle^{-1}		
	Non-saline	Low-saline	High-saline	Non-saline	Low-saline	High-saline
Kuthiru	4.45	5.85	4.25	86.55	133.10	109.45
Orkayama	2.80	6.10	7.10	111.80	145.85	131.80
Ezhome-1	4.45	9.80*	4.90	219.95	243.85*	229.65
Ezhome-2	4.30	7.20	4.85	192.60	186.65	200.25
Ezhome-3	3.80	6.35	5.70	208.75	224.05	215.35
JO 532-1	3.70	4.70	3.65	230.40	217.49	225.07
JK-15	3.50	9.75*	6.00	173.70	191.75	178.69
JK-59	5.15	5.40	5.30	221.60	222.95	215.98
JO-583	4.85	6.25	6.40	165.95	185.60	178.96
Chettivirippu	3.75	6.10	9.40	139.90	163.15	154.88
Cheriviri ppu	4.30	6.45	6.90	137.90	154.65	140.93
Vytilla-1	3.80	4.60	6.35	103.05	134.50	119.32
Vytilla-6	4.00	3.70	6.65	163.00	181.05	158.18
Pokkali	6.20*	7.75	8.60	240.00*	239.15	233.99*
FL-478	4.05	4.65	-	172.95	194.30	-
Nona Bokra	5.35	5.90	7.70	220.25	243.05	216.62
IR-29	4.10	7.75	5.35	211.15	234.45	232.95*
Jyothi	3.95	3.60	-	103.25	136.25	-
CV (%)	**3.93**	**5.85**	**23.24**	**1.84**	**5.02**	**1.64**
C.D. (0.05)	**0.35**	**0.76**	**NS**	**6.71**	**20.21**	**6.45**
C.D. (0.05) G×E			**1.64**			**12.22**

(*= Significant)

The genotypes 'Kuthiru', 'Orkayama', 'Ezhome-1', 'Ezhome-3', 'JK-15', 'JO-583', 'Chettivirippu', 'Cheriviriippu', 'Vytilla-1', 'Vytilla-6', 'FL-478', 'Nona Bokra' and 'Jyothi' recorded the highest number of spikelets per panicle in low-saline condition. 'JK-59' and 'Pokkali' recorded same result in all three conditions and 'Ezhome-2' showed the highest result in high-saline condition and 'JO-532-1' showed the highest spikelets number in non-saline condition.

4.2.4.3. Number of filled grains per panicle

Filled grains panicle^{-1} of rice genotypes grown in three soil conditions varied from 63.45-182.6 (Table 40). In non-saline condition, 'Ezhome-3' and 'JK-59' followed by 'Ezhome-2' and 'Pokkali' recorded maximum number of filled grains and 'Kuthiru' recorded the minimum number of filled grains. In low-saline condition, 'Ezhome-3','Nona Bokra' and 'JK-59' recorded maximum filled grains per panicle and 'Vytilla-1' and 'Jyothi' recorded minimum filled grains per panicle which was on par with that of 'Kuthiru'. In high-saline condition, 'Ezhome-3' and 'JK-59' recorded maximum filled grains per panicle and 'Kuthiru' recorded minimum filled grains.

All the genotypes recorded the highest filled grains per panicle in low-saline condition than in non-saline and high-saline Kaipad.

4.2.4.4. Seed setting %

Seed setting per cent of rice genotypes grown in three soil conditions was recorded after harvest and it varied from 52.4-81.5 % (Table 40). In non-saline condition, 'Chettivirippu', 'Ezhome-3', 'Ezhome-2', 'Vytilla-1' and 'Cheriviriippu' recorded maximum seed setting percentage and 'JO-532-1' recorded minimum seed setting percentage. In low-saline condition, 'Ezhome-3', 'JK-15' and 'Ezhome-2' recorded maximum seed setting per cent which was on par with that of 'Chettivirippu', 'JK-59', 'JO-532-1', 'Orkayama', 'Cheriviriippu' and 'Kuthiru'. 'IR-29' recorded minimum seed setting per cent which was on par with that of 'Pokkali', 'Ezhome-1' and 'JO-532-1'. In high-saline condition, 'Ezhome-3' recorded the maximum seed setting per cent and was on par with that

Plate 7. High yielding variety 'JO-532-1' ('Ezhome-4') at low-saline Kaipad

Plate 8. High yielding variety 'JO-532-1' ('Ezhome-4') at high-saline Kaipad

of 'Ezhome-2' and 'Nona Bokra'. 'Kuthiru' recorded minimum seed setting per cent which was on par with that of 'IR-29' followed by 'Orkayama' and 'Ezhome-1'.

The genotypes 'Kuthiru', 'Orkayama', 'Ezhome-1', 'Ezhome-2', 'Ezhome-3', 'JK-15', 'JK-59', 'JO-583', 'Chettivirippu', 'Cherivirippu', 'Vytilla-6', 'FL-478' and 'IR-29' showed similar seed setting percentage in non-saline and low-saline conditions. 'Pokkali' and 'Nona Bokra' showed uniform result in all three conditions and in case of 'JO-532-1' the highest seed setting percentage was recorded in low-saline condition and 'Vytilla-1' recorded the highest result in non-saline condition.

Table 40. Mean performance of rice genotypes for number of filled grains per panicle and seed setting %

Genotypes	Filled grains panicle^{-1}			Seed setting %		
	Non-saline	Low-saline	High-saline	Non-saline	Low-saline	High-saline
Kuthiru	63.45	100.25	57.35	72.90	75.31	52.40
Orkayama	83.85	111.20	75.50	75.34	76.31	57.29
Ezhome-1	146.20	160.85	132.75	66.47	65.95	57.80
Ezhome-2	153.70	147.45	146.60	79.81*	79.00*	73.20
Ezhome-3	167.65*	182.60*	157.15*	80.32*	81.49*	73.98*
JO 532-1	137.00	145.25	123.40	59.45	67.54	54.82
JK-15	132.50	153.45	126.05	76.29	80.04*	70.54
JK-59	165.45*	172.70*	155.50*	74.66	77.40	72.00
JO-583	122.75	143.30	116.60	73.99	77.21	65.20
Chettivirippu	113.00	126.25	104.40	80.82*	77.41	67.41
Cherivirippu	109.50	117.15	96.60	79.41*	75.75	68.55
Vytilla-1	81.90	97.15	71.65	79.57*	72.23	60.10
Vytilla-6	121.45	127.75	102.75	74.53	70.535	64.95
Pokkali	153.55	155.50	145.00	63.99	65.02	61.97
FL-478	123.05	134.40	-	71.16	69.16	-
Nona Bokra	152.50	174.40*	144.85	69.24	71.75	66.86
IR-29	135.30	144.40	122.75	64.07	61.61	52.69
Jyothi	77.75	94.40	-	75.39	69.27	-
CV (%)	**1.50**	**3.85**	**1.55**	**1.50**	**4.13**	**1.31**
C.D. (0.05)	**5.26**	**11.25**	**3.90**	**2.32**	**6.36**	**1.78**
C.D. (0.05) G×E			**7.15**			**4.04**

(*= Significant)

4.2.4.5. Sterility %

Sterility per cent of rice genotypes grown in three soil conditions are recorded after harvest is presented in Table 41. It varied from the range 1.62 - 15.4 % . In non-saline condition, 'Pokkali' recorded maximum sterility per cent followed by 'JO-532-1', 'JK-59', 'Cheriviripp u', 'Vytilla-1' and 'Nona Bokra'. 'Ezhome-3' and 'Ezhome-1 showed minimum sterility per cent which was on par with that of 'FL-478', 'JK-15', 'IR-29' and 'JO-583'. In low-saline condition, 'Vytilla-1' recorded maximum sterility % and was on par with that of 'Jyothi' and 'Vytilla-6'. 'JO-583', 'JK-15', 'Ezhome-1' recorded minimum sterility per cent in low-saline condition. 'Ezhome-3' recorded minimum sterility per cent and was on par with that of 'JK-59' and 'Ezhome-2'. In high –saline condition, 'Chettivirippu' recorded the highest sterility per cent followed by 'Kuthiru', 'JO-583', 'Orkayama' and 'Cheriviripp u'. 'Ezhome-1' recorded the lowest sterility per cent and was on par with 'Nona Bokra', 'Pokkali', 'Ezhome-3' and 'JK-59'.

All the genotypes showed the highest sterility per cent in high-saline condition than in non-saline and low-saline condition except 'Pokkali'. 'Pokkali' showed the highest sterility per cent in non-saline and low-saline condition.

4.2.4.6. Length of panicle

Mean length of panicle of rice genotypes grown in three soil types recorded varied from 20.4 - 28.7 cm (Table 41). In non-saline condition, 'Chettivirippu' recorded the highest panicle length which was on par with that of 'Nona Bokra', 'Ezhome-2', 'JO-532-1', 'Pokkali', 'JK-59', 'Orkayama', 'Ezhome-3', 'Ezhome-1' and 'JK-15'. 'Jyothi' recorded the lowest panicle length which was on par with that of 'Vytilla-6', 'IR-29' and 'FL-478'. In low-saline Kaipad, 'Nona Bokra' recorded the highest panicle length which was on par with that of 'JK-15', 'Ezhome-2', 'JO-583', 'JO-532-1' and 'Chettivirippu'. 'Jyothi' recorded the minimum panicle length in low-saline Kaipad. In high-saline Kaipad, 'JO-583', 'Ezhome-2', 'Orkayama', 'Ezhome-3', 'JO-532-1', 'Nona Bokra', 'Chettivirippu' and 'JK-59' recorded the highest panicle length which was on par with that of 'JK-15', 'Ezhome-1' and 'IR-29'. 'Cherivirippu' recorded the minimum panicle length which was on par with that of 'Vytilla-1', 'Pokkali' and 'Vytilla-6'.

All the genotypes showed uniform result in all three conditions except 'JK15'. 'JK-15' showed the highest length of panicle in low-saline Kaipad.

Table 41. Mean performance of rice genotypes for sterility % and length of panicle

Genotypes	Sterility %			Length of Panicle (cm)		
	Non-saline	Low-saline	High-saline	Non-saline	Low-saline	High-saline
Kuthiru	4.21	5.81	13.15	23.95	24.60	23.90
Orkayama	3.40	5.46	12.99	25.70	25.35	25.65*
Ezhome-1	1.62	1.94	5.43	25.60	25.10	24.10
Ezhome-2	3.06	3.13	8.01	27.15	28.25	25.85*
Ezhome-3	1.62	1.91	6.73	25.60	26.60	25.25*
JO 532-1	5.11	6.07	7.12	26.65	27.15	25.20*
JK-15	2.21	2.60	8.32	25.60	28.25	24.40
JK-59	4.69	2.87	6.91	25.85	23.85	25.00*
JO-583	2.69	2.77	13.02	25.30	27.90	25.85*
Chettivirippu	2.81	7.92	15.39*	28.70*	26.90	25.15*
Cherivirippu	4.13	6.45	12.58	24.82	24.48	21.58
Vytilla-1	4.43	10.03*	10.38	25.10	24.46	21.89
Vytilla-6	3.21	8.29	9.79	22.50	24.66	22.66
Pokkali	6.67*	6.90	5.92	26.35	25.71	22.43
FL-478	2.13	6.43	-	23.35	22.79	-
Nona Bokra	4.37	4.73	5.74	28.40	28.47*	25.16*
IR-29	2.22	6.38	10.70	22.95	25.50	24.10
Jyothi	3.58	9.58	-	20.35	20.74	-
CV (%)	**15.35**	**16.81**	**7.65**	**6.05**	**3.23**	**4.45**
C.D. (0.05)	**1.12**	**1.95**	**1.55**	**3.22**	**1.74**	**2.30**
C.D. (0.05) G×E			**1.46**			**3.67**

(*= Significant)

4.2.4.7. 1000 grain weight

1000 grain weight of rice genotypes grown in three soil conditions are recorded after harvest and it varies from the range 31.45-56.405 (Table 42a). In

Plate 9. Variety 'Vytilla-6' at low-saline Kaipad

Plate 10. Variety 'Ezhome-1' at low-saline Kaipad

non-saline and low-saline conditions, 'Ezhome-3' recorded maximum 1000 grain weight followed by 'Ezhome-2', 'JO-532-1', 'Ezhome-1' and 'Pokkali'. 'Vytilla-6' recorded the minimum 1000 grain weight. In high-saline condition, 'Ezhome-2' recorded the maximum 1000 grain weight and 'IR-29' recorded the minimum 1000 grain weight.

All the genotypes showed the highest result in low-saline condition than non-saline and high-saline condition except for the genotypes 'Ezhome-2', 'Cheriviruppu', 'Vytila-1', 'Vytilla-6' and 'Pokkali', these genotypes showed the highest 1000 grain weight in high-saline condition.

4.2.4.8. Grain yield per plot

Grain yield per plot of rice genotypes grown in three different soil conditions are recorded after harvest and it varies from range 0.51-9.585 Kg (Table 42a). In non-saline condition, 'Ezhome-2' recorded maximum yield which was on par with that of 'Ezhome-3', 'JK-15', 'Vytilla-6' and 'Vytilla-1'. 'JO-532-1' recorded the lowest yield which was on par with that of 'Pokkali', 'JK-59', 'Cheriviruppu', 'Chettivirippu', 'Kuthiru' and 'Ezhome-1'. In low-saline Kaipad soil, 'Orkayama' recorded the maximum yield followed by 'JK-59', 'Vytilla-6', 'Nona Bokra', 'Ezhome-2', 'JO-532-1' and 'JO-583'. 'Kuthiru' recorded the lowest yield which was on par with that of 'Chettivirippu', 'IR-29'and 'JK-15'. In high-saline Kaipad soil, 'JO-532-1' recorded the maximum yield followed by 'JO-583', 'Nona Bokra' and 'Ezhome-1'. 'Kuthiru' recorded the lowest yield which was on par with that of 'Orkayama', 'JK-59', 'JK-15', 'Chettivirippu' and 'Pokkali'.

All the genotypes showed the highest grain yield in low-saline condition than in non-saline and high-saline conditions except 'Kuthiru', 'Ezhome-3' and 'JK-15', theses genotypes showed the highest yield in non-saline condition than in saline condition.

Table 42a. Mean performance of rice genotypes for 1000 grain weight, grain yield per plot and straw yield per plot

Genotypes	1000 grain weight (gm)			Grain yield $plot^{-1}$ (Kg)			Straw yield $plot^{-1}$ (Kg)		
	Non-saline	Low-saline	High-saline	Non-saline	Low-saline	High-saline	Non-saline	Low-saline	High-saline
Kuthiru	36.15	42.20	40.70	2.75	2.52	0.51	4.94	0.64	1.54
Orkayama	33.25	41.20	38.60	3.26	9.58*	0.75	22.30	2.47	3.14
Ezhome-1	41.20	44.05	31.10	2.84	6.06	3.49	10.64	4.02	3.06
Ezhome-2	42.25	43.80	54.20*	5.67*	6.85	2.48	15.34	2.33	3.16
Ezhome-3	52.35*	56.40*	43.05	5.22	5.03	2.76	13.06	2.10	2.40
JO 532-1	41.35	43.80	32.50	0.91	6.52	6.90*	19.53	11.68*	5.84
JK-15	40.35	42.05	41.30	4.99	4.11	1.11	8.35	1.23	1.90
JK-59	34.45	36.80	30.90	2.39	7.65	0.78	15.99	3.63	1.73
JO-583	31.85	35.60	30.80	3.70	6.71	5.59	18.77	3.40	8.97*
Chettivirippu	31.65	41.30	35.30	2.71	2.83	1.31	7.38	0.65	4.17
Cherivirippu	37.65	38.40	42.05	2.51	4.91	2.48	20.59	4.63	2.43
Vytilla-1	31.55	33.80	34.50	4.18	5.73	1.80	20.45	1.48	1.93
Vytilla-6	30.15	32.90	33.50	4.61	7.00	1.82	29.92*	3.15	1.52
Pokkali	40.25	42.60	43.40	2.14	6.43	1.36	10.78	1.76	1.30
FL-478	35.15	39.60	-	3.68	4.51	-	5.04	3.00	-
Nona Bokra	32.45	38.60	36.20	3.61	6.91	4.03	20.03	6.18	3.32
IR-29	31.45	36.60	30.05	3.22	3.86	1.86	14.25	3.24	1.72
Jyothi	31.50	37.50	-	3.53	5.06	-	9.43	1.97	-
CV (%)	**0.15**	**0.05**	**0.06**	**26.69**	**14.49**	**21.92**	**12.38**	**28.09**	**16.78**
C.D. (0.05)	**0.11**	**0.04**	**0.05**	**1.93**	**1.70**	**1.14**	**3.87**	**1.89**	**1.07**
C.D. (0.05) G×E			0.34			1.53			**2.67**

(*= Significant)

4.2.4..9. Straw yield per plot

Mean straw yield per plot of rice genotypes grown in three types of soil was recorded after and it varies from range 0.64-29.92Kg (Table 42a). In non-saline condition, 'Vytilla-6' fallowed by 'Orkayama', 'Cherivirippu', 'Vytilla-1' and 'Nona Bokra' recorded the maximum straw yield. 'FL-478' and 'Kuthiru' recorded the lowest straw yield which was on par with that of 'Chettivirippu' and 'JK-15'. In low-saline Kaipad, 'JO-532-1' recorded the maximum straw yield followed by 'Nona Bokra' and 'Cherivirippu'. 'Chettivirippu' and 'Kuthiru' recorded the lowest straw yield which was on par with that of 'JK-15', 'Vytilla-1',

Plate 11. Variety 'JO-583' at low-saline Kaipad

Plate 12. Variety 'Vytilla-6' at high-saline Kaipad

'Pokkali', 'Jyothi', 'Ezhome-3', 'Ezhome-2'and 'Orkayama'. In high-saline Kaipad soil, 'JO-583' recorded the maximum straw yield followed by 'JO-532-1', 'Nona Bokra' and 'Ezhome-2'. 'Pokkali' recorded the lowest straw yield which was on par with that of 'Vytilla-6', 'Kuthiru', 'IR-29', 'JK-59', 'JK-15' and 'Vytilla-1'.

All the genotypes showed the highest straw yield in non-saline condition than in saline condition.

Table 42b. Mean performance of rice genotypes for grain yield and straw yield per hectare

Genotypes	Grain yield (Kg/ha)			Straw yield (Kg/ha)		
	Non-saline	Low-saline	High-saline	Non-saline	Low-saline	High-saline
Kuthiru	1377.97	1263.00	256.66	2472.23	320.00	774.16
Orkayama	1631.52	4792.25*	378.33	11150.83	1238.70	1571.67
Ezhome-1	1172.00	3033.00	1747.50	5321.00	2011.00	1281.25
Ezhome-2	2833.64*	2132.00	1224.50	7672.28	1165.55	1441.00
Ezhome-3	2611.12	2516.50	1140.66	6531.00	1052.50	1203.83
JO 532-1	455.50	3428.19	3450.00*	9765.00	5844.00*	2923.50
JK-15	2493.23	2056.75	556.66	4179.29	618.66	953.33
JK-59	1200.00	3827.00	376.50	7995.83	1819.20	866.66
JO-583	1848.81	3355.34	3193.67	9387.97	1695.22	3488.33*
Chettivirippu	1358.33	1417.50	655.00	3698.33	325.00	2087.50
Cherivirippu	1256.42	2454.16	1240.00	10297.50	2316.67	1215.00
Vytilla-1	2092.05	2868.00	899.75	10228.00	744.83	965.71
Vytilla-6	2305.92	3500.00	914.00	14960.00*	1575.50	777.50
Pokkali	1072.50	3215.83	680.66	5393.75	881.67	654.00
FL-478	1842.14	2257.00	0	2521.64	1504.00	0
Nona Bokra	1805.00	3455.00	2016.50	10017.00	3092.50	1662.00
IR-29	1613.28	1933.66	930.00	7126.33	1624.00	864.62
Jyothi	1766.98	2534.00	0	4718.27	985.00	0
CV (%)	**27.42**	**14.52**	**21.29**	**12.37**	**27.62**	**36.26**
C.D. (0.05)	**987.95**	**852.15**	**557.64**	**1935.97**	**933.04**	**1097.84**

(*= Significant)

4.3. Character association

Studies on association of characteristics gain important in plant breeding, because they aim the plant breeders to know the inter-characteristic influence and help to strike economic and reliable balance between various characteristics. Since yield is a complex character, the practice of unilateral selection often results in retrograde or less optimum progress in isolating superior genotypes. Therefore, the knowledge of inter relationships of characteristics, play a vital role in developing appropriate selection criteria for the improvement of complex characteristics like grain yield. The results of correlation and path analysis studies between grain yield and different parameters are presented below.

4.3.1. Correlation

Correlation between characteristics in high-saline Kaipad was assessed. Genotypic and phenotypic correlation coefficients among the 24 characteristics at seedling stage were presented in Table 43 and at flowering stage association were assessed for 26 characteristics and are presented in Table 44.

Genotypic correlation is high and positive for most of the characteristics than the phenotypic correlations at both seedling and flowering stages. The traits which are showing significant positive genotypic correlation are not showing significance at phenotypic level.

Plate 13. Variety 'FL-478' at non-saline at RARS, Pilicode

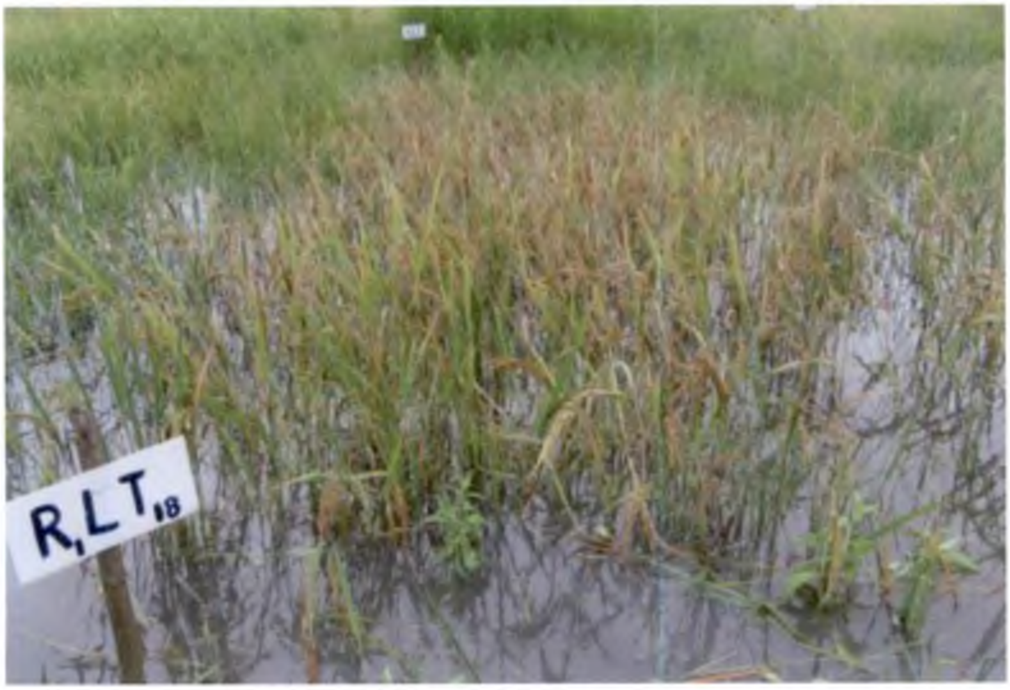

Plate 14. Variety 'Jyothi' at low-saline Kaipad

Table 43. Genotypic and phenotypic correlation coefficients in high-Saline Kaipad at seedling stage

		A	B	C	D	E	F	G	H	I	J	K	L	M
A	Vp	1	0.358	0.328	-0.552*	0.260	-0.053	0.361	0.742**	0.247	0.477	-0.394	-0.160	-0.555*
	Vg	1	0.174	0.215	0.027	0.332	0.844**	0.170	0.001	0.357	0.062	0.131	0.553*	0.026
B	Vp	0.358	1	0.165	-0.019	0.074	0.034	0.054	-0.039	-0.072	0.119	-0.421	0.071	-0.191
	Vg	0.174	1	0.542*	0.945**	0.785**	0.901**	0.842**	0.885**	0.792**	0.661**	0.104	0.794**	0.479
C	Vp	0.328	0.165	1	0.136	0.292	0.384	0.477	0.085	0.085	-0.024	-0.342	0.043	-0.050
	Vg	0.174	0.542*	1	0.616**	0.272	0.142	0.062	0.755**	0.754**	0.929**	0.195	0.876**	0.855**
D	Vp	-0.552*	-0.019	0.136	1	0.111	0.214	0.043	-0.726**	-0.313	-0.541*	0.005	-0.094	-0.520*
	Vg	0.027	0.945**	0.616**	1	0.683**	0.425	0.874**	0.001	0.237	0.030	0.984**	0.728**	0.039
E	Vp	0.260	0.074	0.292	0.111	1	-0.436	-0.283	0.109	0.386	-0.210	-0.175	0.156	0.164
	Vg	0.332	0.785**	0.272	0.683**	1	0.091	-0.287	0.688**	0.139	0.434	0.517*	0.565*	0.543*
F	Vp	-0.053	0.034	0.384	0.214	-0.436	1	0.555*	-0.064	-0.400	0.000	-0.006	-0.417	0.023
	Vg	0.844**	0.901**	0.142	0.425	0.091	1	0.025	0.815**	0.125	0.999**	0.984**	0.108	0.933**
G	Vp	0.361	0.054	0.477	0.043	-0.283	0.555*	1	0.227	-0.189	0.079	-0.201	-0.293	-0.223
	Vg	0.170	0.842**	0.062	0.874**	-0.287	0.025	1	0.399	0.483*	0.772**	0.456	0.271	0.407
H	Vp	0.742**	-0.039	0.085	-0.726**	0.109	-0.064	0.227	1	0.426	0.308	-0.056	-0.124	-0.382
	Vg	0.001	0.885**	0.755**	0.001	0.688**	0.815**	0.399	1	0.099	0.245	0.836**	0.648**	0.145
I	Vp	0.247	-0.072	0.085	-0.313	0.386	-0.400	-0.189	0.426	1	-0.188	0.233	0.221	0.069
	Vg	0.357	0.792**	0.754**	0.237	0.139	0.125	0.483*	0.099	1	0.487*	0.385	0.411	0.800**
J	Vp	0.477	0.119	-0.024	-0.541*	-0.210	0.000	0.079	0.308	-0.188	1	-0.204	0.251	-0.895**
	Vg	0.062	0.661**	0.929**	0.030	0.434	0.999**	0.772**	0.245	0.487*	1	0.449	0.349	0.000
K	Vp	-0.394	-0.421	-0.342	0.005	-0.174	-0.006	-0.201	-0.056	0.233	-0.204	1	-0.190	0.267
	Vg	0.131	0.104	0.195	0.984**	0.517*	0.984**	0.456	0.836**	0.385	0.449	1	0.480	0.317
L	Vp	-0.160	0.071	0.043	-0.094	0.156	-0.417	-0.293	-0.124	0.221	0.251	-0.190	1	-0.348
	Vg	0.553*	0.794**	0.876**	0.728**	0.565*	0.108	0.271	0.648**	0.411	0.349	0.480	1	0.187
M	Vp	-0.555*	-0.191	-0.050	-0.520*	0.164	0.023	-0.223	-0.382	0.069	-0.895**	0.267	-0.348	1
	Vg	0.026	0.479	0.855**	0.039	0.543*	0.933**	0.407	0.145	0.800**	0.000	0.317	0.187	1
N	Vp	0.177	0.216	-0.312	-0.272	0.115	-0.115	-0.364	0.430	0.131	0.176	-0.048	-0.026	0.011

	Vg	0.512	0.421	0.239	0.308	0.671**	0.672*	0.166	0.090	0.629**	0.514*	0.860**	0.924**	0.967**
O	Vp	0.437	0.272	0.285	0.008	0.571*	-0.219	0.222	0.165	0.090	-0.123	-0.260	0.170	-0.141
	Vg	0.091	0.309	0.285	0.976**	0.021	0.415	0.408	0.543*	0.741**	0.650**	0.331	0.530*	0.602*
P	Vp	-0.438	-0.513*	-0.694**	0.095	-0.080	-0.192	-0.530*	-0.092	0.030	-0.216	0.479	-0.045	0.177
	Vg	0.090	0.042	0.003	0.727**	0.769**	0.477	0.035	0.736**	0.913**	0.423	0.061	0.869**	0.511*
Q	Vp	-0.266	-0.404	-0.692**	-0.021	0.023	-0.345	-0.533*	0.023	0.185	0.032	0.497*	0.205	-0.070
	Vg	0.319	0.121	0.003	0.940**	0.934**	0.191	0.034	0.933**	0.493*	0.906**	0.050	0.446	0.796**
R	Vp	0.184	0.102	-0.227	-0.162	0.259	-0.369	-0.235	0.167	0.348	0.409	0.150	0.578*	-0.436
	Vg	0.494*	0.708**	0.397	0.549*	0.332	0.159	0.381	0.538*	0.186	0.115	0.578*	0.019	0.092
S	Vp	0.220	0.213	0.826**	0.049	0.323	0.198	0.274	0.042	0.071	-0.149	-0.316	0.073	0.192
	Vg	0.413	0.428	0.000	0.856**	0.222	0.462	0.305	0.878**	0.793**	0.581*	0.232	0.790**	0.476
T	Vp	-0.127	-0.761**	-0.077	-0.245	-0.172	-0.103	-0.051	0.188	0.223	0.171	0.544*	0.121	-0.121
	Vg	0.640**	0.001	0.777**	0.361	0.525	0.704**	0.851	0.485*	0.406	0.527*	0.030	0.656**	0.656**
U	Vp	0.186	0.129	-0.193	-0.456	-0.321	-0.175	0.153	0.404	0.225	0.240	-0.122	0.409	-0.324
	Vg	0.490*	0.634**	0.475	0.076	0.225	0.517*	0.573*	0.120	0.403	0.371	0.653**	0.116	0.220
V	Vp	-0.144	-0.355	-0.068	-0.076	-0.031	-0.056	-0.339	-0.005	0.164	0.128	-0.143	0.294	-0.182
	Vg	0.594*	0.177	0.802**	0.779**	0.910**	0.837**	0.200	0.984**	0.544*	0.638**	0.597*	0.270	0.501*
W	Vp	0.035	-0.434	0.293	-0.216	0.170	-0.070	-0.226	0.079	0.140	0.254	-0.146	0.386	-0.221
	Vg	0.898**	0.093	0.271	0.422	0.529	0.797**	0.400	0.772**	0.606**	0.342	0.590*	0.140	0.411
X	Vp	0.194	0.185	-0.325	-0.277	-0.056	0.060	-0.015	0.036	-0.235	0.579*	0.243	0.007	-0.554*
	Vg	0.471	0.494*	0.219	0.299	0.838**	0.820**	0.956**	0.894**	0.381	0.019	0.363	0.978**	0.026

Continued…

		N	O	P	Q	R	S	T	U	V	W	X
A	Vp	0.177	0.437	-0.438	-0.266	0.184	0.220	-0.127	0.186	-0.144	0.035	0.194
	Vg	0.512*	0.091	0.090	0.319	0.494*	0.413	0.640**	0.490*	0.594*	0.898**	0.471
B	Vp	0.216	0.272	-0.513*	-0.404	0.102	0.213	-0.761**	0.129	-0.355	-0.434	0.185
	Vg	0.421	0.309	0.042	0.121	0.708**	0.428	0.001	0.634**	0.177	0.093	0.494*
C	Vp	-0.312	0.285	-0.694**	-0.692**	-0.227	0.826**	-0.077	-0.193	-0.68	0.293	-0.325
	Vg	0.239	0.285	0.003	0.003	0.397	0.000	0.777**	0.475	0.802**	0.271	0.219
D	Vp	-0.272	0.008	0.095	-0.021	-0.162	0.049	-0.245	-0.456	-0.076	-0.216	-0.277
	Vg	0.308	0.976**	0.727**	0.940**	0.549*	0.856**	0.361	0.076	0.779**	0.422	0.299
E	Vp	0.115	0.571*	-0.080	0.023	0.259	0.323	-0.172	-0.321	-0.031	0.170	-0.056
	Vg	0.671**	0.021	0.769**	0.934**	0.332	0.222	0.525*	0.225	0.910**	0.529*	0.838**
F	Vp	-0.115	-0.219	-0.192	-0.345	-0.369	0.198	-0.103	-0.175	-0.056	-0.070	0.060
	Vg	0.672**	0.415	0.477	0.191	0.159	0.462	0.704**	0.517*	0.837**	0.797**	0.825**
G	Vp	-0.364	0.222	-0.530*	-0.533*	-0.235	0.274	-0.051	0.153	-0.339	-0.226	-0.015
	Vg	0.166	0.408	0.035	0.034	0.381	0.305	0.851**	0.573*	0.200	0.400	0.956**
H	Vp	0.430	0.165	-0.092	0.023	0.167	0.042	0.188	0.404	-0.005	0.079	0.036
	Vg	0.090	0.543*	0.736**	0.933**	0.538*	0.878**	0.485*	0.120	0.984**	0.772**	0.894**
I	Vp	0.131	0.090	0.030	0,185	0.348	0.070	0.223	0.225	-0.164	0.140	-0.234
	Vg	0.629**	0.741**	0.913**	0.493*	0.186	0.793**	0.406	0.403	0.544*	0.606**	0.381
J	Vp	0.176	-0.123	-0.216	0.032	0.409	-0.149	0.171	0.240	0.128	0.254	0.579*
	Vg	0.514*	0.650**	0.423	0.906**	0.115	0.581*	0.527*	0.371	0.638**	0.342	0.019
K	Vp	-0.048	-0.260	0.479	0.497	0.150	-0.316	0.544*	-0.122	-0.143	-0.146	0.243
	Vg	0.860**	0.331	0.061	0.050	0.578*	0.232	0.030	0.653**	0.597*	0.590*	0.363
L	Vp	-0.026	0.170	-0.045	0.205	0.578*	0.073	0.121	0.409	0.294	0.386	0.007
	Vg	0.924**	0.530*	0.869**	0.446	0.019	0.790**	0.656**	0.116	0.270	0.140	0.978**
M	Vp	0.011	-0.141	0.177	-0.070	-0.436	0.192	-0.121	-0.324	-0.182	-0.221	-0.554*

	Vg	0.967**	0.602	0.511*	0.796**	0.092	0.476	0.656**	0.220	0.501*	0.411	0.026
N	Vp	1	-0.288	0.038	0.144	0.274	-0.065	-0.125	0.191	-0.008	-0.122	0.103
	Vg	1	0.279	0.888**	0.595*	0.304	0.811**	0.644**	0.478	0.976**	0.652**	0.705**
O	Vp	-0.288	1	-0.150	-0.026	0.272	0.274	-0.192	0.045	-0.290	-0.037	0.134
	Vg	0.279	1	0.579*	0.925**	0.308	0.305	0.475	0.868**	0.275	0.891**	0.622**
P	Vp	0.038	-0.150	1	0.892**	0.129	-0.756**	0.297	-0.117	0.406	0.079	0.120
	Vg	0.888**	0.579*	1	0.000	0.633**	0.001	0.264	0.665**	0.119	0.771**	0.658**
Q	Vp	0.144	-0.026	0.892**	1	0.556*	-0.746**	0.354	0.116	0.279	0.044	0.287
	Vg	0.595*	0.925**	0.000	1	0.025	0.001	0.178	0.669**	0.296	0.870**	0.281
R	Vp	0.274	0.272	0.129	0.556*	1	-0.204	0.177	0.431	-0.086	-0.010	0.417
	Vg	0.304	0.308	0.633**	0.025	1	0.448	0.511*	0.095	0.750**	0.970**	0.108
S	Vp	-0.065	0.274	-0.756**	-0.746**	-0.204	1	-0.033	-0.083	-0.256	0.236	-0.375
	Vg	0.811**	0.305	0.001	0.001	0.448	1	0.903**	0.759**	0.338	0.378	0.153
T	Vp	-0.125	-0.192	0.297	0.354	0.117	-0.033	1	0.017	0.296	0.538*	0.074
	Vg	0.644**	0.475	0.264	0.178	0.511*	0.903**	1	0.950**	0.265	0.032	0.786**
U	Vp	0.191	0.045	-0.117	0.116	0.431	-0.083	0.017	1	-0.269	-0.272	-0.148
	Vg	0.478	0.868**	0.665**	0.669**	0.095	0.759**	0.950**	1	0.314	0.308	0.584*
V	Vp	-0.008	-0.290	0.406	0.276	-0.086	-0.256	0.296	-0.269	1	0.767**	-0.045
	Vg	0.976**	0.275	0.119	0.296	0.750**	0.338	0.265	0.314	1	0.001	0.869**
W	Vp	-0.122	-0.037	0.079	0.044	-0.010	0.236	0.538*	-0.272	0.767**	1	-0.038
	Vg	0.652**	0.891**	0.771**	0.870**	0.970**	0.378	0.032	0.308	0.001	1	0.890**
X	Vp	0.103	0.134	0.120	0.287	0.417	-0.375	0.074	-0.148	-0.045	-0.038	1
	Vg	0.705**	0.622**	0.658	0.281	0.108	0.153	0.786**	0.584*	0.869**	0.890**	1

****= Significant at 0.05 and 0.01 level, *= significant at 0.05 level, Vg= genotypic correlation, Vp= phenotypic correlation**

A= plant height, B= number of tillers, C= survival per cent, D=SLA, E=RWC, F= SCMR values, G= biomass, H= root length, I= root volume, J= leaf proline content, K= leaf calcium content, L= leaf chloride content, M= leaf sulphate content, N= root CEC, O= productive tillers per plant, P= total spikelets per panicle, Q= filled grains per panicle, R= seed setting per cent, S= sterility per cent, T= length of panicle, U= 1000 grain weight, V= grain yield W= straw yield X= leaf Na / K ratio.

Grain yield showed significant positive genotypic correlation with plant height, survival per cent, root volume, root length, leaf proline content, leaf calcium content, leaf sulphate content, root CEC and leaf Na / K ratio at both seedling and flowering stages. SLA, RWC and SCMR at seedling stage, number of tillers, uppermost internodal length, seed setting percentage and biomass at flowering stage showed significant positive genotypic correlation with grain yield.

Survival per cent showed significant positive genotypic correlation with number of tillers, SLA, root volume, leaf proline content, leaf chloride content and leaf sulphate content at both seedling and flowering stages. Uppermost internodal length, RWC, biomass, length of panicle, grain yield and 1000 grain weight at flowering stage, root length at seedling stage showed significant positive genotypic correlation with survival per cent.

Biomass showed significant positive genotypic association with number of tillers, SLA, root volume and leaf Na / K ratio at both seedling and flowering stages. Leaf proline content at seedling stage, plant height, survival per cent, SCMR values, root length, root CEC, total spikelets per panicle, filled grains per panicle, 1000 grain weight, sterility percentage and grain yield at flowering stage showed significant positive genotypic correlation with biomass.

Straw yield showed significant positive genotypic association with plant height, root length, root volume, leaf calcium content, leaf Na / K ratio and root CEC at both seedling and flowering stages. SCMR values at seedling stage, and number of tillers per panicle, number of internodes, uppermost internodal length, SLA, RWC, leaf sulphate content, productive tillers per plant, seed setting per cent and filled grains per panicle and total spikelets per panicle at flowering stage showed significant positive genotypic correlation with straw yield.

Some of the characteristics showed high significant phenotypic correlation but non-significant genotypic correlation. This reflects the influence of environment on these traits. The details of significant correlations are described below.

At seedling stage phenotypic correlation of root length with plant height, biomass with SCMR and leaf Na / K ratio with leaf proline content were found to be significant and positive. At flowering stage at phenotypic correlations namely level plant height with RWC, number of tillers with number of internodes, number of internodes with uppermost internodal length, leaf proline content with SLA, leaf chloride content with survival per cent, root CEC with RWC, productive tillers per plant with number of tillers per plant and number of internodes, filled grains per panicle with leaf calcium content, length of panicle with survival per cent and leaf calcium content, leaf Na / K ratio with leaf proline and sulphate content, total spikelets per panicle with filled grains per panicle, seed setting percentage with leaf calcium content and filled grains per panicle, and straw yield with length of panicle and grain yield were found to be significant.

At seedling stage SLA with plant height, leaf proline content and root length; leaf sulphate content with leaf proline content and plant height showed significant negative phenotypic correlation. At flowering stage phenotypic correlation of survival per cent with total spikelets per panicle and filled grains per panicle; leaf chloride content with leaf proline content and plant height; 1000 grain weight with SLA; leaf Na / K ratio with leaf sulphate content, and sterility per cent with total spikelets per panicle and filled grains per panicle were found to be significantly negative.

Table 44. Genotypic and phenotypic correlation coefficients in high-saline Kaipad at flowering stage

		A	B	C	D	E	F	G	H	I	J	K	L	M
A	Vp	1	0.403	0.399	0.493	0.360	-0.476	0.502*	-0.144	0.020	0.328	-0.180	0.477	-0.389
	Vg	1	0.121	0.125	0.052	0.171	0.062	0.047	0.594*	0.941**	0.214	0.505*	0.062	0.136
B	Vp	0.403	1	0.535*	0.485	0.167	0.013	0.007	-0.282	0.061	0.423	0.350	-0.166	-0.051
	Vg	0.121	1	0.033	0.057	0.537*	0.961**	0.980**	0.290	0.821**	0.103	0.184	0.538*	0.851**
C	Vp	0.399	0.535*	1	0.723**	0.312	0.379	-0.060	0.010	0.386	0.377	0.157	-0.381	-0.112
	Vg	0.125	0.033	1	0.002	0.239	0.147	0.826**	0.970**	0.140	0.151	0.561	0.146	0.680**
D	Vp	0.493	0.485	0.723*	1	0.067	0.026	0.154	-0.095	0.437	0.133	0.107	-0.247	-0.174
	Vg	0.052	0.057	0.002	1	0.804**	0.924**	0.569*	0.725**	0.090	0.623**	0.693**	0.355	0.518*
E	Vp	0.360	0.167	0.312	0.067	1	0.043	-0.079	0.483	0.004	0.356	0.118	-0.012	-0.304
	Vg	0.171	0.537*	0.239	0.804**	1	0.875**	0.772**	0.058	0.987**	0.175	0.663**	0.966**	0.252
F	Vp	-0.476	0.013	0.379	0.026	0.043	1	-0.287	0.269	0.122	0.086	0.284	-0.607*	-0.304
	Vg	0.062	0.961**	0.147	0.924**	0.875**	1	0.282	0.314	0.653**	0.753**	0.286	0.013	0.049
G	Vp	0.502*	0.007	-0.060	0.154	-0.079	-0.287	1	-0.050	-0.261	-0.018	0.131	0.422	-0.263
	Vg	0.047	0.980**	0.826**	0.569*	0.772**	0.282	1	0.855**	0.329	0.948**	0.630**	0.103	0.326
H	Vp	-0.144	-0.282	0.010	-0.095	0.483	0.269	-0.050	1	0.048	0.068	0.061	-0.212	0.043
	Vg	0.594*	0.290	0.970**	0.725**	0.058	0.314	0.855**	1	0.859**	0.803**	0.822**	0.430	0.876**
I	Vp	0.020	0.061	0.386	0.437	0.004	0.122	-0.261	0.048	1	-0.028	-0.005	-0.469	-0.351
	Vg	0.941**	0.821**	0.140	0.090	0.987**	0.653**	0.329	0.859**	1	0.919**	0.986**	0.067	0.183
J	Vp	0.328	0.423	0.377	0.133	0.356	0.086	-0.018	0.068	-0.028	1	0.400	-0.139	0.150
	Vg	0.214	0.103	0.151	0.623**	0.175	0.753**	0.948**	0.803**	0.919**	1	0.125	0.607*	0.579*
K	Vp	-0.180	0.350	0.157	0.107	0.118	0.284	0.131	0.061	-0.005	0.400	1	-0.467	0.038
	Vg	0.505*	0.184	0.561	0.693**	0.663**	0.286	0.630**	0.822**	0.986**	0.125	1	0.068	0.890**
L	Vp	0.477	-0.166	-0.381	-0.247	-0.012	-0.607*	0.422	-0.212	-0.469	-0.139	-0.467	1	-0.152
	Vg	0.062	0.538*	0.146	0.355	0.966**	0.013	0.103	0.430	0.067	0.607*	0.068	1	0.575*
M	Vp	-0.389	-0.051	-0.112	-0.174	-0.304	-0.304	-0.263	0.043	-0.351	0.150	0.038	-0.152	1
	Vg	0.136	0.851**	0.680**	0.518*	0.252	0.049	0.326	0.876**	0.183	0.579*	0.890**	0.575*	1
N	Vp	-0.114	0.152	-0.265	-0.210	0.106	-0.367	-0.140	-0.217	-0.203	-0.119	0.082	0.270	-0.206
	Vg	0.674**	0.575*	0.321	0.434	0.695**	0.162	0.604*	0.419	0.451`	0.660**	0.762**	0.312	0.445

O	Vp	-0.610*	-0.080	0.280	0.131	-0.051	0.775**	-0.400	0.243	0.372	0.033	0.437	-0.920**	0.296
	Vg	0.012	0.768**	0.294	0.628**	0.852**	0.000	0.125	0.365	0.156	0.904**	0.090	0.000	0.266
P	Vp	0.185	-0.381	0.022	0.363	-0.239	-0.119	0.501*	-0.152	0.133	-0.419	-0.157	0.201	-0.082
	Vg	0.492*	0.145	0.936**	0.168	0.373	0.661**	0.048	0.574*	0.623**	0.106	0.561*	0.456	0.763**
Q	Vp	0.437	0.905**	0.515*	0.387	0.272	-0.008	0.009	-0.341	0.233	0.272	0.287	-0.116	-0.289
	Vg	0.091	0.000	0.041	0.139	0.309	0.976**	0.972**	0.196	0.384	0.308	0.281	0.668**	0.277
R	Vp	-0.438	0.041	-0.283	0.079	-0.698**	0.200	-0.083	-0.076	0.097	-0.122	0.146	-0.220	0.482
	Vg	0.090	0.880**	0.289	0.772**	0.003	0.458	0.761**	0.780**	0.722**	0.652**	0.589*	0.413	0.058
S	Vp	-0.266	0.142	-0.330	0.036	-0.698**	-0.019	0.039	-0.276	-0.104	-0.106	0.178	0.028	0.499*
	Vg	0.319	0.600*	0.212	0.895**	0.003	0.944**	0.886**	0.301	0.701**	0.697**	0.510*	0.919**	0.049
T	Vp	0.184	0.258	-0.212	-0.060	-0.240	-0.383	0.273	-0.474	-0.391	-0.069	0.154	0.407	0.142
	Vg	0.494*	0.334	0.432	0.825**	0.370	0.143	0.306	0.063	0.134	0.799**	0.568*	0.118	0.599*
U	Vp	0.220	0.116	0.487	0.124	0.847**	0.223	-0.052	0.219	0.047	0.283	0.184	-0.138	-0.338
	Vg	0.413	0.668**	0.055	0.646**	0.000	0.407	0.850**	0.416	0.862**	0.288	0.495*	0.611**	0.200
V	Vp	-0.127	0.075	-0.041	-0.102	-0.026	0.237	0.140	0.190	-0.479	0.469	0.278	0.176	0.557*
	Vg	0.640**	0.782**	0.881**	0.708**	0.923**	0.377	0.604*	0.481	0.061	0.067	0.297	0.514*	0.025
W	Vp	0.186	0.011	0.054	-0.012	-0.176	-0.507*	-0.069	-0.267	0.167	0.153	-0.241	0.231	-0.141
	Vg	0.490*	0.969**	0.844**	0.965**	0.514*	0.045	0.799**	0.317	0.536*	0.572*	0.369	0.390	0.603*
X	Vp	-0.144	-0.153	-0.463	-0.001	-0.069	-0.214	0.218	0.290	-0.156	-0.084	0.063	0.116	-0.114
	Vg	0.594*	0.571*	0.071	0.996**	0.799**	0.425	0.418	0.276	0.563*	0.758**	0.817**	0.668**	0.674**
Y	Vp	0.035	0.034	-0.138	0.030	0.322	-0.007	0.181	0.279	-0.276	0.181	0.176	0.253	-0.127
	Vg	0.898**	0.899**	0.611**	0.911**	0.223	0.978**	0.502*	0.296	0.301	0.502*	0.514*	0.345	0.639**
Z	Vp	0.256	0.244	-0.165	-0.008	-0.278	-0.080	0.323	-0.095	-0.128	-0.117	-0.178	0.505*	0.279
	Vg	0.339	0.362	0.542*	0.976**	0.298	0.767**	0.223	0.726**	0.635**	0.665**	0.509*	0.046	0.296

Continued...

		N	O	P	Q	R	S	T	U	V	W	X	Y	Z
A	Vp	-0.114	-0.610*	0.185	0.437	-0.438	-0.266	0.184	0.220	-0.127	0.186	-0.144	0.035	0.256
	Vg	0.674**	0.012	0.492*	0.091	0.090	0.319	0.494*	0.413	0.640**	0.490*	0.594*	0.898**	0.339
B	Vp	0.152	-0.080	-0.381	0.905**	0.040	0.142	0.258	0.116	0.075	0.011	-0.153	0.034	0.244
	Vg	0.575*	0.768**	0.145	0.000	0.880**	0.600*	0.334	0.668**	0.782**	0.969**	0.571*	0.899**	0.362
C	Vp	-0.265	0.280	0.022	0.515*	-0.283	-0.330	-0.212	0.487	-0.041	0.054	-0.463	-0.138	-0.165
	Vg	0.321	0.294	0.936**	0.041	0.289	0.212	0.432	0.055	0.881**	0.844**	0.071	0.611	0.542*
D	Vp	-0.210	0.131	0.363	0.387	0.079	0.036	-0.060	0.124	-0.102	-0.012	-0.001	0.030	-0.008
	Vg	0.434	0.628**	0.168	0.139	0.772**	0.895**	0.825**	0.646**	0.708**	0.965**	0.996**	0.911**	0.976**
E	Vp	0.106	-0.051	-0.239	0.272	-0.698**	-0.698**	-0.240	0.847**	-0.026	-0.176	-0.069	0.322	-0.278
	Vg	0.695**	0.852**	0.373	0.309	0.003	0.003	0.370	0.000	0.923**	0.514*	0.799**	0.223	0.298
F	Vp	-0.367	0.775**	-0.119	-0.008	0.200	-0.019	-0.383	0.223	0.237	-0.507*	-0.214	-0.007	-0.080
	Vg	0.162	0.000	0.661**	0.976**	0.458	0.944**	0.143	0.407	0.377	0.045	0.425	0.978**	0.767**
G	Vp	-0.140	-0.400	0.501*	0.009	-0.083	0.039	0.273	-0.052	0.140	-0.069	0.218	0.181	0.323
	Vg	0.604*	0.125	0.048	0.972**	0.761**	0.886**	0.306	0.850**	0.604*	0.799**	0.418	0.502*	0.223
H	Vp	-0.217	0.243	-0.152	-0.341	-0.076	-0.276	-0.474	0.219	0.190	-0.267	0.290	0.279	-0.095
	Vg	0.419	0.365	0.574*	0.196	0.780**	0.301	0.063	0.416	0.481	0.317	0.276	0.296	0.726**
I	Vp	-0.203	0.372	0.133	0.233	0.097	-0.104	-0.391	0.047	-0.479	0.167	-0.156	-0.276	-0.128
	Vg	0.451	0.156	0.623**	0.384	0.722**	0.701**	0.134	0.862**	0.061	0.536*	0.563*	0.301	0.635**
J	Vp	-0.119	0.033	-0.419	0.272	-0.122	-0.106	-0.069	0.283	0.469	0.153	-0.084	0.181	-0.117
	Vg	0.660**	0.904**	0.106	0.308	0.653**	0.697**	0.799**	0.288	0.067	0.572*	0.758**	0.502*	0.665**
K	Vp	0.082	0.437	-0.157	0.287	0.146	0.178	0.154	0.184	0.278	-0.241	0.063	0.176	-0.178
	Vg	0.762**	0.090	0.561*	0.281	0.589*	0.510	0.568*	0.495*	0.297	0.369	0.817**	0.514*	0.509*
L	Vp	0.270	-0.92**	0.201	-0.116	-0.220	0.028	0.407	-0.138	0.176	0.231	0.116	0.253	0.505*
	Vg	0.312	0.000	0.456	0.668	0.413	0.919**	0.118	0.611*	0.514*	0.390	0.668**	0.345	0.046
M	Vp	-0.206	0.296	-0.082	-0.289	0.482	0.499*	0.142	-0.338	0.557*	-0.141	-0.114	-0.127	0.279
	Vg	0.445	0.266	0.763	0.277	0.058	0.049	0.599*	0.200	0.025	0.603*	0.674**	0.639**	0.296
N	Vp	1	-0.316	-0.024	0.232	-0.111	0.141	0.561*	0.143	0.143	0.385	0.269	0.422	-0.002
	Vg	1	0.232	0.931**	0.388	0.684**	0.601*	0.024	0.598*	0.597*	0.141	0.313	0.103	0.995**

O	Vp	-0.316	1	-0.032	-0.098	0.293	0.043	-0.386	0.140	-0.063	-0.341	-0.096	-0.159	-0.498*
	Vg	0.232	1	0.905**	0.718**	0.271	0.874**	0.140	0.606*	0.817**	0.197	0.722**	0.556*	0.050
P	Vp	-0.024	-0.032	1	-0.289	0.035	0.146	0.287	-0.028	-0.089	0.160	0.052	-0.021	0.032
	Vg	0.931**	0.905**	1	0.278	0.897**	0.590*	0.282	0.918**	0.743**	0.554*	0.848**	0.939**	0.905**
Q	Vp	0.232	-0.098	-0.289	1	-0.150	-0.026	0.272	0.274	-0.192	0.045	-0.290	-0.037	0.195
	Vg	0.388	0.718**	0.278	1	0.579*	0.925**	0.308	0.305	0.475	0.868**	0.275	0.891**	0.470
R	Vp	-0.111	0.293	0.035	-0.150	1	0.892**	0.129	-0.756**	0.297	-0.117	0.406	0.079	0.338
	Vg	0.684**	0.271	0.897**	0.579*	1	0.000	0.633**	0.001	0.264	0.665	0.119	0.771**	0.201
S	Vp	0.141	0.043	0.146	-0.026	0.892**	1	0.556*	-0.746**	0.354	0.116	0.279	0.044	0.444
	Vg	0.601*	0.874**	0.590*	0.925**	0.000	1	0.025	0.001	0.178	0.669**	0.296	0.870**	0.085
T	Vp	0.561*	-0.386	0.287	0.272	0.129	0.556*	1	-0.204	0.177	0.431	-0.086	-0.010	0.300
	Vg	0.024	0.140	0.282	0.308	0.633**	0.025	1	0.448	0.511*	0.095	0.750**	0.970**	0.259
U	Vp	0.143	0.140	-0.028	0.274	-0.756**	-0.746**	-0.204	1	-0.033	-0.083	-0.256	0.236	-0.499*
	Vg	0.598*	0.606*	0.918**	0.305	0.001	0.001	0.448	1	0.903**	0.759**	0.338	0.378	0.049
V	Vp	0.143	-0.063	-0.089	-0.192	0.297	0.354	0.177	-0.033	1	0.017	0.296	0.538*	0.279
	Vg	0.597*	0.817**	0.743**	0.475	0.264	0.178	0.511*	0.903**	1	0.950**	0.265	0.032	0.295
W	Vp	0.385	-0.341	0.160	0.045	-0.117	0.116	0.431	-0.083	0.017	1	-0.269	-0.272	-0.076
	Vg	0.141	0.197	0.554*	0.868	0.665**	0.669**	0.095	0.759**	0.950**	1	0.314	0.308	0.780**
X	Vp	0.269	-0.096	0.052	-0.290	0.406	0.279	-0.086	-0.256	0.296	-0.269	1	0.767**	0.080
	Vg	0.313	0.722**	0.848**	0.275	0.119	0.296	0.750**	0.338	0.265	0.314	1	0.001	0.767**
Y	Vp	0.422	-0.159	-0.021	-0.037	0.079	0.044	-0.10	0.236	0.538*	-0.272	0.767**	1	0.059
	Vg	0.103	0.556*	0.939**	0.891**	0.771**	0.870**	0.970**	0.378	0.032	0.308	0.001	1	0.828**
Z	Vp	-0.002	-0.498*	0.032	0.195	0.338	0.444	0.300	-0.499	0.279	-0.076	0.080	0.059	1
	Vg	0.995**	0.050	0.905**	0.470	0.201	0.085	0.259	0.049	0.295	0.780**	0.767**	0.828**	1

****= Significant at 0.05 and 0.01 level, *= significant at 0.05 level, Vg= genotypic correlation, Vp= phenotypic correlation**

A= plant height, B= number of tillers, C= number of nodes, D= uppermost internodal length, E= survival per cent, F=SLA, G=RWC, H= SCMR, I= biomass, J= root length, K= root volume, L= leaf proline content, M= leaf calcium content, N= leaf chloride content, O= leaf sulphate content, P= root CEC, Q= productive tillers per plant, R= total spikelets per panicle, S= filled grains per panicle, T= seed setting per cent, U= sterility per cent, V= length of panicle, W= 1000 grain weight, X= grain yield, Y= straw yield, Z= leaf Na / K ratio.

4.3.2. Path analysis

Grain yield is the major economic characteristic in rice which depends on several component traits, which are mutually related. Minimal change in any one of the component would ultimately disturb the complex. Hence, these related traits have to be analyzed for its action namely direct effect of component character on grain yield and the indirect effects through other component traits on grain yield. The estimate of direct and indirect effects of 16 rice genotypes grown in high-saline Kaipad for 24 parameters at seedling stage and 26 parameters at flowering stage which includes morphological, physiological, biochemical and yield parameters on grain yield per plot were described.

Genotypic and phenotypic path coefficient analysis among the 24 characteristics at seedling stage were assessed and presented in Table 45 and at flowering stage 26 characteristics subjected to path analysis and presented in Table 46.

The residual effect of path analysis in high-saline condition at seedling stage was found to be sq (1-1.0572) at genotypic level and 0.1844 at phenotypic level. The parameters those exerted direct positive effects on grain yield per plot at both genotypic and phenotypic levels are survival per cent, relative water content (RWC), root volume, leaf calcium content, leaf potassium content, leaf chloride content, leaf Na / K ratio and root CEC. However the parameters like plant height, number of tillers, specific leaf area (SLA), biomass, root length, leaf proline content, leaf sodium content and leaf sulphate content exhibited direct negative effect on grain yield per plot at both genotypic and phenotypic levels. In the case of SCMR, direct effect is positive at genotypic level but negative at phenotypic level.

The residual effect of path analysis in high-saline condition at flowering stage was found to be sq (1-1.0107) at genotypic level and 0.0865 at phenotypic level. The parameters those exerted direct positive effect on grain yield per plot at both genotypic and phenotypic levels are number of tillers, uppermost internodal

Table 45. Genotypic and phenotypic path analysis in high-saline Kaipad at seedling stage

		A	B	C	D	E	F	G	H	I	J	K	L	M
A	P	**-0.3675**	-0.0843	-0.1426	0.1844	-0.0694	0.0447	-0.0902	-0.2104	-0.0833	-0.1395	0.1174	0.0687	0.0273
	G	**-0.2330**	-0.1653	-0.0814	0.2162	-0.1010	-0.0232	-0.1527	-0.2794	-0.0742	-0.1705	0.1389	0.0723	-0.004
B	P	-0.0079	**-0.0343**	-0.0033	-0.0007	-0.0029	-0.0019	0.000	-0.0014	0.0017	-0.0036	0.013	0.0100	0.0038
	G	-0.0768	**-0.1082**	-0.0276	0.0493	-0.0068	0.0000	-0.0153	0.0191	0.0113	-0.0153	0.0527	0.0431	0.0165
C	P	0.1274	0.0314	**0.3282**	-0.0212	0.0930	0.0730	0.1332	0.0427	0.0438	-0.0066	-0.0984	-0.0093	-0.1663
	G	0.1218	0.0889	**0.3482**	-0.0373	0.1090	0.1895	0.1777	0.0574	0.0488	-0.0079	-0.1167	-0.0077	-0.1249
D	P	0.0636	-0.0024	0.0082	**-0.1267**	-0.0169	0.0006	0.0260	0.0518	0.0062	0.0814	-0.0302	-0.0320	0.0075
	G	0.0362	0.0178	0.0042	**-0.0390**	-0.0073	-0.0046	0.0155	0.0432	0.0026	0.0457	-0.0174	-0.0166	0.0071
E	P	0.1768	0.0782	0.2650	0.1246	**0.9358**	-0.3877	-0.2421	0.1151	0.3468	-0.1953	-0/1628	-0.3659	0.1521
	G	0.3894	0.0567	0./2809	0.1673	**0.8979**	-0.4183	-0.2831	0.0831	0.3621	-0.1904	-0.1576	-0.3568	0.1394
F	P	0.0099	-0.0044	-0.0181	0.0004	0.0337	**-0.0814**	-0.0391	0.0053	0.0295	0.000	0.0003	-0.0213	0.0150
	G	0.0025	0.0000	0.0134	0.0029	-0.0155	**0.0247**	0.0164	-0.0015	-0.0111	0.000	-0.0002	0.0080	-0.0040
G	P	-0.0487	-0.0001	-0.0804	0.0406	0.0513	-0.0951	**-0.1983**	-0.0363	0.0244	-0.0144	0.0360	-0.0319	0.0842
	G	-0.1344	-0.0290	-0.1046	0.0817	0.0646	-0.13621	**-0.2050**	-0.0598	0.0557	-0.0178	0.0462	-0.0416	0.1119
H	P	0.2250	-0.0165	-0.0511	0.1606	-0.0483	0.0255	-0.0719	**-0.3928**	-0.1538	-0.1098	0.0229	0.0888	0.0284
	G	-0.3974	0.0585	-0.0546	0.3674	-0.0307	0.0204	-0.0966	**-0.3314**	-0.1576	-0.1156	0.0183	0.0882	-0.0070
I	P	0.0245	-0.0053	0.0145	-0.0053	0.0401	-0.0392	-0.0133	0.0424	**0.1082**	-0.0199	0.0246	-0.0089	-0.0113
	G	0.0728	-0.0239	0.0321	-0.0155	0.0922	-0.1026	-0.0621	0.1087	**0.2286**	-0.0438	0.0550	-0.0188	-0.0225
J	P	-0.2215	-0.0610	0.0118	0.3747	0.1217	0.0002	-0.0425	-0.1630	0.1072	**-0.5834**	0.1191	0.0494	-0.1329
	G	-0.4705	-0.0910	0.0145	0.7543	0.1364	0.0003	-0.0559	-0.2243	0.1231	**-0.6430**	0.1314	0.0555	-0.1520
K	P	-0.0629	-0.0749	-0.0591	0.0470	-0.0343	-0.0007	-0.0358	-0.0115	0.0448	-0.0402	**0.1970**	0.0475	0.0345
	G	-0.0336	-0.0274	-0.0189	0.0251	-0.0099	-0.0005	-0.0127	-0.0031	0.0136	-0.0115	**0.0563**	0.0138	0.0101
L	P	0.0989	0.1540	0.0149	-0.1333	0.2067	-0.1384	-0.0849	0.1195	0.0432	0.0448	-0.1274	**-0.5286**	-0.0896
	G	0.2101	0.2702	0.0151	-0.2881	0.2692	-0.2197	-0.1375	0.1803	0.0558	0.0585	-0.1663	**-0.6774**	-0.1243
M	P	-0.0991	-0.1461	-0.6767	-0.0791	0.2170	-0.2467	-0.5672	-0.0964	-0.1398	0.3041	0.2339	0.2263	**1.3353**
	G	0.0240	-0.2138	-0.8653	-0.2551	0.2177	-0.2283	-0.7658	0.0297	-0.1378	0.3315	0.2503	0.2573	**1.4023**
N	P	-0.0161	0.0079	0.0069	-0.0319	0.0225	-0.0464	-0.0325	-0.0124	0.0271	0.0354	-0.0265	-0.0040	0.0083
	G	-0.0241	0.0091	0.0106	-0.0500	0.0208	-0.0561	-0.0328	-0.0165	0.0271	0.0323	-0.0243	-0.0037	0.0090

O	P	0.7154	0.2889	0.0692	-1.0630	-0.2664	-0.0400	0.3505	0.5836	-0.1101	1.4883	-0.4447	-0.1534	0.2980
	G	1.4629	0.0091	0.0106	-0.0500	0.0208	-0.0561	-0.0328	-0.0165	0.0271	0.0323	-0.0243	-0.0037	0.0090
P	P	0.1046	0.1402	-0.2015	-0.0844	0.0858	-0.0797	-0.2462	0.2891	0.0972	0.1292	-0.0353	-0.3119	0.0928
	G	0.2088	0.1965	-0.2335	-0.1596	0.0902	-0.0989	-0.3043	0.3734	0.1049	0.1337	-0.0366	-0.3291	0.0997
Q	P	-0.1013	-0.0447	-0.0829	0.0138	-0.1445	0.0773	-0.0299	-0.0214	-0.0164	0.0134	0.0680	0.0178	-0.0418
	G	-0.1598	-0.1135	-0.0658	0.0244	-0.1596	0.0335	-0.0968	-0.0741	-0.0323	0.0340	0.0704	0.0380	-0.0381
R	P	-1.4827	-1.8504	-2.7128	1.0018	-0.3201	-0.7361	-2.0462	-0.3340	0.1053	-0.8847	1.9627	1.0058	2.4392
	G	-2.7373	-2.5798	-3.0852	1.8187	-0.3453	-0.8796	-2.4115	-0.4469	0.1442	-0.9106	2.0244	1.0447	2.5991
S	P	1.0184	1.6168	2.9993	-0.3477	-0.1020	1.4329	2.2420	-0.0775	-0.8083	-0.1446	-2.2399	-0.6390	-2.8304
	G	1.8995	2.3646	3.6315	-0.6433	-0.1121	1.888	2.8833	-0.1511	-0.9476	-0.1590	-2.4625	-0.6992	-3.2144
T	P	0.1805	0.0913	-0.2713	-0.2940	0.3000	-0.3940	-0.2421	0.1537	0.4088	0.4844	0.1791	-0.1578	0.4043
	G	0.3871	0.1954	-0.3524	-0.5729	0.3776	-0.5924	-0.3882	0.3050	0.5001	0.5820	0.2113	-0.1911	0.4918
U	P	-0.0576	-0.0555	-0.2617	-0.0072	-0.1064	-0.0638	-0.0895	-0.0090	-0.0212	0.0490	0.1032	0.0472	0.1721
	G	-0.2322	-0.1914	-0.6167	-0.0801	-0.2215	-0.1402	-0.1905	-0.0414	-0.0537	0.1026	0.2182	0.0972	0.3774
V	P	-0.0107	-0.1227	0.0009	-0.0279	-0.0243	-0.0294	-0.0053	0.0411	0.0312	0.0275	0.0880	0.0552	0.0070
	G	-0.0734	-0.2194	-0.0284	0.0206	-0.0542	-0.0025	-0.0206	0.0302	0.0174	0.0480	0.1517	00980	0.0242
W	P	0.0233	0.0199	-0.0247	-0.0758	-0.0480	-0.0351	0.0178	0.0757	0.0448	0.0585	-0.0205	-0.0477	-0.0341
	G	0.0727	0.0307	-0.0214	-0.1150	-0.0391	-0.0268	0.0073	0.0691	0.0396	0.0438	-0.0162	-0.0350	-0.0294
X	P	-0.0001	-0.0130	0.0109	-0.0035	0.0066	-0.0018	-0.0081	0.0029	0.0055	0.0100	-0.0058	0.0149	0.0073
	G	0.0129	-0.0686	0.0440	-0.0282	0.0204	-0.0116	-0.0293	0.0103	0.0164	0.0299	-0.0170	0.0420	0.0236
Y	P	-0.0391	-0.2300	0.7603	0.3720	-0.8665	0.6809	0.9229	-0.1092	-0..157	-0.4095	0.0700	0.9715	-1.4454
	G	-0.3895	-0.3448	0.9535	0.8006	-0.8864	0.7649	1.2742	-0.3749	-0.0408	-0.4323	0.0810	0.9826	-1.4262

Continued...

		N	O	P	Q	R	S	T	U	V	W	X	Y
A	P	0.0438	0.1576	-0.0520	-0.1213	0.1326	0.0828	-0.0558	-0.0636	0.0215	-0.0459	0.0006	0.0074
	G	0.0458	0.2045	-0.0636	-0.1795	0.1512	0.0892	-0.0636	-0.0798	0.0724	-0.1282	-0.0260	0.0470
B	P	-0.0020	0.0059	-0.0065	-0.0050	0.0154	0.0123	-0.0026	-0.0057	0.0230	-0.0020	0.0112	0.0041
	G	-0.008	0.0238	-0.0278	-0.0592	0.0662	0.0516	-0.0149	-0.0305	0.1004	-0.0252	0.0641	0.0193
C	P	0.0168	-0.0136	-0.0895	0.0887	-0.2167	-0.2179	-0.0750	0.2583	0.0015	-0.0433	0.0899	0.1291
	G	0.0301	-0.0172	-0.1064	0.1104	-0.2547	-0.2549	-0.0866	0.3167	-0.0419	-0.0565	0.1332	0.1721
D	P	0.0299	-0.0808	0.0145	0.0057	-0.0309	-0.0098	0.0314	-0.0027	0.0193	0.0514	0.0112	-0.0244
	G	0.0159	-0.0514	0.0081	0.0046	-0.0168	-0.0051	0.0157	-0.0046	-0.0034	0.0339	0.0095	-0.0162
E	P	0.1553	0.1495	0.1086	0.4409	-0.0729	0.0211	0.2364	0.2995	-0.1240	-0.2402	0.1541	-0.4194
	G	0.1522	0.1516	0.1059	0.6909	-0.0735	0.0203	0.2393	0.2933	-0.2061	-0.2656	0.1579	-0.4124
F	P	0.0279	-0.0020	0.0088	0.0205	0.0146	0.0258	0.0270	-0.0156	0.0131	0.0153	0.0037	-0.0287
	G	-0.0113	0.0006	-0.0032	-0.0040	-0.0051	-0.0094	-0.0103	0.0051	-0.0003	-0.0050	-0.0025	0.0098
G	P	0.0477	0.0417	0.0661	-0.0194	0.0988	0.0984	0.0404	-0.0534	0.0057	-0.0188	0.0406	-0.0947
	G	0.0548	0.0492	0.0816	-0.0957	0.1172	0.1191	0.0562	-0.0576	0.0179	-0.0114	0.0519	-0.1354
H	P	0.0360	0.1375	-0.1537	-0.0274	0.0319	-0.0067	-0.0509	-0.0107	-0.0880	-0.1590	-0.0282	0.0222
	G	0.0445	0.1414	-0.1618	-0.1183	0.0351	-0.0101	-0.0713	-0.0202	-0.0423	-0.1735	-0.0293	0.0644
I	P	0.0217	0.071	0.0142	0.0058	0.0028	0.0194	0.0373	0.0069	0.0184	0.0259	0.0149	-0.0009
	G	0.0505	0.0164	0.0313	0.0356	0.0078	0.0437	0.0807	0.0181	0.0691	0.0686	0.0324	-0.0048
J	P	-0.1528	0.5206	-0.1020	0.0598	0.1257	-0.0187	-0.2380	0.0860	-0.0877	-0.1825	-0.1459	0.1236
	G	-0.1694	0.5778	-0.1124	0.1055	0.1388	-0.0206	-0.2641	0.0973	-0.1308	-0.2133	-0.1662	0.1441
K	P	-0.0386	0.0525	-0.0094	-0.0437	0.0941	0.0977	0.0297	-0.0612	0.0946	-0.0216	-0.0286	0.0071
	G	-0.0111	0.0151	-0.0027	-0.0191	0.0270	0.0280	0.0084	-0.0181	0.0362	-0.0069	-0.0083	0.0024
L	P	0.0156	-0.0486	0.2332	0.0307	-0.1294	-0.0747	0.0703	0.0750	-0.1592	0.1348	-0.1977	-0.2656
	G	0.0206	-0.0666	0.2916	0.1241	-0.1678	-0.0955	0.0914	0.0971	-0.2839	0.1794	-0.2454	-0.3449
M	P	0.0823	-0.2385	0.1677	0.1820	0.7929	0.8365	0.4547	-0.6910	0.0508	-0.2433	0.2449	-0.9983
	G	0.1029	-0.2544	0.1828	0.2575	0.8641	0.9086	0.4867	-0.7805	0.1438	-0.3123	0.2854	-0.0365
N	P	0.1353	-0.0488	-0.0063	0.0211	-0.0102	0.0237	0.0768	0.0147	0.0150	0.0480	0.0538	-0.0245
	G	0.1227	-0.0448	-0.0058	0.0349	-0.0094	0.0216	0.0706	0.0127	0.0201	0.0471	0.0504	-0.0251

O	P	0.6016	**-1.6680**	-0.0187	0.1903	-0.2944	0.1774	0.7211	-0.3152	0.1536	0.5588	0.3620	-0.3520
	G	0.6084	**-1.6661**	-0.0188	0.3232	-0.2971	0.1159	0.7305	-0.3249	0.2706	0.5918	0.3738	-0.3696
P	P	-0.0346	0.0083	**0.7389**	-0.1760	0.0269	0.1065	0.2048	-0.0464	-0.0809	0.1231	-0.0922	-0.2939
	G	-0.0360	0.0086	**0.7646**	-0.2915	0.0279	0.1104	0.2134	-0.0493	-0.1133	0.2338	-0.0986	-0.3217
Q	P	-0.0478	0.0350	0.0730	**-0.3067**	0.0365	0.0057	-0.0655	-0.0690	0.0500	0.0115	0.0117	0.0616
	G	-0.0589	0.0402	0.0791	**-0.2074**	0.0437	0.0080	-0.0797	-0.0770	0.0534	0.0094	0.0079	0.0727
R	P	-0.3095	0.7250	0.1497	-0.4887	**4.1079**	3.6644	0.5207	-3.0808	1.0764	-0.5029	0.3246	-1.4175
	G	-0.3249	0.7520	0.1541	-0.8883	**4.2178**	3.7633	0.5554	-3.2163	1.4857	-0.5533	0.3340	-1.5550
S	P	-0.7919	0.3179	-0.6511	0.0841	-4.0303	**-4.5182**	-2.4990	3.3374	-1.3992	-0.6082	-0.2015	2.0503
	G	-0.8727	0.3451	-0.1762	0.1916	-4.4265	**-4.9612**	-2.7681	3.7376	-2.1047	-0.7060	-0.2202	2.3902
T	P	0.6743	-0.5141	0.3292	0.2537	0.1505	0.6568	**1.1875**	-0.2343	0.1718	0.5521	-0.0145	-0.5058
	G	0.8151	-0.6213	0.3955	0.5445	0.1866	0.7906	**1.4169**	-0.300	0.3207	0.7121	-0.0120	-0.6289
U	P	-0.0360	-0.0628	0.0209	-0.0748	0.2494	0.2456	0.0656	**-0.3325**	0.0056	0.0212	-0.0751	-0.1029
	G	-0.0700	-0.1322	0.0437	-0.2515	0.5171	0.5108	0.1436	**-0.6781**	0.0380	0.0625	-0.1680	-0.2437
V	P	0.0203	-0.0169	-0.0201	-0.0299	0.0480	0.0567	0.0265	-0.0031	**0.1832**	0.0149	0.0817	0.0311
	G	0.0388	-0.0383	-0.0350	-0.0608	0.0831	0.1001	0.0534	-0.0132	**0.2360**	-0.0147	0.1599	0.0468
W	P	0.0663	-0.0627	0.0539	-0.0070	0.0229	0.0252	0.0870	-0.0119	0.0152	**0.1870**	-0.0455	-0.0014
	G	0.0507	-0.0469	0.0404	-0.0060	-0.0173	0.0188	0.0664	-0.0122	-0.0082	**0.1320**	-0.0310	0.0043
X	P	0.0158	-0.0086	-0.0050	-0.0051	0.0031	0.0018	-0.0005	0.0090	0.0177	-0.0097	**0.0398**	0.0014
	G	0.0476	-0.0260	-0.0149	-0.0044	0.0092	0.0051	-0.0010	0.0287	0.0785	-0.0272	**0.1159**	0.0017
Y	P	-0.3505	0.4079	-0.7690	-0.3885	-0.6671	-0.8773	-0.8236	0.5982	0.3281	-0.0147	0.0687	**1.9333**
	G	-0.3946	0.4281	-0.8118	-0.6761	-0.7114	-0.9296	-0.8565	0.6935	0.3828	0.0628	0.0922	**1.9296**

Bold= direct effects, normal= indirect effects, G= genotypic path coefficient, P= phenotypic path coefficient

A= plant height, B= number of tillers, C= survival per cent, D=SLA, E=RWC, F= SCMR, G= biomass, H= root length, I= root volume, J= leaf proline content, K= leaf calcium content, L=leaf sodium content, M=leaf potassium content, N= leaf chloride content, O= leaf sulphate content, P= root CEC, Q= productive tillers per plant, =R total spikelets per panicle, S= filled grains per panicle, T= seed setting per cent, U= sterility per cent, V= length of panicle, W= 1000 grain weight, X = straw yield, Y= leaf Na / K ratio.

Table 46. Genotypic and phenotypic path analysis in high-saline Kaipad at flowering stage

		A	B	C	D	E	F	G	H	I	J	K	L	M	N
A	P	**-0.0896**	-0.0414	-0.530	-0.0784	-0.0142	-0.0020	-0.0110	0.0094	--0.0282	-0.0117	-0.0145	0.0156	0.0204	0.0225
	G	**-0.1253**	-0.0667	-0.1059	-0.1124	-0.0204	-0.0040	-0.0197	0.0190	-0.0452	-0.0200	-0.0255	0.0221	0.0291	0.0333
B	P	0.1119	**0.2420**	0.1181	0.1116	0.0420	-0.0014	0.0049	-0.0735	0.0118	0.0976	0.0585	-0.0392	-0.0100	-0.0314
	G	0.1311	**0.2462**	0.1506	0.1293	0.0355	0.0066	-0.0101	-0.1378	0.0182	0.1096	0.1246	-0.0461	-0.0126	-0.0415
C	P	-0.0429	-0.0354	**-0.0726**	-0.0406	-0.0200	-0.0221	0.0044	0.0099	-0.0265	-0.0239	-0.0158	0.0242	0.0066	0.0190
	G	-0.0559	-0.0404	**-0.0661**	-0.0560	-0.0250	-0.0335	0.0039	0.0125	-0.0281	-0.0305	-0.0029	0.0320	0.0097	0.0251
D	P	0.5699	0.3002	0.3644	**0.6508**	0.0140	0.0274	0.0195	-0.0588	0.2881	0.0339	0.0496	-0.2726	-0.1111	-0.2819
	G	0.7099	0.4154	0.6705	**0.7913**	0.0213	0.0527	0.0202	-0.1093	0.4105	0.0548	0.1133	-0.3339	-0.1357	-0.3419
E	P	0.0483	0.0527	0.0838	0.0065	**0.3037**	0.0183	-0.0109	0.1123	0.0060	0.1096	0.0317	-0.0053	-0.0894	0.0100
	G	0.0552	0.0488	0.1283	0.0091	**0.3386**	0.0078	-0.0463	0.1753	-0.0050	0.1190	0.0475	-0.0065	-0.1071	0.0081
F	P	0.0074	-0.0020	0.1017	0.0141	0.0202	**0.3344**	-0.0761	0.0683	0.0357	0.0376	0.0708	-0.1984	0.1605	0.0867
	G	0.0111	0.0095	0.1783	0.0234	0.0081	**0.3517**	-0.1306	0.0713	0.0496	0.0188	0.1370	-0.2244	0.1822	0.0914
G	P	-0.0611	-0.0101	0.0302	-0.0149	0.0178	0.1130	**-0.4969**	-0.0175	0.1010	-0.0129	-0.0302	-0.1910	0.1143	-0.0335
	G	-0.0706	-0.0184	0.0262	-0.0115	0.0615	0.1669	**-0.4495**	0.0500	0.1565	0.0359	-0.1115	-0.2223	0.1396	-0.0256
H	P	-0.0335	-0.0966	-0.0432	-0.0287	0.1176	0.0649	0.0112	**0.3181**	-0.0641	0.0020	0.0047	-0.0581	0.0243	0.0346
	G	-0.0427	-0.1573	-0.0532	-0.0388	0.1455	0.0570	-0.0313	**0.2811**	-0.0307	-0.0348	0.1133	-0.0715	0.0265	0.0519
I	P	-0.0357	-0.0055	-0.0414	-0.0502	-0.0022	-0.0121	0.0230	0.0228	**-0.1134**	0.0005	-0.0028	0.0487	0.0373	0.0210
	G	-0.0394	-0.0081	-0.0465	-0.0567	0.0016	-0.0154	0.0380	0.0119	**-0.1092**	0.0063	0.0054	0.0547	0.0413	0.0247
J	P	-0.0418	-0.1294	-0.1057	-0.0167	-0.1159	-0.0361	-0.0083	-0.0021	0.0014	**-0.3211**	-0.1135	0.0433	-0.0460	-0.1311
	G	-0.0573	-0.1597	-0.1655	-0.0248	-0.1260	-0.0192	0.0287	0.0444	0.0207	**-0.3587**	-0.1689	0.0537	-0.0562	-0.1526
K	P	0.1574	0.2349	0.2110	0.0741	0.1014	0.2056	0.0591	0.0143	0.0239	0.3433	**0.9714**	-0.4038	0.0352	0.1127
	G	0.1763	0.4383	0.0384	0.1240	0.1215	0.3374	0.2149	0.3492	-0.0427	0.4080	**0.8664**	-0.4688	0.0335	0.1209
L	P	0.0623	0.0580	0.1194	0.1501	0.0063	0.2126	-0.1377	0.0654	0.1540	0.0483	0.1489	**-0.3584**	0.0574	-0.0246
	G	0.0693	0.0737	0.1903	0.1661	0.0075	0.2511	-0.1946	0.1002	0.1969	0.0589	0.2129	**-0.3935**	0.0631	-0.0274
M	P	-0.0951	-0.0173	-0.0382	-0.0713	-0.1230	0.2004	-0.0960	0.0319	-0.1374	0.0599	0.0151	-0.0669	**0.4175**	0.1054
	G	-0.1148	-0.0253	-0.0726	-0.0847	-0.1562	0.2559	-0.1534	0.0466	-0.1866	0.0774	0.0191	-0.0792	**0.4939**	0.1257
N	P	0.2463	0.1268	0.2559	0.4239	-0.0324	-0.2537	-0.0659	-0.1064	0.1811	-0.3995	-0.1135	-0.0671	-0.2469	**-0.9784**

	G	0.2824	0.1790	0.4038	0.4592	-0.0255	-0.2762	-0.0604	-0.1960	0.2407	-0.4520	-0.1483	-0.0739	-0.2705	**-1.0627**
O	**P**	-0.0573	0.4096	-0.4084	-0.1407	-1.2132	0.2946	0.2274	-0.8614	-0.3972	-0.5223	-0.1080	0.3914	0.1696	0.6456
	G	-0.0732	0.6654	-0.9111	-0.1268	-1.5911	0.2344	0.2749	-1.4748	-0.6344	-0.7754	-0.3143	0.4507	0.7104	0.7585
P	**P**	-0.0844	0.0940	-0.2166	-0.1903	0.0216	-0.2984	-0.1093	-0.1033	-0.1573	-0.1038	0.0685	0.2202	-0.1440	-0.0473
	G	-0.0972	0.1471	-0.3671	-0.2201	0.0654	-0.3863	-0.1397	-0.1267	-0.2144	-0.1225	0.0956	0.2580	-0.1699	-0.0620
Q	**P**	-0.1661	0.1407	-0.4334	-0.4792	0.0869	-1.3543	0.6461	-0.4427	-0.6264	-0.0569	-0.7036	1.6663	-0.5343	-0.1487
	G	-0.1954	0.1898	-0.7330	-0.5599	0.1105	-1.6892	0.9689	-0.7618	-0.8455	-0.0727	-1.0665	1.9310	-0.6209	-0.1752
R	**P**	0.2496	-0.2926	0.0178	0.2182	-0.1892	-0.0963	0.3705	-0.0401	0.1018	-0.3284	-0.1136	0.1686	-0.0671	-0.2364
	G	0.2920	-0.3911	0.0299	0.2540	-0.2382	-0.1196	0.5507	-0.0645	0.1369	-0.4208	-0.1708	0.1947	-0.0776	-0.2769
S	**P**	-0.1078	-0.2338	-0.1460	-0.0958	-0.0782	0.0072	0.0031	0.1083	-0.0614	-0.0749	-0.0735	0.0296	0.0689	0.0349
	G	-0.1160	-0.2295	-0.1120	-0.1056	-0.0596	-0.0042	-0.0107	0.1603	-0.0579	-0.0634	-0.0744	0.0341	0.0813	0.0513
T	**P**	0.2403	0.3963	-2.0989	1.4855	-6.1423	1.7651	-0.6759	-0.5009	0.7617	-1.0236	1.2728	-1.9748	4.4272	2.2319
	G	0.3066	0.4756	-3.8571	1.7067	-7.5532	2.1551	-0.9921	-0.9699	1.1735	-1.3919	1.6482	-2.2375	5.0025	2.5605
U	**P**	-0.1645	-1.5584	2.9646	-0.7542	7.3938	0.2408	-0.3321	2.1797	1.0961	1.0885	-1.8246	-0.3515	-5.4820	-1.5424
	G	-0.2036	-1.9988	5.3383	-0.8648	9.0061	0.1973	-0.6247	3.5292	1.3675	1.4021	-2.4323	-0.3973	-6.1861	-1.7859
V	**P**	-0.0231	1.0198	-0.7567	-0.4664	-0.9772	-1.5309	0.9556	-1.3271	-1.4217	-0.2896	0.5129	1.6714	0.5767	-0.5612
	G	-0.0259	1.3556	-1.1839	-0.5449	-1.1150	-1.7956	1.5039	-2.0622	-2.0310	-0.3090	0.8915	1.8758	0.6566	-0.6131
W	**P**	-0.1445	-0.0754	-0.2996	-0.0579	-0.6092	-0.1580	0.0258	-0.1085	-0.0519	-0.1938	-0.1194	0.1128	0.2558	0.0790
	G	-0.1469	-0.1056	-0.5207	-0.0591	-0.7268	-0.1933	0.0608	-0.2617	-0.0186	-0.2555	-0.1807	0.1216	0.2759	0.0982
X	**P**	-0.0068	0.0034	-0.0056	-0.0214	0.0021	0.0224	0.0235	0.0208	-0.0417	0.0434	0.0295	0.0166	0.0548	0.0398
	G	-0.0107	0.0135	-0.0016	-0.0204	-0.0077	0.0232	0.0012	0.0198	-0.0515	0.0472	0.0239	0.0163	0.0523	0.0372
Y	**P**	0.0003	0.0004	0.000	0.0003	0.0008	0.0031	-0.0002	0.0014	-0.0008	-0.0009	0.0010	-0.0018	0.0007	0.0016
	G	0.0004	0.0003	-0.0001	0.0002	0.0008	0.0031	0.0004	0.0020	-0.0007	-0.0008	0.0015	-0.0017	0.0007	0.0016
Z	**P**	-0.0521	-0.0080	0.0393	0.0108	-0.0725	0.0040	-0.0329	-0.0771	0.0768	-0.0396	-0.0355	-0.0637	0.0318	-0.1210
	G	-0.0686	-0.0127	0.0378	0.0156	-0.1172	-0.0006	-0.0815	-0.1232	0.0790	-0.0679	-0.0736	-0.0832	0.0415	-0.1605
AA	**P**	-0.3735	-0.7908	0.0252	-0.6389	1.3581	0.1423	-0.1884	1.0567	0.0651	1.3949	0.1210	-0.1608	-0.1009	1.0700
	G	-0.4733	-1.2455	0.3206	-0.7561	1.7047	0.2596	-0.3707	1.9155	0.1688	1.7662	0.3603	-0.1831	-0.1119	1.1457

Continued….

		O	P	Q	R	S	T	U	V	W	X	Y	Z	AA
A	P	0.0023	0.0093	-0.0082	-0.0271	-0.0335	-0.0023	-0.0013	0.0005	-0.0169	0.0055	0.0052	-0.0184	0.0127
	G	0.0037	0.0219	-0.0117	-0.0383	-0.0699	-0.0037	-0.0021	0.0007	-0.0229	0.0167	0.0108	-0.0267	0.0208
B	P	0.0444	0.0280	-0.0188	-0.0857	0.1962	0.0105	0.0343	0.0602	0.0238	0.0075	-0.0173	0.0076	-0.0725
	G	0.0659	0.0385	-0.0223	-0.1009	0.2719	0.0113	0.0397	0.0731	0.0324	0.0417	-0.0124	0.0098	-0.1077
C	P	0.0133	0.0194	-0.0174	-0.0016	-0.0367	0.0166	0.0196	0.0134	-0.0284	0.0037	-0.0002	0.0112	-0.0007
	G	0.0242	0.0258	-0.0231	-0.0021	-0.0356	0.0246	0.0285	0.0171	-0.0428	0.0014	-0.0014	0.0078	-0.0074
D	P	-0.0410	-0.1525	0.1725	0.1719	0.2161	0.1054	0.0447	-0.0741	0.0492	-0.1261	-0.0316	-0.0276	-0.1576
	G	-0.0404	-0.1849	0.2111	0.2105	0.4020	0.1303	0.0552	-0.0944	0.0581	-0.2016	-0.0357	-0.0385	-0.2100
E	P	-0.1649	0.0081	-0.0146	-0.0695	0.0823	-0.2034	-0.2044	-0.0724	0.0492	-0.1261	-0.0316	-0.0276	-0.1576
	G	-0.2168	0.0235	-0.0178	-0.0845	0.0972	-0.2468	-0.2460	-0.0827	0.3063	-0.0327	-0.0519	0.1233	0.2026
F	P	0.0441	-0.1229	0.2505	-0.0390	-0.0084	0.0644	-0.0073	-0.1249	0.0690	0.0679	-0.1750	-0.0053	0.0180
	G	0.0332	-0.1443	0.2831	-0.0441	0.0071	0.0731	-0.0056	-0.1383	0.0846	0.1020	-0.2109	0.0006	0.0320
G	P	-0.0506	0.0699	0.1776	-0.2227	0.0053	0.0366	-0.0150	-0.1159	0.0167	-0.1055	-0.0159	-0.0642	0.0355
	G	-0.0497	0.0667	0.2075	-0.2593	-0.0231	0.0430	-0.0227	-0.1480	0.0340	-0.0066	0.0386	-0.1138	0.0585
H	P	-0.1163	-0.0405	0.0799	-0.0154	-0.1195	-0.0174	-0.0631	-0.1030	0.0451	0.0598	-0.0744	0.0963	0.1274
	G	-0.1668	-0.0378	0.0960	-0.0190	-0.2169	-0.0263	-0.0800	-0.1269	0.0195	0.0696	-0.1093	0.1076	0.1890
I	P	0.0202	0.0220	-0.0393	-0.0140	-0.0241	-0.0094	0.0113	0.0393	-0.0077	0.0427	-0.0147	0.0342	-0.0028
	G	0.0279	0.0249	-0.0440	-0.0157	-0.0305	-0.0124	0.0121	0.0486	-0.0025	0.0702	-0.0157	0.0268	-0.0065
J	P	0.0751	0.0411	-0.0101	0.1276	-0.0834	0.0358	0.0318	0.0227	-0.0813	-0.1261	-0.0470	-0.0500	-0.1697
	G	0.1119	0.0467	-0.0124	0.1581	-0.1094	0.0482	0.0406	0.0243	-0.1140	-0.2114	-0.0536	-0.0757	-0.2223
K	P	-0.0470	0.0820	0.3781	-0.1335	0.2475	0.1348	0.1613	0.1216	0.1516	0.2590	-0.1731	0.1355	0.0445
	G	-0.1096	0.0879	0.4403	-0.1550	0.3101	0.1378	0.1700	0.1691	0.1948	0.2585	-0.2547	0.1981	0.1096
L	P	-0.0625	-0.0972	0.3297	-0.0731	0.0367	0.0772	-0.0115	-0.1462	0.0528	-0.0539	-0.1121	-0.0896	0.0218
	G	-0.0714	-0.1078	0.3621	-0.0803	0.0646	0.0850	-0.0126	-0.1616	0.0596	-0.0801	-0.1305	-0.1017	0.0253
M	P	0.1158	-0.0740	0.1234	-0.0339	-0.0997	0.2016	0.2083	0.0588	-0.1395	0.2071	-0.0497	-0.0521	-0.0160
	G	0.1411	-0.0891	0.1461	-0.0401	-0.1931	0.2384	0.2465	0.0710	-0.1696	0.3228	-0.0674	-0.0637	-0.0208
N	P	-0.2828	0.0570	-0.0804	0.2799	0.1185	-0.2381	-0.1373	0.1340	0.1010	-0.3522	0.2671	-0.4651	-0.3967
	G	-0.3243	0.0699	-0.0887	0.3083	0.2626	-0.2626	-0.1531	0.1427	0.1299	-0.4934	0.3291	-0.5299	-0.4274
O	P	2.2340	0.0030	-0.1628	-0.0841	0.3314	1.3672	1.4855	0.8401	-1.3140	0.1077	-0.5327	-0.0091	-1.6187

	G	**2.4855**	-0.0103	-0.1881	-0.0969	0.8211	1.5701	1.7093	0.9767	-1.5174	-0.0131	-0.6632	0.0521	-1.7983
P	P	0.0011	**0.8118**	-0.2461	0.0061	0.1143	-0.0513	0.1561	0.4724	0.0789	0.0962	0.2925	0.3251	-0.1451
	G	-0.0039	**0.9417**	-0.2884	0.0072	0.2510	-0.0606	0.1827	0.5555	0.0830	0.1837	0.3714	0.3857	-0.1796
Q	P	0.1317	0.5480	**-1.8079**	0.0595	0.1483	-0.5291	-0.0778	0.6958	-0.2494	0.0985	0.6577	0.2830	-0.1577
	G	0.1588	0.6427	**-2.0987**	0.0691	0.2742	-0.6158	-0.0907	0.8131	-0.2968	0.1590	0.8090	0.3392	-0.1937
R	P	-0.0311	0.0063	-0.0272	**0.8265**	-0.1976	0.0275	0.1207	0.2394	-0.0218	-0.0640	0.2251	-0.0206	-0.1570
	G	-0.0372	0.0073	-0.0314	**0.9547**	-0.3653	0.0318	0.1397	0.2784	-0.0259	-0.1001	0.2756	-0.0245	-0.1913
S	P	-0.0428	-0.0406	0.0237	0.0689	**-0.2884**	0.0343	0.0054	-0.0616	-0.0649	0.0471	0.0108	0.0110	0.0788
	G	-0.00686	-0.0554	0.0271	0.0795	**-0.2078**	0.0438	0.0080	-0.0798	-0.0771	0.0535	0.0094	0.0080	0.1236
T	P	5.6114	-0.5789	2.6832	0.3047	-1.0909	**9.1691**	8.1790	1.1623	-6.8764	2.4026	-1.1225	0.7244	-3.7393
	G	6.5463	-0.6668	3.0408	0.3453	-2.1826	**10.3632**	9.2464	1.3646	-7.9025	3.6504	-1.3594	0.8206	-4.4293
U	P	-7.3057	-2.1121	-0.4727	-1.6044	0.2046	-9.8002	**-10.9866**	-6.0768	8.1154	-3.4025	-1.4790	-0.4900	5.9644
	G	-8.5242	-2.4044	-0.5357	-1.8134	0.4786	-11.0593	**-12.3950**	-6.9158	9.3381	-5.2585	-1.7639	-0.5502	7.0688
V	P	1.5407	2.3843	-1.5768	1.1869	0.8753	0.5193	2.2661	**4.0970**	-0.8084	0.5927	1.9049	-0.0500	-2.0848
	G	1.7947	2.6941	-1.7695	1.3321	1.7549	0.6014	2.5482	**4.5671**	-0.9671	1.0336	2.2952	-0.0388	-2.4537
W	P	0.4502	-0.0743	-0.1056	0.0202	-0.1722	0.5740	0.5654	0.1510	**-0.7654**	0.0129	0.0488	-0.1728	-0.3409
	G	0.4906	-0.0708	-0.1136	0.0218	-0.2981	0.6128	0.6054	0.1702	**-0.8036**	0.0451	0.0741	-0.1991	-0.3530
X	P	0.0053	0.0131	-0.0060	-0.0086	-0.0180	0.0290	0.0342	0.0160	-0.0019	**0.1105**	0.0090	0.0493	0.0227
	G	-0.0004	0.0156	-0.0061	-0.0084	-0.0206	0.0282	0.0340	0.0181	-0.0045	**0.0800**	-0.0050	0.0542	0.0258
Y	P	0.0014	-0.0021	0.0021	-0.0016	0.0002	0.0007	-0.0008	-0.0027	0.0004	-0.0005	**-0.0059**	0.0014	-0.0003
	G	0.0014	-0.0021	0.0020	-0.0015	0.0002	0.0007	-0.0007	-0.0026	0.0005	0.0003	**-0.0052**	0.0012	-0.0002
Z	P	0.0010	-0.1019	0.0398	0.0063	0.0097	-0.0201	-0.0114	0.0031	-0.0575	-0.1135	0.0619	**-0.2545**	-0.0663
	G	-0.0067	-0.1318	0.0520	0.0083	0.0123	-0.0255	-0.0143	0.0027	-0.0798	-0.2180	0.0757	**-0.3219**	-0.0842
AA	P	-1.9122	-0.4716	0.2302	-0.5015	-0.7208	-1.0763	-1.4327	-1.3429	1.1756	0.5425	0.1490	0.6878	**2.6390**
	G	-2.0612	-0.5434	0.2630	-0.5710	-1.6941	-1.2176	-1.6247	-1.5306	1.2514	0.9177	0.0857	0.7457	**2.8489**

Bold= direct effects, normal= indirect effects, G= genotypic path coefficient, P= phenotypic path coefficient

A= plant height, B= number of tillers, C= number of nodes, D= uppermost internodal length, E= survival per cent, F=SLA, G=RWC, H= SCMR, I= biomass, J= root length, K= root volume, L= leaf proline content, M= leaf calcium content, N=leaf sodium content, O=leaf potassium content, P= leaf chloride content, Q= leaf sulphate content, R= root CEC, S= productive tillers per plant, T= total spikelets per panicle, U= filled grains per panicle, V= seed setting per cent, W= sterility per cent, X= length of panicle, Y= 1000 grain weight, Z = straw yield, AA= leaf Na / K ratio.

length, survival per cent, specific leaf area (SLA), SCMR, root volume, leaf calcium content, leaf potassium content, leaf Na / K ratio, leaf chloride content, root CEC, number of spikelets per panicle, seed setting per cent and length of panicle. However the parameters plant height, number of internodes per plant, relative water content (RWC), biomass, root length leaf proline content, leaf sodium content, leaf sulphate content, number of productive tillers, number of filled grains per panicle, sterility percentage, length of panicle, straw yield and 1000 grain weight exhibited direct negative effect on grain yield per plot at both genotypic and phenotypic levels.

At genotypic level the highest positive direct effect on grain yield was exhibited by number of spikelets per panicle (10.3632) followed by seed setting percentage (4.5671), leaf Na / K ratio (2.8489) at flowering, leaf potassium content (2.4855) at flowering, leaf potassium content (1.4023) at seedling, root CEC (0.9547) at flowering, leaf chloride content (0.9417) at flowering, RWC (0.8979) at seedling, root volume (0.8664) at flowering, uppermost internodal length (0.7913) at flowering and root CEC (0.7646) at seedling. Number of filled grains per panicle (-12.3950) followed by leaf sulphate content (-2.0987) at flowering, leaf sulphate content (-1.6661) at seedling, leaf sodium content (-1.0627) at flowering, sterility percentage (-0.8036), leaf sodium content (-0.6774) at seedling and leaf proline content (-0.6430) at seedling showed the highest negative genotypic direct effect on grain yield.

At phenotypic level the highest positive direct effect on grain yield was exhibited by number of spikelets per panicle (9.1691) followed by seed setting percentage (4.0970), leaf Na / K ratio (2.6390) at flowering, leaf potassium content (2.2340) at flowering, leaf potassium content (1.3353) at seedling, root volume (0.9714) at flowering, RWC (0.9358) at seedling, root CEC (0.8265) at flowering, leaf chloride content (0.8118) at flowering, root CEC (0.7389) at seedling and uppermost internodal length (0.6508) at flowering. Number of filled grains per panicle (-10.9866) followed by leaf sulphate content (-1.8079) at flowering, leaf sulphate content (-1.6680) at seedling, leaf sodium content

(-0.9784) at flowering, sterility percentage (-0.7654), leaf proline content (-0.5834) at seedling and leaf sodium content (-0.5286) at seedling showed the highest negative phenotypic direct effect on grain yield.

The highest positive genotypic indirect effect with grain yield was exhibited by number of filled grains per panicle via. sterility percentage (9.3381) followed by number of spikelets per panicle through filled grains per panicle (9.2464), number of filled grains per panicle via. survival per cent (9.0061) at flowering, number of filled grains per panicle through leaf Na / K ratio at flowering (7.0688), number of spikelets per panicle via. leaf potassium content at flowering (6.5463), number of filled grains per panicle through number of internodes at flowering (5.3383), number of spikelets per panicle via. leaf calcium content at flowering (5.0025), number of filled grains per panicle through survival per cent at seedling (3.6315), number of spikelets per panicle via. length of panicle (3.6504), seed setting per cent through SCMR at flowering (3.5292), number of spikelets per panicle via. leaf sulphate content (3.0408), number of filled grains per panicle via. biomass at seedling (2.8833), seed setting per cent via. leaf chloride content at flowering (2.6941), number of spikelets per panicle via. leaf potassium content at seedling (2.5991), seed setting per cent via. number of filled grains per panicle (2.5482), number of spikelets per panicle through leaf sodium content at flowering (2.5605), number of filled grains per panicle via. number of tillers at seedling (2.3646), seed setting per cent through 1000 grain weight (2.2952), number of spikelets per panicle via. SLA at flowering (2.1551) and number of spikelets per panicle via. leaf calcium content at seedling (2.0224).

The highest negative genotypic indirect effect with grain yield was exhibited by number of filled grains per panicle via. number of spikelets per panicle (-11.0593) followed by number of filled grains per panicle via. leaf potassium content at flowering (-8.5242), number of spikelets per panicle through sterility percentage (-7.9025), number of spikelets per panicle via. survival per cent at flowering (-7.5532), number of filled grains per panicle via. seed setting per cent (-6.9158), number of filled grains per panicle via. leaf calcium content at flowering (-6.1861), number of filled grains per panicle via. length of panicle (-5.2585), number of spikelets per panicle via. leaf Na / K ratio at flowering (-4.4293), number of spikelets per panicle through number of internodes at flowering (-3.8571), number of filled grains per panicle via. leaf potassium content at seedling (-3.2144) and number of spikelets per panicle through survival per cent at seedling (-3.0852).

The highest positive phenotypic indirect effect with grain yield was exhibited by number of filled grains per panicle via. sterility per cent (8.1154) followed by number of filled grains per panicle via. survival per cent at flowering (7.3938), number of filled grains per panicle via. leaf Na / K ratio at flowering (5.9644), number of spikelets per panicle via. leaf potassium content at flowering (5.6114), number of spikelets per panicle via. leaf calcium content at flowering (4.4272), number of filled grains per panicle via. survival percentage at seedling (2.9993), number of filled grains per panicle via. number of internodes at flowering (2.9646), number of spikelets per panicle via. leaf sulphate content at flowering (2.6832), number of spikelets per panicle through leaf potassium content at seedling (2.4392), number of spikelets per panicle via. length of panicle (2.4026), seed setting percentage through leaf chloride content at flowering (2.3843), seed setting percentage via. number of filled grains per panicle (2.2661), number of filled grains per panicle via. biomass at seedling (2.2420) number of spikelets per panicle via. leaf sodium content at flowering (2.2319), number of filled grains per panicle through SCMR at flowering (2.1797) and number of filled grains per panicle via. leaf Na / K ratio at seedling (2.0503).

The highest negative phenotypic indirect effect with grain yield was exhibited by number of filled grains per panicle via. number of spikelets per panicle (-9.8002), followed by number of filled grains per panicle via. leaf potassium content at flowering (-7.3057), number of spikelets per panicle via. sterility per cent (-6.8764), number of spikelets per panicle via. survival per cent at flowering (-6.1423), number of filled grains per panicle via. seed setting percentage (-6.0768), number of filled grains per panicle via. leaf calcium content at flowering (-5.4820), number of spikelets per panicle through leaf Na / K ratio at flowering (-3.7393), number of filled grains per panicle via. length of panicle (-3.4025), number of filled grains per panicle through leaf potassium content at seedling (-2.8304), number of spikelets per panicle through survival per cent at seedling (-2.7128), number of filled grains per panicle via. leaf calcium content at seedling (-2.2399), number of filled grains per panicle through leaf chloride content at flowering (-2.1121), number of spikelets per panicle via. number of internodes at flowering (-2.0989), seed setting percentage through leaf Na / K ratio at flowering (-2.0848) and number of spikelets per panicle via. biomass at seedling (-2.0462).

DISCUSSION

5. DISCUSSION

New breeding strategies for saline tracts consists of six stages namely salinity appraisal, mechanism discovery, gene and allele discovery, pre-breeding for salinity tolerance, molecular breeding and participatory evaluation.

Current experiment covers the first stage of salinity appraisal which gives information about the target environment in which the new variety will be deployed, how intense is the salt stress, which ions are involved, at which stages of plant growth salinity is the greatest, traits correlated with salinity tolerance, traits correlated with yield and biomass under saline condition, and variability of different saline tolerant genetic resources under different saline conditions. .

There are three possible causes of stress in plants under hyper saline conditions namely sodium toxicity, chlorine toxicity, osmotic stress and other minor cause is nutritional imbalance (Abdelbagi et al., 2013). The means by which different physiological tolerance mechanisms address varies widely, and no single mechanism appears to be effective in conferring high level of tolerance in any single genetic background. Salinity tolerance at seedling and reproductive stages are weakly associated. Hence, pyramiding of contributing traits at both stages is needed for developing resistant salt tolerant cultivars (Moradi et al., 2003).

Some of the requirements of varieties for salinity tolerance mechanisms that we have studied in the current programme are tissue tolerance in which Na^+ ion is compartmentalized in older plant parts preventing the flow to reproductive organs that means low Na^+ / K^+ ratio, Na^+ exclusion, high K^+ uptake, Cl^+ exclusion and good initial vigour.

The mode of salt tolerance mechanisms may vary with genotypes. Bonilla et al. 2002 reported that highly tolerant crops like rice invariably posses multiple QTL's for salinity tolerance with 6-8 being found in varieties such as 'Pokkali' and 'Nona Bokra. The variation in performance of saline tolerant genotypes evaluated in comparatively high-saline area of Kaipad tract of Kerala and their variability in expression of various traits in stress and non-stress conditions are discussed below.

5.1. Variability

The analysis of variance revealed significant differences among the eighteen rice genotypes in three different situations for all the characteristics at seedling and flowering stages except for survival per cent at seedling and flowering, SLA at seedling and stomatal resistance at seedling in non-saline condition; survival per cent at seedling and flowering, stomatal conductance and resistance at flowering, root culm ratio at seedling and leaf sodium content at seedling in low-saline condition and root culm ratio at seedling, culm calcium content at seedling, root chloride content at seedling and number of productive tillers per plant in high-saline condition. confirming the fact that the material selected was genetically diverse and shows variability. Variability for different characters was previously observed by several workers like Vanaja (1998), Nayak et al. (2001).

The significant interaction effect in pooled analysis showed that the genotypes behave differently in changing stress conditions of salinity with respect to 43 quantitative parameters studied both at seedling and flowering stages except for root culm ratio at seedling stage, number of nodes and leaf proline content at flowering stage.

5.1.1. Morphological parameters

The morphological parameters like plant height and number of tillers at seedling and flowering stages, number of nodes at flowering stage, uppermost internodal length at flowering stage, orientation of flag leaf, lodging / non-lodging and duration of crop were recorded for three soil conditions namely high-saline, low-saline and non-saline for the eighteen rice genotypes and they were found to be significantly different from each other for all characteristics except for number of nodes in low-saline condition showing the divergence among the selected genotypes regarding morphological parameters. The significant interaction effect for the morphological traits plant height, number of tillers and uppermost internodal length reflects the difference in behaviour of genotypes with respect to these characteristics with changing stress environment.

5.1.1.1. Plant height at seedling and flowering stages

At seedling and flowering stages the genotypes 'Cheriviripрu', 'Orkayama' and 'Pokkali' showed moderate to high plant height in both non-saline and saline conditions in which Orkayama' showed stability in high performance of height under heterogeneous conditions confirms their tolerance towards salinity and further indicates that the trait expression in these genotypes is not much influenced by salinity stress, it may be controlled by the structural genes. In high-saline Kaipad, the shortest height of 'Jyothi' and 'IR-29' confirms their nature of susceptibility to salinity. 'Pokkali' is the international donor of salinity tolerance and 'Orkayama' is a recently reported new genetic resource for salinity tolerance which is a traditional variety of Kaipad whose tolerance mechanism is different from that of 'Pokkali' (Vanaja et al., 1998). Cheriviripрu' is a traditional variety of Pokkali tract.

In high-saline and low-saline conditions of Kaipad the lowest plant height was seen in 'Jyothi' a saline susceptible genotype at both seedling and flowering stages indicates that high salinity decreases the plant height report of which is in accordance with the result of Govindaraju and Balakrishnan, (2002). Highest plant height in high-saline Kaipad for 'Ezhome-3', 'JO-532-1' and 'JO-583' at seedling stage and for JK-15', 'JK-59', 'JO-583', 'Nona Bokra' and 'IR-29' at flowering stage than in other two conditions of low saline and non saline shows their more ability to tolerate salinity and also requirement of stress signal for character expression. The reported international saline susceptible variety IR 29 showed comparatively higher performance with respect to height showing the presence of certain tolerance genes in IR 29 towards salinity.

5.1.1.2. Number of tillers at seedling and flowering stages

Less number of tillers of culture 'JK-15' in non-saline condition compared to saline conditions indicates that it needs stress signal to give more number of tillers at non-saline condition. At the same time good performance of the internationally accepted saline susceptible variety 'IR-29' and 'Jyothi' in non-saline condition for tiller production compared to saline conditions confirming the susceptibility nature of these genotypes.

At seedling and flowering stage 'Jyothi' shows high number of tillers in non-saline condition which indicates that the genotype performance was well at non-saline situation than in saline stress condition but in low-saline condition the genotype showing moderate tillering and in high-saline condition tiller number is too less, this indicates that susceptibility of the genotype to high salinity. The same result high salinity decreases the number of tillers was reported by Govindaraju and Balakrishnan, (2002).

5.1.1.3. Number of nodes at flowering stage

Traditional varieties 'Chettivirippu', 'Orkayama' and 'Pokkali' recorded the highest number of nodes at both stress and non-stress conditions showing the consistency of these genotypes in changing stress conditions. Higher number of nodes in these genotypes might be the reason of higher plant height. At the same time among the susceptible varieties 'IR-29' and 'Jyothi', 'Jyothi' showed lower number of nodes than 'IR-29' in saline Kaipad indicating its nature of more susceptibility to salinity.

5.1.1.4. Uppermost internodal length at flowering stage

Uppermost internodal length is having direct contribution towards plant height in all three conditions. The lowest internodal length contributes low plant height. The result of the lowest uppermost internodal length for 'Ezhome-1' and 'Ezhome-2' in non-saline condition compared to its moderate length in high-saline conditions shows their requirement of salinity stress for the character expression which confirms their ability of salinity tolerance. At the same time saline tolerant genotype 'Pokkali' exhibited the highest uppermost internodal length in all the situations which indicates that the particular character may be under structural gene control in this genotype. Exhibition of uniform length of rice genotypes in three conditions indicates that the particular character is not affected by stress condition.

5.1.1.5. Orientation of flag leaf

There is no change in orientation of flag leaf when soil condition changes. It is same even in stress and non-stress conditions indicating that orientation of flag leaf is purely genotypically controlled.

5.1.1.6. Lodging/non-lodging

The observation on lodging and Non-lodging characteristics indicated that the trait will not be changed when the soil condition of heterogeneous stress changes for all genotypes except for 'Pokkali'. In non-saline and low-saline condition 'Pokkali' showed non-lodging but in high-saline condition it showed lodging tendency indicating the fact that high saline acidic nature of the soil makes this variety weak leading to lodging of plant.

5.1.1.7. Duration of crop

There is no change in duration of crop when soil conditions change Hence this character crop duration is purely genotype based. The genotypes FL-478', 'IR-29', 'Kuthiru' and 'Jyothi' showed short duration, remaining 14 genotypes showed medium duration ranging from 116- 122days.

5.1.2. Physiological parameters

The physiological parameters like survival percentage, specific leaf area (SLA), relative water content (RWC), SPAD chlorophyll meter reading (SCMR, stomatal conductance and resistance, biological yield, root length, root volume and root culm ratio were recorded at both seedling and flowering stages for the eighteen rice genotypes in non-saline, low-saline and high-saline conditions and found to be significantly different. The performance of each trait was discussed below.

5.1.2.1. Survival percentage at seedling and flowering stages

Survival per cent is one among the indications of salinity tolerance at seedling and flowering stages. Some genotypes tolerate salinity at seedling stage but not at flowering stage. We need genotypes tolerant to salinity both at seedling and reproductive stages with good survival per cent.

In 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 determes the economic yield in saline stress condition. At high-saline condition the genotype 'JO-532-1' exhibited higher survival per cent and hence higher yield even though it showed comparatively less performance for yield component characteristics than other high yielding saline tolerant varieties. Followed by JO 532-1, the traditional land races of Kaipad namely 'Kuthiru' and 'Orkayama' and pre-release culture'JO-583', and traditional and improved saline tolerant genotypes of Pokkali namely 'Chettivirippu', 'Cherivirippu' and 'Vytilla-6' showed the highest survival per cent indicating the ability to tolerate high acid saline condition.

'FL-478' an international saline tolerant variety did not survive in high-saline condition at reproductive stage. The crop was survived till flowering but collapsed and decayed at harvest stage. This indicates that the international saline tolerant genotype 'FL-478' can not tolerate the high acidic nature of (pH 2.8) Kaipad soil. The genotype 'FL-478' was developed from 'Pokkali' genotype which is tolerant to alkali soil of Pokkali tract. At the same time, the international saline susceptible variety 'IR-29' survived till harvest but 'Jyothi', saline susceptible variety of Kerala decayed at the time of harvest reflecting its more its more susceptibility nature than 'IR-29' for high acidic saline soil (Fig. 1&2).

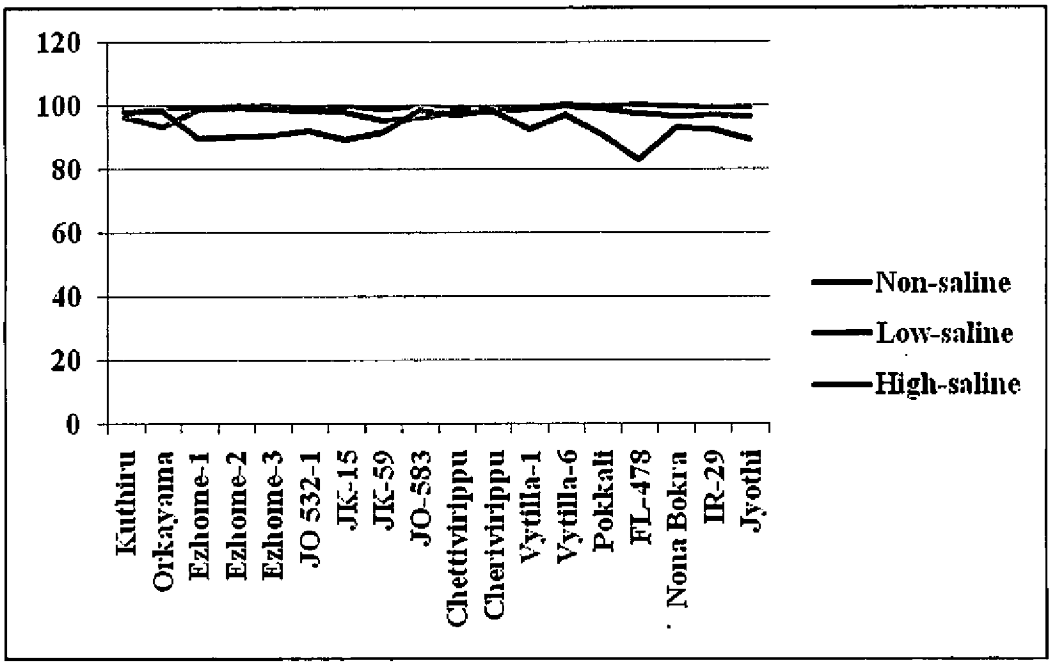

Fig.1. Variation in survival % of 18 rice genotypes grown under different soil conditions at seedling stage.

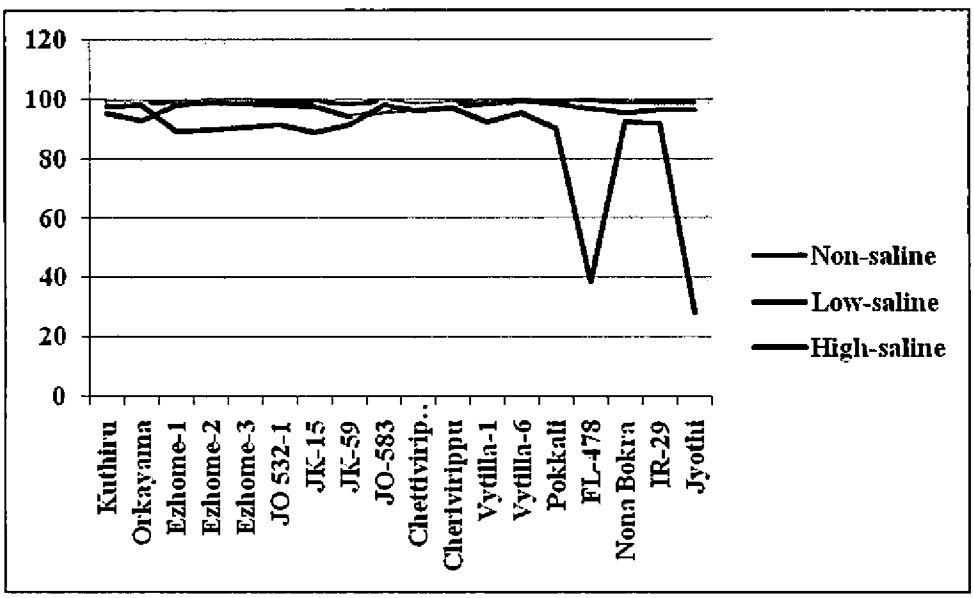

Fig.2. Variation in survival % of 18 rice genotypes grown under different soil conditions at flowering stage.

5.1.2.2. Specific leaf area (SLA) at seedling and flowering stages

SLA is a measure of leaf thickness. Breeding genotypes with enhanced water use efficiency (WUE) is an important strategy to overcome the challenges in water limited conditions (Nautiyal et al., 2002). Salinity is a condition which creates water deficiency with in interior cells. SCMR and SLA are robust and low-cost surrogates of WUE. Therefore understanding their genetic nature and association with yield parameters enables use of SCMR and SLA in breeding programme.

Generally more leaf area was seen during seedling stage than in flowering stage in higher yielding genotypes. Maximum contribution of SLA through photosynthesis towards biomass might be taking place at seedling stage rather than at flowering stage. The genotypes 'Kuthiru', 'JO-532-1'(Ezhome-4), 'FL-478', 'Nona Bokra' and 'Jyothi' do not show much variation in SLA in changing soil conditions both at seedling and flowering stages which indicates that the trait in this genotypes may be under the control of structural genes which is not affected by stress.

The genotypes 'JO-532-1'(Ezhome-4) and 'JO-583' which showed high yield in high-saline condition exhibited lower SLA both at seedling and flowering stages indicating the fact that reduced leaf area prevent high deposit of salt in leaf which may affect yield.

5.1.2.3. Relative water content (RWC) at seedling and flowering stages

Comparing the three soil conditions, majority of the genotypes exhibited high relative water content in saline conditions at seedling stage but at flowering stage high relative water content was seen in non-saline condition. This indicates that at growing stage the genotypes are more sensitive to high salinity. In high-saline Kaipad high salt deposition in the soil causes low water potential zone in the soil making it increasingly difficult for the plant to acquire both water as well as nutrients (Mahajan and Tuteja, 2005). Therefore, salt stress essentially results in a water deficit condition in the plant and takes the form of a physiological drought.

In non-saline condition the result of high RWC for salt sensitive 'Jyothi' variety indicates that low concentration of salt influences high RWC.

In high-saline Kaipad soils the result showed that the tolerant genotypes exhibited maximum RWC than sensitive genotypes except for 'Ezhome-1' and 'Ezhome-2' which showed lower RWC indicating the negative influence of high salinity (EC of 11-16 dsm^{-1}) on these 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.

5.1.2.4. Spad chlorophyll meter reading (SCMR) at seedling and flowering stages

Chlorophyll meter measures green colour intensity and is associated with chlorophyll density (Songgri et al., 2009). The result showed that 'FL-478' an international saline tolerant genotype recorded high chlorophyll content in saline conditions indicating its tolerance capacity.

Performance of other genotypes with respect to chlorophyll content showed varying result in changing soil conditions disregard of salinity intensity. The tolerant genotypes 'Nona Bokra', 'Vytilla-1', 'Chettivirippu', 'JO-532-1', 'Ezhome-3' and 'JK-59' showed comparatively lesser quantum of chlorophyll content in high salinity level indicates in these genotypes some other salinity tolerance mechanism play a major. Similar result was also reported by Chandramohanan et al. (2014).

5.1.2.5. Stomatal conductance and resistance at seedling and flowering stages

With respect to the trait stomatal conductance the result showed that the trait has high value in saline conditions compared to the result of non-saline condition. At the same time stomatal resistance was higher in non-saline condition than in saline condition. This indicates that the salinity will increases the conductance leading to good respiration and transpiration in the plant under stress condition.

In high-saline condition, the highest stomatal conductance recorded by the genotypes 'Vytilla-6' fallowed by 'Ezhome-1', 'Ezhome-2', 'IR-29', 'JO-532-1', 'FL-478', 'Cheriviripppu', 'Orkayama' and 'Vytilla-1' confirming the tolerant nature of these genotypes towards salinity at the same time 'Kuthiru' and 'Ezhome-3' recorded the highest stomatal resistance confirming the susceptibility of the trait with salinity.

5.1.2.6. Biomass at seedling and flowering stages

Biomass is an indicator of economic yield, straw yield and tolerance to salinity. The highest biomass exhibited by 'Orkayama' and 'Pokkali' at both seedling and flowering stages in high-saline condition indicates their tolerance to salinity. But these genotypes have comparatively low grain yield because of high straw production. 'Pokkali' is a renowned saline tolerant variety and 'Orkayama' is newly reported genetic resource for salinity tolerance from Kaipad tract of Kerala.

In high-saline condition at flowering stage the lowest biomass was recorded for 'Ezhome-1' at the same time it produced comparatively more grain yield and straw yield at harvest stage which indicates that there is a high rate of enhancement of biomass between flowering and harvesting stages. The lowest biomass for 'JK-59' at flowering stage reflected low grain yield and straw yield in high-saline condition.

Comparing biomass production of three soil conditions general trend of more biomass at flowering stage was seen in low saline condition followed by non-saline and the least by high-saline condition which reveals that rather than salinity stress, some other soil properties of low salinity might be favourably influenced biomass production at flowering stage in low-saline Kaipad. At seedling stage this trend varies with genotypes (Fig. 3&4).

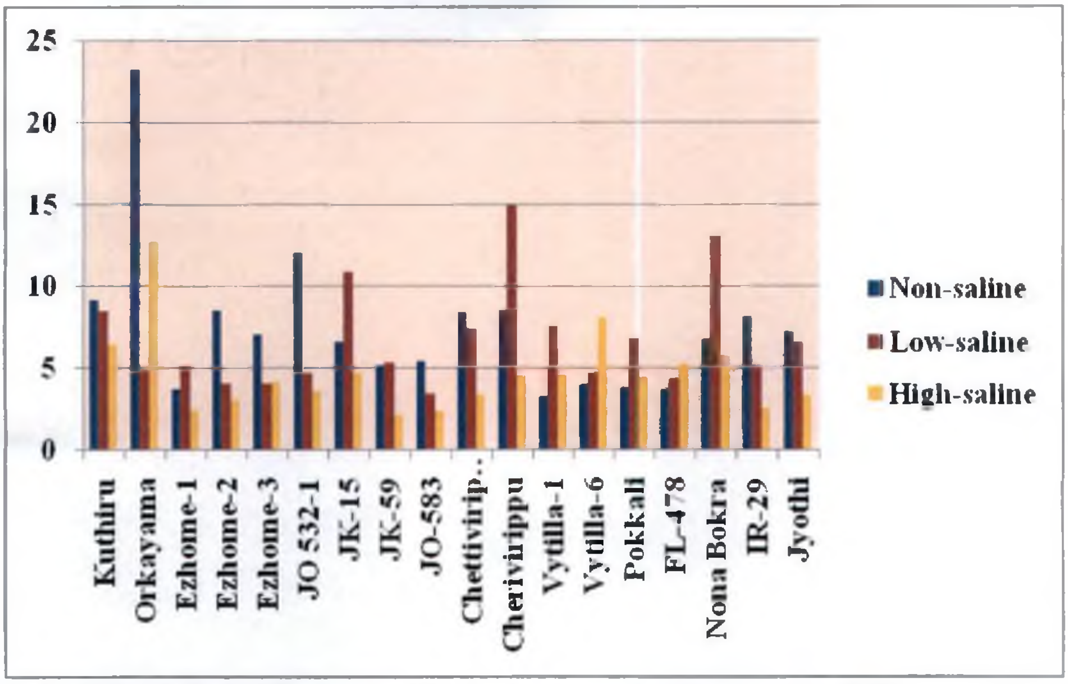

Fig.3. Variation in biomass of 18 rice genotypes grown under different soil conditions at seedling stage

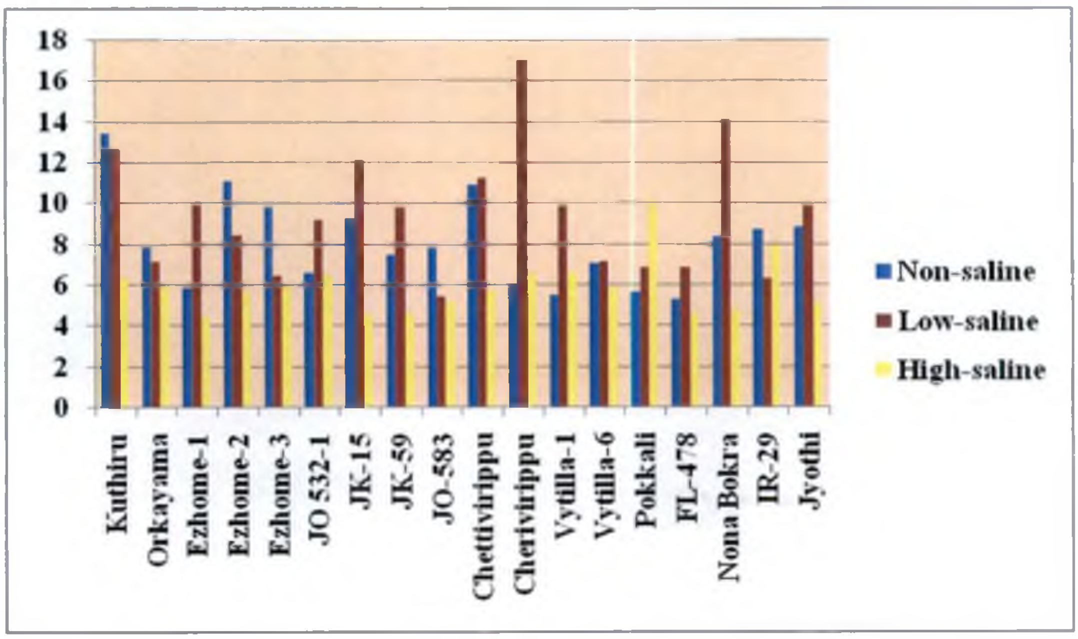

Fig.4. Variation in biomass of 18 rice genotypes grown under different soil conditions at flowering stage

5.1.2.7. Root length

In non-saline condition the saline susceptible variety 'Jyothi' showed high root length but in case of high-saline condition it showed minimum root length indicating that high salt concentration reduces the root length in the case susceptible genotype. In saline Kaipad, the international saline susceptible genotype 'IR-29' also showed minimum root length at both seedling and flowering stages. Saha et al. (2010) reported that salinity stress causes drastic effect on roots causing reduction in root length, number of root hairs and branches, and also roots become stout, brittle and brown in colour. Among the saline tolerant genotypes, csidering seedling and flowering stages together, the genotypes 'Orkayama', 'JO-532-1'(Ezhome -4), 'Pokkali', 'Ezhome-3' 'Nona Bokra', 'Kuthiru' and 'JO583' exhibited high root length indicating the ability of these genotypes to search for water and nutrients in saline condition.

5.1.2.8. Root volume

In high saline Kaipad the highest root length was exhibited by 'Orkayama' followed by 'JO-532-1', and 'Pokkali' at seedling stage and 'Ezhome-3', 'Nona Bokra' and 'Kuthiru' at flowering stage indicating the ability of these genotypes to survive in high saline stress condition.

All the saline tolerant traditional genotypes showed maximum root volume in all three conditions which shows that this trait may be controlled by structural gene(s) rather than stress induced ones in saline tolerant genotypes. With respect to the saline susceptible genotype 'Jyothi', it had recorded maximum root volume in non-saline and low-saline condition (EC of 2-5 dsm^{-1}) and minimum in high-saline (EC of 11-16 dsm^{-1}) condition indicating that high salinity causes the reduction of root volume (Roy et al., 2002) for saline susceptible genotypes. In high saline condition as IR 29 showed more root volume than Jyothi, Kerala's saline susceptible variety Jyothi may be more susceptible than the international saline susceptible variety IR 29 in Kaipad acidic soil.

5.1.2.9. Root shoot ratio at seedling and flowering stages

Higher root shoot ratio may provide the clue about salt tolerance potential of the genotype Ali et al. (2004). In high-saline Kaipad, the international saline tolerant genotype 'Pokkali' followed by 'Kuthiru' , the traditional variety of Kaipad, and 'IR-29',the international saline susceptible genotype recorded the highest root shoot ratio. The higher root shoot ratio of saline susceptible variety IR 29 in high saline Kaipad confirms its ability to survive in Kaipad acidic soil. The maximum root shoot ratio of the saline tolerant released variety 'Ezhome -4' ('JO-532-1') in non-saline condition reflects its ability of good performance in ordinary wetland in addition to saline stress condition.

The saline susceptible 'Jyothi' variety showed minimum root shoot ratio in high-saline Kaipad (EC of 11-16 dsm^{-1}) indicating that high salinity causes the reduction of root shoot ratio in susceptible varieties. The higher value for root shoot volume for the international saline susceptible variety 'IR 29' in high saline condition than 'Jyothi' the susceptible variety of Kerala once again confirms the more susceptible nature of Jyothi variety towards salinity stress.

5.1.3. Biochemical parameters

The biochemical parameters like Proline content in root, culm and leaf at seedling and flowering stages, Calcium, Sodium, Potassium, Chloride and Sulphate content in root, culm and leaf at seedling and flowering stages and root CEC were recorded for the eighteen rice genotypes and each trait was found to be significantly different from each other.

5.1.3.1. Proline content in root, culm and leaf at seedling and flowering stages

Proline is an osmoprotectant which accumulates in the cytosol of cell. High proline content is a mechanism of tolerance to abiotic stress. In this study the saline susceptible varieties 'Jyothi' and 'IR-29' showed the lowest proline content in leaf, shoot and root in all conditions of stress and non-stress confirming their susceptibility nature for salinity.

The highest proline production both in non-saline and saline conditions in almost all the parts at all stages was seen in the genotypes 'JK-59' and 'JO-583' which points out that these genotypes may have structural gene(s) assembly for salinity tolerance which won't change in any situation. The all saline tolerant genotypes showed high proline production in the parts of root, shoot and leaf in high-saline stress condition but less proline in non stress soil indicating that in these genotypes the salinity tolerance mechanism may be through stress induced proline production.

5.1.3.2. Ca^{2+}, Na^{+}, K^{+}, Chloride and Sulphate content in root, culm and leaf at seedling and flowering stages

The Na^{+} and Cl^{-} ions may directly inhibit uptake of other ions. The Na^{+} / K^{+} ratio may reach at unacceptable levels in shoot tissues not only through the entry sodium ions, but also as a result of exclusion of potassium ions. Salinity may also cause deficiency of other ions including calcium, nitrate and the other hand high calcium levels (more than 10m Molar) can often help to prevent nutritional disorders. Under saline conditions water deficit is usually experienced first followed by toxicity effects and then nutritional disorders. However, the temporal separation of these effects and their relative severity are determined by genotype and environment (Ranamunns, 2002) .

Increase in salinity (sodium and chloride ions) causes decrease in calcium and potassium content. In high-saline condition, among the tolerant genotypes, root calcium was high for 'IR-29' fallowed by 'Kuthiru' and 'Ezhome-2'; culm calcium was higher for the genotype 'Orkayama' and leaf calcium was higher for 'JK-59'.

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. Similar result was observed in present study that the susceptible variety 'Jyothi' recorded comparatively higher Na / K ratio in root, culm and leaf at all three conditions. In high saline Kaipad among tolerant genotypes low root Na^+/K^+ ratio was seen in 'Kuthiru', 'IR-29' and 'FL-478' ; low culm Na^+/K^+ ratio was seen in 'Nona Bokra', 'FL-478' and 'Ezhome-1' and low leaf Na^+/K^+ ratio was seen in 'JK-59', 'JK-15', 'Pokkali' and 'Chettivirippu' indicating their tolerant effect towards salinity.

Chloride is toxic to plant. In high saline condition, among the tolerant genotypes low root chloride is seen in the genotypes 'Vytilla-1', 'Vytilla-6', 'JO-532-1', 'JO-583', 'Cheriviripppu' and 'Orkayama'; low culm chloride in the genotypes 'IR-29', 'Ezhome-3', 'JO-583', 'Nona Bokra', 'JO-532-1' and 'Orkayama' and low leaf chloride in the genotype 'IR-29', 'Kuthiru', 'Orkayama', 'JK-15', 'JK-59', 'Pokkali', 'JO-532-1' and 'Ezhome-1' indicating that in these genotypes the salinity tolerance mechanism is exclusion of toxic chloride. At the same time high root chloride is seen in the genotypes 'Ezhome-3' and 'Nona Bokra'; high culm chloride in the genotypes 'Vytilla-6' followed by 'Vytilla-1', 'JK-15', 'JK-59', 'Jyothi' and 'Ezhome-1' and high leaf chloride in saline tolerant the genotypes 'Ezhome-2' followed by 'Nona Bokra', 'Jyothi' and 'JO-583' indicating that in these genotypes the salinity tolerance mechanism is not exclusion but absorption and depositing in cytosol which will not affect the plant.

Sulphate is also toxic to plant. In high saline condition, among the tolerant genotypes low root sulphate is seen in the genotypes 'Ezhome-2' and 'Ezhome-3'; low culm sulphate in the genotypes 'Ezhome-2' and 'FL-478' and low leaf sulphate in the genotypes 'JO-532-1', 'Orkayama', 'Ezhome-3', 'Ezhome-2', 'IR-29' and 'Nona Bokra' indicating that in these genotypes the salinity tolerance mechanism is exclusion of toxic sulphate. At the same time high root sulphate is seen in the saline tolerant genotype 'JO-583'; high culm sulphate in the genotype 'Nona Bokra' and high leaf sulphate in the genotype 'Nona Bokra' at seedling stage and 'IR-29' at flowering stage indicating that in these genotypes the salinity tolerance mechanism is not exclusion but absorption and depositing in cytosol which will not affect the plant.

5.1.3.3. Root CEC

Higher root CEC indicates the presence of high concentration of the exchangeable cations in the plant root system. The results showed that 'FL-478', 'Jyothi' and 'Vytilla-6' recorded the highest root CEC in non-saline and in low-saline conditions. In high-saline Kaipad, the variety 'Ezhome-4' ('JO-532-1') exhibited the highest root CEC followed by 'JK-59', 'Cherivirippu' and 'Ezhome-3' indicating the ability of these genotypes to accumulates more cations even from saline soil to impart tolerance to salinity.

5.1.4. Yield parameters

The yield parameters like number of productive tillers per plant, number of spikelets per panicle, number of filled grains per panicle, seed setting %, sterility %, length of panicle, 1000 grain weight, grain yield per plot and straw yield per plot were recorded for the eighteen rice genotypes and was found to be significantly different from each other. The yield parameters are the deciding factors for assessing the productivity of any crop. The performances of each yield characteristic are discussed below.

5.1.4.1. Number of productive tillers per plant

With respect to the trait, productive tillers per plant the result showed that all the genotypes showed high number of productive tillers in low-saline condition than in non saline condition except 'Vytilla-6' and 'Jyothi'. The reason may be the favourable soil condition of low saline tract with respect to nutrients combined with low salinity signal which might have triggered the gene(s) controlling tiller production per plant. Uniform number of 'JO-532-1', 'JK-59', 'FL-478', 'Jyothi' and 'JO-583' showed uniform result in all three conditions for 'JO-532-1', 'JK-59', 'FL-478', 'Jyothi' and 'JO-583' in all three conditions reveals the presence of structural gene effect for this particular characteristics in these genotypes. At the same time in the case of 'Orkayama', 'Chettivirippu', 'Cherivirippu', 'Vytilla-1', 'Vytilla-6', 'the Pokkali' and 'Nona Bokra' the highest number of productive tillers was seen in high-saline Kaipad showing stress signal induced characteristic expression in these genotypes.

5.1.4.2. Spikelets per panicle

With respect to the trait spikelets per panicle the result showed that the improved rice genotypes 'Ezhome-1', 'JO-532-1', 'JK-59' and 'Ezhome-3', and traditional tolerant lines namely 'Pokkali', and 'Nona Bokra' recorded maximum number of spikelets per panicle in stress and non stress conditions showed the reliability of these varieties in varying soil conditions for higher yield . At the same time the traditional saline tolerant genotypes of Kaipad ('Orkayama' and 'Kuthiru') recorded minimum spikelets number per panicle in all conditions which reflects their non reliability for higher yield in all situations (Fig. 5).

In the case of the susceptible check 'Jyothi', number of spikelets was comparatively less in low-saline condition and in high-saline condition and the crop was not survived at harvesting stage due to high salinity and acidity similar to the result of Hasamuzzaman et al., 2009).

5.1.4.3. Filled grains per panicle

Improved saline tolerant varieties and breeding lines of Kaipad ('Ezhome-2', 'Ezhome-3' and 'JK-59') and international saline tolerant varieties ('Nona Bokra' and 'Pokkali') recorded maximum filled grains per panicle in both saline and non-saline conditions reflecting their tolerant nature to salinity and the consistent expression of the trait changing stress condition. Traditional genotype of Kaipad 'Kuthiru' showed minimum filled grains per panicle in saline and non-saline conditions reveals that the characteristic in this genotype is structural not changed due to stress signal.

(Hasamuzzaman et al., 2009) and Mohammadi-Nejad et al. (2010) reported that salinity stress causes the reduction in number of filled grains per panicle and yield per plant. In this study in the case of 'Jyothi', number of filled grains per panicle was comparatively less in low-saline condition and in high-

5.1.4.4. Seed setting %

The result showed that in all three conditions all most all the tolerant rice genotypes showed comparatively maximum seed setting per cent revealing the tolerant nature and consistent expression of the trait. In the case 'JO-532-1' it had showed minimum seed setting per cent in non-saline condition but in saline condition it has showed comparatively high seed setting per cent than non-saline condition indicates that the particular trait in the genotype needs salinity stimuli to express the trait.

Among the saline tolerant genotypes, in high saline condition the maximum seed setting was exhibited by 'Ezhome-3' followed by 'Ezhome-2', 'JK-15' and 'JK-59' showed the more suitability of these genotypes in high saline condition for high yield performance.

In both low-saline and high-saline conditions the international saline susceptible 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). On par performance of the genotypes 'Pokkali' and 'Nona Bokra' in three soil conditions shows the consistency of these genotypes with respect to this trait.

5.1.4.5. Sterility %

Sterility % is an important yield determining factor. In both saline and non-saline conditions the genotypes 'Ezhome-3', 'Ezhome-1' and 'Ezhome-2' recorded the minimum sterility per cent indicating the consistent nature of these genotypes with respect to this trait expression in changing stress conditions might be due to structural genes.

In high saline condition, the minimum sterility was exhibited by the variety 'Ezhome-1' followed by 'Nona Bokra', 'Pokkali', 'Ezhome-3' and 'JK-59' showing the tolerance ability of these genotypes to high salinity and acidity leading to high production in this type of stress soil. 'Vytilla-1', 'Jyothi' and saline condition the crop collapsed at reproductive stage due to high salinity and acidity indicates more susceptible nature of Jyothi to acidic saline soil.

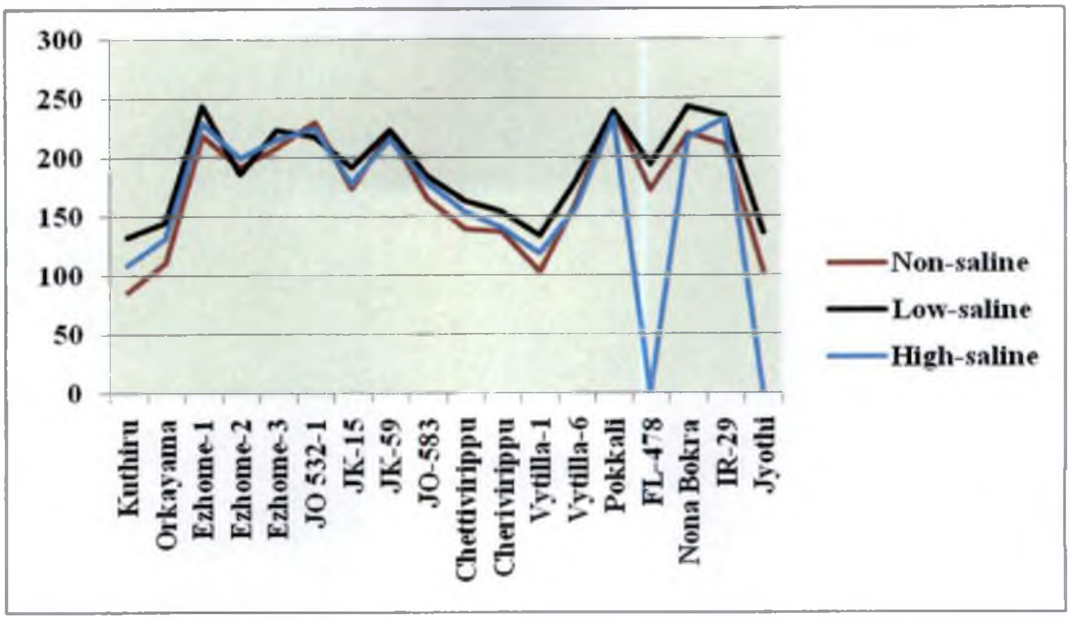

Fig.5. Variation in number of spikelets per panicle of 18 rice genotypes grown under different soil conditions

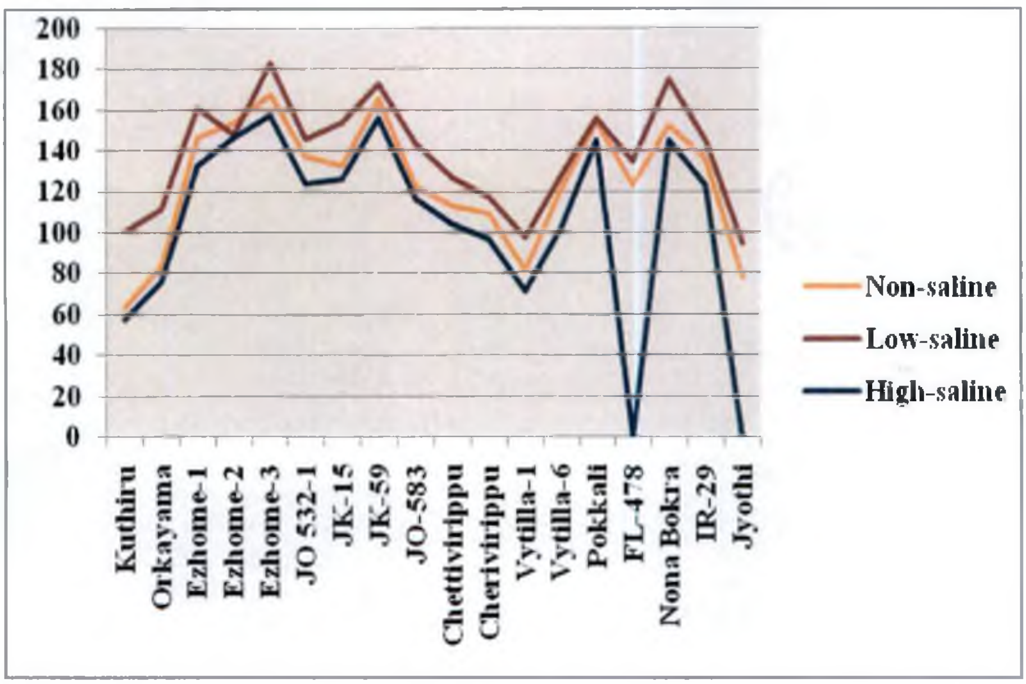

Fig.6. Variation in number of filled grains per panicle of 18 rice genotypes grown under different soil conditions

'Vytilla-6' in low-saline condition and 'Kuthiru', 'JO-583', 'Orkayama' and 'Cheriviripppu' in high saline condition showed high sterility per cent may be due to high salinity and soil acidity. Hasamuzzaman et al. (2009) reported that drastic decrease in spikelet fertility was observed with increase in salinity.

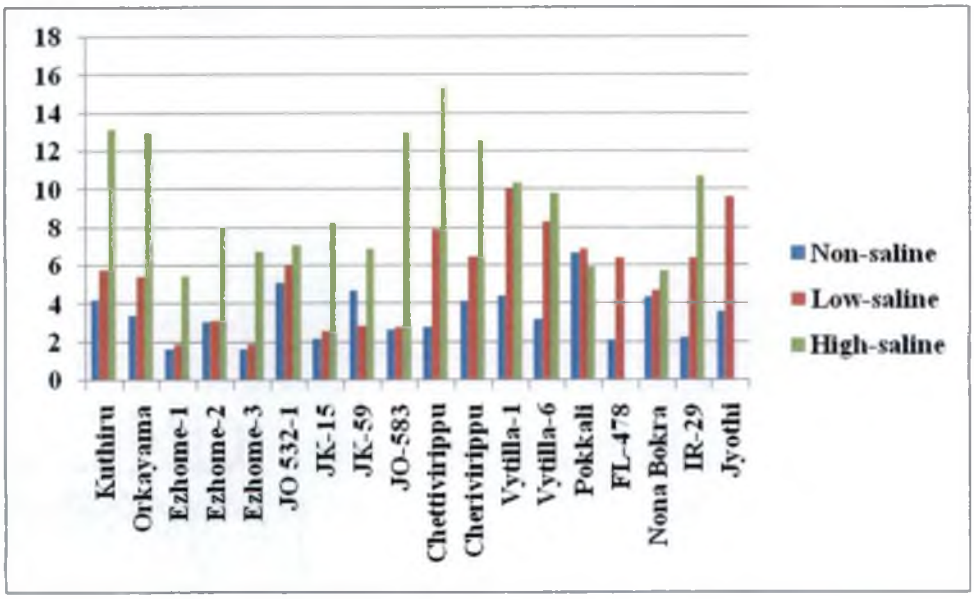

Fig.7. Variation in sterility % of 18 rice genotypes grown under different soil conditions

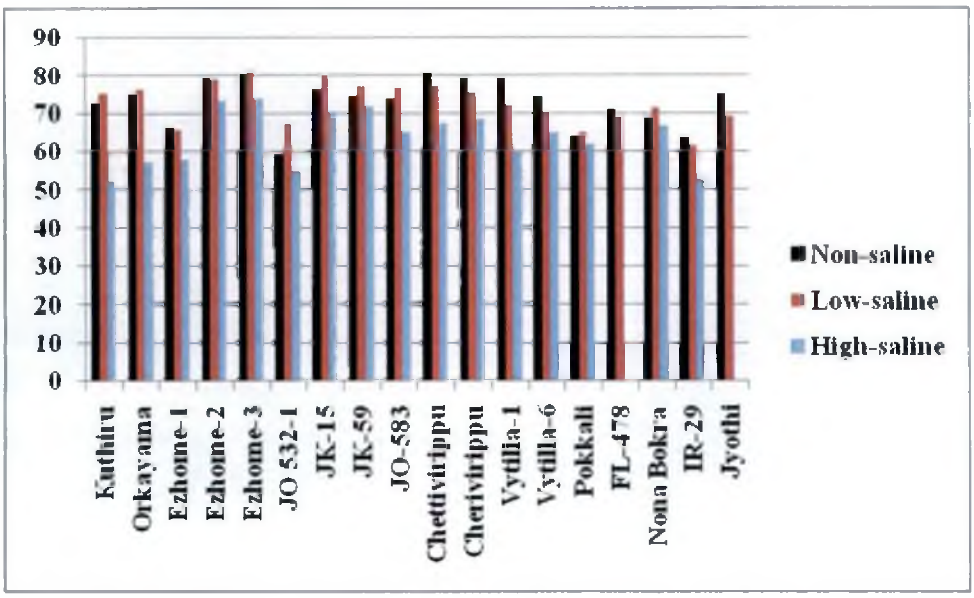

Fig.8. Variation in seed setting % of 18 rice genotypes grown under different soil conditions

5.1.4.6. Length of panicle

Length of panicle is another important yield determining factor. In high saline condition, highest panicle length was recorded for 'Nona Bokra', 'JK-59', 'JO-583', 'Chettivirippu', 'Orkayama', 'Ezhome-2', 'Ezhome-3' and JO 532-1('Ezhome-4') showing the ability of these genotypes to produce more yield in stress condition.

With respect to the trait length of panicle all most all tolerant genotypes recorded the highest panicle length which are having comparatively highest plant height, number of nodes and uppermost internodal length in all three conditions.

5.1.4.7. 1000 grain weight

1000 grain weight is another important yield component. In both low-saline and non-saline conditions the genotypes 'Ezhome-3', 'Ezhome-1' and 'Ezhome-2' recorded the maximum 1000 grain weight indicates low salinity does not affect the trait. In high-saline condition 'Ezhome-2' recorded the maximum weight indicates ability of the genotype to tolerance and also consistent expression of the trait but 'Ezhome-1' has showed minimum 1000 grain weight indicates the influence of high-salinity and soil acidity on the trait (Fig.9).

In high-saline condition the international saline susceptible variety 'IR-29' recorded minimum 1000 grain indicates that high-salinity level reduces the weight of grains. This was also reported by Hasamuzzaman et al. (2009).

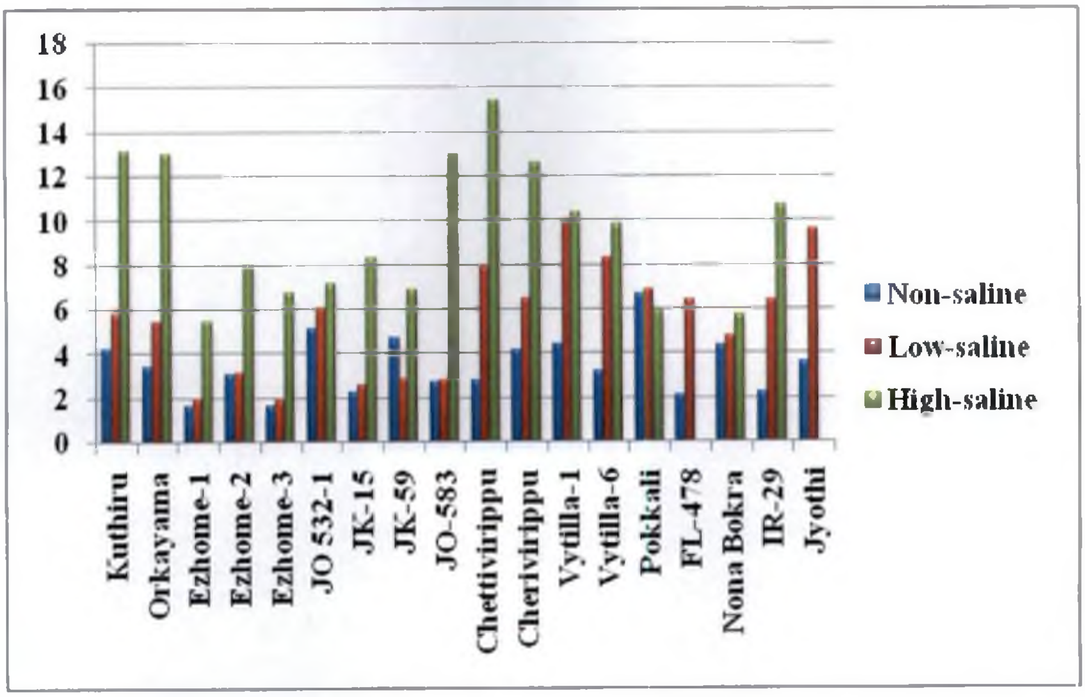

Fig.9. Variation in grain 1000 grain weight of 18 rice genotypes grown under different soil conditions

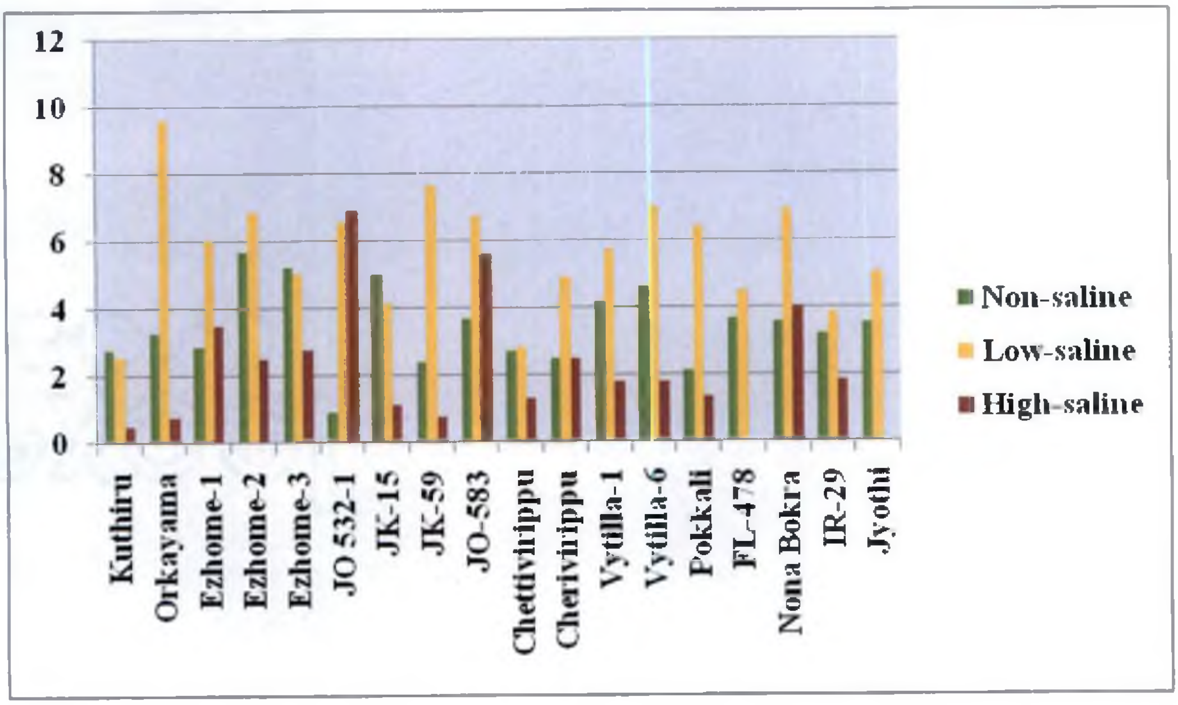

Fig.10. Variation in grain yield of 18 rice genotypes grown under different soil conditions

5.1.4.8. Grain yield per plot

There was significant difference between genotypes in all three conditions of soil and also performance of genotypes vary with respect to change in soil conditions. In high saline Kaipad among the saline tolerant genotypes the highest yield was exhibited by 'JO-532-1' (3450 Kg/ha) followed by 'JO-583' (3193.67 Kg/ha), 'Nona Bokra' (2016 Kg/ha), 'Ezhome-1 (1747 Kg/ha), 'Ezhome-2' (1224.5 Kg/ha) and 'Cherivirippu' (1240 Kg/ha). In low saline the highest grain yield was recorded for the genotypes 'Orkayama' (4792.25 Kg/ha) followed by 'JK-59' (3827 Kg/ha), 'Vytilla-6' (3500 Kg/ha), 'Nona Bokra' (3455 Kg/ha), 'Ezhome-2' (3428.19 Kg/ha), 'JO-583' (3355 Kg/ha), 'JO-532-1' (6.428.19 Kg/ha), 'Pokkali' (3215 Kg/ha) and 'Ezhome-1 (3033 Kg/ha) showing that these tolerant genotypes can be selected for a saline soil having 4.37-5.86 pH and 2.46-5.846 EC. In non saline wetland under organic management the highest grain yield was recorded for the genotypes 'Ezhome-2' (2833.64 Kg/ha), 'Ezhome-3 (2611.12 Kg/ha) and 'JK-15' (2493.23 Kg/ha) followed by 'Vytilla-6' (2305.92 Kg/ha) and 'Vytilla-1' (2092.05 Kg/ha) (Fig.10).

The genotypes 'JO-583' and 'Nona Bokra' showed significantly higher yield in saline and non saline conditions indicating the reliability of these genotypes in changing soil stress conditions and also presence of structural gene(s) for yield trait and 'JO-583' is non-lodging also. The farmers can use the seeds of these varieties in non saline as well as saline rice tracts. At the same time the genotype 'JO-532-1' recorded significantly higher yield in saline acidic soil but poor yield in non saline wetland pointing out the fact that these genotypes require stress signal to induce higher yield. Further, the genotypes 'Orkayama' and 'JK-59' showed significantly higher yield only in low saline but poor yield in both high saline and non saline rice tracts may be these genotypes are tolerant to low salinity and require low salinity signal for yield induction but less tolerant to high salinity.

Comparison of grain yield between non-saline and low-saline condition the result showed that all the genotypes showing higher grain yield in low-saline condition than in non-saline condition except for the genotype 'JK-15' indicates that high grain yield in low-saline condition might be due to low-salinity (EC of 2-5 dsm^{-1}) and high soil productivity. And in case of comparison between high-saline and low-saline except 'JO-532-1' all other genotypes showed higher yield in low-saline condition. This indicates that 'JO-532-1' require high salinity signal for the expression of its high yielding potential. This is an evident that salinity induced yield expression character is most prominent in 'JO-532-1'.

5.1.4.9. Straw yield per plant

There was significant difference between genotypes in all three conditions of soil and also performance of genotypes vary with respect to change in soil conditions. In high saline Kaipad among the saline tolerant genotypes the highest straw yield was exhibited by 'JO-583' (3488.33 Kg/ha) followed by 'JO-532-1' (2923.50 Kg/ha), 'Chettivirippu' (2087 Kg/ha), 'Nona Bokra' (1662.00 Kg/ha), 'Ezhome-2' (1441 Kg/ha), 'Orkayama' (1571 Kg/ha), and 'Ezhome-1' (1281.25 Kg/ha) indicating that these genotypes are able to give more straw yield in high saline acidic Kaipad soil having soil properties namely 3.6-4.7 pH and 11.34-16.03 EC. In low saline the highest straw yield was recorded for the genotypes 'JO-532-1' (5844 Kg/ha), followed by 'Nona Bokra' (3092.5 Kg/ha), 'Cherivirippu' (2316.67 Kg/ha), 'JK-59' (1819 Kg/ha) and 'JO-583' (1695 Kg/ha) showing that these tolerant genotypes can be selected for a saline soil having 4.37-5.86 pH and 2.46-5.846 EC. In non saline wetland under organic management the highest straw yield was recorded for the genotypes 'Vytilla-6' (14960 Kg/ha) and which was on par with that of 'Orkayama' (11150.83 Kg/ha), 'Cherivirippu' (10297.5 Kg/ha), 'Vytilla-1' (10228 Kg/ha), 'Nona Bokra' (10017 Kg/ha), 'JO-532-1' (9765.29 Kg/ha) and 'JO-583' (9387.5 Kg/ha).

The genotypes 'JO-583' and 'Nona Bokra' showed significantly higher straw yield in saline and non saline conditions indicating the reliability of these genotypes in changing soil stress conditions and also presence of structural gene(s) for yield trait and 'JO-583' is non-lodging also. The farmers can use the seeds of these varieties in non saline as well as saline rice tracts. At the same time the genotype 'JO-532-1' recorded significantly higher straw yield in non-saline and low-saline soil but poor yield in high-saline wetland pointing out the fact that these genotype having capacity to produce more straw in these soil conditions and because of high biomass of the genotype leading to the lowest grain yield. Further, the genotypes 'Orkayama' and 'Vytilla-6' showed significantly higher yield only in non-saline but poor yield in both high-saline and low-saline rice tracts may be these genotypes are susceptible to low and high salinity and require normal soil signal for yield induction. Traditional cultivar of Kaipad 'Kuthiru' has recorded comparatively lowest straw yield in saline and non-saline condition indicates the consistency of the genotype for the particular character.

Single physiological mechanism is not sufficient to achieve high-tolerance, combining multiple mechanisms may be well effective. Hence, to develop variety with high-level tolerance for salinity, parents having different physiological mechanisms have to be identified and hybridized to get complementary mechanism in one individual. In the present programme the genotypes identified for various physiological traits responsible for salinity tolerance can be utilized as parents in feature breeding programmes for development of more robust saline tolerant varieties.

5.2. Character association

5.2.1.Correlation

Correlation among 26 characteristics at seedling stage and 28 characteristics at flowering stage recorded in high-saline Kaipad are discussed.

The present investigation showed that the genotypic correlation coefficients were higher than the phenotypic correlation coefficients indicating that the observed relationship among the various characteristics was due to genetic effects. This is in confirmation with the findings of Radhidevi et al. (2002), Najeeb and

Wani (2004), Sarkar et al. (2007), Anbanandan et al. (2009) and Sabesan et al. (2009). Correlation coefficients are discussed in detail. The genotypic correlation values were also in general higher than the phenotypic correlation values indicating that these traits are not influenced by environment. similar results were reported by Rajput et al.(1996).

Among the correlation coefficients of 52 characteristics, grain yield showed significant positive genotypic correlation with plant height, survival per cent, root volume, root length, proline content, calcium content, sulphate content, root CEC and Na / K ratio at both seedling and flowering stages. SLA, RWC and SCMR at seedling stage, number of tillers, uppermost internodal length, seed setting percentage and biomass at flowering stage showed significant positive genotypic correlation with grain yield. This indicates that indirect selection of the above characteristics towards their higher end will indirectly result in higher grain yield.

Significant positive genotypic correlation of survival per cent with number of tillers, SLA, root volume, leaf proline content, leaf chloride content and leaf sulphate content at both seedling and flowering stages; uppermost internodal length, RWC, biomass, length of panicle, grain yield and 1000 grain weight at flowering stage, root length at seedling stage reflects the enhancement of survival of genotypes if we go for indirect selection of the above traits at their increased level.

Significant positive genotypic association of biomass with number of tillers, SLA, root volume and leaf Na / K ratio at both seedling and flowering stages; leaf proline content at seedling stage; plant height, survival per cent, SCMR values, root length, root CEC, total spikelets per panicle, filled grains per panicle, 1000 grain weight, sterility percentage and grain yield at flowering stage indicates the need of indirect selection of these characteristics for high biomass production. High genotypic correlation coefficients than phenotypic correlation coefficients indicates the less influence of environment on these characteristics. Similar results were reported by (Vanaja et al., 1998; Ojo et al., 2006).

Correlation results suggest that higher grain yield could be achieved by exercising indirect selection simultaneously for increased value of dependent morphological traits namely plant height at seedling and flowering, uppermost internodal length at flowering ; physiological characteristics namely, root length at seedling and flowering, survival per cent at seedling and flowering, SLA at seedling, root volume at seedling and flowering, RWC at seedling, SCMR at seedling; biochemical characteristics namely, leaf calcium content at seedling and flowering, leaf potassium content at seedling and flowering, leaf proline content at seedling and flowering, leaf sulphate content at seedling and flowering, leaf Na / K ratio at seedling and flowering and root CEC at seedling and flowering , and yield parameter seed setting per cent.

Similarly highest significant positive genotypic correlation of survival per cent, which is another indicator of salinity tolerance, with the morphological characteristics number of tillers at seedling and flowering, uppermost internodal length at flowering; physiological characteristics namely SLA at seedling and flowering, root volume at seedling and flowering, root length at seedling, RWC at flowering and biomass at flowering; biochemical characteristicsnamely leaf proline content at seedling and flowering, leaf chloride content at seedling and flowering, leaf sulphate content at seedling and flowering; and yield component characteristics namely length of panicle, 1000 grain weight and grain yield points out the fact that improvement in survival percent could be achieved by exercising selection simultaneously for increased 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), Kumar and Nilanjaya, (2014) for number of grains panicle^{-1}; Kole et al. (2008), Chandra et al. (2009),Babu et al. (2012), Nagaraju et al. (2013), Kumar and Nilanjaya, (2014), Karpagam et al. (2014), Allam et al. (2015), for number of productive tillers per plant; Ramakrishnan et al. (2006), Kumar and Nilanjaya, (2014) for seed setting %; Reddy et al. (2013), Allam et al. (2015) for number of spikelets per panicle in different ecosystems.

High phonotypic correlation of the characteristics such as root length with plant height, biomass with SCMR, Na / K ratio with leaf proline content, plant height with RWC, number of tillers with number of nodes, number of nodes with uppermost internodal length, leaf proline content with SLA, leaf chloride content with survival per cent, root CEC with RWC, productive tillers per plant with number of tillers per plant and number of nodes, filled grains per panicle with leaf calcium content, length of panicle with survival per cent and leaf calcium content, leaf Na / K ratio with leaf proline and sulphate content, total spikelets per panicle with filled grains per panicle, seed setting percentage with leaf calcium content and filled grains per panicle, straw yield with length of panicle and grain yield, stage SLA with plant height, leaf proline content and root length, leaf sulphate content with leaf proline content, plant height, survival per cent with total spikelets per panicle and filled grains per panicle, leaf chloride content with leaf proline content and plant height, 1000 grain weight with SLA, leaf Na / K ratio with leaf sulphate content and sterility per cent with total spikelets per panicle and filled grains per panicle shows the contribution of environmental association with the traits. These traits were showing high significant phenotypic associations which are not showing significant genotypic correlation indicates that the effective influence of environment on these traits.

Genotypic correlation is high and positive for most of the characteristics than the phenotypic correlations at both seedling and flowering stages. The traits which are showing significant positive genotypic correlation are not showing significance at phenotypic level which indicates that there is a high influence of significant genotypic correlation which nullifies the environmental effect leading to non-significant phenotypic correlation. High degree of genotypic correlation but non-significant phenotypic correlation shows the reliability of the characteristics.

The characteristics numbers of productive tillers per plant, number of filled grains per panicle, 1000 grain weight are important yield component characteristics in rice. But in the present study these are seen non-significantly correlated with grain yield in high-saline condition. This points to the fact that while selecting genotypes for higher yield in saline condition we should go for an optimal level of the above mentioned characteristics.

5.2.2. Path analysis

Though the correlation studies are helpful in measuring the association between yield and yield components, they do not provide the exact picture of the direct and indirect causes of such associations which can be obtained through path analysis (Wright, 1923). Path analysis is very useful to pinpoint the important yield components which can be utilized for formulating selection parameters.

In the present study path co-efficient analysis performed for 51 characteristics in high-saline condition are discussed.

The very low residual effect obtained in path analysis indicates that the causative factors included in the study have been adequate to explain variability in yield in saline soil. All most 100 % variation in grain yield in saline soil was contributed genotypically by the characteristics included in the study.

In high saline Kaipad, high positive direct effect of number of spikelets per panicle, seed setting per cent and leaf Na / K ratio at flowering, leaf potassium content at flowering, leaf potassium content at seedling on grain yield ; and high positive indirect effects of number of filled grains per panicle via. sterility percentage, number of spikelets per panicle through number of filled grains per panicle, number of filled grains per panicle via. survival per cent at flowering, number of filled grains per panicle through leaf Na / K ratio at flowering , number of spikelets per panicle via. leaf potassium content at flowering , number of filled grains per panicle through number of internodes at flowering , number of spikelets per panicle via. leaf calcium content at flowering and number of filled grains per panicle through survival per cent at seedling on grain yield reveals that for farming in high saline Kaipad and similar areas varieties having higher performance of these traits have to be selected. At the same time negative direct effect of number of filled grains per panicle, leaf sulphate content at flowering and leaf sulphate content at seedling on grain yield, and negative indirect effects of filled grains per panicle via. number of spikelets per panicle, number of filled grains per panicle via. leaf potassium content at flowering, number of spikelets per panicle through sterility percentage, number of spikelets per panicle via. survival per cent at flowering, number of filled grains per panicle via. seed setting per cent, number of filled grains per panicle via. leaf calcium content at flowering, number of filled grains per panicle via. length of panicle and number of spikelets per panicle via. leaf Na / K ratio at flowering indicates that while selecting varieties for high saline area the reduced value of the above mentioned characteristics have to be given importance.

The characteristic number of spikelets per panicle which showed high positive direct effect on grain yield exhibited non-significant correlation. The diminished correlation coefficient of number of spikelets per panicle with yield compared to its high direct effect might be due to the combined effects of its negative indirect effects via. flowering stage spikelet sterility percentage, survival per cent, and number of internodes; seedling stage survival per cent, plant height and number of tillers. Next highest positive direct effect on grain yield was contributed by seed setting per cent and leaf Na / K ratio at flowering, the highest direct effect exerted may be due to the high positive significant genotypic correlation of these characteristics with yield. The characteristics filled grains per panicle and leaf sulphate content at flowering stage exerted the highest negative direct effect on yield, but their correlation with yield is positive and non-significant at genotypic level. This may be due to high positive indirect effect of filled grains per panicle via. flowering stage sterility per cent, survival per cent, leaf Na / K ratio and number of internodes, seedling stage survival per cent and flowering stage leaf sulphate content via. flowering and seedling stage leaf proline content.

Correlation and path analysis studies conducted in the present investigation reveals that, in yield and salinity tolerance improvement programmes of rice, breeder should give emphasis for number of spikelets per panicle, leaf Na / K ratio at flowering, number of filled grains per panicle, survival per cent at seedling and flowering, seed setting percentage, leaf proline content at seedling and flowering, leaf sulphate content at seedling and flowering, leaf potassium content seedling and flowering, root volume at seedling and flowering, RWC at seedling, leaf calcium content at seedling and flowering, root CEC at seedling and flowering, uppermost internodal length at flowering, 1000 grain weight and number of productive tillers per plant.

Single physiological mechanism is not sufficient to achieve high-tolerance, combining multiple mechanisms may be well effective. Hence, to develop variety with high-level tolerance for salinity, parents having different physiological mechanisms have to be identified and hybridized to get complementary mechanism in one individual. In the present programme the genotypes identified for various physiological traits responsible for salinity tolerance can be utilized as parents in feature breeding programmes for development of more robust saline tolerant varieties.

On visual observation basis it was revealed that non-lodging trait is correlated with biomass, plant height, root volume and root length.

Yeo and Flowers (1986) opined that resistance to salinity is conferred not by any single attribute, but is the sum of a number of factors all of which contribute to the overall resistance, and all of which may vary within and between varieties. These factors include the entry of sodium and chloride ions into the tissue, the ability to direct the ions to older, rather than younger leaves and tolerance of ions once in the tissues. Hence it was suggested that the salt resistance can be increased by selecting separately for underlying physiological characteristics and combining them.

5.3. Identification of salinity tolerance mechanism in tolerant genotypes

Table. 47. Salinity tolerance mechanism of rice genotypes taken for the study

	AA	BB	CC	DD	EE	FF	GG	HH	II	JJ	KK	LL	MM	NN	OO	PP	QQ	RR
A	×	*	×	×	×	×	*	×	×	*	*	×	×	*	×	*	×	×
B	*	×	×	×	×	*	*	*	*	*	*	*	×	*	×	*	*	×
C	*	*	×	×	*	*	*	*	*	*	*	*	×	*	×	*	×	×
D	*	×	×	×	×		×	×	×	*	*	×	×	*	×	*	*	×
E	×	×	*	×	*	×	×	×	×		×	×	*	×	×	×	*	×
F	*	×	×	×	×	*	*	*	*	*	*	*	*	*	*	*	*	*
G	×	*	*	×	×	*	×	×	×	×	*	×	*	×	*	×	×	*
H	*	*	×	×	*	*	×	×	×	×	*	*	×	*	×	×	*	×
I	*	*	×	*	*	*	*	*	×	*	*	×	×	*	×	*	×	×
J	*	*	×	×	*	×	×	×	*	×	×	×	×	×	×	*	×	×
K	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	×	×
L	*	*	*	*	*	*	*	*	*	*	*	*	*	*	×	*	*	×
M	×	×	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	×
N	*	×	*	*	*	*	*	*	×	*	*	×	×	*	×	×	*	×
O	×	×	*	*	*	*	×	*	×	×	×	×	×	*	-	*	*	-
P	×	×	*	*	*	*	*	*	*	×	×	×	×	*	-	*	*	-
Q	×	×	*	*	*	*	*	*	×	×	×	×	*	*	-	*	×	-
R	×	×	×	*	*	×	*	*	*	*	*	*	*	*	-	*	×	-
S	×	×	*	*	*	*	×	×	*	×	*	×	×	*	-	*	×	-

***= Favourable for salinity tolerance ×= Not favourable for salinity tolerance -=Not estimated**

A= number of tillers at flowering, B=plant height at seedling, C= plant height at flowering, D=uppermost internodal length, E=SLA at seedling, F=RWC at seedling, G=SCMR at seedling, H=biomass at flowering, I=root length seedling, J=root length flowering, K= proline content at both seedling and flowering, L=survival % at seedling and flowering, M=leaf Na / K ratio at seedling and flowering, N= root CEC at seedling and flowering, O=spikelets per panicle, P=filled grains per panicle, Q=sterility %, R=seed setting %, S= grain yield.

AA= Kuthiru, BB= Orkayama, CC= Ezhome-1, DD= Ezhome-2, EE= Ezhome-3, FF= JO-532-1 (Ezhome-4), GG= JK-15, HH= JK=59, II= JO-583, JJ= Chettivirippu, KK= Cheriviríppu, LL= Vytilla-1, MM= Vytilla-6, NN=Pokkali, OO=FL-478, PP= Nona Bokra, QQ= IR=29, RR= Jyothi.

Salinity tolerance characteristic is a complex trait of various morphological/physiological/biochemical mechanisms which will vary with genotypes. The various mechanisms that might have prevalent in the 16 saline tolerant genotypes used in the present study are depicted below (Table 47). The probable salinity tolerance mechanism, involving morphological, physiological and biochemical parameters, of 16 saline tolerant genotypes used in the study is appraised based on variation, correlation and path analyses studies. Considering the 19 favorable salinity tolerance 'Pokkali' ranked first (16) followed by 'Nona Bokra' (15); 'Cheriviruppu', 'Ezhome-3', 'Ezhome-4'(14); 'JK59', 'JK15'(12); 'Chettiviruppu'(11); and 'JO583','Kuthiru', 'Ezhome-1', 'Ezhome-2'(10). Hence these genotypes having different physiological/biochemical parameters conferring salinity tolerance can be considered as parents for future salinity tolerance breeding programmes. The remaining other saline tolerant genotypes possessing less than 50% of mechanisms studied are namely 'Orkayama', Vytilla-1, Vytilla-6, and FL478. Out of this Orkayama is the popularly grown traditional variety of saline acidic Kaipad. This indicates that Vytilla-1, Vytilla-6, and FL478 which are saline tolerant varieties developed based on 'Pokkali' genotype are comparatively susceptible to acidic Kaipad soil. It also reveals that the salinity tolerance mechanism in 'Orkayama' may be different which is in conformity with the report of Vanaja and Mammootty (2010) based on molecular study. The international saline susceptible variety 'IR 29' possesses 10 favorable mechanisms for salinity tolerance indicating that this genotype is tolerant to acidic saline soils. 'Jyothi' varieties of Kerala possess only two mechanisms confirming the susceptible nature of the genotype in saline acidic Kaipad.

SUMMARY

6. SUMMARY

The present investigation of 'Trait(s) for salinity tolerance, non-lodging and high yield of rice in Kaipad soil of Kerala' was conducted in the Department of Plant Breeding and Genetics, College of Agriculture, Padannakkad, Kerala Agricultural University during 2014- 2016. Two field trials were laid out during Kharif season of 2015 in the naturally organic saline Kaipad rice tract in Ezhome Grama Panchayath of Kannur district, Kerala and one field trial in the same season in the non saline wetland of Regional Agricultural Research Station (RARS), Pilicode of Kerala Agricultural University.

The investigation was conducted for identification of most correlated morphological, physiological and biochemical trait(s) associated with salinity tolerance, high yield and non-lodging at seedling and reproductive stages in Kaipad soil.

The materials comprised of 18 rice genotypes which includes, saline tolerant traditional land races of Kaipad tract (Kuthiru and Orkayama), improved saline tolerant varieties of Kaipad (Ezhome-1, Ezhome-2 and Ezhome-3), improved saline tolerant breeding lines of Kaipad (JO532-1, JK 15, JK 59 and JO 583), saline tolerant traditional land races of Pokkali tract (Chettivirippu and Cherivirippu), improved saline tolerant Pokkali varieties (Vytilla-1 and Vytilla-6), international saline tolerant varieties (Pokkali, FL-478 and Nonabokra), international saline susceptible variety (IR-29) and saline susceptible popular variety of Kerala (Jyothi).

Eighteen rice genotypes were raised in Kaipad rice field of low and high saline soils and in non-saline soil at Regional Agricultural Research Station (RARS), Pilicode during Kharif 2015 in a randomized block design with two replications. In Kaipad fields the management was naturally organic and in non saline field organic management was done. Observations on morphological, physiological, biochemical and yield 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, number of tillers, survival per cent, specific leaf area, relative water content, stomatal conductance and resistance, SCMR, root length, root volume, biomass, root shoot ratio; proline, calcium, sodium, chloride, potassium and sulphate content in leaf, shoot and root, root CEC characteristics at both seedling and flowering stages; number of internodes and uppermost internodal length characteristics at flowering stage and number of productive tillers per plant, number of filled grains per panicle, number of spikelets per panicle, seed setting per cent, sterility per cent, length of panicle, 1000 grain weight, grain yield per plot, straw yield per plot, lodging/non-lodging, orientation of flag leaf and duration of crop at harvesting. Soil analysis of low and high saline Kaipad tracts was separately carried out for 12 months. The data on plant observations were subjected to statistical analyses of variance, correlation and path.

The salient findings of the study are:

1. Soil analyses showed that high saline Kaipad tract is with the soil properties of high pH (3.6-4.7), EC (11.34-16.03), CEC (11.67-13.7), exchangeable cations (2.89), ESP (5.6-7.8), SAR (14.6), chloride (2.3-3.7 mg/kg soil) and sulphate (0.226 mg/kg soil) and low saline Kaipad tract with soil properties of pH (4.37-5.86), EC (2.46-5.846), CEC (12.3-16.6), exchangeable cations (2.66), ESP (3.7-5.2), SAR (13.2), chloride (1.21-1.92 mg/kg soil) and sulphate (0.245 mg/kg soil)

2. The analysis of variance showed significant difference between varieties in all three soil conditions for most of the characteristics studied showing the high variability existing between selected genotypes for the study. There was significant genotype environment interaction effect for most of the characteristics indicating that the performance of genotypes vary with changing soil stress environment.

3. In high saline organic Kaipad of high pH (3.6-4.7) and EC (11.34-16.03), the highest grain yield was recorded for the genotypes 'JO-532-1' (3450 kg/ha) followed by 'JO-583' (3193.67 kg/ha), 'Nona Bokra' (2016.5 kg/ha), 'Ezhome-1' (1747.50 kg/ha, 'Ezhome-2' (1224.5 kg/ha) and 'Cheriviripppu' (124o kg/ha). In low saline organic Kaipad of 4.37-5.86 pH and 2.46-5.846 EC, the highest grain yield was recorded for the genotypes 'Orkayama' (4792.25 kg/ha) followed by 'JK-59' (3827 kg/ha), 'Vytilla-6' (3500 kg/ha), 'Nona Bokra' (3455 kg/ha), 'JO-583' (3355.34 kg/plot), 'JO-532-1' (3428.19 kg/ha), 'Pokkali' (3215.8 ka/ha) and 'Ezhome-1 (3033 kg/ha). In non saline wetland under organic management, the highest grain yield was recorded for the genotypes 'Ezhome-2' (2833.64 kg/ha), 'Ezhome-3 (2611.12 kg/ha) and 'JK-15' (2493.23 kg/ha) followed by 'Vytilla-6' (2305.92 kg/ha) and 'Vytilla-1' (2092.92 kg/ha).

4. The non-lodging genotypes 'JO-583', 'Ezhome-3' and 'Ezhome-2' showed significantly higher yield in saline and non saline conditions indicating the reliability of these genotypes in changing soil stress conditions and also presence of structural gene(s) for yield trait. The farmers can use the seeds of these varieties in non saline as well as saline rice tracts. At the same time the genotype 'JO-532-1' recorded significantly higher yield in saline acidic soil but poor yield in non saline wetland pointing out the fact that this genotype requires stress signal to induce higher yield. Further, the genotypes 'Orkayama' and 'JK-59' showed significantly higher yield only in low saline but poor yield in both high saline and non saline rice tracts may be these genotypes are tolerant to low salinity and require low salinity signal for yield induction but less tolerant to high salinity.

5. In high saline Kaipad, 'FL 478' one of the saline tolerant international varieties decayed after flowering indicating that it is susceptible to high acidic saline Kaipad soil at reproductive stage. It is further confirmed by the presence of only four number of salinity tolerance mechanisms out of 19. At the same time, among the two saline susceptible varieties 'IR 29' and 'Jyothi', in high saline Kaipad susceptible variety of Kerala 'Jyothi' decayed after flowering but not 'IR29'

pointing out the fact that 'Jyothi'(red rice) variety is more susceptible than the international saline susceptible variety 'IR 29'(white rice) in Kaipad acidic saline soil. This result is again confirmed from the fact that Jyothi possessed only two salinity tolerance mechanisms out of 19, but IR 29 possessed 10 tolerance mechanisms.

6. Vytilla -1, Vytilla-6, and FL478 which are saline tolerant varieties developed based on 'Pokkali' genotype are comparatively susceptible to acidic Kaipad soil.

7. Salinity tolerance mechanism in 'Orkayama' may be different from the other saline tolerant genotypes.

8. Out of forty five parameters studied under high saline condition, parameters namely, root volume, leaf calcium , leaf potassium ,leaf proline, root CEC, number of tillers and survival per cent at seedling and flowering stages; SCMR at seedling stage ; and seed setting per cent, leaf Na / K ratio and uppermost internodal length at flowering stage showed both positive significant genotypic correlation and high direct effect with grain yield plant^{-1}. Hence these are the traits for tolerance to salinity as well as for higher yield, improvement of which can be considered for developing saline tolerant as well as high yielding genotypes. The highest degree of significant positive association at genotypic level between survival per cent and grain yield suggests that survival per cent is a highly reliable component of yield in saline condition and can very well be considered as an indicator of yield as well as salinity tolerance.

9. On the basis of visual observation the characteristics correlated to the trait non-lodging are biomass, plant height, root length and root volume.

10. The probable salinity tolerance mechanism, involving morphological, physiological and biochemical parameters, of 16 saline tolerant genotypes used in the study is appraised.

11. In rice generally the characteristics number of productive tillers plant^{-1}, number of filled grains panicle^{-1}, and 1000 grain weight are important yield

component characteristics. But in the present study these were seen non-significantly correlated with grain yield in high-saline condition. This points to the fact that while selecting genotypes for yield in saline condition we should go for an optimal level of the above mentioned characteristics.

10. Based on variation, correlation and path analyses studies, the genotypes which can be selected as parents for future salinity tolerance breeding programmes are Pokkali', 'Nona Bokra', 'Cheriviruppu', 'Ezhome-3', 'Ezhome-4', 'JK59', 'JK15', 'Chettivirippu', 'JO583','Kuthiru', 'Ezhome-1', and 'Ezhome-2'.

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APPENDIX

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Weather data during the crop period

Standard week	Temperature (°C)		Relative humidity (%)		BSS hours	Rainfall (mm)	Evaporation (mm)
	Max	Min	7.22 am	2.20 pm			
April-2015	33.07	23.44	86.00	66.00	6.71	15.00	3.99
May-2015	32.50	24.50	88.14	70.29	3.90	8.10	2.93
June-2015	30.27	23.83	93.17	81.33	2.15	130.80	3.14
July-2015	30.71	23.04	94.57	82.86	2.46	58.80	3.16
August-2015	30.89	22.96	89.00	77.00	2.76	108.60	4.00
September-2015	31.39	23.17	95.29	79.29	2.03	213.80	3.50
October-2015	31.34	23.62	92.84	76.30	2.21	265.70	3.15
November-2015	31.38	23.04	91.37	72.13	3.14	106.80	2.95
December-2015	32.26	21.73	94.10	68.30	5.07	1.60	3.22
January-2015	32.25	19.56	93.42	56.58	4.71	0.00	3.67
February-2015	32.25	21.93	92.24	58.92	3.00	0.00	4.53
March-2015	33.61	24.57	88.50	61.67	2.82	0.00	5.34

TRAITS FOR SALINITY TOLERANCE, NON-LODGING AND HIGH YIELD OF RICE IN KAIPAD SOIL OF KERALA

by

SOWMYA, N.R.

(2014-11-192)

Abstract of the thesis

Submitted in partial fulfilment of the

requirements for the degree of

MASTERS SCIENCE IN AGRICULTURE

Faculty of Agriculture

Kerala Agricultural University

DEPARTMENT OF PLANT BREEDING AND GENETICS

COLLEGE OF AGRICULTURE

PADANNAKKAD, KASARGOD – 671 314

KERALA, INDIA

2016

ABSTRACT

The present investigation of 'Trait(s) for salinity tolerance, non-lodging and high yield of rice in Kaipad soil of Kerala' was conducted in the Department of Plant Breeding and Genetics, College of Agriculture, Padannakkad, Kerala Agricultural University during 2015. Two field trials were laid out during Kharif season of 2015 in the naturally organic saline Kaipad rice tract in Ezhome Grama Panchayath of Kannur district, Kerala and one field trial in the same season in the non saline wetland of Regional Agricultural Research Station (RARS), Pilicode of Kerala Agricultural University in a randomized block design with two replications. The investigation was conducted for identification of most correlated morphological, physiological and biochemical trait(s) associated with salinity tolerance, high yield and non-lodging in saline Kaipad soil.

The materials comprised of 18 rice genotypes which includes, 16 saline tolerant genotypes and two saline susceptible genotypes. Observations were taken on plant height, number of tillers, survival per cent, specific leaf area, relative water content, stomatal conductance and resistance, SCMR, root length, root volume, biomass, root shoot ratio; proline, calcium, sodium, chloride, potassium and sulphate content in leaf, shoot and root, root CEC characteristics at both seedling and flowering stages; number of internodes and uppermost internodal length characteristics at flowering stage and number of productive tillers per plant, number of filled grains per panicle, number of spikelets per panicle, seed setting per cent, sterility per cent, length of panicle, 1000 grain weight, grain yield per plot, straw yield per plot, lodging/non-lodging, orientation of flag leaf and duration of crop at harvesting. Soil analysis for low and high saline Kaipad tracts was separately carried out for 12 months. The data on plant observations were subjected to statistical analyses of variance, correlation and path co-efficient.

Soil analyses showed that high saline Kaipad tract is with the soil properties of pH (3.6-4.7), EC (11.34-16.03), CEC (11.67-13.7), exchangeable cations (2.89), ESP (5.6-7.8), SAR (14.6), chloride (2.3-3.7 mg/kg soil) and sulphate (0.226 mg/kg soil) and low saline Kaipad tract with soil properties of pH (4.37-5.86), EC (2.46-5.846), CEC (12.3-16.6), exchangeable cations (2.66), ESP

(3.7-5.2), SAR (13.2), chloride (1.21-1.92 mg/kg soil) and sulphate (0.245 mg/kg soil).

The analysis of variance of plant characteristics showed significant difference between varieties in all three soil conditions for most of the characteristics. Thus shows the high variability existing between selected genotypes. There was significant genotype environment interaction effect for most of the characteristics indicating that the performance of genotypes vary with heterogeneous saline soil conditions of Kaipad.

In high-saline organic Kaipad, the highest grain yield was recorded for the genotypes 'JO-532-1' ('Ezhome-4) followed by 'JO-583', 'Nona Bokra', 'Ezhome-1', 'Ezhome-3', 'Ezhome-2' and 'Cherivirippu'. In low-saline organic Kaipad, the highest grain yield was exhibited by the genotypes 'Orkayama' followed by 'JK-59', 'Vytilla-6', 'Nona Bokra', 'Ezhome-2', 'JO-583', 'JO-532-1' ('Ezhome-4'), 'Pokkali' and 'Ezhome-1'. In non-saline wetland under organic management, the highest grain yield was recorded for the genotypes 'Ezhome-2', 'Ezhome-3' and 'JK-15' followed by 'Vytilla-6' and 'Vytilla-1'. The non-lodging genotypes 'JO-583', 'Ezhome-3' and 'Ezhome-2' showed significantly higher yield in saline and non saline conditions indicating the reliability of these genotypes in changing soil stress conditions and also presence of structural gene(s) for yield trait. At the same time the genotype 'JO-532-1' ('Ezhome-4') recorded significantly higher yield in saline acidic soil but poor yield in non-saline wetland pointing out the fact that these genotypes require stress signal to induce higher yield. Further, the genotypes 'Orkayama' and 'JK-59' showed significantly higher yield only in low-saline but poor yield in both high-saline and non-saline rice tracts, may be these genotypes are tolerant to low salinity and require low salinity signal for yield induction but less tolerant to high salinity. In high saline Kaipad soil the tolerant variety, 'FL 478' of IRRI showed susceptibility towards reproductive stage. 'Jyothi' (red rice) is more susceptible to acidic saline Kaipad soil than international saline susceptible variety 'IR 29'(white rice). Vytilla -1, Vytilla-6, and FL478 which are saline tolerant varieties developed based on 'Pokkali' genotype are comparatively susceptible to acidic Kaipad soil. Salinity tolerance mechanism in 'Orkayama' may be different from the other saline tolerant genotypes.

The traits for tolerance to salinity as well as for higher yield in saline Kaipad soil are root volume, leaf calcium, leaf potassium ,leaf proline, root CEC, number of tillers and survival per cent respectively at seedling and flowering stages; SCMR at seedling stage and seed setting per cent, leaf Na / K ratio and uppermost internodal length at flowering stage. The traits identified for non-lodging are biomass, plant height, root length and root volume.

The probable salinity tolerance mechanism, involving morphological, physiological and biochemical parameters, of 16 saline tolerant genotypes used in the study is appraised. In rice, generally the characteristics such as number of productive tillers per plant, number of filled grains per panicle, and 1000 grain weight are important yield component characteristics. But in saline condition we should go for an optimal level of the above mentioned characteristics for yield enhancement.

Based on variation, correlation and path analyses studies, the saline tolerant genotypes which can be selected as parents for future breeding programmes for development of high yielding saline tolerant rice varieties are 'Pokkali', 'Nona Bokra' (international saline tolerant varieties), 'Cheriviriippu'(traditional genotype of Pokkali), 'Ezhome-3', 'Ezhome-4'(released varieties of Kaipad tract), 'JK59', 'JK15' (pre released Kaipad cultures) 'Chettiviriippu' (traditional genotype of Pokkali), 'JO583' (pre released Kaipad culture),'Kuthiru' (traditional land race of Kaipad tract), 'Ezhome-1', and 'Ezhome-2' (released varieties of Kaipad tract).