PHYSIOLOGICAL RESPONSES OF PIGEONPEA TO DILUTED SEA WATER

THESIS SUBMITTED TO THE
ANDHRA PRADESH AGRICULTURAL UNIVERSITY
IN PARTIAL FULFILMENT OF THE REQUIREMENTS
FOR THE AWARD OF THE DEGREE OF
DOCTOR OF PHILOSOPHY

BY
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1988

C E R T I F I C A T E

Sri T.C.Muniswami Naidu, has satisfactorily prosecuted the course of research and that the thesis entitled "PHYSIOLOGICAL RESPONSES OF PIGEONPEA TO DILUTED SEA WATER" submitted is the result of original research work and is of sufficiently high standard to warrant its presentation to the examination. I also certify that the thesis or part thereof has not been previously submitted by him for a degree of any University.

Date: 5.10.1988 (Dr. A. NARAYANAN)

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C E R T I F I C A T E

This is to certify that the thesis entitled "PHYSIOLOGICAL RESPONSES OF PIGEONPEA TO DILUTED SEA WATER" submitted in partial fulfilment of the requirement for the degree of Doctor of Philosophy in Agriculture in the major subject of Plant Physiology of Andhra Pradesh Agricultural University, Hyderabad is a record of the bonafide research work carried out by Sri T.C. Muniswami Naidu under my guidance and supervision. The subject of the thesis has been approved by the students' Advisory Committee.

No part of the thesis has been submitted for any other degree or diploma or has been published. Published part has been fully acknowledged. All the assistance and help received during the course of the investigations have been duly acknowledged by him.

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C O N T E N T S

L I S T O F T A B L E S

L I S T O F F I G U R E S

A C K N O W L E D G E M E N T S

It gives me an immense pleasure to express my profound sense of gratitude to Dr. A. Narayanan, Principal, Agricultural college Baptala, Professor and University Head, Department of Plant Physiology, Agricultural College, Bapatla and Chairman of my Advisory Committee for his valuable guidance, kind help and suggestions in the successful completion of this thesis.

I express my deep sense of appreciation and gratitude to the members of my Advisory Committee Dr. I.V. Subba Rao, Professor Plant Physiology; Dr B. Gopal Singh, Associate Professor Plant Physiology; Dr M.S.Reddy, Professor, Dept of Genetics and Plant Breeding and Dr. M.S.Santharam, Professor and Head, Dept, of Soil Science and Agricultural Chemistry, College of agriculture, Rajendranagar, Hyderabad.

I always remember the guidance and help given by Staff of the Department of Plany Physiology, Agricultural College, Bapatla; College of Agriculture Rajendranagar, Hyderabad and RARS, Lam, Guntur.

I am indebted to Dr. A. Satyanarayana, Serior Scientist (pulses) and Sri. P. Seenaiah, RARS, Lam for supplying the pigeonpea genotypes for my research work. I am grateful to ICAR for their encouragement through the award of the Senior Fellowship during my Ph.D. Programme.

I register my profound thanks to the members of my family particularly my wife Smt. Vijaya, my son Sarat and parents for their warm encouragement and understanding during this study without which the completion of my research work would not have been possible.

I finally thankful to Mr. K. Sai Kumar, and B.S.Prasad, Softline Computer Services, Guntur for typing this thesis neatly.

(T.C.MUNISWAMI NAIDU)

Title of the Thesis	:"PHYSIOLOGICAL RESPONSES OF PIGEONPEA TO DILUTED SEA WATER"
Name of the Student	: T.C. Muniswami Naidu
Submitted for the award of	: Doctor of Philosophy
Faculty	: Agriculture
Major Adviser	: Dr. A. Narayanan
University	: A.P.Agricultural University
Year of Submission	: 1988

A B S T R A C T

The effect of diluted sea water on the imbibition, germination and seedling growth of pigeonpea genotypes were investigated. Screening of pigeonpea genotypes for salt tolerance at seedling stage and mineral uptake and effect on the hydrolysing enzyme activities were also studied.

As the concentration of the sea water increased the imbibition (percent water uptake) was decreased in genotypes BDN-1 and ICPL-87. Only 2.6 and 6.8 percent germination was observed in these two genotypes even after 84 h; whereas in control it was 84 and 57.3 percent respectively at 24 h. The rate of germination was delayed due to salinity. When the seeds were soaked in distilled water and grown in diluted sea waters the RRGR and radicle length were more than that of seeds germinated directly in diluted sea waters.

Out of the twenty eight genotypes tested only three genotypes germinated at 24 h with 40 percent sea water, whereas with distilled water all the genotypes germinated. Maximum reduction in 40 percent sea water over control was observed in PDA5 and ICPL 296 (46.3 and 43.4 percent respectively) at 48 h after sowing. Genotypes BDNA-5; ICPL-312, C-11, MRG 67, BDNA 3 and ICPL 338 showed 100 percent germination in 40 percent sea water. Dry weight of the leaves, stem and root was reduced in almost all the genotypes due to sea water treatment. Highest leaf phytomass of 46.7 and 44.0 mg plant^{-1} for control and sea water respectively was recorded for ICPL 270. The percentage of decrease in leaf phytomass and stem dry weight in ICPL 342 was 45.0 and 37.0 percent respectively which was maximum as compared to other genotypes. The percentage reduction in root dry weight was maximum in ICPL 337 (31.0 percent) due to sea water treatment. All the genotypes except C-11 showed

a reduction in root length due to the treatment.

Among the three plant parts the increase in sodium content due to sea water treatment was more in roots followed by stem and leaves. Minimum Sodium percent was found in C-11. There was a decrease in K and Zn content in all the plant parts of pigeonpea due to 15 percent sea water treatment. The Mn content of leaves, stem and root was increased due to treatment. The copper content was decreased in leaves and roots in most of the genotypes tested. There was an increase in the iron content of leaves, stems and roots of all genotypes grown in sea water. Reduction in α amylase activity due to sea water treatment was also observed during germination. Genotypic differences were observed for reduction of α amylase activity due to sea water treatment.

INTRODUCTION

Agricultural crops in general show marked differences in their ability to grow under salt stress conditions and great variability in this regard has been reported at varietal and species levels. The salt in the nutrient media have different effects on growth, physiology and accumulation of various organic and inorganic solutes in legumes. Though the salt tolerance of a species or a variety is highly dynamic and changes with the stages of growth but a satisfactory percentage of germination is very essential for maintaining an optimum population density in the field to get higher yields. Salinity causes specific ion effects coupled with osmotic effects on various growth processes of plant. The most important initial stages of plant growth are germination and seedling development. Therefore studies on the effect of salinity on these physiological processes had been carried out in various crops in order to investigate the nature of damage caused by salinity, mechanism of salt injury and genetic tolerance.

Salt stress usually leads to suppression of growth and it increases as the salt concentration increasees in the soil until the plants dies off (Gauch and Eaton, 1942; Mass and Nieman, 1978). The varietal differences in salt tolerance are known to exist in certain crops (Wallhab, 961; Bernstein, 1975). While reviewing salt tolerance at ermination stage, Maliwal and Paliwal (1969) pointed out at germinating capacity of a seed significantly varies

with the nature of crop, its variety, type of culture medium, effective salinity, its chemical composition and pretreatment of the seed, if any. They found that varieties showed significant differences in their salt tolerance behaviour and elongation of shoots. Most of pigeonpea and cowpea varieties are salt tolerant from 6 to 12 dSm^{-1}. In general, pigeonpea is more tolerant than cowpea. The effects of salinity on plant growth may vary depending on its stage of development. Responses may be different at germination stage than at later stages. Generally, established plants have a greater degree of salt tolerance than the germinating seeds. The general concept that the established plants tolerate salt stress more efficiently than the germinating seed was explained by Kling (1954) by suggesting that the initiation of photosynthetic activity in seedlings increased their osmotic pressure and hence the increased salt tolerance. Higher levels of salinity aggravate the delay in germination and retard final emergence percentage (Paliwal and Maliwal, 1972; Varshney and Baijal, 1977a).

The mechanism of salt tolerance of cultivated crop species differ considerably in tolerance to salinity. Suppression of plant growth under saline conditions may either due to osmotic reduction in water availability or to a specific ion effect. The ions present in excess in saline soils bring out specific changes in some plant species. Beyond certain levels, salt concentrations within the plant

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cell alter the rate of metabolic reactions to various degrees depending upon the plant species. The free proline content in the wheat plants decreased with NaCl salinity and with $CaCl_2$ and $MgCl_2$ salinities (Chauhan et al. 1983).

Hitherto in most of the experiments the salt stress was induced by NaCl, KCl or $CaCl_2$. Sea water contains large amount of salts (about 3% with high EC value (40 dSm^{-1}) which impairs the normal growth and development of the plant. Number of varieties of pigeonpea have screened for salt tolerance using NaCl, KCl and $CaCl_2$ etc., but not with sea water which contains predominently Na and Cl (457 and 536 mM).

The possibility of using saline water for irrigation, specially underground water, is very limited because, this water contains a considerable amount of harmful salts. The applicability of saline water for irrigation is first depends upon the concentration and composition of salts dissolved therein, and upon the degree to which plants are salt-resistant (Saidi and Hawash, 1971). Peacock and Dudeck (1986) studied the physiological responses of turfgrass to increasing levels of salinity derived from synthetic water in solution culture. Recently the possibilities of Using saline water and sea water to supplement the irrigation of plants growing on sandy soils have been investigated in many countries (Kurian, 1977). Therefore an investigation has

been envisaged with the following objectives.

1. To study the effect of diluted sea water on imbibition, germination and seedling growth of pigeonpea.

2. Screening of pigeonpea genotypes for salt tolerance at germination stage.

3. Screening of pigeonpea genotypes for salt tolerance at seedling stage.

4. To study the mineral uptake and effect on the hydrolysing enzyme activities.

REVIEW OF LITERATURE

Salt affected soils cause reductions in yield of many crops. Salinity decreases plant growth and yield to various degrees depending on plant species, salinity level and ionic composition of the salts that contribute to salinity. On a world-wide basis it is estimated that there are between 400 and 950×10^6 hectares are primarily located in arid or semi-arid areas where the problem may become further exacerbated by use of low-quality (i.e. saline) irrigation water. Both the extent of salt - affected land and economic losses are likely to increase in the future because of competition for high-quality water between agriculture and growing urban populations.

Salinity is characterized by two main creteria namely low osmotic potential and high concentrations of potentially toxic ions such as Na, Ca, Cl and others. Plants grown in saline soil are subjected to salt stress. Various modes of action of salinity in affecting plant responses have been advanced from time to time. These include a reduced water availability in the substrate, that is "Physiological drought" in the sense that effects of salinity may be similar to effects of low soil water content, and an excessive ion accumulation in the plant tissues possibly combined with a reduced uptake of essential mineral elements.

Salinity affects plants at all stages of development,

but sensitivity sometimes varies from one growth stage to the next. A comparison of salt tolerance during germination and emergence with later growth stages is difficult because different criteria must be used to evaluate plant response. A comparison of 50% reduction in yield and emergence of several crops is shown by Maas (1986). Usually, crops are as tolerant, if not more so, at the germination stage as at later stages. One known exception is sugarbeet, which is more sensitive during germination. Other crops, e.g. barley, corn, cowpea, rice, sorghum and wheat are most sensitive during early seedling growth and then become increasingly tolerant during later stages of growth and development.

When a viable seed is wetted, water is taken up, respiration, protein synthesis and other metabolic activities begin and after a certain period of time the embryo from the seed, generally redicle first; the seed has germinated. Various requirements must obviously be satisfied before these events can occur. The first process which occurs during germination is the uptake of water by the seed. This uptake is due to the process of imbibition. The extent to which imbibition occurs is determined by three factors, the composition of the seed, the permeability of the seed coat or fruit to water, and the availability of water in liquid or gaseous form in the environment.

2.1 IMBIBITION

Imbibition is a physical process which is related to the properties of colloids. The composition of the germination medium also determines the imbibition of seeds, as it determines the availability of water. This is of significance under natural conditions where the solution in which the seeds are found is not usually pure water. As the concentration of solutes in the solution increases, imbibition decreases. This is largely due to osmotic effects. In addition, however, a direct effect of the ions on the seed is also frequently observed. Toxic effects may be present, for example under very saline conditions. Younis and Hatata (1971) found that high concentrations of salt adversly affected the seeds during imbibition and as a result they lost their viability.

2.2 GERMINATION

The first phase of plant growth, the germination and seedling emergence, is the controlling factor in crop yield, because the ability of a given species or its variety to germinate is generally a limiting factor in the crop production under such conditions (Kapp, 1947; Devalle and Babe 1947).

Ayers and Hayward (1948) observed that the first effec-

tive increment of salinity for a given crop generally retards germination with little or no effect on the ultimate number of seedling which emerges. Higher level of salinity delays emergence of seedlings and also decreases final germination. At a moisture level of 75% of the water holding capacity 100 percent germination of maize was (Wahaab, 1961) observed upto 0.3 percent NaCl concentration but 0.6 percent Na concentration reduced the germination to 50 percent. In case of rice 0.4 percent salt concentration did not effect the germination, but 0.6 percent salt markedly reduced the germination. A concentration of 0.2 per cent had no effect on germination of cotton but 0.6 percent salt concentration reduced it to 30 per cent. An attempt was made by Maliwal and Paliwal (1966, 1967) to study salt tolerance at germination stage of some crop species at different salinity and sodium absorption ratio levels. On the basis of this study on bajra, maize, jowar, paddy, tobacco, mung, wheat and barley using 25 solutions of varying salinities (4, 8, 16, 32 and 64 me/l.) and SAR (5, 10, 25, 50 and 100) values, they observed that emergence time was delayed and percentage germination decreased linearly as the degree of salinity or SAR or both were decreased. It was also noted that germination percentage did not generally increase after the 10th day and at lower salinity the maximum germination percentage was almost independent of SAR. Bains et al (1966) reported that berseem is a sensitive crop to salinity at germination and the seedling stages.

Abel and Mackenzie (1964) evaluated six soybean varieties for their reactions to salinized during germination and later growth. Seed germination studies at 28°C ±1°C with soil salinities ranging from 3.1 to 13.7 dSm^{-1} showed that salinity decreased percent and rate of emergence. And he also found that there is no apparent relation between salt tolerances of a variety during germination and during later growth.

Younis and Hatata (1971) investigated the effects of single salt solutions of NaCl, Na_2So_4, KCl, K_2SO_4, $MgCl_2$ and $MgSO_4$ on germination of wheat grains and it was found that the germination capacity decreased with increase of salt concentration beyond certain level characteristic for each salt. The chlorides and sulphates of each cation were equally effective on germination at equi-equivalent concentrations. They found that the suppressive action of germination decreased in the order of Mg --> K --> Na forequi-equivalent concentrations. They concluded that the suppressive action of salts on germination could be attributed to their effect on metabolism and not their osmotic action. At different salinity levels at various concentratins of NaCl + $CaCl_2$ Paliwal and Maliwal (1973) observed the reduction in germination percentage and seedling height in all varieties of Cajanus indicus and V. sinensis.

Salinity generally decreases germination. But if the

solution concentration between the growth medium and seeds is reduced by way of pre-irrigation or increasing moisture content of seed or lowering the concentration gradient between seed and solution phase, a better germination can be obtained. Durrant et al (1974) observed that soaking sugar-beet seed in 1.0 M Sodium Chloride solution killed 6 per cent of the seeds but the remainder germinated when transferred to more dilute (<0.28 M) solutions. Padmanathan and Rao (1975) reported that artificial salinisation resulted in a reduction in germination in sorghum varieties. Narayanan (1975) observed that germination was depressed in all wheat varieties used and the reduction in germination increased with increase in the level of salinity, but the degree of reduction at each level of salinity varied in different varieties. He also reported that salt stress, not only brought about a reduction in the final number of germinated seeds but also delayed the initiation as well as the competetion of germination of the sprouted seeds thus hampered germination. Rathore et al (1977) studied the effect of different levels of salinity (0, 24, 32 and 40 dSm^{-1}) on germination of the seeds of 22 varieties of barley (Hordeum vulgare L.). They observed that germination was delayed and the percentage of germination decreased with an increase in salinity levels. DL-70 and RDB-57 varieties of Barley showed only 13-16% germination at 20 dSm^{-1} EC level Kumar et al (1981). The percentage of germination decreased and germination was delayed with an increase in salinity in the

varieties of corn (Zea mays L.) also (Lal et al(1981).

In a study of five levels (3 to 18 dSm^{-1}) of salinity on germination Paliwal and Maliwal (1982) observed that germination of crop varieties of groundnut, sesamum, soybean and mustard was decreased as well as delayed with the increase of salinity. Sinha et al (1982) reported that the seed germination of all three grasses under study was delayed and finally suppressed by all the stress conditions, and the magnitude of reduction was related to the kind and level of stress as well as to the species.

Soil crusting and salinity reduce emergence of seedlings and stands of many crops throughout the world. Sexton and Gerard (1982) found that the emrgence force of cotton seedlings was a curvilinear function of soil salinity in the range EC_e (the electrical conductivity of the soil solution) of 4.0 to 17.0 dSm^{-1} caused an average decrease of 23.5 g of emergence force. Emergence force by a cotton grown in saline solutions of 9 to about 30 $mmhos.cm^{-1}$ was a linear function of solution salinity caused a 20 g decrease in emvergence force. Sarma et al (1983) reported that increasing salinity of water decreased germination, infiltration rate and yield of ragi. Francois et al (1984) reported that grain sorghum was significantly more tolerant at germination than at later stages of growth. Total germination of 6 cultivars of perennial ryegrass (Lolium perenne L.) was unaffected by

upto 10,000 ppm of salinity in the germination medium, but rate of germination decreased quadratically with increased salinity. No interactions of cultivar x salinity were found (Dudeck and Peacock 1985).

Kent and Lauchli (1985) studied the effects of NaCl salinity on germination and early seedling growth of cotton. They found that germination was both delayed and reduced by 200 mol m^{-3} NaCl in the presence of a complete nutrient medium. The addition of supplemental Ca^{2+} (10 mol m^{-3} as SO_4 or Cl^{-1}) to the medium did not improve germination but, to a large degree, offset the reduction in root growth caused by NaCl. Kenaf (Hibiscus cannabinus L.) a stem-fiber plant was only slightly impaired by NaCl salinity upto 200 m mol L^{-1}. (Curtis and Lauchli 1985).

2.3 SEEDLING DEVELOPMENT

The degree of salinity injury was noted to be proportional to the osmotic lowering that impairs uptake of water whether by seed or seedlings. The seed germination and subsequent seedling growth are seed reserve dependent. The polymerized reserves are metabolically hydrolized following uptake. Seedling vigor, particularly root growth, is extremely important for stand establishment. In addition to inhibition of germination, early seedling growth stages may also be quite sensitive to salinity.

Kaddah (1963) reported that the young rice seedlings were highly sensitive to salt. He observed that Nahda rice seedlings were much more tolerant to sulphates than to chlorides at equal osmotic concentration. Addition of 10 $me.l^{-1}$ of $NaHCO_3$ to irrigation water was very harmful to young rice seedlings. Working with the rice, Pearson et al (1966) also observed that the dry weight of rice seedlings was reduced 50% weight at a mean E.C value of 6.4 dSm^{-1}. So the ability of rice seed to germinate at high salinity values (30 to 40 dSm^{-1}) is of no practical significance, since the young seedlings were very much less tolerant to saline conditions. But the seedlings of wheat were susceptible to salt concentrations even at 5 dSm^{-1}. Carbonate and bicarbonate salts were more detrimental than sulphate and chloride salts. Calcium chloride promoted growth at 5 mmhos and was less harmful than the othr salts (Sharma et al 1971).

Kumar et al (1981) observed that length and dryweight of shoot and root of barley seedlings decreased as the level of stress increased except in varieties DL-157 and DL-171 which showed initially an increasing trend upto 12 dSm^{-1} EC level and declined thereafter. Number of roots also decreased as the level of salt stress increased in all the varieties.

Paliwal and Maliwal (1982) observed that height of the seedlings of groundnut, sesamum, soyabean and mustard was adversely influenced by increasing salinity. Sodium chloride salinity in the range 0-90 mm was found to be inhibited growth of sorghum seedling by Amthor (1983). He also observed that seedlings derived from samll seeds were most sensitive to salinity.

There are some reports in the literature pertaining to the importance of adequate levels of Ca^{2+} in alleviating the deleterious effects of salinity on plant growth (Epstein, 1961, 1972; Rains 1972). Two processes of great importance in the establishment of seedlings in a saline environment are cell elongation and maintainence of a balanced nutrient ion uptake, both of which require Ca^{2+} (Epstein 1972; Mengel and Kirkby, 1982).

Kent and Läuchli (1985) observed large reduction in Na/K+Ca ratios in the salt stressed roots of seedlings of cotton grown with suplemental Ca^{2+} may vary well have a significant effect on the metabolic functions of the plant, particularly on enzymic activity. They also observed the maintenance of K^+/Na selectivity in the plant, due to the presence of supplemental Ca^{2+} in a highly saline medium. Lauchli and Stelter (1982) found K^+/Na^+ selectivity to be an important factor in the salt tolerance of cotton.

2.4 VARIETAL DIFFERENCES

Not only the plant species but also their varieties show a differential behaviour to salt at germination and seedling stages. Significant varietal differences were demonstrated by Ota and Yasue (1957) for salt tolerance of wheat when germinated upto one percent solution of sodium chloride. Kaddah (1963) observed that Rice varieties differed in their tolerance at the seedling stage. The order of tolerance might not confirm with the varietal order for grain production when salinity is introduced after the seedling stage. Abel and Mackenzie (1964) reported that in soyabean varietal differences in emrgence rate at the lower salinities were not related to the differences in the emergence rate at the higher. Uptake of chloride in stems and leaves of salt tolerant varieties was controlled to an exceedingly low level. The more salt sensitive varieties accumulated chloride and plant mortality occured when chloride contents of stems and leaves exceeded 15,000 ppm and 30,000 ppm respectively.

Pearson et al (1966) studied relative salt tolerance of 14 rice varieties during germination in sand culture. Rice seeds germinated in solutions having electrical conductivity values as high as 40 dSm^{-1} and the electrical conductivity values associated with a 50 per cent reduction in germination one week after planting ranged from 21.2 to 30.5 dSm^{-1}.

for these varieties.

While studying thirty-three varieties of pearl millet and ten of sorghum for salt tolerance, Abichandani and Bhatt (1965) observed that among the pearl millet varieties, eleven showed no significant differences upto an EC of 16 dSm^{-1} and nineteen showed no differences in germination upto 8 dSm^{-1} only. Maliwal and Paliwal (1966, 1967) and Maliwal (1967) studied few varieties of some crop species at different salinity and SAR levels. Germination work on 15 varieties of pearl millet, 11 of maize, 6 of Paddy, 18 of sorghum, 6 of tobacco, 6 of mung, 13 of barley and 13 of wheat showed significant varietal differences among the crop species studied. Further work on two varieties of each crop showed that germination percentage increased by replacing fifty percent sodium by potassium in the above solutions. A better response was observed in solutions of high SAR values. The tolerance of varieties of barley to salt stress was found to differ significantly at different salinity levels Kumar et al (1981).

In a study of salt tolerance of five varieties of corn at salinity levels of 0, 40, 80, 120, 160 and 200 $me.l^{-1}$. Lal et al (1981) found that there was a significant difference among varieties in germination and seedling growth. In general Neelum was found to be more tolerant than the other varieties. Germination studies were carried out by

Maliwal and Paliwal (1982) on 18 varieties of chickpea and 6 of linseed, some varieties of groundnut, sesamum, soyabean and mustard at five levels of salinity (3,6,9,12 and 18 dSm^{-1} in 1/5 Hoagland solution in sand culture. They found that varieties showed significant differences in relation to duration and percentage of germination and height of the seedlings. Salt tolerant cell lines of Oryza sativa L. Cvs Kiran and Madhu have been isolated by exposing the cultures, to increase levels of NaCl (0.5%, 1%, 2% and 3% w/v). The salt selected line of cells grow better than un-selected cells at high level of salt (Paul and Ghosh 1986).

2.5 MINERAL NUTRITION

Plants need minerals in sufficient quantities, but an excess of inorganic ions in the soil affects plant growth in several respects. In most cases it is not the major plant nutrients such as nitrogen, phosphate and Potassium that prevail in salt affected soils, but ions of minor importance such as Na^{+}, Cl^{-}, HCO_3^{-}, Mg^{2+}, sulphate and borate (Szabolcs 1971).

In saline soils the ionic composition of the soil solution is often unbalanced and the excess of a single ion species may excert a specific toxic effect on plants. In this respect, high concentrations of borate, sulphate and magnesium of calcium are particularly harmful. In most

cases, however, poor plant growth in saline medium is not attributable to the toxic effect of an individual ion species but is expected by the high osmotic value of the soil solution (Bernstein and Hayward, 1958). For this reason the availability of the soil water is decreased and the uptake of water by plant roots is reduced. This reduction is not necessarily connected with a reduced rate of uptake (Hanson and Bonner, 1954), but a lower water uptake mostly means lower transpiration and threrefore in many cases also a hampered transport of inorganic and organic solutes from the roots to the upper parts of the plant.

2.5.1 Mineral composition of plants

Apart from osmotic effects, soil salinity is known to exert its deleterious effects on plant growth through causing ionic imbalance and nutritional deficiencies (Bernstein et al., 1974). Salinity responses on mineral composition and ionic balance in plants might depend on a variety of factors including the doses of salinity application and its timing as well as the nature of species and crop.

Palfi(1965) found that shoots of rice plants grown on a nutrient medium rich in Na contain less nitrogen and phosphorus than plants grown in a normal nutrient containing same amount of Na and P as the 'high Na medium'. The presence of Na^+ ions impairs the uptake of ammonium ions

into the plant. The high Na- content exerts a differential effect, on uptake of N and P. The Na/P quotient was 4.2 in the control and it amounted to 5.2 in the high Na medium.

Narayanan (1975) reported that K/Na and K/Ca decreased progressively with increase in soil salinity in all the plant parts of three varieties of wheat tested. Irrigating the rice plants grown in plastic pots with irrigation water at three salinity levels showed that Ca, Na and Cl increased with increasing salinity; Mg and K contents were not affected by irrigation salinity, soil type, and drainage rate (Kaddah et al, 1975). The experimental data of Helal et al (1975) showed that NaCl salinazation resulted in increased Na contents of roots and shoots of barley plants. This increase of Na content was considerably higher than the increase in the K content caused by the additions of KCl. There is a reduction in Ca and Mg contents in roots and shoots caused by NaCl salinization and this reduction had no great influence on plant growth, since in the treatments with KCl additions the highest yields were obtained, although the Mg and Ca contents were low.

The mineral analyses of the leaves and stem of pearl millet seedlings irrigated with sea water reveals that Sodium and Potassium were most accumulated in stem whereas nitrogen, calcium and magnesium were accumulated to a greater extent in the leaves. The nitrogen and calcium con-

tent of the leaves and the stem were more or less directly proportional to the concentration of those minerals in the irrigation media, suggesting that their uptake was not hindered by salinity (Kurian 1976). Salinity-fertility studies showed a marked interactive effect of salinity and nutrient Pi(P inorganic) on Corn Plants. Nieman and clark (1976) reported two effects of salinity on P Utilization that suggest damage to transport processes; a loss of control of internal Pi concentration and an accumulation of P-esters in source leaves. In the presence of 0.1 mM Pi, salinity decreased the concentration of Pi in leaves by nearly half.

Heikal (1977) found that species differed in their mineral composition when they were grown in saline culture solutions prepared by adding NaCl and $CaCl_2$ to Pfeffer's nutrient solution. Sodium and calcium content of all safflower, sunflower, wheat and radish plants was generally increased progressively with salinity. The total nitrogen content of safflower and sunflower leaves was significantly increased, whereas that of wheat and radish leaves was almost significantly decreased by salinity. Salinity induced non-significant effect on phosphorus content of all test plants. Potassium content of the test plants was significantly reduced by salinity. Magnesium content of safflower and sunflower was significantly decreased by salinity, but the effect was not significant in case of wheat and radish

leaves.

Shanon (1978) evaluated a screening procedure for salt tolerance in detecting variations among introductions of tall wheat grass (Agropyron elongatum). Mineral analysis indicated that tolerance was associated with restricted accumulation of Na, Ca and Cl in the shoots. The disturbance of the K/Na balance in young barley plants led to impairment of protein (enzyme) metabolism (Helal and Mengal 1979). Peanut plants, when grown under saline conditions showed growth suppression. Growth depression under saline conditions, apart from other factors results from sharp decrease in the uptake of nutrients particularly phosphorus.

Malakondaiah and Rao (1979) sprayed the peanut leaves with phosphorus and found that there was an increase in accumulation of P both in control and salinized plants. The sodium content was high in all plant parts of salinized plants compared to control plants. In a sand culture studies with pearl Millet, sorghum, greengram and blackgram at different salinity levels it was found that Na:K ratio in the plant was nearly constant or slightly decreased with the increase of salinity. In roots, the trend was similar except in pearl millet where this ratio increased with salinity. The Ca:Mg ratio both in plant and root was drastically reduced with the increase of salinity in all the crops. The ratio of Ca/Na and (Ca+Mg) (Na + K) regularly decreased with

the increase of salinity in the plants and roots of all the crops (Paliwal and Maliwal 1980).

Chavan and Karadge (1980) had made an attempt to study the effect of NaCl and Na_2SO_4 salinities on uptake and distribution of some important mineral elements in peanut variety TMV-10. Analysis of mineral constituents in root, stem, leaf and gynophore showed that alongwith increse in salinity Na accumulates in all parts of the plant and in this respect NaCl is more effective than Na_2SO_4. The Cl content in plants treated with NaCl also registers considerable rise in all parts. K content in various parts of salt stressed peanut plants was differentially influenced by NaCl and Na_2SO_4. As against K and Ca, P, Fe and Mn content increased due to salt stress in all plant parts. In a similar study Rathert (1983) grown two cotton varieties Dandara and Giza 45 in saline media with a ratio of 20 KCl:180 NaCl m mol.l^{-1}. The results showed that salt stress increased Na^+ nd Cl^- in tissues of both varieties. It also decreased K^+, $^{2+}$, and Mg^{2+} in both. There were some differences between varieties, for example, cations tended to be little her under stress in Giza 45, but Cl^- was higher in Dan-

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Robinson et al (1983) also observed that spinach leaves from plant grown with 200 mM NaCl contains more leaf Na^+ and leaf Cl^- and leaf K^+ than control plants.

In French Beans also Bhivare and Nimbalkar (1984) observed that salt rich environement disturbed the normal inorganic contents in Phaseolus vulgaris (L) var.Vaghya. The contents of Na, Ca, Fe and Mg were greater while those of N,K,Cu and Zn were low. The contents of P and Mn showed a differential response.

Lal and Bhardwaj (1984) studied the effect of salinity on mineral composition in Field Pea (Pisum sativum L.var. Arvensis). The results showed that in salt affected organs total nitrogen, potassium and magnesium contents were decreased, while contents of phosphorus, calcium, sodium and chloride were enhanced. Salt stress also disturbed the ratios of N/P, K/p, K/Na, K/Ca and of monovalent and divalent cations.

Joshi (1984) found the content of phosphorus and potassium were lowered while those of calcium, magnesium, sodium, chloride and sulphate were increased in the leaves of pigeonpea (Cajanus cajan L. Var.C-11) under sodium chloride and sodium sulphate salinities. The poor performance of the salt sensitive variety of wheat under NaCl was traced to excessive accumulation of Na and Cl ions and the better performance of the salt resistant kharchia was because of its success in osmotic adjustment without exposing itself to excess of ions. Kent and Lauchli (1985) studied the germina-

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tion and root growth of cotton seedlings raised in saline medium supplemented with Ca^{2+}. They observed that supplemental Ca^{2+} to a large degree, offset the reduction in root growth caused by NaCl. The benefecial effect of high Ca^{2+} concentrations on root growth of cotton seedlings in a saline environment may be due to maintainence of K/Na selectivity and adequate Ca status in the root.

2.5.2 Absorption and translocation

Salinity effects on the absorption and translocation of minerals by the plant. Calcium is considered to maintain the integrity of plant cell membranes and hence to prevent the free diffusion of potentially toxic ions prevalent in a saline environment. It also influence on selective absorption and transport of other ions in plants. The results of Ayoub (1974) showed that calcium inhibited the sodium uptake and translocation in beans grown in saline media. This effect is clearly illustrated when the marked decrease in the Na contents in the roots at substrate Ca levels from 2 to 8 mM.

Helal et al (1975) observed that salinization had a negative influence on N uptake, which became particularly evident in the high NaCl treatment in young barley plants. This negative influence was alleviated by the K^{+} additions to a remarkable extent. It is supposed that the negative ef-

fect of salinization and the positive influence of K^+ on N uptake are not specific effects, but rather are related to the overall metabolism which in the first case was weakened and the latter improved. Salt stress reduced the potassium uptake of wheat plants and thus brought about an ionic imbalance (Narayanan 1975). Another interesting finding of his study was an enhancement of total phosphorus absorption by wheat varieties due to salt stress. Similar response was reported by Ehrler and Bernstein (1958) for rice and Asana and Kale (1965) for wheat. In solution culture trials with pearl millet, sorghum, greengram, and blackgram Paliwal and Maliwal (1980) observed that relative uptake of K in plant was not much affected by salinity: Ca and Mg uptake was more affected that that of Na.

Chavan and Karadge (1980) studied the effect of sodium chloride and sodium suphate on mineral nutrition of groundnut var. TMV-10. They reported that uptake of K was hampered by both salts whereas Ca uptake was retarded mainly by Na_2SO_4. By using a multi-compartment transport box with excised roots of barley Kawasaki et al (1983) examined the effects of high concentration of NaCl and PEG with excised barley roots when no Ca was added, a high concentration of NaCl inhibited the absorption and translocatin of K and P, although the inhibition of K was more pronounced as compared with that of P. The drastic inhibition of ion absorption by a high conc. of NaCl was recovered in the presence of Ca.

Salinization of the medium inhibited both K uptake by excised barley roots and K release from their stele, as measured by short-term ^{86}Rb.

2.6 ENZYMES

There is a lack of agreement among various laboratories on the effect of salinity on enzyme levels in plants. Some investigators believe that the level of several key enzymes is lower in salt-damaged plants than in control plants (Hason and Mayber, 1969; Horovitz and Waisel, 1970) while others have reported that there are no differences in specific activities of the enzymes they have extracted from such plants. The plants grown in saline media were stunted but the specific activities of the 18 enzymes were the same in the given tissues of all plants. Also the electrophoretic pattern of isozymes of malate dehydrogenase was not altered by growth of the plants in a saline medium, However, the isozyme pattern of peroxidase from roots of salt-grown plants was altered in that two of the five detectable isozymes migrated a little more slowly than those in extracts from non saline plant tissues (Weimberg, 1970).

Hiatt and Evans (1960) found that optimal concentration of sodium salts of chlorine, fluorine, iodine, bromine, nitrate and phosphate increased the activity of the malic dehydrogenase enzyme by two to three fold. Potassium salts

of these ions produced similar effects in spinach leaves. Enzymes extracted from plants salt sensitive of Phaseolus vulgaris, salt tolerant Atriplex spongiosa and Salicornia australis grown in saline cultures showed no important changes in specific activity or salt sensitivity. Interaction of P^H optima and NaCl concentrations suggests that enzymes may differ in the way they respond to salt treatment (Greenway and Osmond 1972).

Inhibition of phosphoenol pyruvate carboxylase by the inorganic salts KCl, NaCl, and Na_2SO_4 depended on the source of the enzyme. Osmond and Greenway (1972) reported that PEP corboxylase isolated from leaves of C_4 plants was extremely sensitive, whereas the enzyme extracted from roots of C_4 plants or from both shoots and roots of C_3 plants was much less sensitive. Ribulose - 1,5 bisphosphate corboxylase was less salt-sensitive than the PEP-Corboxylase. Salt tolerant wheat variety H.D-4502 showed a higher increse in polyphenol oxidase activity under stress treatments and showed a decrease in content of total phenolics ad compared to the tolerant variety Kharchia (Sharma and Bal, 1982). Rathert (1983) studied the salt stress effects on the activity of amylases, phosphorylase and invertase of two cotton varieties Dandara and the more salt-tolerant Giza 45. He observed at little change in amylolytic activity while a marked rise of phosphorylasee activity in both varieties was of no correlation with the starch content.

Nitrate reductase activity, determined by either *in vitro* or "anaeaerobic" *in vivo* assay was affected similarly when the barley seedlings were grown in saline solutions. In contrast, when salts were added in the assay medium, the *in vitro* enzymatic activity was severely inhibited, where as the "anaerobic" *in vivo* nitrate reductase activity was affected only slightly. This indicates that *in situ* nitrate reductase activity is protected from salt injury. Aslam *et al* (1984).

2.7 SEA WATER - BASED CROP PRODUCTION

Salinity is the feature that makes seawater unfit to drink and unfit for conventional irrigation of crops Epstein and Norlyn (1977). Murthy (1985) Epstein (1978); Abd - El - rahman *et al* (1975) estimated various elements preseent in seawater.

Element	Milligram/L	Element	Milligram/L
Chlorine	19,000	Tin	0.003
Sodium	10,000	Uranium	0.003
Magnesium	1,300	Manganese	0.002
Potassium	380	Nickel	0.002
Bromine	65	Cerium	0.0004
Strontium	8	Lanthanum	0.0003
Lithium	0.2	Chromium	5×10^{-5}
Rubidium	0.12	Mercury	3×10^{-5}
Iodine	0.05	Boron	4.6
Aluminium	0.01	Silicon	3.0
Zinc	0.01	Calcium	4.0
Copper	0.002		

The total amount of disolved inorganic solids in grams per thousand grams of seawater is 35 gms per Kilogram. Inspite of marked variations in the total salt content of different sample of seawater the concentration ratio of major dissolved components remains essentially constant. There is no fundamental biological imcompatability between plant life and highly saline conditions; wittness the marine algae and the halophy terrestrial plants-those indigenous to the seashore, the estuaries and deltas, and to salt marshes and

saline desert soils. And although nearly all crop plants are sensitive to salinity, much variability neverthless exists in this regard.

The possibility of using saline water for irrigation, is very limited because, this water contain a considerable amount of harmful salts. The applicability of saline water for irrigatin is first of all dependent upon the concentration of salts dissolved therein, and upon the degree to which plants are salt-resistant. From the study of Lunin et al (1961) it was observed that gradual salinization initiated at preplanting of beans was more inhibitory than like salinity levels introduced abruptly at later stages of development. Yields, moisture content, and Cation accumulation were also significantly influenced by the stage of growth at which salinization occurred. Lunin et al. (1964) given supplemental irrigation with dilutions of synthetic sea water to the small pots containing alfalfa, Kentucky 31 Fescue, Orehardgrass, and ladino clover. They obtained significant increases in yield due to irrigation in only a few instances during the second through fourth year of study, but during the first year two of the four cuttings of all four crops responded to supplemental irrigation. Where several irrigations were applied, yields tended to decrease with increasing salinity, with ladino clover being the most sensitive of the four crops tested. The Na content of all plant parts tended to increase with increasing salinity,

with the greatest accumulation occurring in the ladino clover.

Saidi and Hawash (1971) studied the effect of using saline water for irrigation on the growth, the economic yield, and chemical properties of the rosselle plants (Hibiscus sabdariffa L.). They supplied irrigation with tap water as control, and water containing 4000 PPm. of NaCl and Na_2SO_4 and 6000 PPm NaCl and Na_2SO_4 as treatments. It was observed that salinity caused a decrease in plant height, dry weight of roots, stem and leaves, and this was related to the level of salts in irrigation water. Using saline water for irrigation in general caused an increase in total nitrogen and total phosphorus in the stem and leaves on the other hand, the total carbohydrate content decreased and salinity delayed flowering date about one week. Bernstein and Francois (1975) found that the average height of all bell pepper plants sprinkled with low-salt water was 94 cm, decreasing to 84 cm and 69 cm with increasing salinity of the irrigation water. Thus height decreased overall only 27% when yield decreases averaged 57%. Low frequency sprinkling (average interval, 4.75 days) produced taller plants than more frequent sprinkling.

The results of a three year study (Dhir et al. 1975) on crop growth under saline to highly saline sodic water irrigation in cultivars fields in an arid environment showed

that Ec of irrigation water less than 10.0 dSm^{-1} and that of saturated extract of soil less than 11.5 dSm^{-1} average to good yields of 'Kharchia' wheat were obtained. Growth, chemical composition and yield in two varieties of rice have been studied on plants growing at EC of 4 and 8 dSm^{-1} of salinity through addition of synthetic sea water (Paricha et al. 1975). It was observed that growth was reduced in treated plants but for a given salinity level growth and yield were much higher in the resistant variety, Kaohsivng - 22.

Kurian (1976) raised pearl millet seedlings as a rainfed crop in pots containing seashore sand. Fortyday old plants were irrigated with 10,000 PPm Sea water alone and supplemented with various nutritive salts and with 15,000 PPm sea water. He observed that irrigation with Seawater alone reduced the growth and yield of the crop, but some of the modifications to the 10,000 PPm Seawater resulted in increased yield. The results shows that pearl millet is tolerant of diluted seawater and the deleterious effects of irrigation with Seawater can be reduced to a certain extent by appropriate supplemening with nutritive salts. Epstein and Norlyn (1977) studied the possibillity of growing barley in seawater culture. They concluded that barley has marked phenotypic plasticity enabling it to make appreciable physiological adjustments to seawater culture. There exists in barley much genotypic diversity making it possible to

select and breed barley for Seawater culture.

Sonneveld and Voogt (1978) investigated the salt sensitivity of cucumbers. The EC of the irrigation water used in the experiment ranged from 0.1 to 4.5 dSm^{-1} at 25°C. There was a linear decrease in the yields of cucumbers as the salt concentration of the irrigation water increased. The yield reduction was about 17% for a 1 $mmho.cm^{-1}$ increase in EC. Shanon and Francois (1978) irrigated the 3 muskmelon cultivars (Cucumis melo L. Cv. Top mark, PMR 45, and Hales Best) raised in field plots with Riverside tap water to which 0,35,70 and 105 meq/liter of Nacl and $Cacl_2$ were added in a 1:1 milliequivalent ratio. Salinity levels of the irrigation waters were 0.76, 4.6, 7.8 and 11.0 dSm^{-1}, respectively. Marketable yield, total dry weight, vinedry weight, and total fruit weight of all cultivars decreaseed with increasing salinity. Reddy et al. (1982) also observed that the increase in the salinity of irrigation water, significantly decrease in pod yield of groundnut.

Sharma et al (1983) reported that ragi crop could be grown satisfactorily using saline water having EC upto 4 dSm^{-1} on light soils of coastral region. When using saline water of 4 dSm^{-1}, 25 percent increase in seed rate is neccessary to compensate the loss in population. Irrigation water of higher salinity level led to significant decrease in drymatter, yield, leaf area, height and nutrient uptake of maize and sorghum genotypes (Torawat and Mehta, 1985).

Pastermark et al (1985) planted Atriplex nummularia a halophyte in field plots and irrigated with 15,50,75, and 100% Sea Water. The corresponding annual yields of drymatter were 1.53, 2.12 and 2.89 $Kg.m^{-2}$. The ash content was very high, from 25 to 40% of the dry weight, depending on the treatment and season. The crude protein content was 15-12%. Dudeck and peacock(1985); Peacock and Dudeck (1985) studied the effect of synthetic sea water on growth and mineral nutrition of seashore paspalum. Synthetic sea water formulated with a salt mixture was added at 0, 3.5,10.5,17.5,24.5 and 31.5 $g.l^{-1}$ in half-strength Hoagland's number 2 solution to give electrical conductivity (EC) levels of 0.9, 6.2, 15.6, 24.7, 32.9 and 39.7 dsm^{-1}, respectively. It was observed that top growth in both cultivars Adalayd, FSP-1 decreased quadratically with increased salinity. Root growth response of 'Adalayd' decreased linearly, but rooting in 'FSP-1' was unaffected, crown tissue in 'FSP-1' was unaffected, whereas crown tissue in 'Adalayd' decreased linearly in response to salt levels. Salinity differentially affected tissue content of Ca, Cl, K, Mg, and Na between grasses but had no affect on N which averaged 37.3 g Kg^{-1}.

Peacock and Dudeck (1986) exposed the eight turfgrass cultivars to increasing levels of sea water mixture. They observed that cultivars differed in their response in leaf water potential and osmotic potential as salinity increased. All grasses rapidly adjusted osmotically within 48 h following increase in salinity.

MATERIALS AND METHODS

The following experiments were conducted at the Plant Physiology Laboratory of Agricultural College, Bapatla.

Sea water from Bay of Bengal 10 km from Bapatla was collected in glass containers. It was filtered to remove the sand particles and other inert materials. The filtered sea water was analysed for EC, pH and total salts and chemical composition. The results are shown in Table 1.

Table 1:

Electrical conductivity	:	40 dSm^{-1}
pH	:	8.03
Total salts	:	2.4%
Ca	:	17.5 $meq1^{-1}$
Mg	:	97.5 "
Na	:	402.2 "
K	:	9.4 "
HCO_3	:	7.5 "
Cl	:	475.0 "
SO_4	:	33.5 "
B	:	5.52 ppm

3.1 EFFECT OF DILLUTED SEA WATER ON IMBIBITION OF SEEDS

Pigeonpea cv ICPL 87 supplied by Regional Agricultural Research Station, Lam Farm, APAU was used for this study. Damaged and insect attacked seeds were discarded. The treatments consisted of the following dilutions of sea water.

1. 100% Sea water (pure sea water)
2. 75% sea water (75 ml of sea water + 25 ml of distilled water)
3. 50% sea water (50 ml of sea water + 50 ml of distilled water)
4. 25% sea water (25 ml of sea water + 75 ml of distilled water)
5. Distilled water.

Twenty five pigeonpea cv ICPL 87 seeds were sown in each petridish filled with Quartz Sand of particle size 0.5 to 0.7 mm. The sand was thoroughly washed with tap water and then soaked with 10% HCl for over night. It was then washed with tap water followed by demineralised water until the rinsings were acid free. Afterwards it was washed with distilled water. Fifty ml of test solution was added to each petridish excess watering was avoided. Seeds were sampled at 2 h intervals. The seeds were blotted with blotting paper to remove the moisture droplets present on the surface of the seeds. Immediately after blotting fresh weight of the seeds

were recorded. Later the seeds were dried in a hot air oven at 80°C for 48 h, and then dry weight was taken. The per cent of water uptake was calculated from the data on initial weight basis.

$$\frac{W_2 - W_1}{W_1}$$

Where, W_1 : Initial weight of the seed

W_2 : Weight of the seed after imbibition.

This experiment was replicated thrice with 25 seeds in eahc replication.

The experiment was repeated following the same procedure. The sampling was done at 2 h interval starting from sowing upto 12 h. The water uptake was calculated based on the basis of seed dry weight.

$$\text{Per cent of water} : \frac{W_2 - W_1}{W_1} \times 100$$

Where W_2 : Fresh weight of the seed after imbibition

W_1 : Dry weight of the seed.

The difference in per cent of water between intervals are the per cent of water imbibed by the seed during that period.

3.2 EFFECT OF DILUTED SEA WATER ON GERMINATION OF PIGEONPEA

Pigeonpea cvs ICPL 87 and BON-1 supplied by Regional Agricultural Research Station, APAU, Lam Farm were used for this study. The seeds were treated with 0.1% mercuric chloride to arrest the fungal infection. Twenty five good seeds were sown in petridishes filled with Quartz Sand of particle size 0.5 to 0.7 mm. The same was thoroughly washed as explained earlier in section 3.1

The seeds were placed on the sand in the petridish and covered with a layer of sand. Sufficient amount of test solution was added to each petridish. Excess watering was avoided to prevent the anaerobic conditions. Germination countings were taken at 24 h interval from sowing upto 84 h Radical emergence from the seed was considered as germination. The experiment was replicated thrice with twenty five seeds in each replication.

The treatments consisted of the following dilutions of sea water

1. 100% sea water
2. 87.5% sea water (87.5 ml sea water + 12.5 ml distilled water)
3. 75.0% sea water (75.0 ml sea water + 25.0 ml distlled water)

4. 62.5% sea water (62.5 ml sea water + 37.5 ml distilled water)
5. 50.0% sea water (50.0 ml sea water + 50.0 ml distilled water)
6. 37.5% sea water (37.5 ml sea water + 62.5 ml distilled water)
7. 25.0% sea water (25.0 ml sea water + 75.0 ml distilled water)
8. 12.5% sea water (12.5 ml sea water + 87.5 ml distilled water)
9. Distilled water

Based on the results the concentration of test solution and sampling interval was decided to screen the genotypes of salt tolerance.

3.3 EFFECT OF DILUTED SEA WATER ON ROOT GROWTH OF PIGEONPEA

3.3.1 Seeds germinated and grown in different concentrations of sea water.

Seeds of pigeonpea cv BDN-1 was used for this study. Fully developed seeds were sown in washed Quartz sand soaked with different concentrations of sea water. After 48 h of sowing the seedlings were transfered into test tubes lined inside with a roll of filter paper in such a way that radicle pointed downward and plumule upward. The seedlings were in between the walls of the test tube and filter paper roll.

Sea water at different dilutions was added into the test tubes. Care was taken in maintaining the filter paper always in moist conditions. This experiment was conducted in normal conditions. Radicle length was taken from third day from sowing upto 8th day. Absolute root growth rate (AGR), relative root growth rate (RGR) was calculated from the data.

$$AGR : \frac{L_2 - L_1}{T_2 - T_1} \text{ cm. day}^{-1}$$

$$RGR : \frac{\text{Log } L_2 - \text{Log } L_1}{T_2 - T_1} \text{ cm.cm}^{-1} \text{ day}^{-1}$$

Where L_2 and L_1 = length of root in cm at T_2 and T_1 times respectively.

T_2 and T_1 = Time in days.

The treatments consisted of the following dilutions of sea water:

1. 62.5% sea water (62.5 ml sea water + 37.5 ml distilled water)
2. 50.0% sea water (50.0 ml sea water + 50.0 ml distilled water)

3. 37.5% sea water (37.5 ml sea water + 62.5 ml distilled water)
4. 25.0% sea water (25.0 ml sea water + 75.0 ml distilled water)
5. 12.5% sea water (12.5 ml sea water + 87.5 ml distilled water)
6. Distilled water.

3.3.2 Seeds germinated in distilled water and grown in different concentrations of sea water.

A similar experiment was conducted in the same way as the above experiment. But in this experiment the seeds were first imbibed in distilled water for one day and on the next day the sprouts were transfered into test tubes lined with filter paper. The treatments were same as above.

3.4 SCREENING OF GENOTYPES FOR SALT TOLERANCE AT GERMINATION STAGE:

Twenty eight pigeonpea genotypes received from Regional Agricultural research Station, Lam Farm, Guntur were used for this study.

Ten seeds were sown in each petridish filled with washed quartz sand, of particle size 0.5 to 0.7 mm. The sand was thoroughly washed with tap water and then soaked with

Pigeonpea Genotypes used for the study were:

S.No.	Genotype	S.No.	Genotype
1	PANT A 106	15	S-80
2	BDNA 5	16	RMG 66
3	ICPL 312	17	PDM 1
4	C-11	18	BDN 3
5	MRG 67	19	ICPL 333
6	PDA 5	20	MRG 53
7	ICPL 361	21	MA 162
8	JNA 421	22	ICPL 295
9	BDNA 7	23	ICPL 296
10	ICPL 344	24	ICPL 348
11	ICPL 362	25	PDA 3
12	ICPL 273	26	ICPL 338
13	ICPL 270	27	ICPL 337
14	6223-5	28	ICPL 342

10% HCl for overnight, and washed with tap water followed by demineralised water until the rinsings were free of acid. Afterwards it was washed with distilled water. The pH of the washings of the sand was tested and neutral. The seeds were first washed with 0.1% mercuric chloride followed by distilled water. The sand was wetted with 40% sea water and for control with distilled water. Care was taken to keep the sand always in moist condition. Excess watering was avoided to remove the anerobic conditions.

Germination countings were taken at 24 h, 36 h and 48 h after sowing. As soon as radicle emerged from the seed coat it was considered that the seed was germinated. Germination percentage and rate of germination were calcualted as:

$$\text{Germination percent} = \frac{\text{No.of seeds germinated}}{\text{Total no.of seeds kept for germination}} \times 100$$

Rate of germination : No. germinated h^{-1}

3.5 SCREENING OF PIGEONPEA FOR SALT TOLERANCE AT SEEDLINGS STAGE:

Twenty eight pigeonpea cvs received from Regional Agricultural Research Stat ion, Lam Farm were used for this study.

Seeds were germinated in plastic trays filled with washed quartz sand of particle size 0.5 to 0.7 mm. For germination distilled water was used. Plastic trays were provided with a drainage hole to remove the excess water. Excess watering was avoided to remove the anaerobic conditions. The sides of the trays were covered with brown paper to prevent algal growth in the sand. The seeds were sown in the sand and covered with a layer of sand.

The 10 day old seedlings from sand culture were transferred into 1L capacity beakers filled with 1/2 Hoagland solution prepared with distilled water (Epstein, 1972), (Table 2). The beakers were wrapped with brown paper. After five days the solution was changed with 1/2 Hoagland solution prepared with 15% sea water. For the control the seedlings were grown in 1/2 Hoagland solution prepared with distilled water.

Aeration to the roots was provided by bubbling air in the solution using an aquarium air pump. Asbestas sheet painted white on the top and black at the bottom, with holes for the plants were used as a lid for the beaker. The seedlings were carefully introduced through the hole and fixed with a pad of cotton so as the roots were completely immersed in the solution. The seedlings were raised for 5 days after introducing the treatments and sampled.

Twenty day old plants were harvested. Roots were separated, rinsed with distilled water and blotted to remove

Table 2: Composition of 1/2 strength Hoagland solution

Compound	Molecular weight	Concentration of stock solution (M)	Concentration of stock solution ($g l^{-1}$)	Volume of stock solution per lit. of final solution (ml)	Element	Final concentration of element (um)	Final concentration of element (ppm)
Micronutrients							
KNO_3	101.10	1.00	101.10	3.0	N	8000	112.0
$Ca(No_3).4H_2O$	236.16	1.00	236.16	2.0	K	3000	117.5
$NH_4H_2PO_4$	115.08	1.00	115.08	1.0	Ca	4000	80.0
$MgSO_4.7H_2O$	246.49	1.00	246.49	0.5	P	1000	31.0
					S	500	16.0
					Mg	500	12.0
Micronutrients							
KCl	74.55	50.0	3.728	0.5	Cu	25.00	0.89
H_3BO_3	61.84	25.0	1.546		B	25.00	0.14
$MnSO_4.H_2O$	169.01	2.0	0.338		Mn	1.00	0.055
$ZnSO_4.7H_2O$	287.55	2.0	0.575		Zn	1.00	0.065
$CuSO_4.5H_2O$	249.71	0.5	0.125		Cu	0.25	0.016
H_2MoO_4 (85% MoO_3)	161.97	0.5	0.081		Mo	0.25	0.025
Fe-EDTA	–	–	–		Fe	–	2.50

Preparation of Fe-EDTA: Dissolved 26.1 g EDTA in 286 ml of N KOH. Mixed this with 24.9 g $FeSO_4.7H_2O$ and diluted to 1 L before aeration. 0.5 ml of this solution provided 2.50 ppm in 1 L.

the adhering water. After measuring the length the fresh weight was taken with a electrical balance. The top was divied into leaves and stem. The leaf area was measured by graphic method. After taking fresh weight, all the plant parts were dried in a hot air oven at 80°C for 48 h. After determining the dry weight of these samples, they were ground to powder in a wiley mill using a 40 mesh screen. The ground samples were analysed for Mn, Zn, Fe, Cu, Na, K. In cotyledons the amalyse activity was measured.

specific leaf area = $\frac{\text{Area of the leaf}}{\text{weight of the leaf}}$. ($cm \cdot wt^{-1}$)

Moisture Content of the Seedling: Fresh weight - Dry weight of the Seedling

3.5.1 Chemical analysis:

Mn, Zn, Fe, Cu, Na, K in plant parts were estimated in an extract obtained from wet digestion of the samples (Piper, 1950).

Wet digestion:

0.5 g of oven dry powered plant material was digested in 10 ml of tri-acid mixture prepared in 9:2:1 proportion of nitric, sulphuric and perchloric acid respectively. The extract was made upto 25 ml and suitable aliquot was used for estimation of Mn, Zn, Fe, Cu, Na, K. These elements were determined by direct feeding of the extract to the Atomic absorption spectrophotometer after adjusting the instruments with suitable standards as per the method given by Allan (1970).

3.5.2 Assay of ∝- amalyse activity in germinating pigeonpea seeds:

Extracts were prepared by grinding the seeds with cold distilled water. The resulting homogenate was passed through muslin cloth and centrifuged at 12,000 x g for 10 min at 4°C. The supernatant solution was used as a enzyme.

Amylase activity was determined by a method given by Shioster and Gifford (1962). A starch solution was prepared by heating to boil 67 mg of soluble starch in 100 ml of 0.06 m KM_2PO_4. One ml of this solution was added to enzyme and water to give a final volume of 2.0 ml. After 5 min incubation at 25°C the reaction was stopped by the addition of 1.0 ml of Iodine-HCL solution, consisting at 60 mg of KI and 5 mg of I in 100 ml of 0.05 HCl. Then 5 ml of water was added and the optical density of the resulting values which are proportion to enzyme concentration. Specific gravity is defined as milligrams of soluble starch hydrolyzed per mg of protein per minute.

Standard curve

To 0.2, 0.4, 0.8, 1.0 ml of starch solution, 1 ml of KI was added and final volume at whole solution to 5 ml with glass distilled water and read absorbance at 620 nm.

3.5.2 Assay of α- amalyse activity in germinating pigeonpea seeds:

Extracts were prepared by grinding the seeds with cold distilled water. The resulting homogenate was passed through muslin cloth and centrifuged at 12,000 x g for 10 min at 4°C. The supernatant solution was used as a enzyme.

Amylase activity was determined by a method given by Shioster and Gifford (1962). A starch solution was prepared by heating to boil 67 mg of soluble starch in 100 ml of 0.06 m KM_2PO_4. One ml of this solution was added to enzyme and water to give a final volume of 2.0 ml. After 5 min incubation at 25°C the reaction was stopped by the addition of 1.0 ml of Iodine-HCL solution, consisting at 60 mg of KI and 5 mg of I in 100 ml of 0.05 HCl. Then 5 ml of water was added and the optical density of the resulting values which are proportion to enzyme concentration. Specific gravity is defined as milligrams of soluble starch hydrolyzed per mg of protein per minute.

Standard curve

To 0.2, 0.4, 0.8, 1.0 ml of starch solution, 1 ml of KI was added and final volume at whole solution to 5 ml with glass distilled water and read absorbance at 620 nm.

3.5.3 Sea water analysis

Sea water was analysed as per the methods given United States Salinity laboratory staff (1954).

pH: pH of sea water was measured by using a Digital pH meter.

Electrical conductivity: EC was measured by EC meter.

3.5.4 Total salts

An porcelin dish was carefully cleaned and weighed in sensitive balance. 100 ml of sea water (after filtration) was transfered to the porcelain dish and evaporated to dryness on a water bath and in an oven at 100-105°C. Cooled in a dessicator and weighed. The weight of the residue represented the total salts in 100 ml sea water.

3.5.5 Determination of calcium

50-100 ml of sea water was taken and added 2-3 crystals of carbamate and 5 ml of 16% NaOH solution. To it 40-50 mg of the indicatory powder was added. It was titrated with 0.01N EDTA solution till the colour gradually changed from orange red to reddish violet (purple). The end point was compared with a blank reading.

$$\text{Milli equivalents of calcium present} = \frac{\text{ml of versanate used} \times \text{normality of versanate}}{\text{ml of aliquot taken}} \times 100$$

3.5.6 Determination of Magnesium

25 ml of sea water was taken and added 2-5 crystals of carbamate and 5 ml of ammonium chloride ammonium hydroxide buffer. To it 3-4 drops of crichrome black T indicator was added. It was titrated with 0.01N Versanate till the colour changed to bright blue or green and or tinge of wine red colour remained behind.

$$\text{Milliequivalents of Ca + Mg per litre} = \frac{\text{ml of EDTA} \times \text{normality of EDTA}}{\text{ml of solution taken}} \times 100$$

me of Mg per litre = me (Ca+Mg) - me of Ca

3.5.7 Determination of sodium and potassium

Sodium and potassium was estimated directly feeding the sea water into flame photometer.

3.5.8 Determination of carbonate and Bicarbonate

Taken 50-100 ml of sea water with pipette into a clean flask. Added 5 drops of 1% phenophthalein indicator. Pink colour showed the presence of carbonates. It was titrated against 0.1N sulphuric acid, till the solution becomes colourless.

To the same added 2-3 drops of methyl red solution and titrate with 0.1N sulphuric acid till the colour changed from yellow to rose red.

$$\text{meq of } CO_3^{2-} \text{ per litre} = 2x \times 0.0030 \times \frac{100}{50} \times \frac{1000}{30}$$

Where $2x$ = Total acid required for the complete neutralization of carbonate

$$\text{Milli equivalents of M } CO_3^{--} \text{ per litre} = \frac{(y-x) \times 0.0061 \times 1000 \times 1000}{50 \times 61}$$

Where $y-x$ = Total acid required for the complete neutralization of bicarbonate originally present in water.

3.5.9 Determination of chlorides

Chloride ions in irrigation water can be determined by titration with standard solution of Ag No_3 using K_2 Cr O_4 as an indicator. Taken 100 ml of sea water and added sufficient 0.1N H_2SO_4 to neutralise carbonate and bicarbonate completely and added a few mg of $CaCO_3$ and a few drops of the indicator and titrated with standard Ag No_3 solution until the chacolate red colour appeared. Repeated this process twice or thrice so as to get a number of concordant reading. In the same way conducted a blank titration also and substaracted this reading from the actual calculated results as Cl ions per 1000 litres (ppm)

3.5.10 Determination of sulphate by turbidimetric method

5 ml of sea water was taken in a 25 ml flask and added 10 ml buffer, 1 ml gum acacia and 1 g of $BaCl_2$. Shaken well. Made up the volume to the mark by adding distilled water and shaken well. Read the absorbance of this solution at 440 nm and then calculated the conc. of sulphate by comparing with the standard.

3.5.11 Determination of Boron

2 ml of sea water was taken in an Erlenmeyer flask. Added 2 drops of concentrated hydrochloric acid and 10 ml of concentrated sulphuric acid mixed well and cooled. 10 ml of the indigo-carmine solution was added to this and allowed to stand atleast for 45 minutes for colour development. Determined the percent transmittance at 585 nm against a reference solution of 2 ml of distilled water carried through the same procedure. Calculated the boron concentration from the standard curve which has been drawn by taking 0, 1, 2, 4, 6, 8 and 10 ml of boric acid solution and developed colour as outlined above.

3.6 Statistical analysis.

The data was analysed statistically (Panse and Sukhatme, 1978).

RESULTS

4.1 EFFECT OF DILUTED SEA WATER ON IMBIBITION OF SEEDS:

Experiments were conducted to study the effect of different dilutions of sea water on Imbibition of seeds. In the first experiment the imbibition in terms of per cent water uptake was calculated based on initial seed weight. The initial weight of twenty five seeds var ICPL 87 used in different treatments was almost same (Table 3). There was a increase in the weight of the seeds due to imbibition over time. But there was no particular trend in imbibition among the treatments. This was because of hard seeds present in seed lot which are not imbibed.

The per cent of water uptake during imbibition was calculated based on the initial seed weight and given in Table 4. The per cent of water uptake increaesd over time. There was about 16.7 per cent water uptake in 100% sea water, whereas with distilled water it was 10.2 per cent after 2 hours imbibition. Even after 8 h 15.2 per cent more water was taken in distilled water treatment over 100 per cent sea water, there was no particular trend in imbibition among the treatments. As stated earlier this may be due to hard seeds present in the seed lot.

Table 3 : Effect of diluted Sea water on Imbibition of pigeonpea Seeds Cv. ICPL-87.

(Weight (g) of 25 Seeds)

S.NO	Treatment/h after Sowing	2h		4h		6h		8h	
		Initial	Final	Initial	Final	Initial	Final	Initial	Final
1	100% sea water	2.71	3.17	2.44	3.49	2.54	3.64	2.52	3.95
2	75% sea water	2.44	2.86	2.53	3.48	2.50	3.68	2.59	4.23
3	50% sea water	2.54	2.88	2.57	3.33	2.57	3.80	2.60	4.26
4	25% sea water	2.54	2.96	2.50	3.51	2.40	3.80	2.40	3.83
5	Distilled water	2.46	2.71	2.50	3.32	2.45	3.36	2.48	4.27
	Standard deviation	0.11	0.17	0.05	0.09	0.07	0.18	0.08	0.21

Table 4: Percent of water uptake (on fresh weight basis) by pigeonpea seeds cv. ICPL-87 at different dilutions of sea water.

S.No.	Treatment/h after sowing	2h	4h	6h	8h	Mean
1	100% sea water	16.7(24.1)*	43.0(40.9)	43.5(41.3)	56.7(48.8)	39.9
2	75% sea water	16.9(24.3)	37.6(37.8)	47.1(43.3)	62.9(52.5)	41.1
3	50% sea water	13.3(21.4)	29.7(33.0)	47.8(43.7)	63.7(52.9)	38.6
4	25% sea water	16.7(24.1)	40.6(39.6)	58.3(49.8)	59.2(50.3)	43.7
5	Distilled water	10.2(18.6)	32.8(34.9)	36.8(37.3)	71.9(57.9)	37.9
Mean		14.8	36.7	46.7	62.9	

LSD(0.05) Treatment : 1.72**

Time : 1.54

Treatment x time: 3.45

* Values in parenthesis represente the Arcsin $\sqrt{\text{percentage}}$ transformed values

** Calculated on transformed values

To avoid this lacuna similar experiment was conducted, but calculated the percent of water uptake on dry weight basis. The fresh weight and dry weight of seeds was shown in Table 5. The fresh weight of the seeds was not significantly different among treatments after imbibition at each interval, but there was a significant increase over time. The dry weight of the seeds also not significant different among the treatmments and also at different intervals.

The percent of water uptake calculated on dry weight basis is given in Table 6. The percent of water uptake from undiluted sea water was 39.0 after 2 h and 108.3 after 12 h. Whereas it was 49.8 after 2 h and 135.5 after 12 h from distilled water. The water uptake by imbibition increased with decrease in concentration of sea water. Such result was very clear only from 8 h imbibition onwards. Earlier to this period the differences in water uptake varied considerably with the treatment. The uptake of water was more during initial stages of imbibition but during later stages it was less or almost constant. With sea water and 75 percent sea water the uptake of water extended upto 12 h but with rest of the treatments it was only upto 10 h.

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Table 5 . Effect of diluted sea water on Imbibition of pigeonpea seeds cv. ICPL-87.
(Weight of (g) 25 seeds)

No.	Treatment/h after sowing	2h		4h		6h		8h		10h		12h	
		Fresh weight	Dry weight	Fresh weight	Dry weight	Fresh weight	Dry weight	Fresh weight	Dry weight	Fresh weight	Dry weight	Fresh weight	Dry weight
	100% sea water	2.11	1.52	1.99	1.30	2.60	1.47	2.76	1.51	3.66	1.87	3.51	1.68
	75% sea water	1.42	1.09	2.07	1.18	2.22	1.27	2.91	1.51	3.73	1.80	3.56	1.65
	50% sea water	1.75	1.26	2.21	1.25	2.87	1.47	2.49	1.18	3.55	1.65	3.04	1.42
	25% sea water	1.82	1.27	1.89	1.10	2.67	1.44	2.92	1.39	3.14	1.39	4.06	1.83
	Distilled water	1.62	1.08	2.01	1.16	2.42	1.20	3.04	1.38	3.97	1.68	3.56	1.51
	Standard deviation	0.25	0.18	0.12	0.08	0.25	0.13	0.21	0.14	0.31	0.18	0.36	0.16

ble 6: Percent of water uptake (on Dry weight basis) by pigeonpea seeds cv. ICPL-87 at different dilutions of sea water.

No.	Treatment/h after sowing	2h	4h	6h	8h	10h	12h	Mean
	100% sea water	39.0(38.6)*	52.9(46.7)	77.3(61.5)	82.9(65.6)	91.3(72.8)	108.3(106.7)	76.6
	75% sea water	30.5(33.5)	75.9(60.6)	72.5(58.4)	92.0(73.6)	105.9(104.1)	114.9(112.7)	81.9
	50% sea water	41.1(39.9)	76.2(60.8)	95.3(77.5)	112.5(110.7)	115.2(112.9)	114.7(112.5)	92.5
	25% sea water	45.9(42.6)	70.7(57.2)	85.5(67.6)	108.9(107.4)	125.1(120.1)	122.5(118.3)	93.1
	Distilled water	49.8(44.9)	76.6(61.1)	106.3(104.5)	121.4(117.6)	136.3(127.0)	135.5(126.6)	104.3
ın		41.3	70.4	87.4	103.5	115.9	119.2	

)(0.05) Treatment : 9.33**

Time : 10.23

Treatment x time: 22.87

alues in parenthesis represente the Arcsin $\sqrt{\text{percentage}}$ transformed values

** Calculated on transformed values. $(\sqrt{X+1.0})$

4.2 EFFECT OF DILUTED SEA WATER ON GERMINATION OF PIGEONPEA SEEDS CV ICPL 87 AND BDN-1:

Germination of pigeonpea seeds of cv ICPL 87 in diluted sea water is shown in Table 7. In sea water the seeds started germination only after 72 h and 1.66 seeds out of 25 seeds germinated after 84 h. In 87.5 percent sea water the germination started 24 h earlier than in sea water and about 5 seeds germinated after 84 h, but in 75, 62.5 and 50 percent sea water the seeds started germination even after 36 h. In 37.5, 25.0, 12.5 percent sea water and distilled water the seeds started germination after 24 h and reached the maximum at 48 h. Afterwards there was no significant increase in germination. There was a significant difference in germination with salinity treatments.

The germination percent of seeds is given in Figure 1. In sea water only 6.6% germination was observed at 84 h. As the dilution of sea water was increased the seed germination was more in lesser time. In distilled water 94.6 percent germination was observed within 48 h. As the concentration of sea water increased there was a reduction in germination percentage. The rate of percent of germination was given in Table 8. Germination was delayed with the increase in the concentration of sea water. Up to 62.5 percent sea water the maximum rate of germination was only after 36 h, while in other treatments the maximum rate was observed between 24

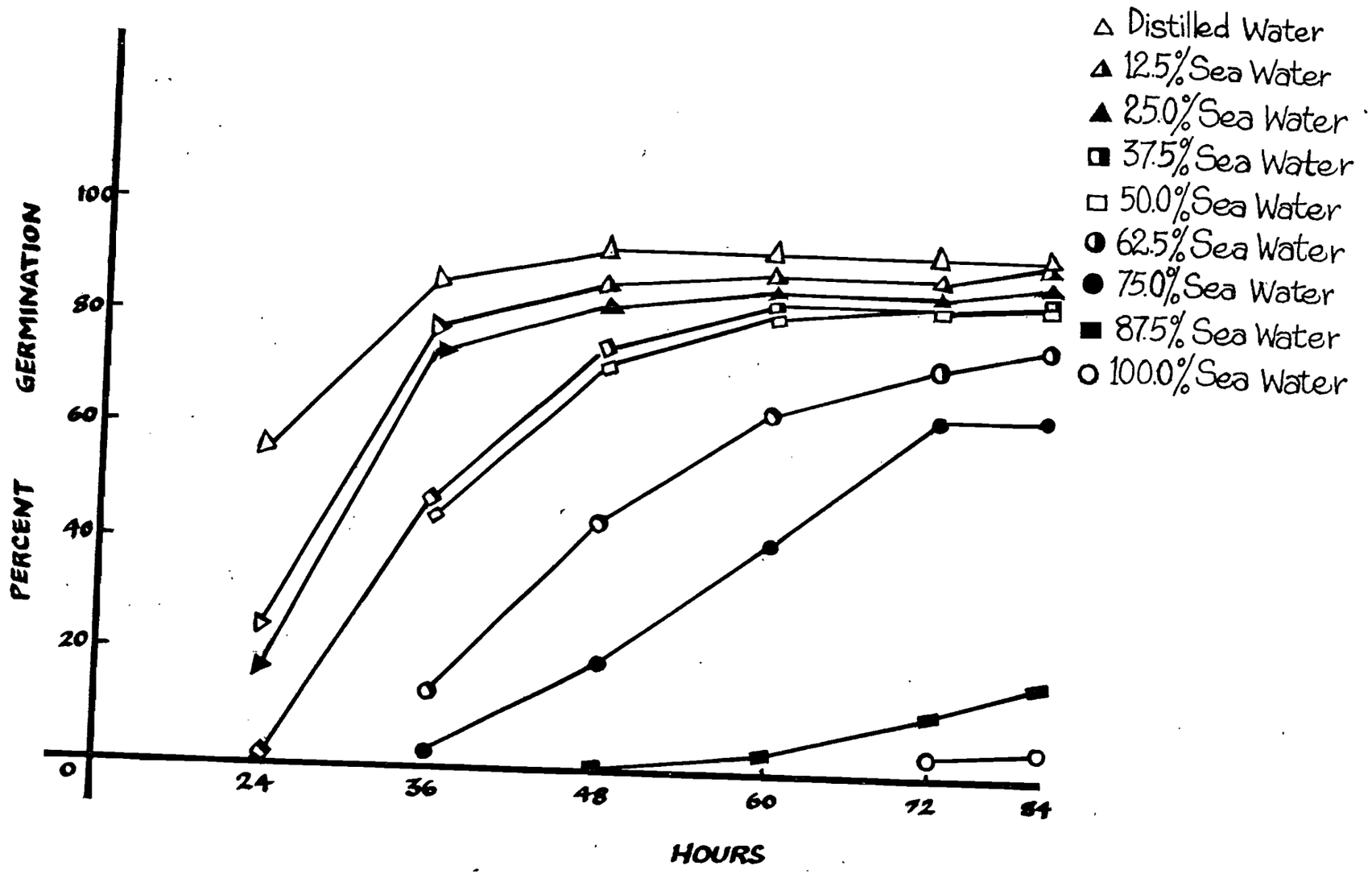
PERCENT GERMINATION
100
80
60
40
20
0
24
36
48
60
72
84
HOURS
Distilled Water
12.5% Sea Water
25.0% Sea Water
37.5% Sea Water
50.0% Sea Water
62.5% Sea Water
75.0% Sea Water
87.5% Sea Water
100.0% Sea Water

Table 7 : Effect of diluted sea water on germination of pigeonpea seeds cv. ICPL-87 (out of 25 seeds)

S.No.	Treatment/h after sowing	24	36	48	60	72	84	Mean
1	100% sea water	0.0	0.0	0.0	0.0	1.3	1.7	1.5
2	87.5% sea water	0.0	0.0	0.3	1.0	3.0	4.7	2.25
3	75.0% sea water	0.0	1.0	5.0	10.7	16.7	17.3	10.14
4	62.5% sea water	0.0	3.7	11.3	16.3	18.7	19.7	13.94
5	50.0% sea water	0.0	11.6	24.9	28.0	28.4	28.9	24.36
6	37.5% sea water	0.3	12.3	19.3	21.3	21.3	21.6	16.02
7	25.0% sea water	4.6	19.0	21.0	22.0	22.0	22.3	18.48
8	12.5% sea water	6.3	20.0	22.0	22.6	22.6	23.3	19.46
9	Distilled water	14.3	20.7	23.6	23.6	23.6	23.7	21.58
	Mean	2.8	9.8	14.2	16.2	17.5	18.1	

LSD(0.05) Treatment : 0.15*

Time : 0.12

Treatment x time: 0.36

* Values are based on transformed values. $(\sqrt{X + 1.0})$

Table 8:Rate of percent of germination of pigeonpea seeds cv. ICPL-87 grown with diluted sea water.

S.No.	Treatment/h after sowing	0-24	24-36	36-48	48-60	60-72	72-84
1	100% sea water	0.0	0.0	0.0	0.0	0.0	0.3
2	87.5% sea water	0.0	0.0	1.3	2.7	8.0	6.2
3	75.0% sea water	0.0	4.0	16.0	22.6	24.0	2.7
4	62.5% sea water	0.0	14.6	30.7	20.0	9.3	4.0
5	50.0% sea water	0.0	46.6	28.0	9.4	1.3	1.3
6	37.5% sea water	1.3	48.0	28.0	8.0	0.0	1.3
	25.0% sea water	1.9	74.1	8.0	4.0	0.0	1.3
	12.5% sea water	25.3	54.7	8.0	2.6	0.0	2.7
	Distilled water	57.3	25.7	11.6	0.0	0.0	0.0

and 36 h except in distilled water where the maximum rate of germination was within 24 h.

Germination of pigeonpea seeds cv BDN 1 is given in Table 9. In sea water only 0.65 seeds out of 25 seeds germinated after 84 h in 87.5 percent sea water the germination started 24 h early and 4.6 seeds out of 25 seeds germinated after 84 h. With 75.0 percent sea water the germination started only at 48 h and 17.6 seeds germinated after 84 h. In 37.5, 25.0, 12.5 percent sea water and distilled water the germination started at 26 h. In distilled water even at 24 h, 21 seeds out of 25 seeds germinated and the maximum was reached after 36 h.

The germination percent is shown in Fig.2. In sea water only 2.6 percent germination was observed even after 84 h, whereas in distilled water maximum percentage was reached by 48 h. With 50, 37.5 and 25 percent sea water 50 percent germination was observed after 36 h. The results show that as the sea water concentration was increased the percent germination reduced.

The rate of germination is given in Table 10. In sea ıter the germination was started after 72 h only. The rate s 2.4 between 72 and 84 h. As the concentration of sea :er was increased the rate of germination was delayed.with 12.5 percent sea water and distilled water. The maximum

and 36 h except in distilled water where the maximum rate of germination was within 24 h.

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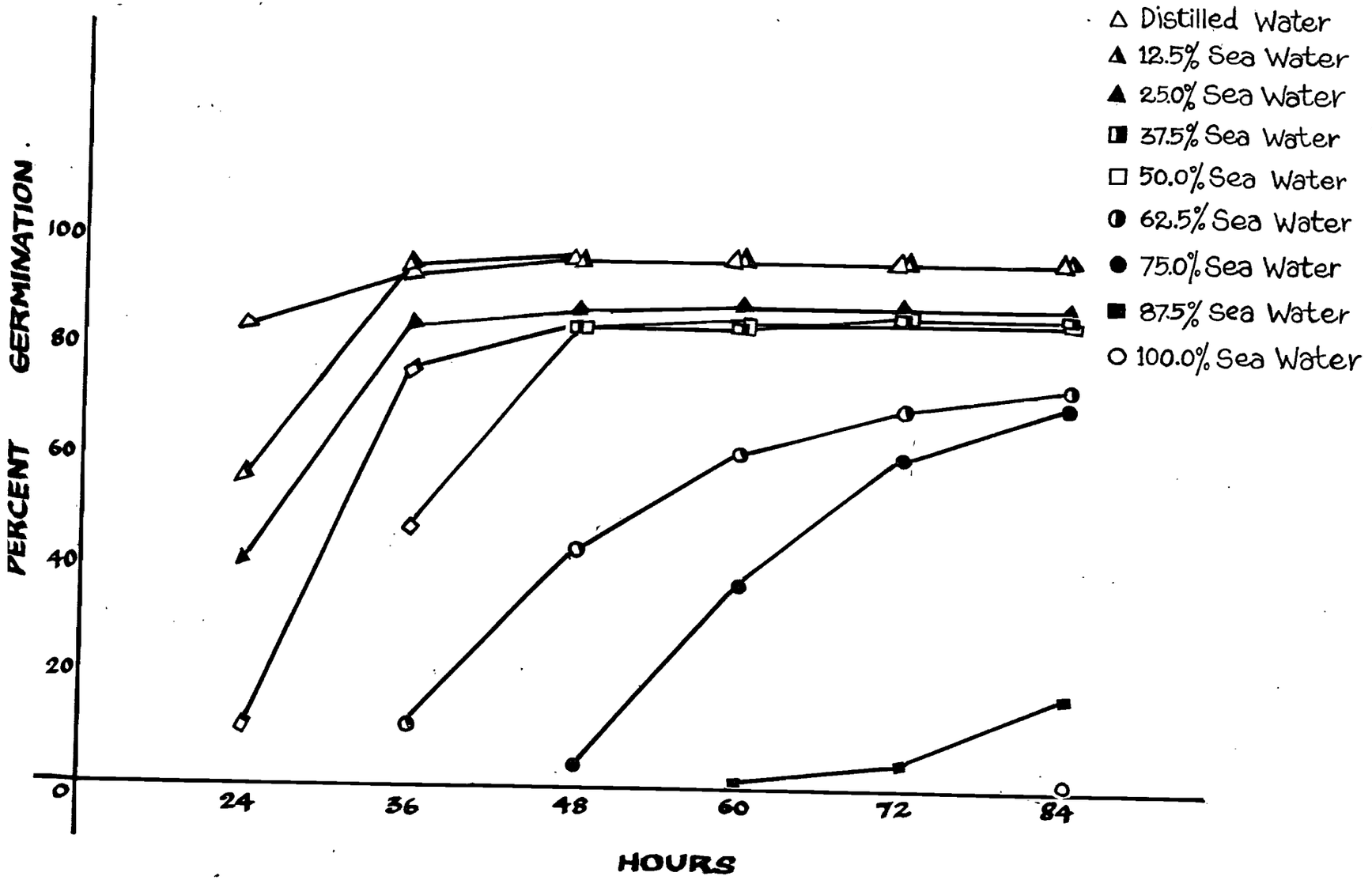
△ Distilled Water
▲ 12.5% Sea Water
▲ 25.0% Sea Water
◨ 37.5% Sea Water
□ 50.0% Sea Water
◑ 62.5% Sea Water
● 75.0% Sea Water
■ 87.5% Sea Water
○ 100.0% Sea Water
PERCENT GERMINATION
100
80
60
40
20
0
24
36
48
60
72
84
HOURS

Table 9 : Effect of diluted sea water on germination of pigeonpea seeds cv. BDN-1 (out of 25 seeds)

S.No.	Treatment/h after sowing	24	36	48	60	72	84	Mean
1	100% sea water	0.0	0.0	0.0	0.0	0.0	0.6	0.6
2	87.5% sea water	0.0	0.0	0.0	0.6	1.3	4.6	2.2
3	75.0% sea water	0.0	0.0	1.0	9.6	15.3	17.6	10.9
4	62.5% sea water	0.0	3.0	11.0	15.6	17.6	18.6	13.2
5	50.0% sea water	0.0	12.0	21.3	21.6	21.6	21.6	19.6
6	37.5% sea water	2.6	19.3	21.3	21.3	22.0	22.0	18.1
7	25.0% sea water	10.6	21.3	22.0	22.3	22.3	22.3	20.1
8	12.5% sea water	14.3	24.0	24.3	24.3	24.3	24.3	22.6
9	Distilled water	21.0	23.6	24.3	24.3	24.3	24.3	23.6
	Mean	5.4	11.5	13.9	15.5	16.5	17.3	

LSD(0.05) Treatment : 0.16*

time : 0.13

Treatment x time: 0.39

* Values are based on transformed value

Table 10 : Rate of percent germination of pigeonpea seeds cv. BDN-1 growth with diluted sea water.

S.No.	Treatment after sowing	0-24	24-36	36-48	48-60	60-72	72-84
1	100% sea water	0.0	0.0	0.0	0.0	0.0	2.4
2	87.5% sea water	0.0	0.0	0.0	2.6	2.7	13.3
3	75.0% sea water	0.0	0.0	4.0	34.6	22.7	9.3
4	62.5% sea water	0.0	12.0	32.0	18.6	8.0	4.0
5	50.0% sea water	0.0	48.0	37.3	1.3	0.0	0.0
6	37.5% sea water	10.6	66.7	8.0	0.0	2.7	0.0
	25.0% sea water	42.6	42.7	2.7	1.3	0.0	0.0
	12.5% sea water	57.3	38.7	1.3	0.0	0.0	0.0
	Distilled water	84.0	10.6	3.0	0.0	0.0	0.0

rate was within 24 h after sowing, afterwards it was decreased. In 50, 62.5, 75 and 87.5 percent sea water the maximum rate was delayed by 12 h, 24 h, 36 h and 60 h respectively.

4.3 EFFECT OF DILUTED SEA WATER ON RADICLE GROWTH OF PIGEONPEA CV BDN-1:

Radicle length of pigeonpea grown in various dilutions of sea water is given in Table 11.

4.3.1 Seeds germinated and grown in different concentrations of sea water:

In 62.5% sea water there was a increase in radicle length upto 5d. afterwards, there was no significant increase. In 50.0 and 37.5 percent sea water the increase was upto 7 d. In 25.0, 12.5 percent sea water and distilled water there was increase in root length even after 8 h(11A). There was significant reduction in root length with increase in the sea water concentration at all times. Maximum reduction was observed in 62.5% sea water treatment. Significant differences were observed between 12.5% sea water and distilled water treatments at all intervals. At higher concentrations of sea water (62.5, 50.0 and 37.5 percent sea water), the root growth was inhibited after certain period.

Table 11 : Effect of diluted sea water on Radicle length (cm) of pigeonpea cv. BDN-1

S.No.	Treatment/days after sowing	3	4	5	6	7	8	Mean
(A)1	62.5% sea water	0.60	0.76	0.94	1.04	1.11	1.11	0.69
2	50.0% "	1.05	1.30	1.53	1.72	1.92	1.92	1.18
3	37.5% "	1.42	1.76	2.29	2.81	3.12	3.15	1.82
4	25.0% "	1.89	2.56	3.47	4.59	5.82	8.18	3.31
5	12.5% "	1.96	3.00	4.69	6.53	8.68	10.86	4.46
6	Distilled water	1.20	2.58	4.93	8.11	9.70	11.20	4.71
(B)7	62.5% sea water	0.68	1.21	1.32	1.35	1.36	1.37	0.91
8	50.0% "	0.75	1.27	1.91	2.28	2.51	2.53	1.41
9	37.5% "	0.91	1.35	2.20	3.17	3.61	3.96	1.90
10	25.0% "	1.15	1.57	3.25	4.42	5.81	8.98	3.15
11	12.5% "	1.13	2.07	4.39	6.83	9.52	11.80	4.47
12	Distilled water	1.11	2.57	5.03	8.19	10.28	12.90	5.01
	Mean	1.15	1.83	2.99	4.25	5.29	6.49	

LSD (0.05) Treatment : 0.27

time : 0.19

Treatment x time: 0.66

4.3.2 Seeds germinated in distilled water and grown in different concentrations of sea water:

In this experiment also the results showed that with 62.5% sea water the radicle grow in length upto 5 d. afterwards the increase was not significant. In 50% sea water the root length increased upto 7 d, but in 37.5, 25.07, 12.5 percent sea water and distilled water there was an increase in root length even after 8 d (Table 11 B). There was a gradual significant reduction in root length with the increase in sea water concentrations. Here also the maximum reduction was in 62.5% sea water.

The radicle length was more when the seeds were pregerminated in distilled water. The final length of the root, on 8 d. was also more in different tratments of the second experiment (4.3.2) compared with the same treatment of the first expermiment (4.3.1).

Relative radicle growth Rate (RRGR):

The increase in radicle length based on the initial length of radicle was calculated as relative radicle growth rate and presented in Table 12.

(4.3.1) The RRGR differed with sea water treatments. With increase in the concentration of sea water, there was a

Table 12 :Effect of diluted sea water on Relative radicle growth rate (RRGR) of pigeonpea cv. BDN-1. ($cm.cm^{-1}.d^{-1}$)

S.No.	Treatment/days after sowing	3-4	4-5	5-6	6-7	7-8
(A) 1	62.5% sea water	0.23	0.21	0.10	0.06	0.00
2	50.0% "	0.21	0.16	0.11	0.11	0.00
3	37.5% "	0.21	0.26	0.20	0.10	0.01
4	25.0% "	0.63	0.30	0.27	0.23	0.34
5	12.5% "	0.42	0.44	0.33	0.28	0.22
6	Distilled water	0.76	0.64	0.49	0.17	0.14
(B) 7	62.5% sea water	0.57	0.08	0.02	0.01	0.01
8	50.0% "	0.52	0.40	0.17	0.09	0.01
9	37.5% "	0.39	0.48	0.36	0.13	0.09
10	25.0% "	0.31	0.72	0.30	0.27	0.43
11	12.5% "	0.60	0.75	0.44	0.33	0.21
12	Distilled water	0.83	0.67	0.48	0.22	0.22

decline in RRGR at all sampling time. Maximum growth rate was observed in distilled water treatment. In 62.5 and 50.0 percent sea water the growth rate was nil between 7 and 8 d. But in 25.0 percent sea water the RRGR decreased upto 7 d and afterwards there was an increase. The RRGR declined with time in all treatments including the distilled water treatment.(Table 12 A)

(4.3.2) When the seeds were imbibed in distilled water and grown in diluted sea water, the RRGR decreased with the increase in the concentration of sea water. There was an increase in RRGR from 3 to 5 d but later it was declining in all treatments except in 25 percent sea water treatment. The highest RRGR was observed in distilled water and lowest in 62.5% sea water. RRGR was more when the seeds were soaked in distilled water and grown in diluted sea waters, than when germinating in diluted sea waters. Such higher RRGR was observed in all the treatments in all sampling times.(Table 12B).

Absolute growth rate of radicle (AGR)

The absolute growth rate of radicle is given in Table 13. In 62.5, 50.0 and 37.5 percent sea water AGR increased upto 5 d and later it was decreased. In 25.0 and 12.5 percent seawater the AGR increased linearly. In distilled water the growth rate reached its peak of 3.18 cm d^{-1} between 5

Table 13 : Effect of diluted sea water on Absolute growth rate of radicle (AGR) of pigeonpea cv. BDN-1. $cm.d^{-1}$

S.No.	Treatment/days after sowing	3-4	4-5	5-6	6-7	7-8
(A)1	62.5% sea water	0.16	0.18	0.10	0.07	0.00
2	50.0% "	0.25	0.23	0.19	0.20	0.00
3	37.5% "	0.34	0.53	0.52	0.32	0.03
4	25.0% "	0.67	0.91	1.12	1.23	2.36
5	12.5% "	1.04	1.69	1.84	2.15	2.18
6	Distilled water	1.38	2.35	3.18	1.59	1.50
(B)7	62.5% sea water	0.53	0.11	0.03	0.02	0.01
8	50.0% "	0.52	0.64	0.37	0.23	0.02
9	37.5% "	0.44	0.85	0.97	0.44	0.35
10	25.0% "	0.42	1.68	1.17	1.39	3.19
11	12.5% "	0.94	2.32	2.44	2.67	2.28
12	Distilled water	1.46	2.46	3.16	2.09	2.63

and 6 d but later it was declining. As the concentration of sea water increased there was a reduction in growth rates.(Table 13 A)

In 62.5 and 50.0 percent sea water treatments there was a decrease in AGR with time (0.53 cm d^{-1} and 0.01 cm d^{-1} between 3-4 and 7-8 d respectively). In 62.5 and 37.5 percent sea water, there was a increase in growth rate upto 6 d and later it was declined. In 25 and 12.5 percent sea water there was a increase in growth rate with time but in 12.5% sea water the growth rate decreased between 7 and 8 d. In distilled water the growth rate was maximum over other treatments during the initial stages and later it was declined. Increase in concentration of sea water reduced the growth rate.(Table 13 B)

Rate of radicle growth was more when the seeds were germinated in distilled water and later grown in diluted sea water as compared to the seeds germinated and grown in diluted sea water.

4.4 SCREENING OF GENOTYPES FOR SALT TOLERANCE AT GERMINATION STAGE:

The data on germination of twenty eight pigeonpea genotypes are given in Table 14. By 24 h all the genotypes germinated in distilled water and significant differrences

Table 14: Effect of 40% sea water on germination of pigeonpea genotypes.(out of 10 seeds)

S. No	Genotypes/ h after sowing	24h		24-36h		36-48h	
		Distilled water	Sea water (40%)	Distilled water	Sea water (40%)	Distilled water	Sea water (40%)
1	PANT A 106	7.7	0.0	9.7	8.3	9.7	8.3
2	BDNA 5	9.7	0.0	10.0	7.3	10.0	10.0
3	ICPL 312	8.0	3.0	10.0	9.7	10.0	10.0
4	C-11	8.0	0.0	8.0	7.7	8.0	8.3
5	MRG 67	9.3	1.7	9.7	9.3	9.7	9.7
6	PDA-5	3.3	0.0	8.7	4.6	8.7	4.7
7	ICPL-361	7.3	0.0	9.7	7.7	9.7	7.7
8	JNA 421	10.0	0.0	10.0	9.3	10.0	9.3
9	BDNA-7	8.0	0.0	10.0	8.7	10.0	9.7
10	ICPL-344	3.3	0.0	7.7	6.3	7.7	6.4
11	ICPL-262	6.7	0.0	9.0	6.7	9.0	7.7
12	ICPL-273	2.3	0.0	7.7	5.7	7.7	5.7
13	ICPL-270	2.0	0.0	10.0	5.0	10.0	7.7
14	6223-5	6.7	0.0	9.3	7.7	9.3	7.7
15	S-80	4.3	0.0	9.7	7.0	10.0	8.7
16	RMG 66	6.3	0.0	8.0	4.7	8.3	7.7
17	PDM-1	10.0	0.3	10.0	8.3	10.0	9.0
18	BDN-3	7.3	0.0	9.3	7.7	9.3	9.3
19	ICPL 333	8.3	0.0	9.3	5.7	9.3	5.7
20	MRG 53	4.7	0.0	9.0	5.0	10.0	8.0
21	MA 162	5.3	0.0	9.7	6.0	9.7	7.7
22	ICPL 295	4.7	0.0	7.7	5.7	8.3	7.7
23	ICPL 296	4.3	0.0	8.0	4.3	10.0	5.7
24	ICPL 348	7.0	0.0	9.3	7.4	9.3	7.7
25	PDA-3	2.3	0.0	9.0	7.0	9.7	8.7
26	ICPL 338	6.7	0.0	8.7	7.7	8.7	9.0
27	ICPL 337	5.7	0.0	9.7	6.0	9.7	9.0
28	ICPL 342	8.7	0.0	9.0	6.3	9.0	7.7
	Mean	6.3	0.18	9.1	7.2	9.3	7.7

LSD (0.05)

genotype: 0.100
Time : 0.204
Treat : 0.064

genotype x time : 0.054
genotype x treat : 0.354
Time x treat : 0.289

were observed among genotypes. Maximum germination of seeds (10 out of 10 seeds) was observed in JNA 421 and minimum in ICPL 270(2 out of 10 seeds). In 40 percent sea water there was no germination of all the genotypes except ICPL 312 and MRG 67 at 24 h. By 36 h maximum number of seeds of almost all genotypes were germinated in distilled water. In treatment 40 percent sea water maximum germination was observed in ICPL 312 (9.7 out of 10 seeds) and minimum in ICPL 296 (4.3 out of 10 seeds). After 36 h there was no significant increase in germination in most of the genotypes, but there was a significant increase of germination in 40 percent sea water in many genotypes. By 48 h BDNA 5and ICPL 312 showed maximum germination (10 out of 10 seeds) and the minimum was noticed for PDA 5 (4.7 out of 10 seeds). There was a significant interaction between genotype and time, genotype and treatment; time and treatment, and among genotypes, time and treatment.

The percent of germination of 28 pigeonpea genotypes in sea water is given in Table 15. By 24 h seeds of all 28 genotypes germinated. Genotypes significantly varied in germination even in distilled water. Cent percent germination was observed in PDM 1 and JNA 421 whereas ICPL 270 showed the least. By 24 h, genotypes ICPL 312, MRG 67 and PDM 1 only germinated in the treatment with the germination percentage of 30.0, 16.6 and 3.3 respectively. There was reduction in germination because of the treatment at 24 h.

Table 15: Effect of 40% sea water on percent germination of pigeonpea genotypes.

S. No	Genotypes/ h after sowing	24h		36h			48h		
		Distilled water	Sea water	Distilled water	Sea water	% Over control	Distilled water	Sea water	% over control
1	PANT A 106	76.6	0.0	96.6	83.3	86.2	96.6	83.3	86.2
2	BDNA 5	96.6	0.0	100.0	73.3	73.3	100.0	100.0	100.0
3	ICPL 312	80.0	30.0	100.0	96.6	96.6	100.0	100.0	100.0
4	C-11	80.0	0.0	80.0	76.6	95.7	80.0	83.3	104.1
5	MRG 67	93.3	16.6	96.6	93.3	96.6	96.6	96.6	100.0
6	PDA-5	33.3	0.0	86.6	46.5	53.7	86.6	46.6	53.7
7	ICPL-361	73.3	0.0	96.6	76.6	79.2	96.6	76.6	79.2
8	JNA 421	100.0	0.0	100.0	93.3	93.3	100.0	93.3	93.3
9	BDNA-7	80.0	0.0	100.0	86.6	86.6	100.0	96.6	96.6
10	ICPL-344	33.3	0.0	76.6	63.3	82.6	76.6	63.6	83.0
11	ICPL-262	66.6	0.0	90.0	66.6	74.0	90.0	76.6	85.1
12	ICPL-273	23.3	0.0	76.6	56.6	73.9	76.6	56.6	73.9
13	ICPL-270	20.0	0.0	100.0	50.0	50.0	100.0	76.6	76.6
14	6223-5	66.6	0.0	93.3	76.6	82.1	92.3	76.6	82.1
15	S-80	43.3	0.0	96.6	70.0	72.5	100.0	86.6	86.6
16	RMG 66	63.0	0.0	80.0	46.6	58.2	83.3	76.6	91.9
17	PDM-1	100.0	3.3	100.0	83.3	83.3	100.0	90.0	90.0
18	BDN-3	73.3	0.0	93.3	76.6	82.1	93.3	93.3	100.0
19	ICPL 333	83.3	0.0	93.3	56.6	60.7	93.3	56.6	60.7
20	MRG 53	46.6	0.0	90.0	50.0	55.5	100.0	80.0	80.0
21	MA 162	53.0	0.0	96.6	60.0	62.1	96.6	76.6	79.3
22	ICPL 295	46.6	0.0	76.6	56.6	73.9	83.3	76.6	91.9
23	ICPL 296	43.3	0.0	80.0	43.3	54.1	100.0	56.6	56.6
24	ICPL 348	70.0	0.0	93.3	73.6	78.9	93.3	76.6	82.1
25	PDA-3	23.3	0.0	90.0	70.0	77.8	96.6	86.6	89.6
26	ICPL 338	66.6	0.0	93.3	93.3	100.0	93.3	93.3	100.0
27	ICPL 337	56.6	0.0	96.6	60.0	62.1	96.6	90.0	93.2
28	ICPL 342	86.6	0.0	90.0	63.3	70.3	90.0	76.6	85.1
	Mean	61.4	1.8	91.5	69.4	75.8	93.3	77.5	83.1

At 36 h all the genotypes reached maximum percent of germination in distilled water. However the germination percentage was minimum (76.6) in ICPL 344 and ICPL 273. The germination percentage was less in most of the genotypes in 40 percent sea water treatment compared to distilled water control, except in ICPL 338 where it was same percent in both treatments.

AT 48 h in most of the genotypes the percent germination was almost equal in both treatments. The minimum percent germination was observed in PDA 5 having 46.6 percent in treatment and it was 86.6 percent in control.

Maximum reduction in 40 percent sea water, over control was observed in PDA 5 and ICPL 296 (46.3, 43.4 percent respectively). Genotypes BDNA 5, ICPL 312, C 11, MRG 67, BDN 3 and ICPL 338 showed cent percent germination in 40 percent sea water also.

Rate of germination of pigeonpea genotypes:

The rate of germination of 28 pigeonpea genotype is given in Table 16. During 0-24 h period the germination rate per h. was maximum in most of the cultivars. The maximum germination rate was observed in JNA 421 followed BDNA 5. In the sea water treatment all the genotypes except ICPL 312,

Table 16: Effect of 40% sea water on the rate of germination of pigeonpea cultivars.(h^{-1})

S. No	Genotypes/ h after sowing	0-24h		24-36h		36-48h	
		Distilled water	Sea water (40%)	Distilled water	Sea water (40%)	Distilled water	Sea water (40%)
1	PANT A 106	3.19	0.0	1.67	6.94	0.0	0.0
2	BDNA 5	4.02	0.0	0.28	6.11	0.0	2.22
3	ICPL 312	3.33	1.25	1.67	5.55	0.0	0.28
4	C-11	3.33	0.0	0.0	6.38	0.0	0.56
5	MRG 67	3.89	0.79	0.27	6.39	0.0	0.27
6	PDA-5	1.39	0.0	4.44	3.88	0.0	0.0
7	ICPL-361	3.05	0.0	1.94	6.38	0.0	0.0
8	JNA 421	4.17	0.0	0.00	7.77	0.0	0.0
9	BDNA-7	3.33	0.0	1.67	7.22	0.0	0.83
10	ICPL-344	1.39	0.0	3.61	5.27	0.0	0.02
11	ICPL-262	2.77	0.0	1.95	5.55	0.0	0.83
12	ICPL-273	0.97	0.0	4.44	4.72	0.0	0.50
13	ICPL-270	0.83	0.0	6.67	4.17	0.0	2.22
14	6223-5	2.77	0.0	2.22	6.38	0.0	0.00
15	S-80	1.84	0.0	4.44	5.83	0.28	1.38
16	RMG 66	2.62	0.0	1.42	3.88	0.27	2.50
17	PDM-1	4.17	0.14	0.00	6.67	0.0	0.56
18	BDN-3	3.05	0.0	1.67	6.38	0.0	1.39
19	ICPL 333	3.47	0.0	0.83	4.72	0.0	0.00
20	MRG 53	1.94	0.0	3.62	4.17	0.83	2.50
21	MA 162	2.21	0.0	3.63	5.00	0.0	1.38
22	ICPL 295	1.94	0.0	2.50	4.72	0.56	1.67
23	ICPL 296	1.80	0.0	3.06	3.61	1.67	1.11
24	ICPL 348	2.92	0.0	1.94	6.13	0.0	0.25
25	PDA-3	0.97	0.0	5.56	5.83	0.55	1.38
26	ICPL 338	2.77	0.0	2.22	7.78	0.0	0.00
27	ICPL 337	2.36	0.0	3.33	5.00	0.0	2.50
28	ICPL 342	3.61	0.0	0.28	5.27	0.0	1.11
	Mean	2.53	0.07	2.27	5.63	0.15	0.89

MRG 67, and PDM 1 had no germination.

During 24-36 h period the germination rate was maximum in the treatment than in control in most of the genotypes and it was maximum during this period as compared with other intervals. There was no further increase in germination after 24 h in C 11, JNA 421 and PDM 1 in control.

During 36-48 h there was no germination in all the cultivars in control except cv S 80, RMG 66, MRG 53, ICPL 295 and PDA 3. Out of 28, 20 pigeonpea cultivars germinated after 36 h after sowing. The maximum germination rate was observed in cv ICPL 337 and minimum in ICPL 334.

4.5 SCREENING OF GENOTYPES FOR SALT TOLERANCE AT SEEDLING STAGE:

The effects of 15 percent sea water prepared in 1/2 Hoagland solution on the phytomass accumulation in plant parts of 28 genotypes of pigeonpea are given below:

4.5.1 Leaves

The dry weight of leaves of 28 genotypes is given in Table 17. The dry weight of leaves of all genotypes except PANT A 106 was significantly decreased by sea water treatment. Highest leaf phytomass of 46.7 and 44.0 mg per plant for control and sea water respectively was recorded for ICPL

			Leaves			Root			Stem	
		control	15%sea water	% over control	control	15%sea water	% over control	control	15%sea water	% over control
1	PANT A 106	31.4	31.3	99.6	15.4	15.0	97.4	14.6	10.5	71.9
2	BDNA 5	26.7	23.6	88.4	14.2	12.8	90.1	11.2	8.0	71.0
3	ICPL 312	38.2	31.7	82.9	19.4	17.2	88.6	15.2	15.9	104.6
4	C-11	28.5	30.5	107.0	16.8	14.8	88.1	15.8	14.6	92.4
5	MRG 67	35.2	30.9	87.8	15.5	14.0	90.3	13.5	12.5	92.6
6	PDA-5	31.7	29.3	92.4	18.5	15.4	83.2	15.9	13.8	86.8
7	ICPL-361	37.4	36.0	96.2	21.7	20.0	92.2	21.6	18.6	86.1
8	JNA 421	35.2	22.3	63.3	17.0	10.5	61.8	13.5	10.7	79.2
9	BDNA-7	38.1	35.3	92.6	20.5	17.1	83.4	18.8	13.4	71.3
10	ICPL-344	21.5	20.5	95.3	14.0	12.0	85.7	14.7	13.0	88.4
11	ICPL-262	29.9	26.9	89.9	15.2	14.5	95.4	16.4	13.9	84.7
12	ICPL-273	36.4	33.1	90.9	16.8	16.1	95.8	13.0	12.9	99.2
13	ICPL-270	46.7	44.0	94.2	23.4	20.1	85.9	13.0	18.2	140.9
14	6223-5	36.0	34.0	94.4	16.5	15.5	93.9	16.0	13.2	82.5
15	S-80	35.9	34.0	94.7	19.2	20.0	104.2	14.2	14.0	98.6
16	RMG 66	32.5	31.2	96.0	16.2	14.5	89.5	14.0	14.0	100.0
17	PDM-1	32.5	29.2	89.5	16.0	14.8	92.5	18.5	17.4	94.0
18	BDN-3	34.6	31.2	90.2	17.5	15.0	85.7	18.5	16.8	90.8
19	ICPL 333	35.6	28.8	80.9	17.5	15.5	86.6	15.5	13.5	87.1
20	MRG 53	34.0	30.5	89.7	15.5	15.2	98.1	12.8	9.6	75.0
21	MA 162	30.2	31.2	103.3	18.6	16.0	86.0	13.7	13.0	94.9
22	ICPL 295	28.7	30.3	105.5	19.1	18.2	95.3	16.5	14.7	89.1
23	ICPL 296	34.1	30.9	90.6	17.5	16.5	94.3	13.7	10.5	76.6
24	ICPL 348	32.2	28.1	87.3	19.4	20.6	106.2	11.7	15.6	133.3
25	PDA-3	39.5	31.4	79.5	18.5	15.2	82.2	12.2	10.5	86.1
26	ICPL 338	32.5	26.4	81.2	20.0	13.0	65.0	15.7	12.1	77.1
27	ICPL 337	42.4	30.5	71.9	20.9	18.0	86.1	20.3	14.0	68.9
28	ICPL 342	48.0	26.5	55.2	26.2	16.5	62.9	18.6	16.5	88.7
	Mean	34.4	30.4	88.4	18.1	15.8	87.4	15.3	13.6	88.9

		Leaves	Stem	Root
LSD(0.05)	genotypes	: 1.94	2.98	2.35
	treatments	: 0.52	0.799	0.63
	genotypes x treatment	: 2.74	NS	4.36

Contd.

Table 17 Contd.: Influence of 15% sea water on the total plant weight (mg)and root/shoot ratio in pigeonpea cultvars

S. No	Genotypes	Total plant weight			Root/shoot ratio		
		control	15% sea water	% over control	control	15% sea water	% over control
1	PANT A 106	61.4	56.8	92.5	0.31	0.23	74.2
2	BDNA 5	52.1	44.4	85.2	0.27	0.22	81.5
3	ICPL 312	72.8	64.8	89.0	0.26	0.32	123.1
4	C-11	61.1	59.9	98.0	0.35	0.32	91.4
5	MRG 67	64.2	57.4	89.4	0.27	0.28	103.7
6	PDA-5	66.1	58.5	88.4	0.32	0.31	96.9
7	ICPL-361	80.7	74.6	92.4	0.36	0.33	91.7
8	JNA 421	65.7	43.5	85.0	0.26	0.33	126.9
9	BDNA-7	77.4	65.8	85.0	0.33	0.26	78.8
10	ICPL-344	50.2	45.5	90.6	0.47	0.37	78.7
11	ICPL-262	61.5	55.3	89.9	0.36	0.34	94.4
12	ICPL-273	66.2	62.1	93.8	0.24	0.26	108.3
13	ICPL-270	83.1	82.8	99.0	0.18	0.28	155.5
14	6223-5	68.5	62.7	91.5	0.30	0.27	90.0
15	S-80	69.3	68.0	98.1	0.26	0.26	100.0
16	RMG 66	62.7	59.7	95.2	0.29	0.30	103.4
17	PDM-1	67.0	62.7	93.6	0.38	0.39	102.6
18	BDN-3	70.6	63.0	89.2	0.35	0.36	102.8
19	ICPL 333	68.6	57.8	84.2	0.30	0.30	100.0
20	MRG 53	62.3	55.3	88.7	0.26	0.21	80.8
21	MA 162	62.5	60.2	96.4	0.28	0.27	96.4
22	ICPL 295	64.3	63.2	98.4	0.34	0.30	88.2
23	ICPL 296	65.2	51.9	88.0	0.26	0.22	84.6
24	ICPL 348	66.6	64.3	96.5	0.23	0.32	139.1
25	PDA-3	63.3	51.5	81.3	0.21	0.22	104.5
26	ICPL 338	70.2	57.1	81.3	0.30	0.31	103.3
27	ICPL 337	83.6	62.5	74.7	0.32	0.29	90.6
28	ICPL 342	72.8	59.5	81.7	0.25	0.38	152.0
	Mean	67.1	59.9	89.9	0.29	0.29	101.6

		Total Plant weight	Root/shoot ratio
LSD(0.05)	genotypes	: 1.75	0.012
	treatments	: 0.45	NS
	genotype x treatment	: 2.5	0.023

270. Genotypes differed significantly in phytomass content both in control and sea water treatments. The interaction between genotype and tratment was significant. ICPL 344 had the lowest leaf phytomass both in control and in sea water treatments.

The percentage of decrease in leaf phytomass in sea water was more in ICPL 342 (45.0%). The percentage of leaf phytomass was more (7.0%) in C 11 followed by ICPL 295 and MA 162 in sea water. The range of reduction in leaf phytomass was 0 to 45.0% in most of the genotypes only a minimal reduction in leaf phytomass was observed due to sea water treatment.

4.5.2 Stem

The dry weight of the stem of 28 pigeonpea genotypes is given in Table 17. There was a significant reduction in the dry weight of stem with 15% sea water in all the genotypes except PANT A 106, MRG 53. ICPL 342 had highest stem phytomass in control, whereas ICPL 348 had highest stem phytomass in 15% sea water followed by S-80, ICPL 270 and ICPL 361. Genotypes differed significantly in stem dry weight both in control and sea water treatments.

The percent of decrease in stem dry weight was maximum in JNA 421 (38.0%) followed by ICPL 342 (37.0%). There was a

slight increase in stem dry weight (6.0%) in ICPL 348 followed by S 80 (4.0%). About 23 genotypes out of 28 genotypes showed 0 to 20% reduction and 3 genotypes more than 20% reduction in stem dry weight due to sea water treatment.

4.5.3 Root

The dry weight of roots of 28 pigeonpea genotypes is given in Table 17. There was a significant reduction in the dry weight of root with 15% sea water in all the genotypes except in ICPL 273, S-80 and RMG 66. ICPL 361 had highest root phytomass (21.6 mg) both in control and in 15% sea water (18.6 mg). Genotypes differed significantly in root dry matter content both in control and 15% sea water. The interaction between genotype and treatment was significant.

The percent of reduction in root dry weight was maximum in ICPL 337 (31.0%) due to sea water treatment. There was an increase in root dry weight by 40.0% in ICPL 270 followed by ICPL 312 (4.0%). About 7 genotypes showed 0-10% reductions, 9 genotypes 10-20%, 7 genotypes 20-30% and one genotype more than 30% reduction in root growth due to sea water treatment.

The total plant dry weight is given in Table 17. In most of the genotypes, there was a reduction in total plant dry weight due to 15% sea water treatment. ICPL 270 had max-

imum total dry weight and in control (83.1 mg) and in 15% sea water (82.8 mg).

ICPL 337 showed a maximum reduction in total plant dry weight by 25% over control followed by PDA 3, ICPL 338 and ICPL 342 (18%). About 13 genotypes showed reduction in total plant dry weight in the range of 0-10%.

4.5.4 Root/shoot ratio

Root/shoot ratio of 28 pigeonpea genotypes is given in Table 17. In most of the genotypes there was a reduction in root/shoot ratio when grown in 15% sea water treatment. In some genotypes like ICPL 342, ICPL 348, there was an increase in the root/shoot ratio with 15% sea water treatment.

4.5.5 Root length (cm)

The effect of 15% sea water on root length of 28 pigeonpea genotypes is given in Table 18. In general, there was a significant decrease in root length due to sea water treatment and this genotypes differed significantly in their response to sea water. The maximum root length was observed in PDA 5 both in control and in treatment. There was no effect of sea water treatment on root length of C-11. In both cases the root length was 12.8 cm. In control maximum root length was observed in ICPL 295 and ICPL 273 and in treatment with C-11.

Table 18 : Effect of 15% sea water on Root length and stem height of pigeonpea seedlings.

S. No	Genotypes	Root length (Cm)			Stem height (Cm)		
		control	15% sea water	% over control	control	15% sea water	% over control
1	PANT A 106	12.9	12.1	93.7	9.5	7.6	80.0
2	BDNA 5	10.4	10.2	98.1	7.3	6.9	94.5
3	ICPL 312	13.0	11.9	91.5	8.8	7.5	85.2
4	C-11	12.8	12.8	100.8	9.2	8.8	95.6
5	MRG 67	11.4	11.0	96.5	8.1	7.6	93.8
6	PDA-5	8.5	7.0	82.3	9.6	8.5	88.5
7	ICPL-361	11.0	9.2	83.6	11.5	10.1	87.8
8	JNA 421	10.5	8.1	76.9	10.3	8.0	71.3
9	BDNA-7	13.0	10.0	76.9	10.1	7.2	71.3
10	ICPL-344	12.3	10.8	87.8	9.1	8.2	90.1
11	ICPL-262	15.0	12.6	84.0	10.0	7.0	70.0
12	ICPL-273	13.5	11.8	87.0	8.8	7.9	89.8
13	ICPL-270	10.5	8.9	84.0	11.0	9.4	85.4
14	6223-5	10.0	8.2	82.0	9.3	7.5	80.6
15	S-80	11.4	8.6	84.2	9.6	8.5	88.5
16	RMG 66	11.5	10.0	86.9	10.5	9.7	92.4
17	PDM-1	12.4	11.5	92.7	9.9	8.8	88.9
18	BDN-3	12.6	10.1	83.3	10.8	8.6	79.6
19	ICPL 333	12.2	11.6	94.1	11.2	9.2	82.1
20	MRG 53	11.5	9.0	78.3	9.6	8.5	88.5
21	MA 162	13.0	11.2	86.1	9.8	9.0	91.8
22	ICPL 295	13.5	11.3	83.7	8.4	7.6	90.5
23	ICPL 296	11.3	8.7	77.0	8.7	7.7	80.4
24	ICPL 348	12.0	11.4	95.0	10.8	10.4	96.3
25	PDA-3	11.4	9.8	85.9	9.8	9.1	92.8
26	ICPL 338	11.0	10.4	94.5	9.4	8.7	92.5
27	ICPL 337	13.0	11.3	86.9	9.6	8.5	88.5
28	ICPL 342	13.3	11.5	80.5	10.2	9.0	88.2
	Mean	11.9	10.3	86.9	9.6	8.4	86.9

		Root length	Stem height
LSD(0.05)	genotype	: 1.55	1.68
	treatments	: 0.41	0.45
	genotype x treatment	: NS	NS

All the genotypes except C-11 showed a reduction in root length due to sea water treatment. The maximum percent reduction in root length (23%) was observeed in ICPL 296, JNA 421 and BDNA7 Eight genotypes showed a reduction in the range of 0-10% 15 genotypes 10-20% and 4 genotypes showed more than 20 percent of reduction in root length.

4.5.6 Stem height (cm)

The effect of 15% sea water on stem height of 28 pigeonpea genotypes is given in Table 18. There was a significant reduction in stem height in all the genotypes except ICPL 348 and C-11. ICPL 361 had maximum stem height in both the control and sea water treatments. The genotypes differed in their response to salinty.

The percent of reduction over control for ICPL 262 was 30.0% followed by JNA 421 and BDNA 7, (29.0%). The percent of reduction in stem height differed with genotype. Ten genotypes showed reductin in stem height in the range of 0-10%, 14 genotypes in the range of 10-20% and remaining 4 genotypes showed more than 20% reduction over control due to sea water treatment.

4.5.7 Leaf area (cm^2)

The effect of sea water on leaf are is given in Table 19. There was a significant reduction in leaf area of most of cultivars due to sea water treatment. The maximum leaf area of 7.36 cm^2 per plant was observed in ICPL 296 whereas in treatment it was observed in ICPL 337.

The maximum percent reduction over control (70%) was observed in BDN 3 followed by 68% in PANT A 106. The percent of reduction differed with genotype. Two genotypes showed a percent reduction in leaf area over control in the range of 60-70%, 2 genotypes 50-60%, 7 genotypes 40-50%, 3 genotypes 30-40%, 7 genotypes 20-30%, 3 genotypes 10-20%, and 3 genotypes 0-10%. ICPL 295 showed an increase in leaf area due to sea water treatment.

4.5.8 Specific leaf area (SLA) $cm.wt^{-1}$

The effect of sea water on specific leaf area, a measure of leaf thickness is given in Table 19. In all the genotypes except BDNA 5, ICPL 295, ICPL 337 and ICPL 342 there was a reduction in specific leaf area due to sea water treatment. ICPL 344 showed a maximum specific leaf area of 0.2776 and 0.1496 in both control and treatment respectively.

Table 19: Effect of 15% sea water on the Leaf area and specific leaf area of pigeonpea seedlings. (seedling^{-1})

No	Genotypes	Leaf area (cm^2)			Specific Leaf area($cm.Wt^{-1}$)		
		control	15% sea water	% over control	control	15% sea water	% over control
1	PANT A 106	4.34	1.41	32.5	0.138	0.045	32.6
2	BDNA 5	3.54	3.36	94.8	0.132	0.142	107.3
3	ICPL 312	3.80	2.02	52.9	0.099	0.064	63.9
4	C-11	2.55	2.36	92.4	0.089	0.077	86.3
5	MRG 67	4.21	2.19	51.9	0.119	0.071	59.1
6	PDA-5	3.12	2.26	72.5	0.098	0.077	78.5
7	ICPL-361	3.63	2.61	71.9	0.097	0.073	74.8
8	JNA 421	4.49	2.25	49.9	0.128	0.101	78.8
9	BDNA-7	4.50	2.67	59.4	0.118	0.076	64.0
10	ICPL-344	4.89	3.07	62.6	0.278	0.149	53.9
11	ICPL-262	2.68	1.63	60.8	0.089	0.061	67.7
12	ICPL-273	3.79	2.61	68.9	0.104	0.079	75.8
13	ICPL-270	3.95	3.13	79.2	0.085	0.071	84.1
14	6223-5	4.50	3.24	71.9	0.125	0.095	76.0
15	S-80	4.08	3.21	78.6	0.114	0.094	82.9
16	RMG 66	3.12	2.84	90.9	0.096	0.091	94.7
17	PDM-1	3.04	1.71	56.2	0.094	0.059	62.7
18	BDN-3	6.52	1.99	30.5	0.188	0.064	33.9
19	ICPL 333	4.23	3.03	71.5	0.119	0.105	88.5
20	MRG 53	3.24	1.77	54.7	0.095	0.058	61.4
21	MA 162	3.90	2.94	74.3	0.129	0.094	72.8
22	ICPL 295	2.69	3.05	113.4	0.094	0.101	107.5
23	ICPL 296	7.36	3.62	49.1	0.216	0.117	54.2
24	ICPL 348	3.02	2.46	81.2	0.093	0.087	93.9
25	PDA-3	3.81	2.65	83.3	0.096	0.084	87.5
26	ICPL 338	4.26	2.43	57.1	0.131	0.092	70.3
27	ICPL 337	6.15	4.95	80.6	0.128	0.187	146.0
28	ICPL 342	5.94	3.46	58.2	0.124	0.130	105.5
	Mean	4.12	2.67	64.9	0.122	0.090	74.5

Leaf area

LSD(0.05) genotype : 2.18

treatments : 0.61

The percent of reduction in SLA was maximum in 67% in PANT A 106 followed by 66% in BDN 3. Two cultivars showed a reduction in the range of 60-70%; 3 genotypes 50-40%; 5 genotypes 30-40%; 7 genotypes 20-30%; 5 genotypes 10-20%; and 2 genotypes less than 10% reduction in SLA due to sea water treatment.

4.5.9 Moisture content

The effect of sea water on moisture content in various plant organs is given in Table 20.

In leaves, the sea water treatment brought a reduction in water content in all the 28 genotypes. The reduction differed with genotypes. The maximum moisture content of 251.7 mg was observed in the leaves of ICPL 342 in control and it was 103.2 mg for ICPL 312 in sea water treatment.

Maximum percent reduction over control (90%) in moisture content in leaves was in PANT A 106 with least in S 80. The reduction in percent moisture differed with genotype.

In 19 out of 28 genotypes there was an increase in moisture content in roots, due to sea water treatment. The maximum moisture content was observed in ICPL 270 (237.0 mg) with least (31.0 mg) in PANT A 106.

able 20 : Effect of Sea water on Moisture content in various plant parts of pigeonpea genotypes. (mg. seedling^{-1})

o	Genotypes	Leaves			Root			Stem			Total moisture conter		
		control	15%sea water	% over control	control	15%sea water	% over control	control	15%sea water	% over control	control	15%sea water	% over contro
1	PANT A 106	187.8	17.2	9.1	223.0	31.0	13.9	91.4	143.2	116.7	502.2	191.4	38.1
2	BDNA 5	128.0	68.9	53.3	138.8	121.5	87.5	68.7	80.2	43.9	335.5	270.6	80.6
3	ICPL 312	240.6	103.2	42.9	186.1	233.9	125.7	105.5	68.4	64.8	532.2	405.5	76.2
4	C-11	124.8	43.7	38.0	193.2	164.7	85.2	84.5	71.5	84.6	402.5	282.2	70.1
5	MRG 67	120.4	43.1	35.8	76.5	138.1	180.5	85.0	47.2	55.5	281.9	228.4	81.4
6	PDA-5	144.7	91.0	62.9	87.0	90.5	104.0	89.0	66.4	74.6	320.7	247.9	77.3
7	ICPL-361	231.4	41.8	18.1	206.6	207.6	100.4	45.2	45.7	100.8	483.3	335.0	69.3
8	JNA 421	186.6	40.2	21.5	138.6	65.4	47.2	90.5	39.7	43.9	415.7	145.3	34.9
9	BDNA-7	217.3	60.2	27.7	221.6	156.4	70.6	128.1	62.1	48.5	567.0	278.7	49.1
0	ICPL-344	107.2	78.1	72.8	123.2	149.5	121.3	94.8	119.2	125.7	355.2	346.8	106.6
1	ICPL-262	193.5	16.5	8.5	238.8	126.2	52.8	84.3	46.6	55.3	516.6	189.3	36.6
2	ICPL-273	185.4	55.1	29.7	143.7	153.1	106.5	89.9	46.1	51.3	419.0	254.3	60.7
3	ICPL-270	100.7	50.2	49.8	104.5	237.0	226.8	103.8	98.3	94.7	309.0	385.5	124.7
4	6223-5	186.0	75.5	40.6	201.3	192.8	98.8	101.6	64.9	63.8	489.9	333.2	68.1
5	S-80	53.9	47.5	88.2	143.2	182.0	127.1	90.6	78.0	86.1	287.6	307.5	106.9
6	RMG 66	100.0	80.2	60.2	148.3	119.7	80.7	74.3	55.0	74.0	322.6	234.9	72.8
7	PDM-1	168.0	40.5	24.1	137.5	203.8	148.2	87.2	40.5	46.4	392.7	284.8	72.5
8	BDN-3	155.9	22.1	14.2	133.5	157.0	117.6	92.7	46.7	50.4	382.1	225.8	67.6
9	ICPL 333	174.8	47.2	27.0	126.8	137.9	108.7	78.5	73.2	93.2	380.1	258.3	67.9
0	MRG 53	85.4	33.3	38.9	113.9	100.3	88.1	69.7	21.7	31.1	269.0	155.3	57.7
1	MA 162	174.9	17.4	9.9	136.5	156.8	114.9	79.6	67.9	85.3	391.0	242.1	61.9
2	ICPL 295	144.6	19.7	13.6	125.6	191.7	152.6	107.7	60.9	56.6	377.9	272.3	72.0
3	ICPL 296	183.3	18.6	10.1	164.6	187.9	114.1	90.9	31.3	34.4	438.5	237.8	54.2
4	ICPL 348	150.2	24.4	16.2	60.1	209.8	349.2	82.0	81.2	99.1	292.3	315.4	107.9
5	PDA-3	118.3	16.4	13.9	58.6	127.3	217.2	92.0	50.8	55.2	268.9	194.5	72.3
6	ICPL 338	173.4	7.3	4.2	100.6	114.4	113.7	106.7	25.8	24.2	380.7	147.5	58.7
7	ICPL 337	224.9	47.5	21.1	193.3	136.4	70.6	107.6	50.2	46.7	525.7	234.1	44.5
8	ICPL 342	251.7	49.0	19.5	77.6	138.9	174.6	120.4	69.0	57.5	469.3	256.9	54.7
	Mean	161.2	44.1	31.1	142.9	151.1	121.3	90.8	62.5	66.6	395.6	259.3	71.2

	Leaves	Root	Stem	Total moisture content
D(0.05) genotypes	: 29.8	15.6	10.1	30.1
treatments	: 0.5	5.0	3.5	7.8
genotypes x treatment	: 32.1	20.1	17.2	35.2

The maximum percent moisture content (249.2) over control was found in ICPL 348. In roots of JNA 421 there was 53% percent reduction in moisture content due to sea water treatment. The change in moisture content differed with genotypes.

There was a reduction in moisture content in stem in all the genotypes except in PANT A 106, ICPL 361 and ICPL 344. The maximum moisture content was observed in PANT A 106 (143.2 mg) in sea water treatment.

The percent of increase in moisture content over control in ICPL 344, PANT AI06 and ICPL 361 was 25.7, 0.8 and 16.7 respectively. The maximum reduction of 76% over control was observed in ICPL 338.

The total moisture content in plant was given in Table 20. Except in ICPL 270, ICPL 344, ICPL 348 and S-80 all the other genotypes showed less total moisture content than in control. The maximum moisture content of 567.0 mg was present in BDNA 7 in control and 405.5 mg in ICPL 312 in sea water treatment.

ICPL 270, ICPL 348, S-80 and ICPL 344 showed an increase in total plant moisture content by 24.7, 7.9, 6.9 and 6.6% respectively. The maximum of 65% reduction in total plant moisture content was observed in JNA 421.

4.6. CHANGES IN PERCENTAGE OF Na, K, Zn, Mn, Cu, and Fe:

4.6.1 Sodium

The data on percentage of sodium in various plant parts of 28 pigeonpea genotypes are presented in Table 21. The percentage of sodium in root was more and less in leaves in both the treatments. The percentage of sodium in the leaves was in the range of 0.09 to 0.17 in control. There was a increase in the percentage of sodium about 0.2 to 0.3% due to 15% sea water treatment, in all genotypes. The maximum increase was in PANT A 106 (0.20%) and the minimum increase (0.05%) in ICPL 344.

The percent of sodium increased in stem with 15% sea water treatment. There was not much difference in percent sodium content in stem among the genotypes in the control. The maximum percentage of Na was 0.203 in BDNA 7 and minimum 0.017 in ICPL 348. The increase in sodium percent in stem due to treatment was in the rage of 0.16 to 0.43. The minimum percent increase (0.16) was in ICPL 344 and maximum 0.43 percent in ICPL 338 followed by PANT A106 and ICPL 348. The maximum sodium percent was found in MRG 67 (0.163%).

The percent of sodium in root was increased due to sea water treatments in all the 28 genotypes tested. The increase was maximum in (0.94) PDA 3 over control and minimum

Table 21 : Effect of 15% sea water on percentage of sodium in various plant parts of pigeonpea

S. No	Genotypes	Control			15% sea water		
		Leaves	Stem	Root	Leaves	Stem	Root
1	PANT A 106	0.126	0.143	0.164	0.321	0.536	0.975
2	BDNA 5	0.135	0.147	0.176	0.252	0.387	0.987
3	ICPL 312	0.182	0.162	0.173	0.416	0.354	0.875
4	C-11	0.121	0.180	0.162	0.241	0.512	0.756
5	MRG 67	0.143	0.158	0.156	0.346	0.613	1.026
6	PDA-5	0.171	0.173	0.192	0.352	0.384	1.037
7	ICPL-361	0.123	0.160	0.190	0.320	0.416	0.853
8	JNA 421	0.122	0.176	0.172	0.402	0.472	1.056
9	BDNA-7	0.128	0.203	0.164	0.413	0.538	0.947
10	ICPL-344	0.263	0.178	0.122	0.210	0.381	0.928
11	ICPL-262	0.134	0.162	0.158	0.350	0.502	1.027
12	ICPL-273	0.154	0.118	0.171	0.426	0.312	1.008
13	ICPL-270	0.112	0.120	0.178	0.378	0.426	0.928
14	6223-5	0.126	0.109	0.169	0.289	0.396	0.907
15	S-80	0.113	0.116	0.152	0.301	0.406	1.063
16	RMG 66	0.121	0.126	0.168	0.312	0.397	0.943
17	PDM-1	0.136	0.128	0.170	0.409	0.426	0.875
18	BDN-3	0.127	0.118	0.163	0.382	0.452	1.024
19	ICPL 333	0.119	0.121	0.141	0.392	0.376	0.945
20	MRG 53	0.102	0.122	0.139	0.407	0.472	0.976
21	MA 162	0.100	0.118	0.160	0.282	0.392	0.873
22	ICPL 295	0.131	0.109	0.170	0.342	0.421	0.921
23	ICPL 296	0.142	0.110	0.186	0.315	0.526	1.087
24	ICPL 348	0.117	0.107	0.178	0.372	0.497	0.984
25	PDA-3	0.134	0.126	0.167	0.384	0.482	1.131
26	ICPL 338	0.128	0.180	0.153	0.306	0.612	0.982
27	ICPL 337	0.130	0.178	0.159	0.315	0.482	1.097
28	ICPL 342	0.098	0.188	0.183	0.374	0.516	1.048
	Mean	0.133	0.144	0.166	0.343	0.453	0.973
	Standard deviation	0.031	0.029	0.015	0.057	0.075	0.084

in (0.61%) C-11. There was not much difference in root sodium content of 28 genotypes in control. The maximum percent of sodium was found in ICPL 337 and minimum in C-11.

Among the three plant parts, the increase in sodium content was more in roots in all the 28 genotypes tested followed by stem and leaves.

4.6.2 Potassium

The data on percentage of potassium in various plant parts of 28 pigeonpea genotypes are presented in Table 22. The percentage of potassium was more in leaves followed by stem and root. There was a decrease in potassium content of leaves due to sea water treatment, in all the genotypes. The decrease was more in C-11, and minimum in ICPL 342. The percentage of potassium was in the range of 2.05 in C-11 to 3.12 in BDNA 7. There was not much difference in leaf potassium content among the genotypes.

The percent of potassium in stem also decreased due to 15% sea water treatment when compared with control in all the genotypes. In control, the maximum percent of potassium was found in ICPL 361 and ICPL 273; and PDA 3 with the treatment. Decrease in potassium content in stem was in the range of 0.01 to 1.1 percent. There were differences in stem potassium content among the genotypes with the treatment.

Table 22 : Effect of 15% sea water on percentage of potassium in various plant parts of pigeonpea

S. No	Genotypes	Control			15% sea water		
		Leaves	Stem	Root	Leaves	Stem	Root
1	PANT A 106	3.04	2.78	2.52	2.84	2.72	1.97
2	BDNA 5	2.96	2.59	2.25	2.75	2.04	1.80
3	ICPL 312	2.56	2.32	2.34	2.12	1.97	1.78
4	C-11	2.84	2.57	2.31	2.05	1.87	2.10
5	MRG 67	2.78	2.58	2.40	2.52	2.42	1.92
6	PDA-5	2.54	2.62	2.56	2.21	1.54	2.50
7	ICPL-361	3.12	2.81	2.48	2.78	2.12	2.13
8	JNA 421	3.06	2.52	2.36	2.36	2.71	2.02
9	BDNA-7	2.87	2.41	2.51	3.12	2.21	1.98
10	ICPL-344	2.52	2.56	2.01	2.42	1.50	0.96
11	ICPL-262	3.16	2.42	2.53	2.78	1.90	1.98
12	ICPL-273	2.79	2.81	2.39	2.18	1.76	2.16
13	ICPL-270	3.04	2.46	2.42	2.52	2.14	1.92
14	6223-5	3.15	2.58	2.46	3.06	1.98	2.29
15	S-80	3.19	2.34	2.37	2.82	2.16	1.93
16	RMG 66	2.86	2.61	2.58	2.70	2.51	2.42
17	PDM-1	2.90	2.78	2.41	2.40	2.05	1.96
18	BDN-3	2.92	2.76	2.52	2.12	2.22	1.83
9	ICPL 333	3.12	2.31	2.45	2.85	1.72	1.89
0	MRG 53	2.79	2.70	2.39	2.86	2.51	2.05
1	MA 162	2.85	2.58	2.41	2.64	2.17	1.92
?	ICPL 295	3.16	2.49	2.52	2.98	1.96	1.82
	ICPL 296	2.89	2.61	2.48	2.64	2.53	2.10
	ICPL 348	3.01	2.71	2.56	2.42	2.24	2.21
	PDA-3	2.85	2.69	2.43	2.79	2.79	1.84
	ICPL 338	2.41	2.59	2.51	2.30	2.16	1.75
	ICPL 337	2.78	2.64	2.59	2.64	2.48	2.13
	ICPL 342	2.48	2.60	2.34	2.51	2.41	1.83
	Mean	2.17	2.59	2.43	2.58	2.17	1.97
	Standard deviation	0.22	0.14	0.12	0.29	0.34	0.27

Table 22 : Effect of 15% sea water on percentage of potassium in various plant parts of pigeonpea

S. No	Genotypes	Control			15% sea water		
		Leaves	Stem	Root	Leaves	Stem	Root
1	PANT A 106	3.04	2.78	2.52	2.84	2.72	1.97
2	BDNA 5	2.96	2.59	2.25	2.75	2.04	1.80
3	ICPL 312	2.56	2.32	2.34	2.12	1.97	1.78
4	C-11	2.84	2.57	2.31	2.05	1.87	2.10
5	MRG 67	2.78	2.58	2.40	2.52	2.42	1.92
6	PDA-5	2.54	2.62	2.56	2.21	1.54	2.50
7	ICPL-361	3.12	2.81	2.48	2.78	2.12	2.13
8	JNA 421	3.06	2.52	2.36	2.36	2.71	2.02
9	BDNA-7	2.87	2.41	2.51	3.12	2.21	1.98
10	ICPL-344	2.52	2.56	2.01	2.42	1.50	0.96
11	ICPL-262	3.16	2.42	2.53	2.78	1.90	1.98
12	ICPL-273	2.79	2.81	2.39	2.18	1.76	2.16
13	ICPL-270	3.04	2.46	2.42	2.52	2.14	1.92
14	6223-5	3.15	2.58	2.46	3.06	1.98	2.29
15	S-80	3.19	2.34	2.37	2.82	2.16	1.93
16	RMG 66	2.86	2.61	2.58	2.70	2.51	2.42
17	PDM-1	2.90	2.78	2.41	2.40	2.05	1.96
18	BDN-3	2.92	2.76	2.52	2.12	2.22	1.83
9	ICPL 333	3.12	2.31	2.45	2.85	1.72	1.89
0	MRG 53	2.79	2.70	2.39	2.86	2.51	2.05
1	MA 162	2.85	2.58	2.41	2.64	2.17	1.92
2	ICPL 295	3.16	2.49	2.52	2.98	1.96	1.82
3	ICPL 296	2.89	2.61	2.48	2.64	2.53	2.10
4	ICPL 348	3.01	2.71	2.56	2.42	2.24	2.21
5	PDA-3	2.85	2.69	2.43	2.79	2.79	1.84
6	ICPL 338	2.41	2.59	2.51	2.30	2.16	1.75
7	ICPL 337	2.78	2.64	2.59	2.64	2.48	2.13
8	ICPL 342	2.48	2.60	2.34	2.51	2.41	1.83
	Mean	2.17	2.59	2.43	2.58	2.17	1.97
	Standard deviation	0.22	0.14	0.12	0.29	0.34	0.27

The highest potassium content (2.79%) was found in PDA 3 and minimum (1.90) in ICPL 262.

The percent of potassium in root was decreased due to sea water treatment in all the 28 genotypes. The decrese was maximum (1.15%) in ICPL 344 over control and minimum (0.06%) in PDA 5. The maximum percent of potassium was found in PDA 5 and minimum in ICPL 344. There was not much difference in root potassium content among 28 genotypes.

There was a decrease in potassium content in all the plant parts of pigeonpea due to 15% sea water treatment. The decrease was more in roots in most of the genotypes.

4.6.3 Zinc

The data on concentration of zinc in various plant parts of 28 pigeonpea genotypes are presented in Table 23. The concentration of zinc was more in leaves followed by root and stem in both control and treatment. There was no particular trend in increasing the zinc content in leaves due to 15% sea water treatment. Thirteen genotypes showed an increase in zinc content due to the treatment, but others showed decrease in zinc content in leaves with treatment. The maximum decrease was in 3.3% in C-11 due to the treatment.

Table 23 : Effect of 15% sea water on Zinc content (ppm) in various plant parts of pigeonpea

S. No	Genotypes	Control			15% sea water		
		Leaves	Stem	Root	Leaves	Stem	Root
1	PANT A 106	77.5	56.4	65.8	78.5	56.0	63.1
2	BDNA 5	82.3	56.4	78.0	82.4	55.8	76.5
3	ICPL 312	79.6	58.4	70.4	81.2	56.8	70.1
4	C-11	83.4	61.8	79.4	80.6	61.2	76.8
5	MRG 67	76.2	49.5	64.8	74.8	50.1	62.8
6	PDA-5	82.6	53.2	75.2	80.5	53.3	75.0
7	ICPL-361	83.3	60.4	79.5	84.8	60.0	78.5
8	JNA 421	80.6	58.5	70.4	81.4	57.8	69.2
9	BDNA-7	79.7	44.7	72.8	79.7	43.8	71.8
10	ICPL-344	77.5	47.5	65.8	75.2	48.1	66.2
11	ICPL-262	82.7	52.0	70.3	81.8	49.4	68.4
12	ICPL-273	81.8	51.4	69.0	81.0	48.7	69.4
13	ICPL-270	76.8	49.9	67.8	76.9	49.0	67.2
14	6223-5	81.6	55.3	65.8	82.2	53.5	64.8
15	S-80	80.1	54.0	70.8	78.1	55.2	71.2
6	RMG 66	83.1	51.1	78.4	83.5	50.9	78.1
7	PDM-1	74.4	49.6	67.8	75.1	47.6	66.2
)	BDN-3	79.5	50.9	65.2	80.0	49.8	65.0
	ICPL 333	76.4	54.1	68.4	77.1	52.8	67.8
	MRG 53	80.5	58.5	70.8	80.5	56.9	68.8
	MA 162	78.8	57.6	69.1	76.5	57.0	66.5
	ICPL 295	77.4	55.5	68.5	77.0	54.8	68.0
	ICPL 296	78.4	53.5	70.5	77.2	53.5	69.2
	ICPL 348	85.7	49.5	76.4	83.5	48.4	76.8
	PDA-3	81.9	52.1	70.3	82.2	50.8	70.3
	ICPL 338	79.9	50.1	70.1	80.1	50.2	69.4
	ICPL 337	78.3	49.2	68.5	79.2	48.4	68.5
	ICPL 342	83.0	50.6	74.8	84.2	49.3	72.8
ean		80.1	53.3	70.9	79.8	52.5	69.9
andard eviation		2.8	4.1	4.3	2.8	4.2	4.4

Table 23 : Effect of 15% sea water on Zinc content (ppm) in various plant parts of pigeonpea

S. No	Genotypes	Control			15% sea water		
		Leaves	Stem	Root	Leaves	Stem	Root
1	PANT A 106	77.5	56.4	65.8	78.5	56.0	63.1
2	BDNA 5	82.3	56.4	78.0	82.4	55.8	76.5
3	ICPL 312	79.6	58.4	70.4	81.2	56.8	70.1
4	C-11	83.4	61.8	79.4	80.6	61.2	76.8
5	MRG 67	76.2	49.5	64.8	74.8	50.1	62.8
6	PDA-5	82.6	53.2	75.2	80.5	53.3	75.0
7	ICPL-361	83.3	60.4	79.5	84.8	60.0	78.5
8	JNA 421	80.6	58.5	70.4	81.4	57.8	69.2
9	BDNA-7	79.7	44.7	72.8	79.7	43.8	71.8
10	ICPL-344	77.5	47.5	65.8	75.2	48.1	66.2
11	ICPL-262	82.7	52.0	70.3	81.8	49.4	68.4
12	ICPL-273	81.8	51.4	69.0	81.0	48.7	69.4
13	ICPL-270	76.8	49.9	67.8	76.9	49.0	67.2
14	6223-5	81.6	55.3	65.8	82.2	53.5	64.8
15	S-80	80.1	54.0	70.8	78.1	55.2	71.2
16	RMG 66	83.1	51.1	78.4	83.5	50.9	78.1
17	PDM-1	74.4	49.6	67.8	75.1	47.6	66.2
18	BDN-3	79.5	50.9	65.2	80.0	49.8	65.0
19	ICPL 333	76.4	54.1	68.4	77.1	52.8	67.8
20	MRG 53	80.5	58.5	70.8	80.5	56.9	68.8
21	MA 162	78.8	57.6	69.1	76.5	57.0	66.5
22	ICPL 295	77.4	55.5	68.5	77.0	54.8	68.0
23	ICPL 296	78.4	53.5	70.5	77.2	53.5	69.2
24	ICPL 348	85.7	49.5	76.4	83.5	48.4	76.8
25	PDA-3	81.9	52.1	70.3	82.2	50.8	70.3
26	ICPL 338	79.9	50.1	70.1	80.1	50.2	69.4
27	ICPL 337	78.3	49.2	68.5	79.2	48.4	68.5
28	ICPL 342	83.0	50.6	74.8	84.2	49.3	72.8
	Mean	80.1	53.3	70.9	79.8	52.5	69.9
	Standard deviation	2.8	4.1	4.3	2.8	4.2	4.4

The content of zinc in stem decreased due to treatment in all genotypes except in MRG 67, ICPL 344 and S-80. The maximum decrease was found in ICPL 273. The maximum content of zinc was found in C-11 in both control and treatment.

There was a decrease in zinc content of roots in treatment compared to control in all the 28 pigeonpea genotypes except S-80. The decrease was in the range of 0 to 2.7 ppm. The maximum zinc content was in C-11 in both the control and treatment.

There was a decrease in Zn content in root due to treatment in all the genotypes except ICPL 344, ICPL 270, RMG 66 and ICPL 348. The genotypes differed in the zinc content in leaves due to treatment, except three genotypes, all the others showed a decrease in stem zinc content due to treatment.

4.6.4 Manganese

The data on concentration of manganese in various plant parts of 28 pigeonpea genotypes are given in Table 24. The content of manganese was more in leaf followed by stem and root.

The content of manganese in leaves was in the range of 25.5. to 28.4 ppm. With the treatment of sea water, only a

Table 24 : Effect of 15% sea water on Manganese content(ppm) in various plant parts of pigeonpea

S. No	Genotypes	Control			15% Sea Water		
		Leaves	Stem	Root	Leaves	Stem	Root
1	PANT A 106	28.2	21.5	9.5	29.1	22.4	10.2
2	BDNA 5	27.5	20.2	8.5	28.0	21.5	9.3
3	ICPL 312	25.5	22.0	7.9	25.9	23.1	8.5
4	C-11	26.5	21.9	10.2	26.3	22.8	10.7
5	MRG 67	28.4	22.5	8.5	28.7	23.1	8.9
6	PDA-5	25.6	19.8	8.2	26.2	21.2	9.5
7	ICPL-361	26.8	18.9	9.2	27.0	19.5	9.7
8	JNA 421	27.2	20.3	9.1	28.1	21.4	9.8
9	BDNA-7	28.1	21.2	8.6	28.5	22.6	9.4
10	ICPL-344	27.8	20.9	8.7	27.9	23.4	9.7
11	ICPL-262	28.4	22.2	7.9	28.3	22.5	8.9
12	ICPL-273	27.9	22.0	8.1	28.2	22.7	10.3
13	ICPL-270	26.8	24.8	7.8	27.5	25.3	8.2
14	6223-5	27.4	19.2	8.5	28.2	20.8	9.2
15	S-80	27.0	19.8	9.0	27.9	20.3	9.6
16	RMG 66	28.2	19.7	8.8	28.7	19.5	8.9
17	PDM-1	28.3	20.2	7.6	29.1	21.6	8.7
18	BDN-3	27.9	20.6	7.8	27.8	20.8	8.6
19	ICPL 333	27.3	19.8	7.8	27.2	21.5	8.6
20	MRG 53	26.7	19.5	7.5	27.3	22.4	8.6
21	MA 162	27.4	20.2	8.2	28.2	22.2	9.9
22	ICPL 295	28.4	20.5	8.5	28.9	20.0	9.7
23	ICPL 296	25.5	18.4	7.1	27.5	20.7	8.4
24	ICPL 348	26.5	19.6	7.5	26.8	22.4	8.3
25	PDA-3	27.5	19.9	7.9	28.4	23.4	8.5
26	ICPL 338	27.4	20.5	8.2	27.0	22.3	9.0
27	ICPL 337	28.0	21.6	8.0	26.8	23.4	9.2
28	ICPL 342	27.8	21.2	9.6	28.4	22.9	8.5
	Mean	27.4	20.7	8.3	27.8	21.9	9.1
	Standard deviation	0.9	1.3	0.7	0.9	1.3	0.7

marginal increase was observed in most of the genotypes. The increase was in the range of 0.1 to 2.0%.

The content of manganese in stem increased in all the genotypes with the treatment. The maximum increase (2.9 ppm) was found in MRG 53. There was not much difference in stem manganese content in control. The maximum stem manganese content was found in ICPL 344 and ICPL 337.

The content of manganese in root was increased due to treatment. The increase was in the range of 0.1 to 2.2 ppm over control with maximum increase in ICPL 273. The maximum manganese content of 10.7 ppm and 10.2 ppm were found in C-11 in the treatment and control respectively.

4.6.5 Copper

The effect of sea water on concentration of copper in various plant parts of pigeonpea are given in Table 25. The concentration of copper was more in root followed by leaf and stem in both control and treatment.

The copper content in leaf w_s^a decreased marginally in 19 genotypes. The decrease was in the range of 0.1 to 1.1 ppm over control. Remaining 9 genotypes showed a slight increase in copper content. The increase was in the range of 0.1 to 1.1 ppm. In C-11 the leaf contained maximum when com-

Table 25 : Effect of 15% sea water on Copper content (ppm) in various plant parts of pigeonpea

S. No	Genotypes	Control			15% Sea Water		
		Leaves	Stem	Root	Leaves	Stem	Root
1	PANT A 106	19.1	16.8	25.5	18.0	17.5	25.7
2	BDNA 5	20.5	20.2	28.0	21.2	20.5	28.7
3	ICPL 312	18.1	17.5	30.8	17.2	17.8	29.4
4	C-11	21.5	19.8	29.8	22.0	20.1	28.5
5	MRG 67	19.8	19.0	26.8	19.4	18.7	26.2
6	PDA-5	17.6	17.7	24.5	17.0	17.5	25.6
7	ICPL-361	18.3	17.8	27.9	17.9	18.2	26.5
8	JNA 421	17.8	18.2	28.4	18.1	18.1	28.0
9	BDNA-7	16.7	14.8	23.3	16.5	15.2	22.2
10	ICPL-344	16.5	15.3	20.5	15.9	16.1	18.5
11	ICPL-262	17.2	16.4	24.7	17.5	16.8	25.0
12	ICPL-273	19.4	17.8	26.4	19.0	17.5	26.2
13	ICPL-270	20.1	15.4	25.8	19.8	15.1	24.9
14	6223-5	19.8	17.1	25.0	18.7	17.5	25.3
15	S-80	18.7	18.8	27.1	18.0	18.5	25.8
16	RMG 66	17.9	18.2	28.0	17.2	17.8	27.5
17	PDM-1	17.5	18.1	27.3	17.0	17.5	26.2
18	BDN-3	19.0	17.8	25.6	18.9	18.0	25.0
19	ICPL 333	18.1	16.5	26.4	18.3	16.2	25.9
20	MRG 53	18.4	18.2	27.2	18.0	17.9	26.8
21	MA 162	17.8	17.1	30.1	17.9	17.0	28.1
22	ICPL 295	18.8	17.9	27.7	18.2	17.7	27.6
23	ICPL 296	19.1	19.0	30.2	18.4	17.9	28.4
24	ICPL 348	18.6	18.4	28.3	18.0	18.2	30.1
25	PDA-3	17.9	17.6	28.6	17.6	16.5	27.4
26	ICPL 338	17.4	17.0	27.0	16.9	16.5	25.6
27	ICPL 337	18.2	18.3	24.7	18.1	17.9	22.5
28	ICPL 342	18.6	18.8	25.9	18.8	19.4	24.8
	Mean	18.5	17.7	26.8	18.2	17.6	26.1
	Standard deviation	1.1	1.3	2.2	1.3	1.2	2.4

pared with other genotypes both in control and treatment.

The genotypes differed in their response in copper content in the stem. Twelve cultivars showed a slight increase in their copper content due to the treatment and other 16 genotypes showed a marginal decrease in the copper content. The maximum content was present in BDNA 5 both in control and treatment.

The copper content in root decreased in treatment compared with the control was observed in twenty two cultivars. The decrease was in the range of 0.1 to 1.8 ppm. Maximum decrease was found in ICPL 348, and the maximum copper content was found in the same genotype in the treatment.

4.6.6 Iron

The effect of sea water on iron content in various plant parts are given in Table 26. The concentration of iron was more in root followed by leaf and stem.

There was an increase in the iron content of leaf in treatment than control in all the genotypes. The maximum increase was found in PDA 3 and minimum in C-11. The maximum iron content was found in the leaf of ICPL 344 and minimum in ICPL 278.

Table 26 : Effect of 15% sea water on Iron content (ppm) in various plant parts of pigeonpea

S. No	Genotypes	Control			15% Sea Water		
		Leaves	Stem	Root	Leaves	Stem	Root
1	PANT A 106	286.5	240.8	342.8	296.5	256.5	376.8
2	BDNA 5	261.4	259.4	335.7	285.2	272.8	385.6
3	ICPL 312	305.7	280.7	328.1	315.4	308.8	360.5
4	C-11	305.1	256.7	325.8	295.6	315.1	388.4
5	MRG 67	315.7	270.5	334.5	325.6	322.8	395.8
6	PDA-5	315.3	267.5	318.4	324.8	315.9	365.2
7	ICPL-361	310.1	251.1	316.8	330.5	320.4	370.3
8	JNA 421	319.4	258.1	333.4	326.5	325.6	409.1
9	BDNA-7	285.1	271.2	325.4	315.4	294.3	378.0
10	ICPL-344	326.4	269.5	335.9	334.8	335.6	381.2
11	ICPL-262	284.5	258.1	345.8	290.5	295.4	389.7
12	ICPL-273	279.0	249.2	334.5	283.6	285.1	380.4
13	ICPL-270	289.9	274.5	324.2	305.8	285.1	375.4
14	6223-5	274.8	281.7	342.6	289.4	290.5	400.5
15	S-80	285.7	259.3	328.4	304.5	295.4	372.3
16	RMG 66	315.5	254.8	330.8	326.4	326.6	385.2
17	PDM-1	305.6	265.7	346.5	325.6	306.1	395.8
18	BDN-3	280.7	243.4	329.6	295.8	285.6	378.4
19	ICPL 333	288.4	256.5	334.5	300.3	298.4	384.1
20	MRG 53	309.3	261.0	336.9	319.5	315.6	385.0
21	MA 162	289.9	249.9	340.6	306.9	304.2	372.6
22	ICPL 295	315.3	250.5	349.8	323.7	325.7	379.4
23	ICPL 296	303.0	248.7	335.3	315.8	309.4	370.5
24	ICPL 348	284.4	252.6	325.6	304.6	295.8	384.2
25	PDA-3	295.4	249.6	339.5	325.4	307.4	385.4
26	ICPL 338	280.9	251.1	328.8	290.7	289.2	384.5
27	ICPL 337	307.4	258.7	342.8	310.8	324.5	395.5
28	ICPL 342	287.1	250.9	333.9	301.8	298.4	385.4
	Mean	296.7	258.6	333.8	309.7	303.8	382.7
	Standard deviation	16.1	10.6	8.2	15.2	18.3	10.7

In the stem also the iron content was increased due to the treatment in all the genotypes. Maximum increase 75.7 ppm over control was found in JNA 421. The minimum increase 29.6 ppm was found in ICPL 295.

The iron content in root was increased due to treatment in all the genotypes. Maximum increase was found in JNA 421 (75.7 ppm).

Of all the three plant parts, the increase was more in root in most of the genotypes.

4.6.7 α-Amylase activity

The effect of sea water on the α-amylase activity was given in the Table 27. There was a reduction in amylase activity due to sea water treatment. Maximum activity was found in C-11 (24.4 mg reducing sugar/g fresh wt/hr) and least was in ICPL 337 in control. Varietal differences were observed in the reduction of α-amylase activity due to sea water treatment. Maximum reduction in α-amylase activity was found in RMG 66 and minimum in S-80.

Table 27 : Effect of 15% sea water on α-amylase activity in the cotyledons of pigeonpea

No.	Genotypes	α-Amylase activity (mg reducing sugar/g F.Wt/h)	
		Control	15% Sea water
1	PANT A 106	22.6	19.2
2	BDNA 5	22.8	18.9
3	ICPL 312	23.2	20.1
4	C-11	24.4	21.8
5	MRG 67	23.1	21.1
6	PDA-5	23.5	17.4
7	ICPL-361	23.3	20.0
8	JNA 421	23.4	20.8
9	BDNA-7	22.8	19.5
10	ICPL-344	22.5	19.2
11	ICPL-262	22.0	19.0
12	ICPL-273	22.2	18.9
13	ICPL-270	23.6	20.2
14	6223-5	23.1	20.0
15	S-80	22.4	20.1
16	RMG 66	23.3	18.1
17	PDM-1	22.8	20.0
18	BDN-3	22.1	19.4
19	ICPL 333	23.9	19.9
20	MRG 53	22.5	18.7
21	MA 162	23.1	19.7
22	ICPL 295	23.0	19.3
23	ICPL 296	22.7	18.4
24	ICPL 348	22.2	19.0
25	PDA-3	23.1	19.5
26	ICPL 338	22.9	18.7
27	ICPL 337	21.9	18.9
28	ICPL 342	22.4	19.2
	Mean	22.9	19.4
	Standard deviation	0.6	0.9

DISCUSSION AND CONCLUSIONS

Seed germination which starts with imbibition of water is adversely effected due to salinity due to decreased water availability by lowered water potential. The percent of water uptake by the pigeonpea seeds showed (Table 4) that the sea water effected the imbibition of water by seed. This was because of high concentration of salts present in sea water. Similar results were found by Ramesh Babu and Sunil Kumar (1979) in C. cajan and C. arietinum where the water uptake after 24 hours of imbibition was low as the (E.C. of the medium increase) osmotic potential decreased. The reason was largely due to osmotic effects. Younis and Hatata (1971) also found that high concentrations of salt adversely affected the seeds during imbibition and as a result they lost their viability.

As the concentration of the sea water decreased the imbibition (% water uptake) was increased, because of the dilution of salts producing less detrimental effect. Maximum imbibition was observed in distilled water (with minimum imbibition at 100% sea water) at all intervals and confirmed that salts present in the sea water reduced the imbibition process. The rate of water uptake was also maximum in distilled water(49.8%) when compared to the treatment (39.0) even at 2 h after sowing.

When seeds placed in distilled water in petridishes under optimum conditions for germination showed a triphasic pattern of water uptake. Initial uptake of water in phase I (i.e. imbibition) was a consequence of the matric forces of the cell walls and cell contents of the seed, phase II was the lag period of water uptake, phase III associated with visible germination. The percentage of water uptake (Fig.3) showed that with distilled water the seeds have entred into phase II 10 h after sowing, but 100% sea water, and 75% sea water the phase I was still continuing even after 12 h after sowing.

The results of Jaiswal and Singh (1985) suggested that high salt concentration not only inhibited the germination of seeds of Tomoto but also delayed. Similar results were also obtained in the present study. In both the genotypes, there was no germination upto 72 h after sowing with 100% sea water. Only 2.6% and 6.8 percent germination was observed in BDN-1 and ICPL 87 respectively even after 84 h. Whereas in control it was 84% and 57.3% in BDN-1 and ICPL 87 respectively at 24 h. The inhibition of germination in comparison to control may be associated with osmotic effect, specific ion or altred enzyme activities (Kurian and Iyengar, 1967). Nieman (1962) associated the poor germination of seed to the specific ion effect or the abnormal activities of enzymes. Prisco and oleary (1970) reported that the inhibition of germination was due to both toxic and osmotic

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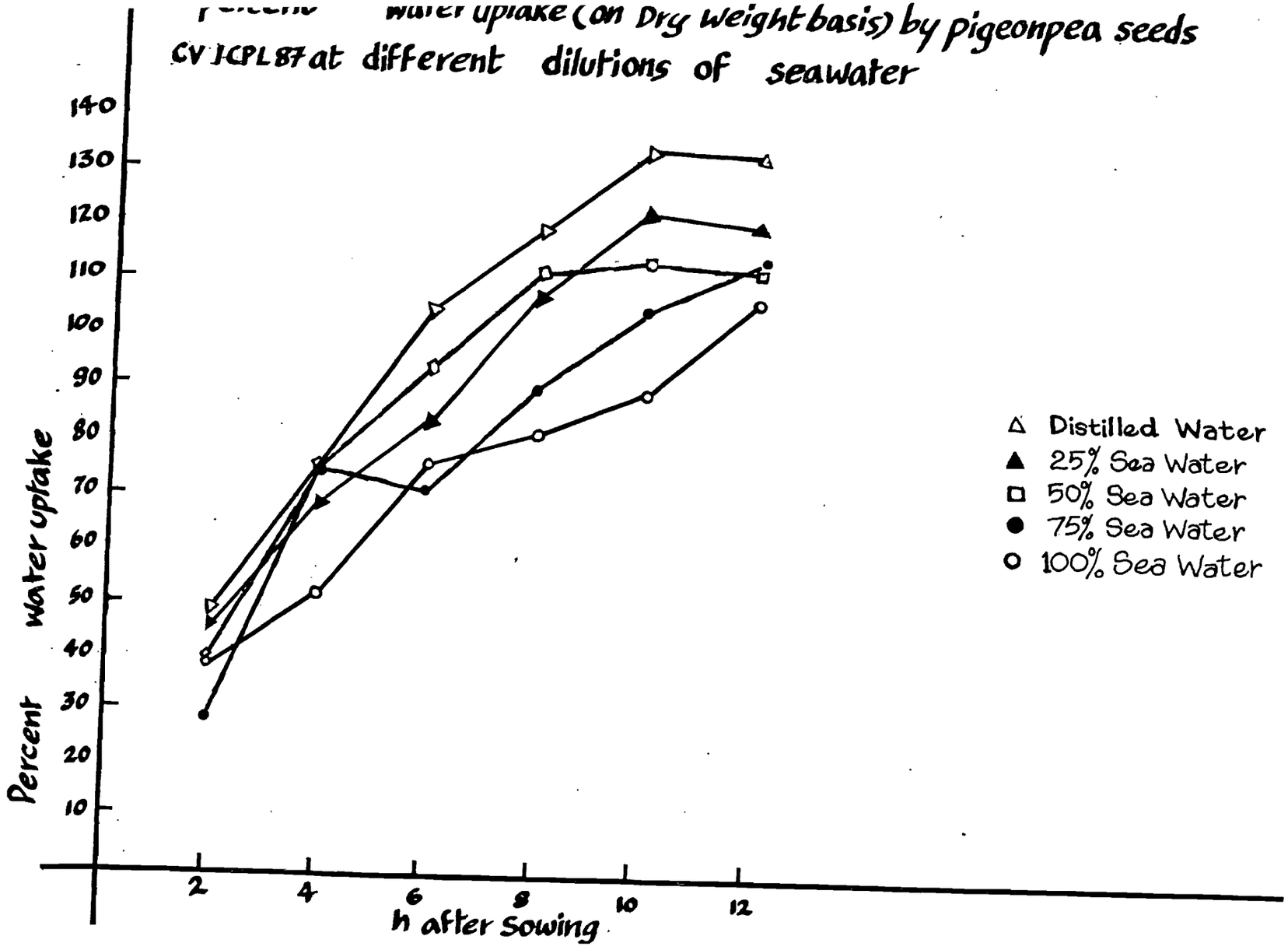
Percent Water uptake (on Dry weight basis) by pigeonpea seeds CV ICPL 87 at different dilutions of seawater



pressure effect of higher salt concentration.

Similar results of reduction of germination due to salinity was observed by many authors (Abel and Mackenzie 1964; paliwal and Maliwal, 1973; Rathore et al., 1977).

The rate of germination was delayed due to the salinity. In both the genotypes, the germination started by 24 h with 37.5% sea water and reached maximum within 24 h, whereas increased concentration of sea water delayed the initiation of germination. The final germination percentage by 84 h was decreased with the increased salinity. 97.3%, 97.3%, 89.3%, 88.0%, 86.6%, 74.6%, 70.6%, 18.6% and 2.6% in BDN-1 in distilled water, 12.5%, 25.0%, 37.5%, 50.0%, 62.5%, 75.0%, 87.5% and 100% sea water respectively. Similar trend was also found in pigeonpea genotype ICPL 87. Paliwal and Maliwal (1973) also got the same results with some arhar and cowpea varieties. The major metabolic events which take place in preparation for germination undoubtedly occur during phase II. This was shown by recent work on a variety of seeds (like Allium cepa. Daucus carota, Apium grareolens, Impatiens sp.) (Bewley and Black, 1978). At high concentrations of salts, the seeds allow phase I to occur but not phase III, and seeds were held in phase II for long time and thus germination delayed. This may be the reason for delayed germination at 72 h in both the genotypes. Similarly Paliwal and Maliwal (1982) observed that germination of crop

varieties of groundnut, sesamum, soybean and mustard was decreased as well as delayed with the increase of salinity (3 to 18 $dSmP^{-1}$). The interaction between salt concentrations and time was significant.

The length of the radicle was decreased with increasing salinity (Table 11). At 62.5% sea water the radicle length was increased upto 5th day and afterwards there was no increase. This may be due to high osmotic pressure, which binds the water and renders it less available to plant roots. As the concentration of sea water decreased the root length was increased and reached maximum in distilled water. The root length was more in Experiment(B) than Experiment(A) at all intervals. The reason is that in Experiment (B) the seeds were first imbibed in distilled water so at the later stage the growth was more in all the treatments when compared with the same treatments in Experiment (A)

The relative growth rate was also decreased with increasing sea water concentration. RRGR of root growth showed a decline over time. In 62.5% sea water and, 50.0% sea water the RRGR was zero between 7-8 days after sowing in Experiment(A). This confirms that eventhough there was a limited root growth during initial period, because of high concentration of the salts in the medium, the growth was later affected. As the concentration of the sea water decreased the RGR was increased to maximum in distilled

water. This again showed that as the concentration of salts is decreased it had less detrimental effect on root growth. Kent and Läuchli (1985) observed that NaCl salinity reduced the germination and early seedling growth of cotton.

When the seeds were imbibed in distilled water and then transferred to sea water solution (Table 12) the RGR was more at all the concentrations of the sea water at all the times than when the seeds were imbibed in sea water. This appears that the root developed when the seeds were imbibed in distilled water it had contributed during later growth of root, but when the seeds were soaked in sea water, only slight root growth took place, but its contribution for newer root growth was decreased. This was again depended on the concentration of the sea water. Experiment (B) also showed decreased root RGR over time and decreased with the increased concentration of the sea water.

The rates of growth of root in length was given in Table 13. The rate of growth was also decreased with the increasing salinity. But at 37.5% sea water the rate of growth was maximum between 7-8 days interval in both the experiments.

It was fixed that 40% sea water may be optimum for screening various genotypes at germination stage. At 36 h (Fig.2) when 94.6% of seeds were germinated in distilled

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water, 48% of seeds were germinated 50% sea water and 77.3% in 37.5% sea water. So the concentration that reduced 50% germination was considered as a optimum concentration for screening.

The data on germination percentage for the 28 pigeonpea genotypes are given in Table 14. Out of twenty eight genotypes tested only three germinated at 24 h with 40% sea water, whereas with the distilled water all the genotypes germinated.

At 36 h ICPL 270, PDA-5 and ICPL 296 showed 50.0%, 46.3%, 45.9% reduction in germination percentages compared to control. Genotypic differences were observed in germination with 40% sea water. Similar observation was made with the varieties of pigeonpea and cowpea by Paliwal and Maliwal (1973) and in wheat (Narayanan 1975). Padmanathan and Rao (1975) reported that artificial salinisation resulted in a reduction in germination in sorghum varieties.

At 48 h after sowing all the 28 genotypes reached it maximum percentage of germination. But, 53.7% and 56.6%, 60.7% germination over control was observed in PDA-5, ICPL-296 and ICPL 333 respectively. Not only the plant species but also their genotypes showed and a differential behaviour to salt at germination and seedling stage. While studying 30 varieties of barley under controlled conditions, Ayers

(1953) found that there were significant differences in salt tolerance which may be of great importance. Similar observations were made by Bhumbla *et al*. (1966) and Harris and Pittman (1919).

The differential behaviour of pigeonpea genotypes may be due to their individual genetic ability to tolerate excess salts. Similar results on differential varietal response were also reported by Kaliappan and Rajagopal (1970) in chillies and Jaiswal *et al* (1975) in peas. Salt stress may affect germination by increasing the osmotic pressure of the soil solution to a point which will retard or prevent the intake of water (Bernstein, 1961) or by causing toxicity to the embryo (Mehta and Desai, 1958). Keren and Evanari (1974) reported that an osmotic potential of −19 bars (of NaCl, 450 mM or sea water diluted 0.75) was the upper limit for germination of *Pancratium maritinum*. The germination percentages reached were found to be inversely proportional to the osmotic potential of the solution. *Triglochin maritima* germinated poorly in treatments with sea water (Binet 1960). Seeds germinated in fresh water at 83.0% versus 30.0% in half strength water. Yadava *et al*. (1975) also found significant differences in the germination response of 9 varieties of guar, when subjected to electrical conductivity levels from 0 to 11 dSm^{-1}.

Genotypes differed in rate of germination also. In most of the genotypes the germination rate was maximum between 24-36 h after sowing. Similar delayed germination was observed by Paliwal and Maliwal (1973); Narayanan (1975).

The dry weight of leaves, stem and root was reduced in almost all the genotypes due to the sea water treatment, but the degree of reduction was differed among genotypes (Table 17). Working with rice, Pearson et al. (1966) also observed that the dry weight of rice seedlings was reduced 50% at weight mean EC value of 6.4 dSm^{-1}. In pigeonpea genotypes ICPL 342 and JNA 421 the reduction was 45% and 36.7% over control respectively. The dry weight of the root of barley seedlings decreased as the level of stress increased except in varieties DL 157 and DL 171 which showed initially an increasing trend upto 12 mmhos EC level and declined thereafter (Kumar et al., 1981).

The dry weight of stem also significantly decreased in all the genotypes. In this, JNA 421 and ICPL 342 showed a reduction of 38.0% and 37.0% over control respectively. Significant genotypic differences were also observed. Amthor (1983) observed that the sodium chloride salinity with range of 0-90 mM was found to inhibit growth of sorghum seedling.

The dry weight of the root also decreased in almost all he genotypes due to salt treatment but percent reduction of

dry weight was more in root than leaves and stem. Similar observations were made by Kumar *et al.*(1981). They found that the dry weight of the root of barley seedlings decreased as the salt stress increased. Number of roots also decreased as the level of salt stress increased in all the varieties.

The total plant dry weight also decreased due to treatment in all the genotypes. The reduction was maximum (18.7%) in PDA 3 and ICPL 338. Prisco and O' Leary (1973) observed a substantial reduction in growth of roots, shoots and leaf area of *Phaseolus vulgaris* by salt stress. In general the presence of soluble salts in the nutrient medium can affect plant growth in two ways. In the first place high concentrations of specific ions can be toxic and induce physiological disorders. Secondly, soluble salts depress the water potential of the nutrient medium and hence restrict the water uptake by plant roots.

The root/shoot ratio decreased with the treatment in 14 genotypes out of 28 genotypes tested. The maximum reduction was (25.8%) observed in PANT A 106. Ahmed (1978) showed that the salt marsh *A. stolonibera* plants were able to maintain root/shoot ratios when grown in water culture containing sodium chloride at concentrations upto 200 mM whereas other two ecotypes showed depressed root/shoot ratios at salt concentrations greater than 100 mM. Except PANT A 106 all other

11 genotypes showed less than 20% reduction over control.

The root length and stem height (Table 18) showed a significant reduction due to treatments. Similar response was observed by Padmanathan and Rao (1975) in sorghum seedlings. The tolerant varieties recorded better root development as compared to susceptable varieties. They also observed this in shoot length. Maximum reduction in root length and stem height was observed in JNA 421, BDNA 7 and ICPL 262. Paliwal and Maliwal (1973) observed that weight of the seedlings of pigeonpea was decreased by 50 to 90 per cent at the highest level of salinity (8 mmhos/cm).

Kent and Läuchli (1985) also found that the addition of 200 mol m^{-3} NaCl to growing media resulted in a large reduction in root fresh weight, but this was ameliorated by about 50% by the addition of 10 mol m^{-3} $CaSO_4$ or $CaCl_2$. Probably, the salinity caused inhibition of root growth which persisted at high Ca^{2+} supply is related to the difference in water potential of the control and high salt treatment and thus due to an osmotic effect.

The leaf area was decreased due to the treatment in all the genotypes except ICPL 295 (Table 19). Out of 28 genotypes tested, 11 genotypes showed more than 40% reduction in leaf area over control. It is in confirmation with the results of Joshi and Nimbalkar (1983). They observed

that leaf area was reduced due to NaCl and Na_2SO_4 salts in Cajanus cajan L. var. C-11. The aerial growth of leaves was primarily through an increase in cell number, cell enlargement, contributing mainly to growth in thickness. Wieman (1965) observed that the salinity suppressed cell enlargement and cell division proportionally in bean leaves. Chloride salinity decreased leaf size of cotton, increased size of epidermal cells and stomata per unit area, and thickened leaves because of excessive developement of palisade and spongy layers (Strogonov, 1964). Sarin and Narayanan (1965) also observed that the rate of expansion of wheat was slower in salt stressed plant which may be due to moisture stress cause by salt stress. The interaction of variety and treatment was found to be significant and the maximum reduction was found in BDN-3.

Specific leaf area (SLA) a measure of leaf thickness was reduced due to salinity. Five genotypes showed more than 40% reduction in SLA due to the salinity. Joshi and Nimbalkar (1983) also observed that leaf thickness of Cajanus cajan was increased due to NaCl and Na_2SO_4 salts. Gauch and Gardens (1968) observed that high salinity caused fewer epidermal cells and stomata per unit area increased surface size of epidermal cells and increased leaf thickness. Genotypes differed in their SLA due to salinity.

Moisture content in various plant organs are given in Table 20. The moisture content was reduced in all the plant organs. The reduction was more in leaves followed by stem and root. Out of 28 cultivars the roots of 17 cultivars showed more moisture content than control. There have been conflicting views expressed in the litrature over the question of whether osmotic stress causes a water deficit in plant tissue and hence inhibits growth (Wainwright, 1980).

The percentage of sodium content in various plant parts was given in Table 21. The Na percent was increased due to the treatment in leaves, stem and root in all the genotypes. Similar observation was by Joshi (1984). He observed that sodium content increased to a considerable extent only at 15 dSm^{-1} of both salts. It increased more under Na_2SO_4 salinity than under NaCl salinity. Increase Na content disturbed the nutrient balance, osomotic regulation and caused specific ion toxicity under saline conditions (Bedunah and Trilica 1979). Kurian (1975) also observed that more Na was accumulated in the stem than the leaves of pearl millet due to the water dilutions . Similar results were obtained in the present study also. Accumulation of Na was more in roots followed by stem and leaves. Per cent of sodium was differed with cultivars. Lal and Bharadwaj (1984) while working with field pea observed enhancement of S, Na content in the plant due to salinity.

Potassium content was decreased due to salinity in all the cultivars in leaves, stem and root, reduction was maximum in root. Potassium not only participate in osomotic adjustment under saline condition but also in turgor mediated response like stomatal and leaf movements. Pigeonpea fails in selective absorption of K under NaCl and Na_2SO_4 salinities (Joshi, 1984). Increased Na content decreases the K content suggesting an antagonism between Na and K. Similarly observations were made in the present study also. Lal and Bharadwaj (1984) also observed decreased content of potassium due to salinity in field pea.

K/Na ratio was decreased due to the salinity (Table 28) when compared with the Control. Narayanan (1975) observed that the K/Na selectivity in the plant , due to the presence of supplemental Ca^{2+} in a highly saline medium. Lauchli and Ostler (1982) found K^+/Na^+ selectivity to be an importnat factor in the salt tolerance of cotton.

Marginal fluctuations were observed in the zinc content in leaf and stem (Table 23), but Zn content of roots was reduced in all the cultivars tested due to salinity. Cultivars differed in the reduction. Maximum reduction was observed in cv. PANT A 106 and cv. C-11. Bhivare and Nimbalkar (1984) observed that salt rich environment disturbed the normal inorganic contents in Phaseolus vulgaris (L) var. Vaghya. The content of Zn was decreased due to the salinity.

Table 28 : Effect of 15% sea water on K/Na ratio in various plant parts of pigeonpea

S. No	Genotypes	Control			15% Sea Water		
		Leaves	Stem	Root	Leaves	Stem	Root
1	PANT A 106	24.13	19.44	15.36	8.85	5.07	2.02
2	BDNA 5	21.92	17.62	12.78	8.16	5.27	1.82
3	ICPL 312	14.06	14.32	13.53	5.09	5.56	2.03
4	C-11	23.47	14.27	14.25	8.51	3.65	2.78
5	MRG 67	19.44	16.33	15.38	7.28	3.05	1.87
6	PDA-5	14.85	15.14	13.33	6.28	4.01	2.43
7	ICPL-361	25.36	17.56	13.05	8.69	5.09	2.49
8	JNA 421	25.08	14.32	13.72	5.87	5.74	1.91
9	BDNA-7	22.42	11.87	14.08	7.55	4.11	2.09
10	ICPL-344	9.58	14.38	16.47	11.52	3.94	1.03
11	ICPL-262	23.58	14.94	16.01	7.94	3.78	1.93
12	ICPL-273	18.48	23.81	13.98	5.12	5.64	2.14
13	ICPL-270	27.14	20.50	13.59	6.67	5.02	2.07
14	6223-5	25.00	23.67	14.57	10.58	4.97	2.52
15	S-80	28.20	19.83	15.59	9.37	5.32	1.81
16	RMG 66	21.03	20.39	15.18	6.60	5.89	2.76
17	PDM-1	21.32	21.72	14.18	5.87	4.81	2.24
18	BDN-3	22.99	23.39	15.46	5.55	4.91	1.79
19	ICPL 333	26.22	19.09	17.37	7.30	4.57	2.00
20	MRG 53	27.35	22.13	17.19	7.03	5.32	2.10
21	MA 162	28.50	21.86	15.06	9.36	5.53	2.19
22	ICPL 295	24.12	22.84	14.82	8.71	4.65	1.98
23	ICPL 296	20.35	21.93	13.33	8.38	4.80	1.93
24	ICPL 348	25.72	25.33	14.38	6.50	4.51	2.24
25	PDA-3	21.26	21.35	14.55	7.26	5.79	1.63
26	ICPL 338	18.83	14.39	16.40	7.52	3.53	1.78
27	ICPL 337	21.38	14.83	16.29	7.87	5.14	1.94
28	ICPL 342	25.31	13.83	12.79	6.71	4.67	1.75
	Mean	22.39	18.61	14.74	7.58	4.79	2.04
	Standard deviation	4.39	3.88	1.29	1.55	0.75	0.35

Manganese content (Table 24) was marginally increased due to the salinity. Chavan and Karadge (1980) noted that there was a increase in Mg content due to the salt stress in all plant parts of groundnut but Bhivare and Nimbalkar (1984) observed that content of Mn showed differential response.

The copper content was decreased in the roots due to the salinity. Bhivare and Nimbalkar (1984) observed the copper content was low in Phaseolus vulgaris in the treatment when compared with the control.

The iron content was increased in all the plant parts of 28 cultivars tested. The increase was more in roots followed by stem and leaves. The content Fe was increased due to salinity in Phaseolus vulgaris (Bhivare and Nimbalkar, 1984). There were marked differences in the increase of iron content due to salinity.

The effect of sea water on the α-amylase activity was given in the table 27. There was a reduction in α-amylase activity due to sea water treatment. Maximum activity was found in C-11 (24.4 mg reducing sugar/g fresh wt/hr) and least was in ICPL 337. Sudhakar et al (1987) reported that the salt stress induced inhibition of α-amylase activity and stimulation of starch phosphorylase activity in the cotyledons of horesegram during early period of germination.

Varietal differences were observed in the reduction of ∝amylase activity due to sea water treatment. Maximum reduction in ∝amylase activity was found in RMG 66 and minimum in S-80. [illegible] and Sarin and Narayanan (1968) proved that a supply of salt resulted in the reduction of amylase activity observed could be either due to a lowering of the synthesis of the amylase enzyme protein or to an inhibition of the enzyme activity.

Thus from the above mentioned studies it is concluded that the high salt content inhibit the imbibition by the pigeonpea seeds, leading to delay in the germination. The salinity also caused a reduction in seedling growth. In pigeonpea cultivars the salt tolerance at germination and seedling stage were different.

The mineral uptake by the plant at a fixed concentration of salt solution can be taken as a criteria for screening the cultivars. Minimum sodium percent was found in C-11, suggesting that this variety may be tolerant to salinity. The uptake of potassium also highly decreased in C-11 with the sea water treatment. The ∝ amylase activity reduced with the increase in the salt content in water. Maximum activity was found in C-11. Genotypic differences were observed for reduction of ∝ amylase activity due to sea water treatment.

SUMMARY

The effect of diluted sea water on imbibition of water by pigeonpea seeds, germination of seeds was studied. Also the screening of pigeonpea germplasm was done and estimated the chemical components in various plant parts.

The percent of water uptake by the pigeonpea seeds showed that the sea water affected the imbibition of water by seeds. As the concentration of the sea water increased the imbibition (percent water uptake) was decreased in genotypes BDN-1 and ICPL 87. There was no germination upto 72 h after sowing with 100 percent sea water. Only 2.6% and 6.8% germination was observed in BDN-1 and ICPL 87 respectively even after 84 h. Whereas in control it was 84 percent and 57.3 percent for BDN-1 and ICPL 87 respectively at 24 h. The rate of germination was delayed due to salinity.

When the seeds were germinated and grown in different concentrations of sea water, the radicle length decreased with increasing salinity. At 62.5 percent sea water the radicle length was increased upto 5th day and afterwards there was no increase. As the concentration of sea water decreased the radicle length was increased and reached maximum in distilled water. The radicle length was more when the seeds were germinated in distilled water. When the seeds were soaked in distilled water and grown in diluted sea

waters, the RRGR was more than that of seeds germinated in diluted sea waters. As the concentration of sea water increased there was a reduction in Absolute growth rate of radicle. Rate of radicle growth was more when the seeds were germinated in distilled water and later grown in diluted sea water as compared to the seeds germinated and grown in diluted sea water.

Out of twenty eight genotypes tested only three germinated at 24 h with 40 percent sea water, whereas with distilled water all the genotypes germinated. During 24-36 h period the germination rate was maximum in the treatment than in control in most of the genotypes.

Dry weight of leaves, stem and root was reduced in almost all the genotypes due to the sea water treatment, but the degree of reduction differed among genotypes. The root/shoot ratio decreased with the treatment in 14 genotypes out of 28 genotypes tested. The root length and stem height showed a significant reduction due to sea water treatment. The leaf area was also decreased due to the treatment in all the genotypes except ICPL 295. In all the genotypes except BDNA 5, ICPL 295, ICPL 337 and ICPL 342 there was a reduction in specific leaf area due to sea water treatment.

The total moisture content in plant was decreased with sea water treatment in all the genotypes except ICPL 270, ICPL 344, ICPL 348 and S-80.

There was an increase in the percentage of sodium about 0.2 to 0.3 percent due to 15 percent sea water treatment in all genotypes. The increase in sodium per cent in stem due to treatment was in the range of 0.16 to 0.43. Among the three plant parts the increase in Sodium cotent was more in root in all the 28 genotypes tested followed by stem and leaves.

There was a decrease in potassium content of leaves due to 15 percent sea water treatment in all the genotypes. The decrease was highest in C-11 and least in ICPL 342. The per cent of potassium in stem and root also decreased in all the 28 genotypes due to 15 percent sea water treatment. Among the three plant parts the decrease in potassium content was more in roots in most of the genotypes.

Thirteen genotypes showed an increase in zinc content due to the treatment, but others showed decrease in zinc content in leaves. The content of zinc in stem decreased due to treatment in all genotypes a except in MRG 67, ICPL 344 and S-80. There was a decrease in Zn content in root due to treatment in all th genotypes except ICPL 344, ICPL 270.

With the treatment of sea water only a marginal increase in Mn content of leaves observed in most of the genotypes. The content of the manganese in stem increased in all the genotypes with the treatment. The content of manganese in root also increased due to treatment.

The copper content in leaf decreased marginally in 19 genotypes. The genotypes differed in their response in copper content in the stem. The copper content in root decreased in treatment compared with the control was observed in twenty two cultivars.

There was an increase in the iron content of leaves of plant grown in sea water in all the genotypes. Iron content in stem and root was also increased due to the treatment in all the genotypes. The maximum increase in stem was found in PDA 3 and in root in the case of JNA 421.

The α amylase activity reduced with the increase in the salt content in water. Varietal differences were observed in the reduction of amylase activity due to sea water treatment. Maximum reduction in α amylase activity was found in RMG 66 and minimum in S-80.

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