INFLUENCE OF SALINITY ON THE GERMINATION AND GROWTH CHARACTERISTICS OF RICE

By

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THESIS

SUBMITTED IN PARTIAL FULFILMENT OF THE REQUIREMENTS FOR THE DEGREE OF MASTER OF SCIENCE IN AGRICULTURE (CHEMISTRY) OF THE UNIVERSITY OF KERALA.

DIVISION OF AGRICULTURAL CHEMISTRY,
AGRICULTURAL COLLEGE AND RESEARCH INSTITUTE,
VELLAYANI.

1963

C E R T I F I C A T E

This is to certify that the thesis herewith submitted contains the results of bonafide research work carried out by Smt. B. Remani under my supervision. No part of the work embodied in this thesis has been submitted earlier for the award of any degree.

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16-8-1963.

ACKNOWLEDGEMENTS

The author desires to acknowledge and express her sincere gratitude and deep appreciation to:

Dr. N.S. Money, Additional Professor of Agrl. Chemistry, for his guidance in the planning and execution of this work,

Shri. E.J. Verghese, Professor of Agrl. Chemistry, for the keen interest evinced by him in this investigation,

Shri. M.M. Koshy, Junior Professor of Agrl. Chemistry, for perusing the manuscript and offering constructive suggestions,

Dr. C.K. N. Nair, Principal, for facilities provided and other courtesies extended,

The members on the staff of the Agricultural Chemistry Division for their kind cooperation and the help rendered during the course of this work.

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CHAPTER I

INTRODUCTION

Rice, the staple food of the people of Kerala, is grown over an area of approximately 19 lakhs of acres. Nearly half of this area is single crop land, where it is grown only once in a year during the summer months of January to May. For the rest of the year these lands are submerged under water which makes farming operations practically impossible. Such lands are situated mainly in the low-lying areas of the West Coast or in the basins and valleys between the hills and hillocks of the Midland region. Where they occur on the coastal backwater region, especially in areas like Kuttanad in the vicinity of the Vembanad Lake, these fields are subject to periodical inundation with sea water. Depending upon the variations in the tidal influence of the sea, the ingress of brine may occur at any stage in the growth period of a standing rice crop. The total area of lands affected in this manner is estimated at 2 lakhs of acres. Attempts have been made to control the incursion of the sea by major engineering works, but salinity still presents serious hazards to rice cultivation in Kuttanad and similar areas.

It would thus be clear that the saline soils existing on the coastal regions of Kerala are very different in their nature and properties from those occurring in other parts of India. Salinity is generally a condition of the soil resulting in an accumulation of soluble salts in the surface layers as a result of improper irrigation and impeded drainage. Such soils are base-saturated and alkaline in reaction. In Kerala the soils designated as 'saline' are, on the other hand, acidic in reaction and base-unsaturated. Salinity in these soils is a temporary phenomenon brought about by periodical inundation of the soil with sea water.

The effects of salinity on germination, growth and yield of various crops have been studied extensively. The results of these investigations generally indicate that the harmful effects of salinity might be attributed to its osmotic influence. There are also indications that some of the salts may be characteristically toxic. The experience of farmers in Kerala shows that the stage at which sea water enters the fields is important, but no precise information is available regarding the effect of the stage at which salt water incursion takes place on the nature of the injury. The present investigation was, therefore, undertaken with a view to securing more accurate information regarding the nature of salt injury to crops, especially the effect of the periodical inundation with sea water on the growth and yield of rice. The major aspects investigated are,

(1) The influence of salinity on the germination of some of the more important rice varieties of Kerala; and

(2) The effect of inundation of the soil with sea water at different stages in the growth period of rice on its growth characteristics, yield and chemical composition.

As the incursion of sea water has its impact not only on crop growth, but also on the soil characteristics, a study has, further, been made of the changes in the electrical conductivity measurements of soils treated with salt solutions. Details of the procedure adopted and the results obtained are presented, discussed and summarised on the subsequent pages.

CHAPTER II

REVIEW OF LITERATURE

A. General Effects of Salinity on Soils and Crops

During the last fifty years, the causes and effect of salinity and alkalinity in soils have been studied extensively. Among the earlier workers, mention may be made of Kelley and Thomas (1920) who studied the effects of excessive concentrations of salts in irrigation water on citrus trees grown under orchard conditions. They reported that an excess of chloride caused yellowing of the margins and burning of the tips, followed by heavy shedding of leaves in lemon trees. With orange trees, mottling of leaves was one of the primary symptoms occasionally accompanied by browning and curling of leaves and dieback of young tender shoots.

Harley and Lindner (1945) were of opinion that plants might develop an intense chlorosis under certain soil conditions, either associated with calcareous soils or with the use of irrigation water containing a high level of bicarbonate.

According to Kellogg (1947) one of the most important dangers of irrigation was the concentration of soluble salts in the soil. Very few plants could be grown in a soil in which more than 0.2 per cent of the soil mass was soluble.

Ashgar and Dhawan (1949) found that the irrigation or leaching of soils with water containing 10-60 ppm. of $Na_2 CO_3$, $Na HCO_3$, Na Cl or $Na_2 SO_4$ tended to increase the pH and the degree of alkalization. Eaton (1950) postulated the theory that irrigation water containing an excess of carbonates and bicarbonates might precipitate much of the calcium and magnesium and cause sodium to become the predominant cation in the soil solution.

According to Pijls (1953) the upper limits allowed for mineral ash and sodium chloride in horticultural soils were 0.04 per cent and 0.4-0.5 per cent respectively. Irrigation water should not contain more than 0.5 g./l of sodium chloride.

In a study of the high bicarbonate factor Wilcox, Blair and Bower (1954) concluded that bicarbonate had to exceed a concentration of 1.25 me./l of water before it could be considered as injurious. Bower (1954) has recommended the use of fibrous rooting crops and the application of gypsum for the rehabilitation of soils damaged by the incursion of sea water.

Brown and Voth (1955) reported that the use of irrigation water containing 100 ppm. of sodium chloride in furrows, reduced the first yield of strawberries appreciably, without any other visible symptom of injury. In their experiment with lucerne using irrigation water containing 0, 3000, 6000 and 9000 ppm. of a 50:50 mixture of sodium and calcium chlorides, Brown and Hayward (1956) noticed that the plants in the salinized plots were smaller and exhibited a dark blue-green colour which deepened with increase in the salt concentration. The average yield of all the varieties was depressed to 79, 60 and 42 per cent of that of the control for the treatments with water containing 3000, 6000 and 9000 ppm. of the salt respectively.

Reeve (1957) investigated the relation of salinity to irrigation and drainage requirement and derived some equations relating to the depth of irrigation water to meet crop yield and leaching requirements. Barnes and Peele (1958) reported that snap beans on fine sandy loam were little affected by water containing 1000 ppm. salt while a concentration of 2000 ppm. reduced the yield by 20-40 per cent.

Lunin, Gallatin and Batchelder (1961) investigated the effect of saline water applied to beans in pots before planting and 10-40 days after germination. They found that there was a moderate increase in the soluble and exchangeable cation content of the variously treated soil at the time of harvest.

Kelley, Chapman and Pratt (1961) found that the absorption and transpiration of water by Sudan grass for seven consecutive years without drainage, resulted in a soil solution more than twelve times as concentrated as the applied irrigation water. Differential rates of absorption of ions resulted in considerable change in the ratios between the soluble ions in the soil as compared with the corresponding ions in the irrigation water.

Brito Mutunayagam, Nambiar and Abraham (1948) reported that when Kuttanad soils were flooded with sea water, they became considerably poor in exchangeable calcium but rich in exchangeable sodium and magnesium. The replacement of calcium ions was more when a pure solution of sodium chloride was used because with sea water, the small quantities of $CaSO_4$ present, retarded the replacement of calcium by sodium. Soil flooded with sea water was found to develop unfavourable physical conditions which constituted the main cause for the infertility in these soils.

B. Effects of Salinity on Germination and Seedling Development

Germination and seedling growth under saline soil conditions are critical since the ability of a variety to germinate and establish, is frequently the limiting factor in crop production. Saline soils affect germination in two different ways. Firstly, there may be enough soluble salts in the seed bed to build up the osmotic pressure of the soil solution to a point which will retard or prevent the intake of necessary water. Secondly, certain constituent salts or ions may be toxic to the embryo and seedling. One of the processes associated with germination is imbibition which is governed by osmotic forces. It is natural, therefore, that imbibition should be retarded in salt solution.

Buffum (1896, 1899) from his early works on the effect of high osmotic pressure of the soil solution concluded that the retarding effect of a salt solution on the germination of seeds is in direct proportion to its osmotic pressure when the solutions were sufficiently concentrated.

Slosson and Buffum (1898) and Stewart (1898) found that if the osmotic pressure was high enough, no germination occurred; but it was noted that at a given salt concentration various species of crops exhibited differential salt tolerance with respect to germination.

Hicks (1900) working with fertilizer salts concluded that the chief injury to germination from chemical fertilizers was inflicted upon the young sprouts after they had left seed coat and before they emerged from the soil.

Kearney and Harter (1907) tested seedlings of maize, sorghum, oats, cotton and sugarbeets in water cultures using $NaCl$, $MgCl_2$ and $MgSO_4$ as single salts, to determine the critical concentrations at which half of the root tips of seedlings exposed to these concentrations for twenty four hours failed to survive when subsequently transferred to water. They found great differences in the resistance to magnesium and sodium salts in solution among the eight species tested, maize being most resistant and cotton the least.

From his work with salt levels ranging from 0-10,000 ppm. using various single salts and combination of salts, Harris (1915) concluded that crops varied greatly in their relative resistance to alkali salts. He found the relative toxicity of soluble salts to be in the descending order, $NaCl$, $CaCl_2$, KCl, $MgCl_2$, KNO_3, $Mg(NO_3)_2$, Na_2CO_3, Na_2SO_4 and $MgSO_4$.

Shive (1916) using sand culture technique and single salts, tested the germination of beans and corn at osmotic pressures ranging from 0.5-8.0 atmospheres. His data indicated that retarded germination was directly related to the amount of water absorbed by the seeds, which in turn was dependent upon the concentration of the soil solutions.

Harrison (1917) conducted similar experiments in which it was noted that 'bara' soils freed from salts by washing, still inhibited germination. He explained the phenomenon on the basis of the formation of black alkali soils in the absence of soluble salts.

Harris and Pittman (1918) compared the relative toxicity of $NaCl$ at concentrations of 0-4000 ppm. and of Na_2CO_3 and Na_2SO_4 at concentrations upto 10000 ppm. at moisture levels ranging from 20-32 per cent. Up to 1000 ppm. all the salts were beneficial, but above 1500 ppm. all salts were increasingly toxic, chloride being most so, sulphate the least and carbonate halfway between.

Rudolfs (1921, 1925) used the seeds of different species of plants in germination studies. The seeds were presoaked and allowed to germinate on beds of filter paper saturated with different salt solutions of osmotic pressures varying upto seven atmospheres. Except for some of the weaker solutions the absorption of water, germination and the growth of roots decreased with the increase in the concentration of the salts.

Rader <u>et</u> <u>al</u>. (1943) have indicated that fertilizer injury to seeds and reduction in stand were osmotic phenomena similar to the action of alkali salts. It appeared that the seeds would germinate at higher osmotic pressures than those the shoot would tolerate later in its growth period, but high osmotic pressures retarded germination and probably resulted in a weakened radicle and plumule.

Kelley (1927) in his studies on the germination of barley in alkali soils, reported that the soil solution in contact with the seeds did not materially reduce germination but that the seeds in contact with the alkali soil failed to germinate properly.

Tiedjens and Schermerhorn (1936) in discussing greenhouse problems stated that the ratio of available calcium to potassium was extremely important for germination of seed and growth of vegetable crops on coastal plain soils.

Mehta and Desai (1958) conducted germination studies in a garden soil at field capacity using eight different concentrations of sodium and calcium chlorides ranging from 0-2.5 per cent. The results showed that under increased soil salinity, germination was delayed and the percentage of emergence increased.

Uhvits (1946) studied the effect of osmotic pressure on water absorption and germination of alfalfa seeds using sodium chloride and mannitol solutions of osmotic pressures ranging from 1 - 15 atmospheres. She found that germination was inhibited when sodium chloride solutions of 12 - 15 atmospheres osmotic pressure were used and that the reduction and retardation of germination were greater on sodium chloride than on mannitol substrates. The difference in response on the two substrates at isosmotic concentrations suggested a toxic effect of sodium chloride and this assumption was supported by data showing the accumulation of chloride in alfalfa seeds after four days of treatment.

Ayers et al. (1952) suggested that in selecting crops for saline soils particular attention should be given to the salt tolerance of the crop during germination, because poor crops frequently resulted from a failure to obtain satisfactory stand. Ayers (1953) conducted tests with different barley varieties in a fine sandy loam salinized with 0.05 - 0.4 per cent of sodium chloride which showed marked difference in tolerance to salinity. Salinity tended to increase the time of emergence and the percentage of seeds emerging. Most of the varieties failed to germinate at soil moisture stresses exceeding 16 atmospheres but the more tolerant of the varieties germinated even at pressures as high as 19 atmospheres.

Bernstein, Mackenzie and Krantz (1955) determined the influence of bed shape, planting and irrigation practice on the germination of row crops on a series of artificially salinized plots. It was found that sloping beds presented the least salinity hazard because in this case the salt effectively carried away from the seed row by the advancing wetting front accumulated on the top of the bed.

Hoshino, Ikeda and Matsumota (1959) found that in the diluvial volcanic-ash soil, Italian rye grass, orchard grass, timothy, red clover, ladinoclover and lucerne showed good germination at 40 - 70 per cent of the maximum water holding capacity. Germination decreased with increasing osmotic pressure until at 20 atmospheres it was almost totally inhibited. Orchard grass and ladinoclover were the most severely affected.

According to Ludecke and Winner (1959) high concentrations of mineral salts may inhibit germination without damage to the embryo. The decay of young seedlings might be attributed to the harmful osmotic effect of high salt concentrations rather than to soil pathogens.

The influence of temperature as related to the effect of salt on germination has been studied by various workers. Edwards (1934) reported that the optimum temperature for soybean germination was 33-36.5°C. The longest seedlings were, however, obtained at a temperature of 28-31°C. Ahi and Powers (1938) found the best temperature for germination of seeds to be 55°F. At this temperature strawberry clover could tolerate as much as 5600 ppm. of sea salts. In their study with strawberry clover and alfalfa temperatures were controlled at 55°, 70° and 90°F. They observed a definite decrease in the percentage of germination with increase in temperature as well as salt concentration. At 90°F there was practically no germination regardless of the salt level; but at 55°F 47.7 per cent of the strawberry clover and 38 per cent of the alfalfa seeds germinated. The work of Ogasa (1939) on the effect of sodium chloride solution on soybeans at high and low temperatures has confirmed these findings.

In their experiments on the preservation of sprouted paddy seeds for the saline tracts of Kerala, Vijayan, Chacko and Peter (1961) reported that seeds, if initially soaked for twenty four hours, could be kept for as many as thirty days without any adverse effect upon the germination. When soaked for six hours, germination was significantly lowered after the twentieth day. Preliminary soaking for twenty four hours was found to be superior to soaking for eighteen, twelve and six hours irrespective of the number of days kept before the second soaking.

C. Effects of Salinity on Vegetative Growth and Maturation

The effects of increased salt concentrations on the growth and structure of leaves have been reported differently by various workers. Harter (1908) working with wheat, oats and barley found that increasing the salinity of a non-saline soil to 0.5 per cent caused significant modifications in leaf structure. The leaf developed a pronounced waxy bloom, a thickened cuticle and the size of the epidermal cells was decreased.

Hayward and Long (1941) have shown that the growth of tomato stems as measured by the height, diameter and dry weight was less at high salt concentrations than at control level. The smaller diameter of the stems could be attributed to a reduction in the formation of tissues. Uphof (1941) in his review of the literature on halophytes pointed out that such plants showed a tendency towards succulence with thicker leaves and stems, more pronounced palisade parenchyma and smaller intercellular spaces.

The primary effect of increasing concentration of salt on vegetation was usually a reduction in the rate of growth which might not be accompanied by any visible symptoms of injury. As Eaton (1942) has pointed out, this absence of leaf symptoms of diagnostic significance or other pronounced outward abnormalities suggested that a substantial proportion of the curtailed production of crops in irrigated areas which was attributed to nutritional deficiencies or unfavourable water relations was in fact due to saline conditions customarily regarded as insufficiently high to be a cause of reduced yields.

Magistad and Reitemeier (1943) showed that the soil solution held at 15 atmospheres suction with an osmotic pressure of less than 2 atmospheres and which contained less than 0.4 per cent of dissolved salts did not harm the crops. But when the osmotic pressure at this suction was raised to 10 atmospheres most crops suffered severely. Newton (1925) showed that the energy expended by the barley plants to absorb water increased with the osmotic pressure of the solution in which they were growing. Hayward and Spurr (1943) have shown that maize roots absorbed water three times more from a solution of osmotic pressure of 0.8 atmospheres than from a solution of 4.8 atmospheres.

In a study of the effect of salt on legumes, Gauch and Magistad (1943) found no evidence for considering a given concentration of solution critical for plant growth but they were convinced that an inverse relationship existed between the concentration of the solutions and the growth of plants.

According to Long (1943), Rosene (1941) and Tagawa (1934) controlled studies have proved that there might be morphological changes brought about by salinity effects, before other detectable symptoms were manifested.

Retzer and Mogen (1946) found that guayule was usually killed when salt concentrations were 0.6 per cent in either the first or the second foot of the soil. Wadleigh, Gauch and Strong (1947) observed that the roots of all plants showed a decrease in the ability to remove water as the salt content of the soil increased.

Dam (1954) were of opinion that the success of a crop in salt-impregnated soil was largely but not solely dependent on the sodium chloride concentration of the soil solution. Pearson, Goss and Hayward (1957) found an inverse relationship between the fresh weight of plants and the electrical conductivity of the saturation extract of the soil.

Piruzyan (1959) studied the effect of soil salinization on the development of maize. Cob yields on slightly saline soil, soils of average salinity and a solonchak were 62, 50 and 13 per cent respectively of the yield on a non-saline soil. Plants in soils containing 1 per cent or more of salts showed morphological adaptations to salinity.

Leverington (1960) reported that in sand cultures the growth of roots and shoots was reduced at osmotic concentrations of 2.5 atmospheres and over. Ayers and Eberhard (1960) observed that *Vicia fala* showed a moderate sensitivity to salinity, a 50 per cent decrease in yield occurring at salinities corresponding to a conductivity of 6-7 m. mhos/cm in the saturation extract.

According to Clay and Hudson (1960) the growth and yield of tomatoes were suppressed when conductivity of the 1:2.5 soil-water suspension exceeded 1300 m. mhos/cm. Inclusion of gypsum among the salts did not significantly affect the yield. Blossom-end rot was prevalent where salinity level was high but blotchy ripening was less as salinity increased. Highest yields and best quality of fruits were produced at moderate levels of salinity.

Lagerwerff and Eagle (1962) found that the ion concentration gradient between root-adjacent soil and the surrounding soil was positively related to the rate of transpiration by the plant and the osmotic concentration of the growth medium, and negatively related to the rate of back diffusion of excluded ions. Standards to evaluate the chemical conditions of root adjacent soil should, therefore, be based on soil diffusivity for ions and water at given soil moisture tensions.

D. Specificity of Crops to Salt Tolerance

Early investigations indicated that various species and varieties of crops exhibited differential salt tolerances when tested under uniform conditions of salinity. Thus Briggs and Shantz (1912) have shown that plants possess varying abilities to extract water from soils in the wilting range. For instance, plants that are natural inhabitants of saline soils tend to have greater ability to extract water from soils at the drier end of this range.

Outlining the difficulties in evaluating the salt tolerance of various crops, Harris (1920) has pointed out that this character may be influenced to different extents in different crops by conditions such as soil properties, moisture and climate. According to Loughridge (1901), and Kelley and Thomas (1920) the citrus species are extremely sensitive to salt particularly sodium chloride.

Kearney and Scofield (1936) reported that the choice of crops for saline lands could be made on the basis of the soluble salt content of the soil. They classified salinity as excessive, strong, medium etc. on the basis of the salt content. They have pointed out that all crops could be classified on the basis of salt tolerance into broad groups such as forage plants, root crops, cereals, fibre plants, garden, vegetable and truck crops and trees and shrubs. A wide variation in salt tolerance could be observed among the members of these groups of plants.

Magistad and Christiansen (1944) found that sugar beets, table beets, tomatoes and asparagus had good to moderate salt tolerance, but most vegetable crops tested did not appear to be able to withstand conditions of high salinity. Hayward and Spurr (1944) while testing Punjab flax in sand cultures, found it to be moderately salt tolerant. At high concentrations of salt the yield was reduced to 25-62 per cent of the control values. Lilleland *et al*. (1945) observed that sodium salts were toxic to almonds. The Texas variety appeared to be more susceptible than the others.

Hayward *et al*. (1946) reported that the Elberta peach was sensitive to moderate concentrations of salt. There was good evidence that the effect of saline substrates might be cumulative and that after many years, even low concentrations of salt may result in a slow but progressive decline of yields.

Wadleigh *et al*. (1947) found Mexican June Corn to be less salt tolerant than alfalfa and more so, than beans. Reeve *et al*. (1948) found that yields of wheat varied inversely with the residual salinity of the soil.

According to Bagdasarashvili (1952) the tolerance of grafted vines towards added sodium salts was greater in soil than in sand culture. This was attributed to the higher moisture content of the soil which reduced the effective salt concentration and to the replacement of calcium in the absorption complex by sodium which tended to reduce the concentration of sodium. Studies made by Ayers (1953) indicate that relative yields of barley were not reduced when the plots were irrigated with water containing as much as 9000 ppm. of salt.

Kofranek, Lunt and Kohl (1956) studied the tolerance of poinsettias to saline conditions and high boron concentrations. They found that the height of the plants and the diameter of the bract decreased with increase in the concentration of the salt from 15 me./l to 135 me./l. High levels of boron were not as harmful as those of salinity but concentration of boron higher than 4.8 ppm. caused intravenal chlorosis and marginal scorch of leaves.

Black (1960) studied the effects of sodium chloride on the ion uptake and growth of Atriplex vesicaria, a xerophytic perennial plant. He concluded that the plant exhibited a very high tolerance to salinity and that the seedlings were successfully established in water cultures containing upto 1 μ sodium chloride. The principal centres of sodium chloride accumulation were found to be the rapidly growing young leaves. Only low levels of sodium chloride were observed in the roots which apparently served for the uptake and transport of ions to the leaves.

E. Salt Tolerance of Rice

Most investigators have used the rice plant in studies relating to growth characteristics in submerged soils which are subjected to salinity and poor drainage. Based on the observations from such studies rice is generally considered as a salt tolerant crop.

Del Valle and Babe (1947), Ayers and Hayward (1948), and Iwaki (1956) have studied the salt tolerance of rice using a variety of techniques which included direct application of salt to the soil, irrigation with saline water and sand culture.

Shimoyama and Ogo (1956) have reported that rice was particularly sensitive to salinity during early seedling development and grain formation.

Kapp (1947) conducted experiments on problems of salinity in the green house and in the field. In green house experiments he found that the addition of 5700 ppm. of sodium chloride to rice soil prevented grain formation, reduced germination and decreased straw production. In field trials germination and consequently yields were adversely affected when 825 lbs. of sodium chloride per acre were applied before sowing and 3300 lbs. per acre were applied before the first watering.

According to Fraps (1927), Iwaki and Ota (1953), Hayward and Bernstein (1958) and Pearson (1959) salinity did not affect the vegetative growth of plants appreciably, whereas, the reproductive growth was seriously affected.

Ota, Yasue and Iwatsuka (1956) have reported that salinity had adverse effects on germination of pollen grains which resulted in an increase in the number of sterile florets per panicle. After flowering salinity apparently had very little effect on the yield of rice.

Iwaki (1956) investigated the effect of sodium chloride concentration on plants at different stages of growth as well as the mechanism of salt injury. Germination was considerably reduced by 1.0-1.5 per cent sodium chloride and completely prevented by concentrations higher than 2.5 per cent. A concentration of 2.5 per cent appeared to be critical as far as rooting and root elongation were concerned. Sodium chloride concentration of 0.1-0.3 per cent delayed growth and 0.5 per cent eventually caused death during the vegetative period.

According to Bernstein and Hayward (1958) and Iwaki (1956) the tolerance of rice to salt was again decreased during panicle formation from the boot stage through the fertilization period. Ting and Fang (1957) did not agree with the above view. The steady increase in yield on the application of saline water after transplanting, indicated that there was no sensitive stage during the early period of the productive stage of growth. The harmful effects of salinity were less pronounced for weight of straw than for grain yield. Chloride content of the different parts of the plants decreased progressively in the order; stems, leaf sheaths, blades, roots and grain.

In pot experiments using a clay loam irrigated with water containing upto 1 per cent sodium chloride, Desai, Rao and Hirekerur (1957) found that rice tolerated concentrations of this salt upto 0.2 per cent. There was a steady decrease in yields with further increase in the concentration.

Iwaki, Kawai and Ikemoto (1958) reported that in sand cultures 0.5-0.6 per cent sodium chloride solutions increased the salt and nitrogen contents and decreased the carbohydrate content of plants.

Pearson (1959) reported that rice seedlings were very sensitive to salinity during the early developmental stages but were progressively less so, after about three weeks of growth. The plants were adversely affected by increasing levels of salinity, the effects being less pronounced on vegetative growth than on reproduction. A 50 per cent decrease in yield of grain was associated with a soil solution having a conductivity of 8 m. mhos/cm in the active root zone during the growing season.

According to Pearson and Bernstein (1959) salinity inhibited growth more severely in the early stages than in the later periods. Based on equal weighted-mean conductivities salinity inhibited growth twice as much at tillering as during heading. The relationship between growth and salinity could be closely expressed by a multiple regression equation relating growth to salinity during the tillering, heading and maturation stages. Pearson (1959) further found that salinity did not affect all criteria of growth to the same degree. Thus, for instance, the vegetative growth was less seriously affected than the grain production. At a level of salinity of 11 m. mhos/cm the height of plants, dry weight of straw, number of tillers, weight of grains etc. were all reduced but to different extents.

Shimose (1959) found that in plants grown in solutions containing Cl^{36} the highest radioactivity at maturity was in the roots, the lowest activity being in the ears. Autoradiograms showed a higher concentration of Cl^{36} in the veins and in the blade tips than in the other parts of the leaves and stems at the time of maturity. Absorption of Cl^{36} was not found to be in direct proportion to the amounts applied.

Petrasovits and Darab (1960) conducted germination trials with seven rice varieties grown on solonetz soil in pots and treated with Na_2SO_4, $NaHCO_3$and Na_2CO_3 in different concentrations. Treatment with Na_2SO_4 significantly increased the soluble salt content of the soil, while $NaHCO_3$ and Na_2CO_3 unfavourably affected its physical properties and increased the pH. Height and dry weight of aerial parts of plants were reduced by increasing salt concentrations, while root growth was promoted by small amounts of salts and impaired by high amounts.

Pearson and Ayers (1960) reported that rice tolerated salt during germination, was sensitive to it during the early seedling stage, became tolerant in the tillering and maturation stages and was again sensitive to it at the time of flowering. Ehrler (1960) showed that the addition of NaCl, Na_2SO_4 or $CaCl_2$ to a nutrient solution depressed the grain yield much more than the growth.

Kaddah and Fakhry (1961) suggested that rice was moderately tolerant of salinity but was sensitive in the early stages of growth. All the varieties tested had low tolerance to NaCl and $CaCl_2$ applied fifteen days after transplanting. Weight of straw and total number of tillers were much less affected than was the yield of grain.

Pearson (1961a) showed that rice was tolerant of salinity during germination but was very sensitive at the 1-2 leaf stage. The salt tolerance of rice progressively increased during the tillering and elongation stages of development and again decreased at the time of floret fertilization. Maturation of fertilized florets was apparently unaffected at the salinity levels encountered in the studies.

Pearson (1961b) further concluded that the effect of salinity on the growth of rice depended upon the stage of development at which the salinity occurred. Rice was apparently most tolerant of salinity during the germination stage and most sensitive during the young seedling stage. The degree to which rice was affected by salinity depended upon the criterion measured and the variety involved. Among the varieties tested at the U.S. Salinity Laboratory, vegetative growth was less seriously affected than grain formation. In general, Pearson concluded that the inference regarding the salt tolerance of a particular variety of rice should be based on the relationship between grain production and electrical conductivity of the soil solution in the root zone during the growing season.

CHAPTER III

MATERIALS AND METHODS

A. Germination Studies

The influence of various concentrations of different salts on the germination of rice was studied using the following varieties in Vellayani soil under laboratory conditions.

1. UR. 19
2. PTB. 10
3. *Chettivirippu*
4. *Cheruvirippu* (Salt resistant)
5. *Chootupokali* (,,)

The following salts at six different concentrations viz., 0, 10, 20, 30, 40 and 50 me./100 g. of soil were used.

1. Ammonium chloride
2. Ammonium sulphate
3. Sodium chloride
4. Sodium sulphate
5. Potassium chloride
6. Potassium sulphate
7. Magnesium chloride
8. Magnesium sulphate
9. Calcium chloride

In the actual procedure 100 g. of the soil was taken in a petri dish and treated with the requisite quantity of salt in 100 ml solution. The soil was then air-dried, ground and sown with twenty five rice seeds. The treatments were replicated four times. The soil was moistened to field capacity every morning and allowed to stand for fifteen days. The seeds generally started sprouting on the fourth day. The actual number of plants was counted at the end of fifteen days and the average per cent germination calculated. The data are presented in Table I to IX.

In another experiment the influence of soil salinity on germination was studied using soils collected from Onattukara, Kumarakom, Kuttanad and Vechoor. Of these, the soil from Onattukara, was from a non-saline tract whereas the other three soils were from salt-affected areas. The more important chemical characteristics of these soils as determined by standard analytical methods is given in Table X. One hundred grams of each soil was placed in a petri dish and sown with fifty rice seeds (PTB. 4). The soils were kept moistened with distilled water and observations made as before. The average percentage of germination in the soils is given in Table XI.

B. Pot Culture Experiment

Pot culture studies were carried out to investigate the effect of inundation of the soil with sea water at different stages in the growth period of rice in a 7 x 4 randomised block design. The treatments consisted in flooding the soil with sea water for twenty four hours before the seeds were sown and also flooding the soil for the same length of time two, four, six, eight and ten weeks after sowing. The experiment was carried out with two varieties, Njavara and Chootupokali (salt resistant). The sea water for the treatment was collected from the Kovalam Beach. The soil used was Vellayani sandy clay loam collected from the Agricultural College Farm. One kilogram of the soil was taken in each pot and treated with organic matter in the form of cowdung and green manure at the rate of 4000 lb/acre.

The first set of four replications was set aside as the control. The next set was flooded with sea water for twenty four hours and then drained. All the pots were then sown with fifty seeds and moistened to field capacity. The plants in each pot were thinned out to three in number at the end of two weeks. The process of flooding with sea water was then repeated for the remaining sets after intervals of two, four, six, eight and ten weeks respectively.

The plants in each pot further received nitrogen at the rate of 50 lb./acre in the form of ammonium sulphate solution applied every two weeks.

During the period of growth, observations were made regarding the number of vegetative and productive tillers, maximum height of plants, length of earhead and the fresh weight of panicles. At the end of the experiment the plants were harvested, air-dried and the weights of the straw, grain and chaff recorded separately. The straw in each replication was analysed for moisture, N_2, P_2O_5, K_2O, CaO, MgO and Cl using the methods suggested by Piper (1944). The grains were also analysed for these constituents by mixing the replications and taking the composite samples. The results are presented in Tables XII to XVIII.

C. Conductivity Studies

To study the influence of salinity on the electrical conductivity of soils the following sources of salinity were used.

1. Sea water
2. Bitterns from salt pans
3. Pure sodium chloride solution

The soils used were a sandy clay loam from Vellayani and a Kari from Vechoor. Sea water and bitterns were diluted with distilled water to obtain a concentration of 0.5 per cent soluble salts in the solution. A solution of similar strength was prepared using pure sodium chloride. Fifty gram portions of the soils were taken in different petri dishes and treated with 1, 3, 5, 7, 10, 12 and 15 ml. respectively of each of these solutions. These treatments corresponded to applications of 10, 30, 50, 70, 100, 120 and 150 mg. of salts per 100 g. of soil. The soil was thoroughly mixed with the salt solutions, sun-dried, ground and the electrical conductivity determined in a 1:2.5 soil water extract using a Solu Bridge Soil Tester. The results are presented in Table XXI.

CHAPTER IV

RESULTS

A. Germination Studies

Reference to Tables I to IX reveals that the germination of rice seeds is affected by the nature of the salts as well as their concentrations. Thus the adverse effect of salts on germination increased in the order ammonium sulphate < potassium sulphate < sodium sulphate < magnesium sulphate < potassium chloride < ammonium chloride < sodium chloride < magnesium chloride < calcium chloride. It may be noted that in general, the sulphates were less injurious than the chlorides. Germination percentage, further, decreased with increase in the concentration of the salt. This is in accordance with the findings of several workers who have attributed the injurious effects of salinity to the osmotic forces of the soil solution.

While the general effect of salinity on seeds is to inhibit germination, different varieties of rice are susceptible to this effect to varying extents. Thus the salt tolerance of the varieties used in this study decreased in the order <u>Chootupokali</u> > <u>Cheruvirippu</u> > <u>Chettivirippu</u> > PTB. 10 > UR. 19. Both <u>Chootupokali</u> and <u>Cheruvirippu</u> are well known salt resistant varieties and it is interesting that these varieties not only resist salinity during their growth period, but also offer resistance to the effects of salt even from the time of germination. It may be noted, further, that the difference in the percentages of germination of the ordinary varieties and the salt resistant varieties are statistically significant, while the differences among the varieties in these two groups are not so significant at the levels of salinity used.

It has been observed that for the same concentration different salts affect germination to different extents. Though the concentrations expressed in this study are not on a molar or osmotic pressure basis, it is quite evident from Tables I to IX that the influence of salinity on germination is not merely an effect of the osmotic pressure, but also a characteristic of the individual salts and ions. Thus as indicated earlier the sulphate ion is generally less harmful than the chloride ion (Appendix III). Comparing the effects of the different cations (Appendix II) it is seen that the adverse effects of these ions on germination increased in the order ammonium $<$ potassium $<$ sodium $<$ magnesium $<$ calcium. Ammonium and potassium were the least toxic, sodium and magnesium more so and calcium the most injurious. The differences in the germination percentages with potassium and sodium as well as with magnesium and calcium were highly significant.

TABLE I

Influence of different concentrations of Ammonium sulphate on the germination of rice

Variety	Concentration of salt - ppm.						Mean
	0	10	20	30	40	50	
	Germination - per cent						
UR. 19	76.0	59.3	68.0	65.3	61.3	60.0	66.7
PTB. 10	73.3	69.3	68.0	61.3	64.0	56.0	65.3
<u>Chettivirippu</u>	69.3	72.0	72.0	61.3	64.0	68.0	67.8
<u>Cheruvirippu</u>	73.3	69.3	68.0	72.0	60.0	62.6	67.5
<u>Chootupokali</u>	72.0	68.0	70.6	60.0	60.0	65.3	65.9
Mean	72.8	69.6	69.3	69.3	61.9	62.4	

TABLE II

Influence of different concentrations of Ammonium chloride on the germination of rice

Variety	Concentration of salt - ppm.						Mean
	0	10	20	30	40	50	
	Germination - per cent						
UR. 19	73.3	69.3	64.0	64.0	52.0	56.0	63.1
PTB. 10	72.0	68.0	60.0	64.0	56.0	56.0	62.7
Chettivirippu	69.3	65.3	64.0	56.0	64.0	57.3	62.7
Cheruvirippu	76.0	68.0	64.0	60.0	60.0	64.0	65.3
Chootupokali	72.0	68.0	68.0	64.0	65.3	60.0	66.2
Mean	72.5	67.7	64.0	61.5	59.5	58.7	

TABLE III

Influence of different concentrations of Sodium sulphate on the germination of rice

Variety	Concentration of salt - ppm.						Mean
	0	10	20	30	40	50	
	Germination - per cent						
UR. 19	74.6	64.0	64.0	57.3	52.0	52.0	60.7
PTB. 10	69.3	68.0	56.0	65.3	64.0	49.3	62.0
Chettivirippu	65.3	69.3	60.0	60.0	57.3	52.0	60.7
Cheruvirippu	76.0	73.3	72.0	61.3	66.6	66.6	69.3
Chootupokali	78.6	76.0	76.0	72.0	64.0	68.0	72.4
Mean	72.8	70.1	65.6	63.2	60.8	57.6	

TABLE IV

Influence of different concentrations of Sodium chloride on the germination of rice

Variety	Concentration of salt - ppm.						Mean
	0	10	20	30	40	50	
	Germination - per cent						
UR. 19	74.6	67.3	56.0	53.3	45.3	46.6	55.5
PTB. 10	69.3	61.3	60.0	53.3	56.0	53.0	58.9
<u>Chettivirippu</u>	68.0	60.0	57.3	56.0	42.6	40.0	54.0
<u>Cheruvirippu</u>	74.6	76.0	65.3	57.3	56.0	46.6	62.6
<u>Chootupokali</u>	78.6	72.0	69.3	68.0	61.3	64.0	68.9
Mean	73.0	65.3	61.6	57.6	52.2	50.1	

TABLE V

Influence of different concentrations of Potassium sulphate on the germination of rice

Variety	Concentration of salt - ppm.						Mean
	0	10	20	30	40	50	
	Germination - per cent						
UR. 19	73.3	72.0	76.0	69.3	61.3	57.3	68.2
PTB. 10	68.0	72.0	64.0	61.3	60.0	56.0	63.6
Chettivirippu	65.3	60.0	60.0	69.3	64.0	65.3	64.0
Cheruvirippu	74.6	68.0	68.0	64.0	64.0	60.0	66.4
Chootupokali	77.3	68.0	68.0	60.0	62.6	64.0	66.7
Mean	71.7	68.0	67.2	64.8	62.4	60.5	

TABLE VI

Influence of different concentrations of Potassium chloride on the germination of rice

Variety	Concentration of salt - ppm.						Mean
	0	10	20	30	40	50	
	Germination - per cent						
UR. 19	73.3	59.3	60.0	65.3	52.0	56.0	62.7
PTB. 10	68.0	61.3	64.0	68.0	57.3	56.0	62.4
Chettivirippu	65.3	60.0	68.0	68.0	61.3	64.0	64.4
Cheruvirippu	76.0	64.0	64.0	61.3	68.0	64.0	66.2
Chootupokali	78.6	64.0	68.0	61.3	65.3	64.0	66.9
Mean	72.2	63.7	64.8	64.8	60.8	60.8	

TABLE VII

Influence of different concentrations of Magnesium sulphate on the germination of rice

Variety	Concentration of salt - ppm.						Mean
	0	10	20	30	40	50	
	Germination - per cent						
UR. 19	73.3	58.6	50.6	48.0	45.3	46.6	53.7
PTB. 10	68.0	77.3	72.0	61.3	48.0	46.6	62.2
<u>Chettivirippu</u>	66.6	76.0	72.0	69.3	64.0	48.0	66.0
<u>Cheruvirippu</u>	76.0	73.3	70.6	70.6	72.0	65.3	71.3
<u>Chootupokali</u>	77.3	72.0	72.0	69.3	60.0	64.0	69.1
Mean	72.2	71.4	67.4	63.7	57.9	54.1	

TABLE VIII

Influence of different concentrations of Magnesium chloride on the germination of rice

Variety	Concentration of salt - ppm.						Mean
	0	10	20	30	40	50	
	Germination - per cent						
UR. 19	73.3	68.0	56.0	54.6	49.3	38.6	56.6
PTB. 10	68.0	64.0	57.3	48.0	46.6	37.3	53.5
Chettivirippu	68.6	57.3	58.6	58.6	53.3	38.6	55.8
Cheruvirippu	76.0	70.6	68.0	61.3	52.0	50.6	63.1
Chootupokali	78.6	72.0	69.3	68.6	56.0	62.6	67.9
Mean	72.9	66.4	61.8	58.2	51.4	45.5	

TABLE VIII

Influence of different concentrations of Magnesium chloride on the germination of rice

Variety	Concentration of salt - ppm.						Mean
	0	10	20	30	40	50	
	Germination - per cent						
UR. 19	73.3	68.0	56.0	54.6	49.3	38.6	56.6
PTB. 10	68.0	64.0	57.3	48.0	46.6	37.3	53.5
Chettivirippu	68.6	57.3	58.6	58.6	53.3	38.6	55.8
Cheruvirippu	76.0	70.6	68.0	61.3	52.0	50.6	63.1
Chootupokali	78.6	72.0	69.3	68.6	56.0	62.6	67.9
Mean	72.9	66.4	61.8	58.2	51.4	45.5	

TABLE IX

Influence of different concentrations of Calcium chloride on the germination of rice

Variety	Concentration of salt - ppm.						Mean
	0	10	20	30	40	50	
	Germination - per cent						
UR. 19	72.0	60.0	60.0	48.0	40.0	44.0	54.0
PTB. 10	68.0	68.0	56.0	52.0	44.0	52.0	56.7
Chettivirippu	65.3	60.0	61.3	52.0	44.0	48.0	55.1
Cheruvirippu	76.0	74.6	60.0	57.3	56.0	58.6	63.8
Chootupokali	76.0	69.3	61.3	60.0	52.0	52.0	61.8
Mean	71.5	66.4	59.7	53.9	47.2	50.9	

It is to be noted that the concentrations used in this study are extremely low (10-50 ppm.) as compared to sea water in which the salt concentration is several thousand parts per million. Hence with sea water, the adverse effect on germination is likely to be much more pronounced than those observed in the present study. Both the sodium and the chloride ions in the sea water will be highly injurious to germination. But it is possible that with sea water, the individual effects of ions will be almost entirely masked by the osmotic effects because of the very high concentrations involved. The present study has, however, helped to indicate the trends in the influence of salt concentration and individual ions on the germination of different varieties of rice seeds.

From Table XI showing the influence of soil salinity on germination of rice, it may be seen that germination is drastically inhibited by soil salinity. While the percentage of germination in the non-saline soil collected from Onattukara is 78, it is only 19 in Kumarakom soil and 2 in the soil from Kuttanad (Plate II). In the Kari from Vechoor, germination is totally inhibited. This adverse effect of these soils on germination should be attributed to their high salinity levels.

TABLE X

Chemical characteristics of soils used in Germination studies

	Locality			
	Onattukara	Kumarakom	Kuttanad	Vechoor
N_2 per cent	0.101	0.21	0.37	0.07
P_2O_5 ,,	0.043	0.10	0.01	0.093
K_2O ,,	0.157	0.12	0.31	0.175
CaO ,,	0.121	0.52	Trace	0.187
MgO ,,	0.138	0.31	Trace	0.176
Cl' ,,	Trace	0.21	2.40	0.21
SO_4'' ,,	0.12	0.12	3.2	0.44
pH	5.1	5.5	5.4	5.2
Conductivity m. mhos/cm	2.0	4.2	8.5	10

TABLE XI

Influence of soil salinity on germination of rice

Sl. No.	Locality	Germination per cent
1	Onattukara	78
2	Kumarakom	19
3	Kuttanad	2
4	Vechoor	0

B. Pot Culture Experiment

The pot culture studies have indicated that the stage at which the incursion of sea water occurs, has very significant effects on the growth characteristics of rice. Thus the inundation of the soil with sea water prior to sowing was responsible for considerable delay in the sprouting of the seeds. While the sprouts normally emerged after three days in all the other pots, germination of <u>Njavara</u> was delayed for ten days and that of the salt resistant variety <u>Chootupokali</u> for six days, in the pots previously flooded with sea water. This delay in germination due to salinity is in accordance with the findings of Ayers and Hayward (1948) who reported that higher levels of salinity aggravated the delay in emergence and also decreased the final germination percentage. Though the usual criterion for germination is the percentage of emergence rather than the time required, the latter factor assumes great importance in Kerala where a delay of two or three days in germination may have serious consequences in view of the very limited growth period available between the time of sowing and the onset of the monsoon.

Irrespective of the stage at which the soil was flooded with sea water, the plants generally tended to wilt as a result of the salinity. Wilting was less marked in the case of the salt resistant variety, <u>Chootupokali</u>, as compared to the ordinary variety, <u>Njavara</u>. The tips of the leaves were more affected than the bottom but the plants readily recovered when the sea water was drained off at the end of twenty four hours. The growth of the <u>Njavara</u> variety was, in general, less vigourous than that of <u>Chootupokali</u>, which is a well known salt resistant variety.

The most remarkable effect of salinity on the growth characteristics of rice was observed when the pots were flooded with sea water at the flowering stage, nearly eight weeks after sowing. Application of sea water at this stage induced symptoms similar to those exhibited by plants affected by blast disease. The leaves developed black spots on the surface and the earheads emerged from the sheaths only incompletely. The plants generally presented a stunted appearance. The grains assumed a dark colour and a large number of them remained empty. The striking resemblance to blast is evident from the illustration given in Plate I. The affected plants, however, showed no sign of infestation by fungal organisms. The characteristic symptoms induced by the ingress of sea water at the time of flowering, have often been mistaken for the attack of blast in the salt-affected areas in the State. Only a careful study of the soil conditions and the plant environment would help to distinguish between the effects of salinity and the attack of blast.

PLATE I

Symptomatic effects in the plants as a result of treatment with sea water at the flowering stage.

TABLE XII

Influence of different treatments on tillering

Saline treatment	Vegetative		Productive	
	Njavara	Chootupokali	Njavara	Chootupokali
	Number of tillers			
1 day before sowing	4	6	5	2
2 weeks after sowing	4	5	5	3
4 ,,	2	4	4	4
6 ,,	2	7	5	4
8 ,,	3	7	5	4
10 ,,	3	5	6	3
Control	6	8	6	4

TABLE XIII

Influence of different treatments
on the yield of straw

Saline treatment	Yield in grams	
	Njavara	Chootupokali
1 day before sowing	9.8	12.3
2 weeks after sowing	15.1	14.1
4 ,,	14.2	20.2
6 ,,	13.5	17.8
8 ,,	12.8	12.2
10 ,,	14.5	17.0
Control	13.2	17.0

TABLE XIV

Influence of different treatments
on the yield of grains

Saline treatment	Yield in grams	
	Njavara	Chootupokali
1 day before sowing	0.4	1.7
2 weeks after sowing	2.1	3.5
4 ,,	3.5	5.4
6 ,,	4.9	6.9
8 ,,	4.6	6.2
10 ,,	5.4	8.3
Control	5.0	7.2

TABLE XV

Influence of different treatments on the composition of straw

<u>Njavara</u> variety

Saline treatment	Moisture	N_2	P_2O_5	K_2O	CaO	MgO	Cl'
			Per cent				
1 day before sowing	7.12	0.89	0.14	0.043	0.68	0.006	0.009
2 weeks after sowing	7.96	0.64	0.20	0.019	0.77	0.005	0.007
4 ,,	6.46	0.92	0.23	0.020	0.70	0.008	0.010
6 ,,	6.47	0.88	0.24	0.020	0.82	0.008	0.014
8 ,,	5.73	0.65	0.26	0.025	0.73	0.007	0.025
10 ,,	6.45	0.57	0.20	0.015	0.72	0.007	0.025
Control	5.97	1.11	0.16	0.030	0.67	0.007	0.005

TABLE XVI

Influence of different treatments on the composition of straw

Chootupokali variety

Saline treatment	Moisture	N_2	P_2O_5	K_2O	CaO	MgO	Cl'
			Per cent				
1 day before sowing	7.34	0.84	0.037	0.062	1.10	0.007	0.014
2 weeks after sowing	6.79	0.72	0.027	0.058	0.99	0.009	0.024
4 ,,	6.66	0.89	0.047	0.060	1.03	0.009	0.052
6 ,,	6.69	0.74	0.038	0.046	0.99	0.009	0.070
8 ,,	6.81	0.76	0.039	0.040	0.96	0.031	0.050
10 ,,	6.79	0.91	0.040	0.047	0.93	0.031	0.069
Control	7.73	0.75	0.052	0.057	1.02	0.008	0.021

TABLE XVII

Influence of different treatments on the composition of grains

Njavara variety

Saline treatment	Moisture	N_2	P_2O_5	K_2O	CaO	MgO	Cl'
				Per cent			
1 day before sowing	2.91	0.11	0.34	0.009	0.008	0.006	0.012
2 weeks after sowing	3.01	0.08	0.32	0.008	0.007	0.010	0.021
4 ,,	3.24	0.07	0.29	0.010	0.010	0.005	0.024
6 ,,	2.86	0.08	0.31	0.012	0.010	0.005	0.021
8 ,,	2.54	0.10	0.28	0.008	0.009	0.006	0.010
10 ,,	2.48	0.08	0.27	0.007	0.008	0.006	0.023
Control	2.78	0.10	0.36	0.010	0.009	0.006	0.010

TABLE XVIII

Influence of different treatments on the composition of grains

Chootupokali variety

Saline treatment	Moisture	N_2	P_2O_5	K_2O	CaO	MgO	Cl'
				Per cent			
1 day before sowing	3.86	0.076	1.12	0.010	0.012	0.006	0.053
2 weeks after sowing	3.41	0.084	0.37	0.012	0.012	0.010	0.026
4 ,,	2.98	0.123	0.34	0.012	0.013	0.010	0.015
6 ,,	3.12	0.090	0.36	0.009	0.012	0.009	0.030
8 ,,	2.95	0.080	0.49	0.010	0.008	0.008	0.060
10 ,,	3.08	0.086	0.30	0.010	0.008	0.010	0.009
Control	3.87	0.089	0.57	0.015	0.014	0.008	0.026

It was observed that the production of tillers commenced in both the varieties from the third week after sowing. The maximum number of tillers were produced in the Njavara variety by the end of the nineth week and in the Chootupokali by the end of the tenth week. Growth was generally more rapid and vigourous in the short duration Njavara as compared to the long duration Chootupokali. Similarly Njavara plants attained their maximum height much earlier than the plants of the other variety. The time of irrigation with sea water did not appreciably affect either the total number of tillers or the final height of the plants.

Examination of the root systems revealed that the Njavara plants had extensive spreading type of roots while Chootupokali had a rather thin but long root system. Njavara is a well known drought resistant variety and it is obviously this extensive root system which is responsible for its drought resistant nature. Apart from this varietal difference in the root systems of these two varieties, there was no root symptom which could be attributed to the influence of salinity.

The influence of salinity on the yield of straw and grains is evident from the data in Tables XIII and XIV. The salinity effect is reflected markedly by a reduction in the final yield of grains in the case of plants subjected to salinity during the earlier stages in their growth period as compared to those subjected to salt water ingress during the later stages. The yield of grains in the control pots were lower than that in most other treatments and this might be attributed to the release of other essential cations from the soil by the sodium ions in the brine. Such an effect is possible in a soil treated for the first time with sodium chloride as in the present case, but it may not occur in soils frequently inundated by sea water. The yield of straw was not, however, affected to any appreciable extent by the ingress of sea water. It was further observed that the application of saline water at the tillering stage adversely affected the productive tillers while it had very little effect on the number of vegetative tillers. The appearance of the plants subjected to the different salinity treatments is given in Plates X and XI.

Data relating to the chemical composition of the straw and the grains in the two varieties for the various treatments are presented in Tables XV to XVIII. The levels of N_2 and MgO in the straw of the two varieties for the different treatments are generally similar, but the salt resistant Chootupokali contained a distinctly higher proportion of K_2O, CaO and Cl whereas the Njavara plants contained a much higher proportion of P_2O_5. The capacity to accumulate high levels of cations and chloride without any apparent harmful effect, would evidently explain the salt resistant character of the Chootupokali variety.

TABLE XIX

Influence of different treatments on the Total quantities of nutrients absorbed by rice plants

Njavara variety

Saline treatment	N_2	P_2O_5	K_2O	CaO	MgO	Cl'
	Nutrients - mg./pot					
1 day before sowing	88	15	4.0	67	0.6	1.0
2 weeks after sowing	98	37	3.0	165	1.0	1.5
4 ,,	133	43	3.0	100	1.3	2.2
6 ,,	123	48	3.0	111	1.4	2.9
8 ,,	88	46	4.0	94	1.2	3.7
10 ,,	87	54	3.0	105	1.3	4.8
Control	152	40	5.0	89	1.2	1.1

TABLE XX

Influence of different treatments on the total quantities of nutrients absorbed by rice plants

<u>Chootupokali</u> variety

Saline treatment	N_2	P_2O_5	K_2O	CaO	MgO	Cl'
	Nutrients - mg./pot					
1 day before sowing	105	24	7.7	136	1.1	2.6
2 weeks after sowing	104	17	8.6	140	1.7	4.3
4 ,,	186	28	12.8	209	2.3	11.3
6 ,,	134	31	8.6	172	2.2	14.8
8 ,,	96	30	5.5	117	4.3	9.8
10 ,,	102	32	8.8	159	6.1	12.5
Control	134	50	10.1	174	2.0	5.5

TABLE XXI

Conductivity measurements of soils subjected to different levels of salinity from various sources

Salinity treatment mg. salt/ 100 g. soil	Vellayani sandy clay loam			Vechoor *Kari*		
	Sea water	Sodium chloride solution	Bittern	Sea water	Sodium chloride solution	Bittern
			m. mhos/cm			
10	0.59	0.40	0.28	4.50	5.0	4.6
30	0.62	0.30	0.30	4.60	5.1	4.6
50	0.70	0.35	0.40	4.60	5.3	4.7
70	0.90	0.50	0.80	4.68	5.4	5.0
100	1.00	0.75	0.90	4.70	5.5	5.2
120	1.20	0.80	1.00	4.70	5.7	5.5
150	1.30	0.90	1.10	5.00	6.0	5.5

The difference in the chemical composition of straw was not, however, reflected in the composition of the grains to the same extent. There was nothing remarkable about the effect of the time of inundation on the chemical composition, except that in the plants treated with saline water in the later stages of its growth period, the level of chlorine tended to be high. The total amounts of nutrients absorbed also tended to increase in the case of the plants treated with sea water during the later stages in their growth period (Tables XIX and XX).

C. Conductivity Studies

The resultant conductivity of two soils treated with various levels of salts from different sources are presented in Table XXI. It may be noted that the conductivities of the two soils treated with identical levels of salts are found to be different. This should be attributed to the differences in the chemical and physical properties of the soils especially of their colloidal complex. Similarly when the same level of salinity is applied from the different sources, the resulting conductivities are found to be different. The differences in the nature of the salts involved and the mobilities of their ions would account for these variations.

CHAPTER V

DISCUSSION

Studies relating to the influence of salinity on the growth and yield characteristics of rice are of great importance to a State like Kerala, where some of the major rice growing areas such as Kuttanad are frequently subjected to incursions of sea water. The present investigation reveals that salinity might adversely affect germination of seeds as well as the growth of plants.

That the germination of seeds is considerably reduced by salt concentration has been established by numerous investigators including Harrison (1917), Kelley (1927) and Mehta and Desai (1958) and has been borne out by the results of the present study. According to Hoshino et al (1959) and Ludecke and Winner (1959) the injurious effect of salinity on germination is mainly a consequence of its osmotic influence but the results obtained in this work also indicate that some of the ions like the chloride might be characteristically toxic. However, the salinity effect on germination is not much of a problem in Kerala because the salt-affected areas in this State are generally sown with sprouted seeds. The possibility of the salt water effect on the tender radicles and plumules should not, nevertheless, be overlooked.

The injurious effects of salinity on plant growth were found to be more marked on the younger plants than on the older. Shimoyama and Ogo (1956), Pearson (1959) and Pearson and Bernstein (1959) have also reported similar results. This suggests that the inundation with sea water has to be guarded against, more during the early stages, than during the later stages. However, it is important that the ingress of salinity does not occur during the flowering stage, as it is likely to affect crop yields considerably. Pearson and Ayers (1960) have indicated that the rice plant is tolerant of salinity during germination and tillering but sensitive to salt concentrations during the early stages of growth and flowering. This finding has been corroborated by the results of the present study. Inundation with sea water after the full emergence of the earhead is comparatively innocuous but the degree of salinity and the period of contact may be important factors. According to Eaton (1942), low levels of salinity do not induce any external diagnostic symptoms in plants, but in the present investigation it was observed that salinity at the flowering stage induced symptoms akin to blast. This is a matter of great practical importance as it indicates the necessity for a very careful study of the soil and other environmental conditions lest the symptoms of the one may be mistaken for those of the other.

The plants in the present study did not exhibit any notable root symptoms, but it is significant that the Chootupokali variety developed a deep root system. This is important in view of the observations made by Subramoney (1957) that the salinity level of the ground water in the salt-affected Kuttanad area may not often be high enough to be injurious. The salt resistant varieties are apparently capable of withstanding the temporary salinity in the top few inches of the soil, by sending down long roots to the fresh water underneath. But if the incursion of sea water persists for a long time, the chloride content of the ground water may increase, causing injury to plants.

The chemical composition of the straw and the grains is not seriously affected by the stage at which the incursion of the salt water occurs, but it is interesting that the salt resistant Chootupokali has the capacity to accumulate higher levels of the minerals. This is evidently a genetic character because under identical conditions of salinity the Njavara variety has absorbed only much lower levels of the cations. Using resistant varieties of rice in the salt affected areas will, therefore, help considerably to overcome the adverse effects of salinity.

It is to be noted that in the present study, salt water was allowed to stand in the pots only for a period of twenty four hours after which they were drained and treated with fresh water. Under these conditions, the wilting exhibited by the plants was only temporary, from which they were able to recover in the course of a few days. This is of great practical importance in the cultivation of rice in areas subjected to periodical inundation with sea water, such as, the Pokali and the Kaipad lands. These lands are subject to the alternate ingress of saline and fresh waters. Though the concentration of the salts in the saline water may be very high, the plants manage to survive and produce reasonably good yields, because the subsequent influx of fresh water washes away the salts that might have been left by the brine.

This naturally suggests another effective method of combating salinity; viz., flooding and washing the salt-affected soils with fresh water. This method is likely to give very quick and sure results in Kerala, because the saline soils in this State are very different from those in other parts of this country. Salinity is generally a consequence of improper irrigation resulting in the accumulation of considerable amounts of soluble salts in the upper soil layers. Such soils are base-saturated and the reaction tends to be on the alkaline side. But in contrast to these, the soils designated as 'saline' in Kerala, are heavily leached, base-unsaturated and highly acidic. Salinity in these soils is only a temporary passing phase and is, therefore, easily controlled by simple flooding and washing operations with fresh water. This procedure, in conjunction with the use of salt resistant varieties and the adoption of methods to prevent the ingress of sea water at the flowering and the early stages of growth, will go a long way in combating the ill-effects of salinity in Kerala State.

CHAPTER VI

SUMMARY AND CONCLUSIONS

A study was made of the influence of salinity on the germination, growth and yield of different varieties of rice. Germination was studied in the laboratory for five varieties using nine salts at different concentrations. Growth and yield characteristics were observed for two varieties in a pot culture experiment by flooding the soil with sea water for twenty four hours at different stages in the growth period of the plants.

The percentage germination was reduced in all the varieties with increase in the concentration of the salt. For the same concentration the adverse effects of salts on germination increased in the order ammonium chloride ammonium sulphate < sodium chloride < sodium sulphate < potassium chloride < potassium sulphate < magnesium chloride < magnesium sulphate < calcium chloride. Chlorides were generally more toxic than sulphates. Among the cations, ammonium and potassium were the least toxic, sodium and magnesium were more so, while calcium was the most injurious.

The varietal resistance to salt concentration increased in the order UR. 19 < PTB. 10 < *Chettivirippu* < *Cheruvirippu* < *Chootupokali*.

The pot culture experiments indicated that the ill-effects of salinity on rice were greater during the early stages of development than during the later stages. When the soils were flooded with saline water before sowing, the emergence of the seedlings was delayed by 3-4 days. Flooding with brine at the flowering stage induced symptoms similar to those exhibited by plants affected by blast disease. The effects of salinity were generally less injurious to the vegetative phase than to the reproductive phase.

The time of flooding the soil with sea water did not appreciably affect either the total number of tillers or the final height of plants. The drought resistant *Njavara* variety produced extensive and spreading type of roots while the salt-resistant *Chootupokali* developed a long and deep root system. Growth was more rapid in the case of the short duration *Njavara*.

The yield of grain was considerably reduced in the plants subjected to salinity during the early stages in their growth period.

The chemical composition of the grain in the two varieties for the different treatments was similar. The straw of the salt resistant *Chootupokali* contained high proportions of K_2O, CaO and Cl' while that of Njavara tended to contain more of P_2O_5. In plants treated with sea water in the later stages of its growth period the level of chlorine tended to be high.

Flooding and washing the soil with fresh water, using salt resistant varieties of rice and adopting measures to prevent the ingress of sea water at the flowering and early stages of growth are suggested as methods for combating the ill-effects of salinity in Kerala State.

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* Original not seen.

APPENDIX I

Germination Studies

Analysis of Variance Table

Source	SS	Df	Mean square	F
Whole Plot Treatment	13978.911	53	263.75	97.69*
Block	2.838	2	1.42	0.54
Whole Plot Error	286.586	106	2.70	
Sub Plot Treatment	2609.638	4	652.41	184.91*
Interaction	5393.116	212	25.44	7.21*
Sub Plot Error	1525.735	432	3.53	

* Significant at 0.05 and 0.01 levels.

APPENDIX II

Comparison between Cations

Rank	Cation	Mean
1	Ammonium	54.01
2	Potassium	53.90
3	Sodium	52.39
4	Magnesium	52.04
5	Calcium	49.80

Critical Difference at 0.05 level = 0.357

APPENDIX III

Comparison between Anions

Rank	Anion	Mean
1	Sulphate	54.82
2	Chloride	52.03

Critical Difference at 0.05 level = 0.326

APPENDIX IV

Comparison between Salts

Rank	Salt	Mean
1	Ammonium sulphate	54.81
2	Potassium sulphate	54.28
3	Sodium sulphate	53.87
4	Magnesium sulphate	53.82
5	Potassium chloride	53.58
6	Ammonium chloride	53.20
7	Sodium chloride	50.91
8	Magnesium chloride	50.49
9	Calcium chloride	49.80

Critical Difference at 0.05 level = 0.476

APPENDIX V

Comparison between Concentrations

Rank	Concentration in ppm.	Mean
1	0	58.39
2	10	55.42
3	20	53.57
4	30	51.56
5	40	49.14
6	50	48.23

Critical Difference at 0.05 level = 0.397

APPENDIX VI

Comparison between Varieties

Rank	Variety	Mean
1	Chootupokali	55.23
2	Cheruvirippu	54.56
3	Chettivirippu	51.52
4	PTB. 10	51.29
5	UR. 19	51.00

Critical Difference at 0.05 level = 0.413

APPENDIX VII

Critical Differences for the different Comparisons

(1) Critical difference for comparison between concentrations of the same salt ignoring the varieties = 0.713

(2) Critical difference for comparison between concentrations of the same salt within the same variety = 0.839

(3) Critical difference for comparison between varieties within a particular concentration of a salt = 3.03

(4) Critical difference for comparison between varieties ignoring concentrations of the same salt = 0.777

APPENDIX VIII

Pot Culture Experiment

Total number of Tillers (Njavara)

Analysis of Variance Table

Source	SS	Df	Mean square	F
Total	132.96	27		
Block	32.10	3	10.7	9.3
Treatment	80.21	6	13.37	11.6*
Error	20.65	18	1.15	

Total number of Tillers (Chootupokali)

Analysis of Variance Table

Source	SS	Df	Mean square	F
Total	228.86	27		
Block	49.14	3	16.38	18.52
Treatment	163.61	6	27.27	36.48*
Error	16.11	18	0.89	

*Significant at 0.05 and 0.01 levels.

APPENDIX IX

Pot Culture Experiment

Number of Vegetative Tillers (Njavara)

Analysis of Variance Table

Source	SS	Df	Mean square	F
Total	102.86	27		
Block	23.15	3	7.71	4.101
Treatment	45.86	6	7.64	4.63*
Error	33.85	18	1.88	

Number of vegetative Tillers (Chootupokali)

Analysis of Variance Table

Source	SS	Df	Mean square	F
Total	167.43	27		
Block	11.95	3	3.98	0.7
Treatment	53.93	6	8.99	1.5
Error	101.55	18	5.64	

* Treatment significant at 0.05 and 0.01 levels.

APPENDIX X

Pot Culture Experiment

Number of Productive Tillers (Njavara)

Analysis of Variance Table

Source	SS	Df	Mean square	F
Total	50.68	27		
Block	9.25	3	3.08	1.73
Treatment	9.43	6	1.57	0.88
Error	32.00	18	1.77	

Number of Productive Tillers (Chootupokali)

Analysis of Variance Table

Source	SS	Df	Mean square	F
Total	230.96	27		
Block	24.36	3	8.12	1.22
Treatment	86.71	6	14.45	2.18
Error	119.89	18	6.67	

Treatments not significant.

APPENDIX XI

Pot Culture Experiment

Yield of Straw (*Njavara*)

Analysis of Variance Table

Source	SS	Df	Mean square	F
Total	132.07	27		
Block	14.05	3	4.68	1.84
Treatment	72.34	6	12.06	4.70*
Error	45.68	18	2.54	

Yield of Straw (*Chootupokali*)

Analysis of Variance Table

Source	SS	Df	Mean square	F
Total	247.20	27		
Block	14.81	3	4.94	6.86
Treatment	219.36	6	36.56	50.77*
Error	13.03	18	0.72	

* Significant at 0.05 and 0.01 levels.

PLATE II

Influence of soil salinity on
the germination of rice

A. Onattukara soil
B. Kumarakom ,,
C. Kuttanad ,,
D. Vechoor ,,

APPENDIX XII

Pot Culture Experiment

Yield of Grains (Njavara)

Analysis of Variance Table

Source	SS	Df	Mean square	F
Total	93.22	27		
Block	1.10	3	0.36	0.6
Treatment	80.13	6	13.35	20.2*
Error	11.99	18	0.66	

Yield of Grains (Chootupokali)

Analysis of Variance Table

Source	SS	Df	Mean square	F
Total	135.6	27		
Block	2.0	3	0.67	1.5
Treatment	126.2	6	21.03	52.5*
Error	7.4	18	0.40	

* Significant at 0.05 and 0.01 levels.


A
B
C
D

PLATE III

Effect of sea water on the germination of *Njavara* variety six days after sowing

T_0 - Control

T_1 - Saline treatment one day before sowing

T_2 - Saline treatment to be given two weeks after sowing

PLATE IV

Effect of sea water on the germination of *Chootupokali* variety six days after sowing

T_0 - Control

T_1 - Saline treatment one day before sowing

T_2 - Saline treatment to be given two weeks after sowing


T2
T1
T0

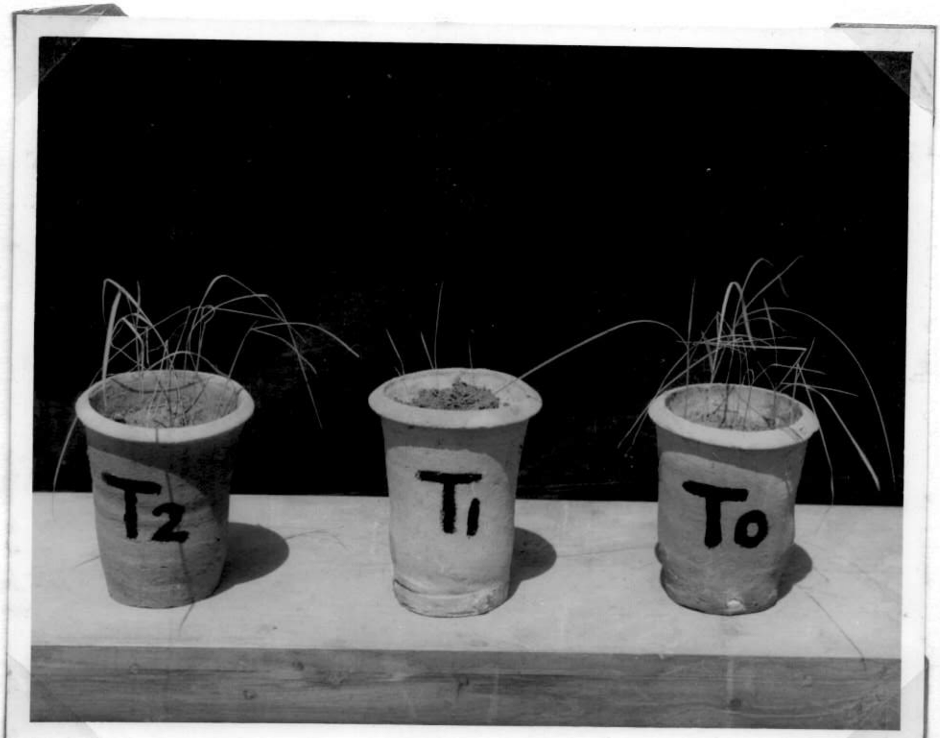

T2
T1
T0

PLATE V

Effect of sea water on the germination of Njavara variety ten days after sowing

T_0 - Control

T_1 - Saline treatment one day before sowing

T_2 - Saline treatment to be given two weeks after sowing

PLATE VI

Effect of sea water on the germination of Chootupokali variety ten days after sowing

T_0 - Control

T_1 - Saline treatment one day before sowing

T_2 - Saline treatment to be given two weeks after sowing


T2
T1
T0


T2
T1
T0

PLATE VII

Appearance of the plants
six weeks after sowing
(*Njavara* variety)

T_0 - Control

T_1 - Saline treatment 1 day before sowing

T_2 - ,, 2 weeks after sowing

T_3 - ,, 4 ,,

T_4 - ,, 6 ,,

T_5 & T_6 - Saline treatment to be given 8 and 10 weeks respectively after sowing

PLATE VIII

Appearance of the two varieties after
treatment with sea water
at the flowering stage

Left - *Njavara*

Right - *Chootupokali*


T5
T2


T 5
T 5

PLATE IX

Appearance of the plants eleven weeks after sowing (_Njavara_ variety)

T_4 - Saline treatment 6 weeks after sowing

T_5 - ,, 8 ,,

(flowering stage)

T_6 - Saline treatment 10 weeks after sowing

PLATE X

Appearance of the plants eleven weeks after sowing (_Chootupokali_ variety)

T_4 - Saline treatment 6 weeks after sowing

T_5 - ,, 8 ,,

(flowering stage)

T_6 - Saline treatment 10 weeks after sowing


T5

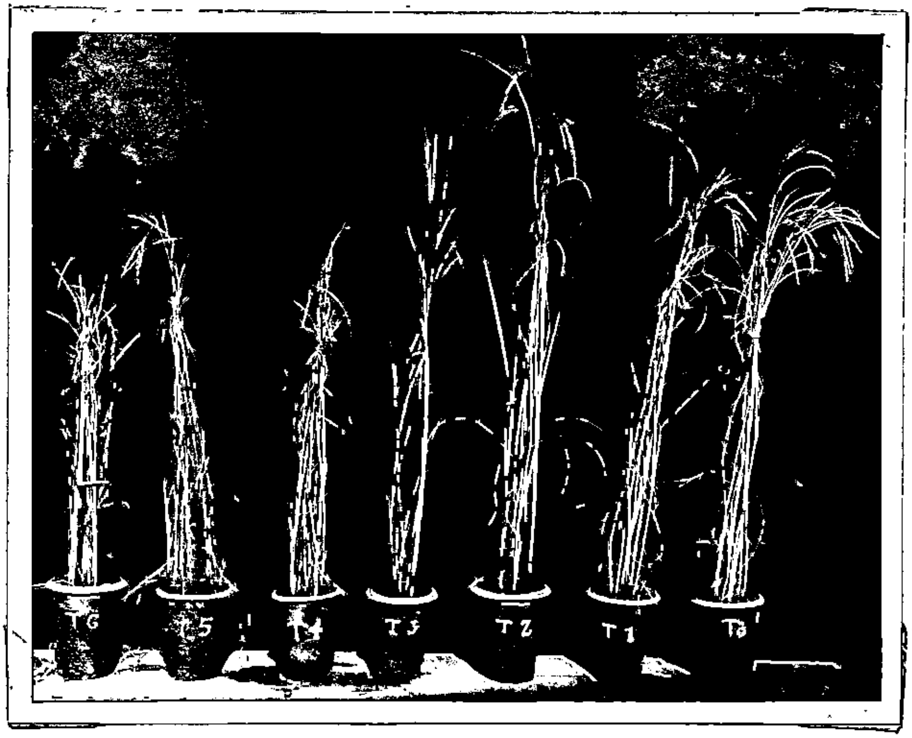

T4
T5

PLATE XI

Appearance of the plants
just before harvest
(*Njavara* variety)

PLATE XII

Appearance of the plants
just before harvest
(*Chootupokali* variety)



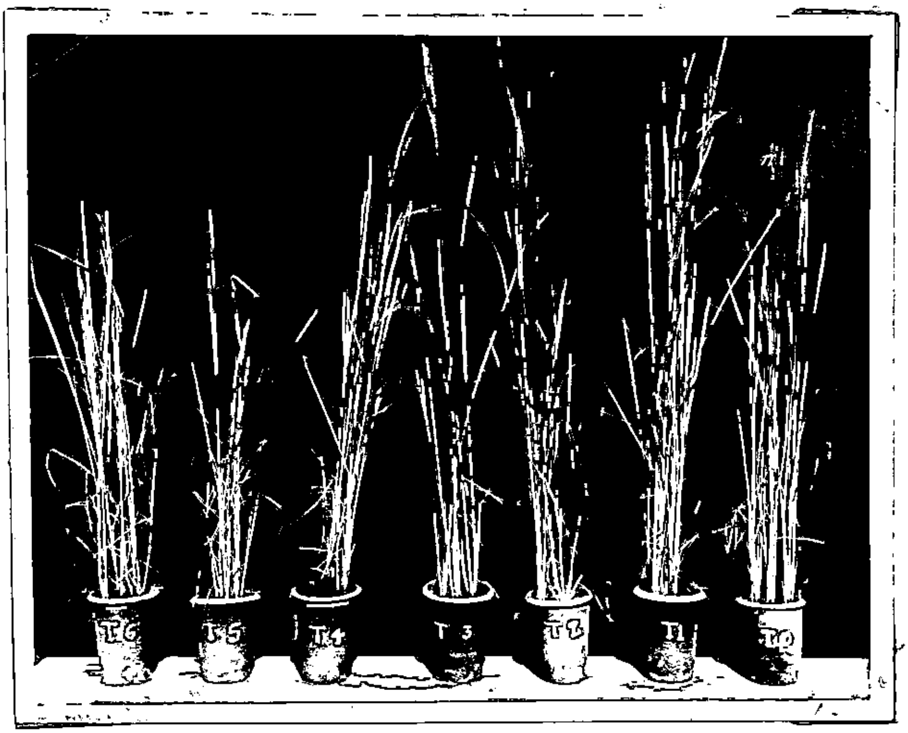


PLATE XIII

General appearance of the

Njavara variety

just before harvest

PLATE XIV

General appearance of the

Chootupokali variety

just before harvest

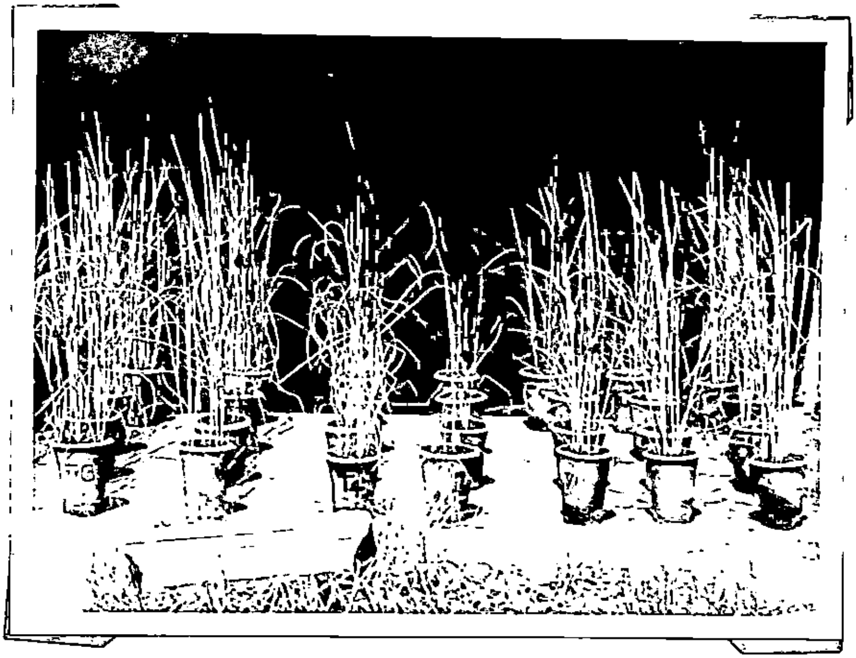


PLATE XV A

&

PLATE XV B

General appearance of the two varieties just before harvest.