PRELIMINARY STUDIES ON INTERRELATED EFFECT OF SODIUM CHLORIDE AND MYCORRHIZAE ON TOMATO PLANTS

BY

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The dissertation submitted by Mr. Tariq Mahmood, in partial fulfilment of the degree of Master of Philosophy, in the Department of Biological Sciences, Quaid-i-Azam University, Islamabad, is found satisfactory and is recommended for the award of degree.

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DEDICATED TO

my honourable Teacher,

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The interrelated effect of NaCl stress (0, 12.50, 25and 50.0 meq/l.) and vesicular-aruuscular mycorrizal inoculation was evaluated for tomato (Lycopersicon esculentum. Mill.) plants grown in pot soil. The salient features studied were the nutrient availability, vegetative and reproductive growth.

The data were recorded at four harvest stages (60, 70, 100 and 130 days) in the absence or presence of natural inoculum. Invitro, other than physical measurements were Flame photometery for Na and K contents, Spectro-photometery for P content in aerial parts of plants and in the soil extracts. While invivo, microscopic observations were carried out to enumerate V.A.M. infection in roots and spores in soil.

Vegetatively, semitolerant tomato plants were well able to cope with salt stress in presence of inoculum. Salt stress tolerance increased as plants grew old. The increase in sodium content of stem and leaves (except fruits) was directly related to its concentration in soil solution. K^+ uptake rather than that of phosphate ions through mycorrhizal roots was hampered by the excess of Na^+ ions. There was insignificant increase in yield by the inoculation.

CHAPTER 1

INTRODUCTION

INTRODUCTION

Pakistan is one of the developing agrarian countries. Her pace of development is limited due to various factors. Her vast plains range amid the arid and semiarid climatic conditions. Precipitation rate is not enough to meet the needs of irrigation. Upward movement of moisture raises the salt level to the fertile furrow slice. Moreover, water seepage from unlined canals adds more salts to the soil. HASSAN et al. (1975) surveyed the total area of 38416.6 thousand acres of which 19546.0 thousand acres of land were salt affected. In addition, QURESHI (1978) pointed out that each year 0.2-0.4 percent of the total arable land is going out of cultivation because of salinity.

When soluble and/or exchangable salts of sodium are in excess, soil structure deflocculates, tilth is impaired and anaerobic conditions pervail. Ultimately the salts interfere with the growth of most of the crop plants. The encroaching salinity has been tackled in the past for which following practices have been used:

Physical methods.

1. Application of excess water for leaching down salts.
2. Provision of artificial drainage both vertical and horizontal.
3. Scraping of surface soil.
4. Ridge sowing.

Chemical treatments.

Gypsum, waste sulphuric acid, crude sulphur etc. bring the soluble salts and sodicity well with in the safe limits.

Biological amendments.

1. Reclamation of saline sodic soils by rice husk added with sulphuric acid yielded the highest average of kallar grass (Diplachne fusca Beauv.) (HUSSAIN and HAMID, 1978).

2. Soil ameliorated by green manure jantar (Sesbania aculeata Poir.) or farm yard manure was recovered effectively (NISHAT, 1978).

3. Plant breeding for salt tolerance.

4. Use of tolerant crop plant species.

5. Mycorrhizal and nitrifying microbes have commendable role in this regard.

Mycorrhizae, that is the association of fungal mycelium with roots of higher plants, help to exchange the required nutrients. HIRREL (1981) has proposed that strains of various endogonaceous species may exist in salt affected soils, which are tolerant to high concentrations of specific ions such as Na^+ and Cl^-. Utilizing such strains would tend to increase the success of establishing mycorrhizae on crops grown in saline soils.

Role and importance of endomycorrhizae are well acclaimed yet only a few references are available regarding their advantage to the crop plants in salt-affected soils. That is why, an experiment was performed to elaborate this impact.

CHAPTER 2

LITERATURE REVIEW

LITERATURE REVIEW

Salinity

Salinity is a common phenomenon of arid and semiarid regions. Although some of the salts reaching the crust of earth are derived from such sources as cosmic dust and volcanic activity however soluble salts can be added from three major sources:

1. Marine source:
    - A. Cyclic salts
    - B. Infiltrating salts
    - C. Fossil salts
2. Lithogenic salts
3. Anthropogenic salts

SUTCLIFFE and BAKER (1974) and KHAN (1978) were of the view that growth is impaired if the concentration in the medium of either essential or non-essential elements exceeds a certain level. This strain could be the result of primary and secondary salt stress of either specific ions or salts present in the medium. The plants show some symptoms indicating the presence of specific salt excess in culture solution. Plants sensitive to sodium show leaf burn symptoms (necrosis) when sodium over accumulates in leaves (HAYWARD and BERNSTEIN, 1958). The leaves of salt sensitive and moderately tolerant plants become deep blue in color (BERNSTEIN, 1960). Increase in concentration of NaCl salt results in the increase of leaf succulence (NIEMAN, 1962 and RASHID, 1976). JENNINGS (1968) explained the leaf succulence and response to sodium depending both on species and composition of nutrient supply, especially on the level of potassium, Moreover, chlorophyll content of leaves decreased and leaves became pale

green (chlorosis) with increasing concentrations of NaCl in beet and pea (NIEMAN, 1962). MASS et al. (1977) added that the salt stressed plants have stunted growth, early defoliation and nutritional imbalances caused by the salinity which creats specific nutrient deficiency symptoms.

AHMED (1965) pointed out the importance of ionic ratios in the soil solution. These have influence on ionic ratios achieved in the plants themselves which inturn would affect growth because only the salts with in the plants and stored in their cells have an influence on the protoplasm and its life functions. Salt-stressed plants frequently resemble P-deficient plants (HEWITT, 1963) in that they have smaller, darker green leaves, decreased shoot/root ratio, decreased tillering, prolonged dormancy of lateral buds, delayed and decreased flowering and fewer and smaller fruits.

BERNSTEIN and HAYWARD (1958) and STROGONOV (1964) have postulated that salt tolerance of plants usually changes during ontogeny. There are several conflicting reports concerning the relative susceptibility of various stages of plant growth to salt stress. DELVALLE and BABE (1947) and KAPP (1947) as refered by BERNSTEIN and HAYWARD (1958) found a linear increase in salt tolerance and age of rice plants. Scientists with the same opinion were STROGONOV (1964), and PEARSON and BERNSTEIN (1959). MAAS et al. (1977) had cited that rice plants in four leaf stage were more sensitive during emergence and early seedling growth than during germination and later stages of growth and grain development. In contrast sugar beet and safflower were more sensitive during germination. OKUSANYA (1980) observed in salt-affected Lavatera

arborea. L. that shoot and root growth was influenced both at the seedling and the young plant stages. Conversely, KOVAL' SKAYA as referred by STROGONOV (1964) found that alfalfa, tomato and rice were more sensitive to salt stress during flowering than at early vegetative stage. Similarly, GREENWAY (1965) found no evidence for an increase in salt tolerance during development of barley.

BERNSTEIN and AYERS (1953,a) stated that size of carrot plants decreased with increasing salinity. Percent decrease in the average weight of roots was pronounced, dry weight increased progressively for tops and roots. However, decrease in stem length, reduction in dry weights, delay in flowering and fruiting due to increasing concentration of NaCl was observed in cotton(WAHHAS et.al., 1975). Similar were the reports of BERNSTEIN and HAYWARD (1958); MUHAMMAD and MAKHDOM (1971); ANSARI and AHMED (1976); CHAUDHRI and WEIBE (1968). HOFFMAN et al. (1978) inferred that increasing salinity consistently reduced the growth of all plant parts and total dry weight of the plant was affected. Although dry weight was not decreased markedly and same was the case with roots (BHATTI et al., 1975).

Other than the vegetative growth, productivity of plants was also affected when grown in saline conditions. The yield fluctuation may depend on the type of salt and its concentrations presence of apparently optimum supply of K the yield increased with the increasing concentrations of NaCl in tomato (BAND, 1980). MAAS and HOFFMAN (1976) got no significant decrease in crop yield until a threshold salinity level was exceeded and then yield decreased almost linearly as salinity increased beyond the threshold.

Comparative studies on the effect of minor quantities of NaCl and Na_2SO_4 proved beneficial for the growth of Basma variety of oriental tobbaco (MORARD et al., 1980). In certain cases available NaCl at lower concentrations in culture solutions proved to be useful for growth. It stimulated the vegetative growth of tomatoes (HAYWARD and LONG, 1941; PEARSON and BERNSTEIN, 1959). Tomato plants are moderately tolerant to high Na concentrations (KLING, 1954 and U.S.S.L. STAFF, 1954). Sodium increased the growth rate in sugar beet (ULRICH and OHKI, 1956; GAUCH, 1957).

Growth of Atriplex halimus. L. was better in presence of NaCl, but excess of salt inhibited the growth (BLUMENTHAL-GOLDSCHMIDT and POLJAKOFF-MAYBER, 1968). Sodium is essential micronutrient for Atriplex vesicaris Heward ex Benth. and increases the dry weight (BROWNELL, 1968) Yet this increase in dry weight which is a function of increased growth, does not signify an increased synthesis of dry matter. GATES et. al. (1966, 1970) studied that Glycine javanica. L. can adapt to high sodicity unaided by divalent ions, provided the increase in salinity is gradual. Increase in total carbohydrates in stem and leaves of rosella plants (Hibiscus sabdariffa L.) was due to increasing concentrations of NaCl (El-SAIDI and HAWASH, 1971).

Diverse opinion has been expressed regarding the competition between sodium and potassium. EPSTEIN and HAGEN (1952) proclaimed that these two ions did not compete on the attachment sites. Whereas, WAISEL (1972) contradicted and was of the opinion that Na^+ and K^+ competed on the same site of metabolic uptake mechanism.

As sodium increased with increase of NaCl, the other contents

like K, Fe, Ca and Mg decreased in different plant organs (GREENWAY, 1962, CHOHAN, 1974; ABDULLAH et al., 1978; KHAN and HAQ, 1978). Decrease in the uptake of K and Mg in presence of high concentrations of NaCl and Na_2SO_4 is followed by an increase in the levels of Ca and Na contents, before folowering in Brassica juncea L.(ANSARI, 1972). Increase in ash, nitrogen, phosphorus, calcium and sodium content of wheat and sorghum was reported by ANSARI and AHMED (1976); however, enzyme activity decreased in wheat in the above mentioned conditions (ANSARI et al., 1977). Further increase in the level of K alongwith Ca, Mg and Cl with the increased uptake of Na in sodic conditions was reported in kallar grass (Diplachne fusca.) by ASLAM et al. (1979).

The presence of Na_2SO_4 alongwith NaCl helps in higher accumulation of Na ions in different parts of Zea mays L. When compared to NaCl alone (KHAN, 1978). While decrease in the upatke of K^+ ions in the presence of higher concentrations of NaCl and Na_2SO_4 is due to the effect of anions (AHMED, 1967). The basic cause of the decrease in the uptake of K in presence of high Na^+ is competitive interrelationship between Na^+ and K^+ (EPSTEIN, 1961; HYDER, 1970). TAL. et al. (1979) observed diminution of K level of NaCl treated plants of jojoba and by the rise in level of Na, the K^+/Na^+ ratio declined to a value about 0.08 in the plants treated with 1000 mmol/l NaCl. The plants deposit much Cl^- and Na^+ ions, while the level of K^+ decreased as compared to control. Contrary to it, BLACK (1960) showed no fall of K^+ level under NaCl salinity in A. vesicaria. GATES et al. (1970) manifested that despite exposing plants to increasing NaCl status in substrate the K content of all glycines

remained higher than that of Na^+ at any treatment level (0.5,35,70,140 meq/l). On increasing NaCl grades NIAZI (1982) has produced obvious inverse effects on the K-uptake in tomato plants. Plants under salt stress show low level of K content. Potassium leakage from roots takes place due to NaCl stress as quoted by WAINWRIGHT (1980).

VANDER HUNERT as referred by WAISEL (1972) suggested that uptake of phosphorus by plant is far higher from alkaline soil, because under such condition P is available as monovalent $H_2PO_4^-$ ion and not as divalent and trivalent ions. GATES et al. (1970) with resistant cultivars of glycine observed marked increase in root P-content with increasing salinity. It may be that the increase in phosphorus was associated with mechanism for controlling the salt entering the roots and preventing it, especially the sodium, from passing to the tops. Such would require energy expenditure and P is usually required for synthesis of metabolic intermediaries in the maintenance of disequilibrium states.

Vesicular-arbuscular mycorrhizae

The members offamily Endog-onaceae exhibit a symbiotic biotrophy by assoicating themselves with roots of plants, where aseptate hyphae form vesicular-arbuscular mycorrhizae (V.A.M) (LAMONT, 1982). TINKER (1980) elaborated the structure of Endomycorrhizae. He explained that they do not have an external sheath, but they form inter and intra-cellular hyphae within the host tissue which are developed by penetrating the roots through a hypha or spore germ tube. The V.A.M. particularly form extensive mycellium within the root cortex and at least two

characteristic structures i.e. arbuscules and vesicles are formed.

TINKER (1980) and LAMONT (1982) observed profusely branched arbuscules originated from "Trunk" hyphae which branches an intercellular hyphae at early stage of infection. The arbuscules are formed in the host cells and are surrounded by its cytoplasm providing an enormous interface for nutrient transfer. More frequently the old mycorrhizae develop bulbous, thick walled vesicles, 50 µm in diameter. They store the absorbed phosphate taken through fungal hyphae and function as store house for the mycorrhizae.

A finely divided root system with abundant root hairs is a "Simple" but efficient device for increasing the absorptive area. Fungal hyphae are even more finely divided than root hairs and substitute for them in special mode of nutrition called mycorrhizas. These "Specialized" roots act by increasing the efficacy of uptake of nutrients. (LAMONT, 1982).

Mycorrhizal maize plants grown by KHAN (1972) were taller with well developed roots and thicker stem. Whereas, inoculated non-phosphate plants have symptoms of P-deficiency, stunted growth with lower desiccated and greenish brown small leaves. Mycorrhizal and non mycorrhizal plants grew alike before transplanting in the field and there were insignificant differences between them fifteen days after transplanting. After 45 days the influence of infection was quite obvious. Dry weight of mycorrhizal non-phosphate plants was much greater than the controls. MORANDI et al. (1979) propagated raspberry plants vegetatively in axenic culture. The plants showed better growth when inoculated with mycorrhizal fungus

at the time of transfer from culture tubes into the soil, mycorrhizal infection level was high (80-90 per 100 roots infected) and the mycorrhizal raspberries were more vigorous and more unifrom in size than N.M. controls. Shoot dry weight production of variety "Bois Blanc" of the raspberry transplanted into acid soil was increased by 71%. DEBAUCHUN et al. (1980) found that all alfalfa cultivars grew more vigorously ($P < 0.05$) in soil inoculated with V.A.M. fungi than in non-inoculated soil.

MOSSE (1973) reviewed that the responses to inoculation were small or insignificant in non sterile soil if the inoculum was mixed with the soil at the time of planting. Responses were large or even larger with rough lemon, troyer citrange and with onion, may be already mycorrhizal or planted/sown on a cushion of inoculum than in "sterilized" soil.

HOLEVAS (1966) and MOSSE (1973) have analysed that potassium concentrations were lower in mycorrhizal plants than in non-mycorrhizal plants. However, inconsistent were the results of few other workers in this regard. POWELL (1974) experimented with the test plant Griselinia littoralis Raoul (Cornaceae) that mycorrhizae augmented K uptake by 23% and total plant growth by 42% with K present in complete solution. There was a further 65% increase in plant growth and 149% increase in K uptake by non-mycorrhizal plants.

Significance of P-absorption by mycorrhizae was initially indicated by the work of BAYLIS (1959). Later on (1970), he

emphasized that plants with poorly developed root hairs may be obligatory mycotrophs in P-deficient soil. The enhanced ability of mycorrhizal maize plants to take phosphorus in P-deficient soils (KHAN, 1972) was akin to the results of previous investigations carried out under controlled green house conditions both by chemical analysis and by feeding ^{32}P to mycorrhizae (GERDEMANN, 1968). POWELL and DANIEL (1978) experimented with rye grass (Lolium perenne L. Cv. Grass land Ruanui) and white clover (Trifolium repens L. Cv. grassland Huia) plants which were infested with Glomus tenuis and other indigenous mycorrhizal fungi recovered 10-27% of phosphate fertilizer supplied to soil, while non-mycorrhizal plants recovered only 0.4-13%.

Salinity and V.A. mycorrhizae

The extramatrical hyphae and spores of V.A.M. species have been discovered in nutrient impoverished soils of maritime sand dunes and in saline sodic soils of arid and semiarid areas (GERDEMANN and TRAPPE, 1974; NICOLSON and JOHNSTON, 1979). Endomycorrhizal association with halophytes and other semi-salt tolerant crop plants is a matter of great consideration (MASON, 1928; BOULARD 1958; BOULARD and DOMINIK, 1966; KHAN, 1976; HIRREL and GERDEMANN, 1980).

GREEN et al. (1976) attempted to germinate endogonaceous spores of Gigaspora coralloidea, which have shown a small percentage of germination at pH 8 in soil extract agar medium. While Glomus mosseae germinated maximum at 15°C and at pH 8. The results were relevant with the environment from where the species were obtained as G. mosseae was obtained from a soil with moderate temperature and

neutral to alkaline pH. HIRREL (1981) germinated 25-30 washed azygospores and compared these in following ionic concentrations of Na^+ and Cl^- $4.30 \times 10^{-2}M$; $8.60 \times 10^{-2}M$; $1.28 \times 10^{-1}M$; $1.71 \times 10^{-1}M$ and $2.14 \times 10^{-1}M$. Preliminary work indicated that germination does not occur in ionic concentrations of $3.4 \times 10^{-1}M$ or greater. Vesicles formed on hyphae of branched germ tubes and were only found in ionic concentrations ineffective to spore germination vegetatively. Spores germinated well in $4.3 \times 10^{-2}M$ and $8.6 \times 10^{-2}M$ concentrations. However, at $1.28 \times 10^{-1}M$ Cl^- germination began to decline.

HIRREL and GERDEMANN (1980) worked on bell pepper (Capsicum annuum L.) and onion (Allium cepa L.) These plants, even inoculated with Gigaspora margaita Beck and Hall did not grow as well and were not extensively colonized as plants inoculated with Glomus fesciculatus (Thaxt sensu Gerd) Gerd and Trappe. Though both mycorrhizal plants grew better than non-mycorrhizal controls. Since the soil in this study was artificially sodified with NaCl, the effect of Na^+ and Cl^- on germination of G. margarita was studied to determine if the low infection obtained in saline soils might be attributed to either or both of these ions.

CHAPTER 3

MATERIALS AND METHODS

MATERIALS AND METHODS

MATERIAL USED:

Seeds.

Tomato (Lycopersicon esculentum Mill.) seeds were obtained from Agriculture Department Rawalpindi. These were sown in earthen pots on 13.6.1981 and they germinated after 12 days of sowing.

Pots and Soil.

In this experiment one hundred and twenty plastic pots were used, as these were durable, portable and there was almost no ionic adsorption on the walls (HEWITT, 1966). Each pot was approximately 20 cm and 14 cm at brim and base respectively and 20 cm deep. To avoid the loss of leachate, no drainage hole was made in the pots, however, quantity of water applied was always kept in mind, not to apply in excess. To fill in the pots, mineral content of the soil was brought from the fields of Agricultural Research Station for Wheat, Rawalpindi, organic matter used was farm yard manure obtained from Nurpur Shahan. Sand fetched from the course of river Swan was also added to keep the soil well porous. Mixture was prepared in the proportions of one part sand, one part organic matter and two parts mineral content of the soil.

Sterilization of soil and inoculation.

Mineral content of the soil used for 60 pots was autoclaved at temperature $110^{o}C$ and pressure 1.6 kg/cm^{2} for half an hour to kill the indigenous flora and fauna of the soil. Whereas, mineral content of other 60 pots was kept unsterilized which contained

indigenous population of 45 endogonaceous spores per 100 grams of soil. This was used as natural inoculum to get the mycorrhizal infection in roots.

Chemical treatment and general care.

All pots were given fertilizer treatment on 6.7.1981. Four sodium chloride levels at the rate of 0.0, 12.5, 25.0 and 50 meq/l were added to the soil twice. First dose was given with the fertilizer application on 6.7.1981, whereas the second dose split by half was given on 27.7.1981 and 8.8.1981.Soil was fertilized to maintain the optimum fertility level with N.P.K in the ratio of 3:2:2. Salts of KH_2PO_4 and NH_4NO_3 were used to prepare nutrient solutions of 10 and 15 meq/l concentration respectively. The pots were kept in a sunfacing corridor of Department of Biological Sciences, Quaid-i-Azam University and its over extended roof intercepted heavy rain showers. Six seedlings per pot were transplanted on 8.7.1981. Weak plants were replaced with flourishing ones from the seedling stock. Later on, plants were thinned to four in each pot.

METHODS USED:

Physical analysis

Plants were first harvested when budding initiated and were sixty days old from the date of sowing. Second harvest was made when plants were in full blossom and were seventy days old. Third harvest was made at the beginning of the fruiting stage, when plants were hundred days old. Final harvest was after one hundred and thirty days, when all fruits were ripe. During each harvest six pots from each salt level were taken at random for morphological and chemical analysis,

three having the inoculum and the other three sterilized. Various features of plants were recorded. Height, number of nodes, fresh and dry weights of shoots were obtained. Number of leaves and their fresh and dry weights were recorded. Absence and presence of flowers was noted. Number of fruits and their fresh and dry weights was an-other parameter studied. Photographs for visual differences in vegetative growth were made as follows:

1. Chlorosis in mycorrhizal and non-mycorrhizal plants.
2. Foliar necrosis.

Chemical analysis.

Plant material was dried at 70°C for 48 hrs and then ground to fine powder. From this 0.5 g powdered material was processed for digestion following mixed acid degestion procedure (ALLEN, 1974). Volume of the digest was raised to 50 ml with distilled water. After filtering through Whatman filter paper No.44,filterate was stored in plastic bottles. Two blanks were prepared for each batch of samples in the same way. Sodium and potassium content was estimated with Flame Photometer (Gallen Kamp No.19/FH. 500), while percent phosphorus content was assayed with Molybdenum blue method (ALLEN, 1974), using the Spectrophotometer (DU-2.Beckman) at 660 n.m.

400 g. soil taken from each representative pot with different salt concent-ration and at each harvest stage was saturated with distilled water to prepare soil paste. Quantity of the water absorbed for each sample was recorded for water holding capacity (CHAPMAN and PRATT, 1961). Insoluble thymol crystals were used as biocide in soil saturation extracts. Extracts were analysed for the soluble content of Na^{+},K^{+} and for extractable phosphate(PO_4^{3-}).

Microscopic observations.

90 grams of soil was sampled from each pot. Wet sieving and decanting technique was used (GERDEMANN and NICOLOSON, 1963). Spores collected on filter paper were counted under stereoscopic microscope (make Olympus) with 10 and 40 magnifications as described by KHAN (1971). Three observations for each pot soil were carried out. To assess fungal colonization, fresh roots were collected and preserved in F.A.A. solution (5 ml. formaldehyde solution, 5 ml. acetic acid and 90 ml 70% alcohol). These roots were cleared in 5% KOH solution in water bath and stained in lactophenol blue stain (0.05 g trypan blue + 20 ml lactic acid + 20 ml glycerol + 20 ml phenol) (PHILLIPS and HAYMAN, 1970). Then ten root pieces each one cm long per sample were mounted in lactophenol and examined under microscope for the following cytological studies:

1. Number of arbuscules and vesicles.
2. Percent infected roots.
3. Length of infected roots.

Occular micrometer was used for above measurements.

Inferrential statistics.

Data were subjected to analysis of variance (ANOVA) on computer system of the Quaid-i-Azam University using the S.S.P package.

Least significant difference (L.S.D) for all possible comparisons of the means of a certain aspect of growth or ionic contents of experimental plants affected by inoculation, sodium chloride treatments and age were calculated as follows:

$$\text{Inoculum Mean} = t \text{ value at } 0.05 \text{ d.f.E (a)} \sqrt{\frac{2 \times \text{M.SE (a)}}{B \times C \times R.}}$$

$$\text{Salinity Mean} = t \text{ value at } 0.05 \text{ d.f.E (b)} \sqrt{\frac{2 \times \text{M.SE (b)}}{A \times C \times R.}}$$

$$\text{Age Mean} = t \text{ value at } 0.05 \text{ d.f.E (c)} \sqrt{\frac{2 \times \text{M.SE (c)}}{A \times B \times R.}}$$

Where, A,B,C and R stand for inoculum (2 levels), sodium chloride (4 concentrations), age (4 intervals) and replicates (3 in number) respectively.

CHAPTER 4

RESULTS AND DISCUSSION

RESULTS AND DISCUSSION

The growth of plant is affected due to various factors. One of these is the presence of salt content in the soil. It has generally been seen that as the concentration of salts increases growth of many plants decreases, for example, growth of Pisum sativum L cv. Alaska had decimated when it was grown in presence of 100mM NaCl (FLOWERS and YEO, 1977) and examples of many other plants are there.

On the other hand, barley plants when grown in the presence of mycorrhizal association grew taller with well developed root system in comparison to the non-mycorrhizal ones (SAIF and KHAN, 1977). Similar were the results of SHUJA (1974) with vegetable plants and SHERRIF O. SANNI (1976) with rice plants.

Therefore, to counteract the stress of NaCl upon the nutritional imbalance of tomato plants role of V.A.mycorrhizae in the nutrients availability and effect on morphological characters were studied. In addition cytological studies of roots and chemical analysis of soils were also carried. The results of all these parameters are discussed under the following headings:

Morphological observations and chemical analysis of aerial parts.

Cytological studies of roots.

Analysis of soil and extracts.

MORPHOLOGICAL OBSERVATIONS AND CHEMICAL ANALYSIS OF AERIAL PARTS

STEM

Stem length.

Stem length as shown in Table No.1 is significantly affected with the presence of inoculum, NaCl treatments and age($P < 0.01$)

The lowest stem length is recorded at the highest NaCl level and it differs from mean stem length obtained in all other cases of NaCl levels ($P < 0.05$). TAL *et al.* (1979) expressed the growth of young jojoba plants (*Simmondsia chinensis*.C.K. Schneid.) by the length of main shoot which fell by the addition of 100-200 mmoles l^{-1} NaCl to the water culture solution. In other experiments, TAL (1971) and RUSH and EPSTEIN (1976) showed that wild tomato species which were originated in arid areas and that of xerophytic species *Atriplex vesicaria* (BLACK, 1960) behave more or less in the same way as the young jojoba plants.

In addition, there is also significant interaction between NaCl levels and age of the plant ($P < 0.05$) as significantly higher mean stem lengths have been recorded at each increasing age interval. This increase in the stem length is self explanatory as it is a natural physiological process. There are insignificant interactions between inoculum and NaCl levels and inoculum and age intervals.

Number of nodes

Data analysed in table No.2 for the number of nodes shows that NaCl levels and age factors are more significant than inoculum.

Table No.1 (a)

ANOVA for stem length alongwith levels of significance for the factors and their interactions.

Source of Variation	Sum of Squares (S.S.)	Degrees of Freedom (D.F.)	Means of Squares (M.S.)	F. Values
Inoculum (A)	432.35	1	432.35	67.89^{**}
Replication (R)	50.06	2	25.03	$3.93^{n.s}$
Error (a) E(a)	12.74	2	6.37	—
Salt Stress (B)	661.08	3	220.36	7.14^{**}
A X B#	238.89	3	79.63	$2.58^{n.s.}$
Error (b) E(b)	370.60	12	30.88	—
Age (C)	19245.12	3	6415.04	227.31^{**}
A X C#	205.62	3	68.54	$2.43^{n.s.}$
B X C#	619.05	9	68.78	2.44^{*}
A X B X C#	482.83	9	53.65	$1.90^{n.s.}$
Error (c) E(c)	1354.61	48	28.22	—

** Significant at $P < 0.01$.
* Significant at $P < 0.05$.
n.s. Insignificantly different at both levels.
Interaction of relevant factors.

Table No.1 (b)

Significance of difference in the mean value of stem length at different NaCl treatment, age intervals and in the absence or presence of inoculum.

Inoculum Means	Non-Inoculated		Inoculated	
	55.41		59.55	
Salt Stress Means	0.00 meq/l	12.50 meq/l	25.00 meq/l	50.00 meq/l
	60.24^{a}	57.56^{a}	58.98^{a}	53.15
Age Means	60 days	70 days	100 days	130 days
	39.1	48.61	68.85	73.41

All the mean values showing common letters are insignificantly different. Otherwise there is a significant difference at $P < 0.05$.

Table No.2 (a)

ANOVA for number of nodes alongwith levels of significance for the factors and their interactions.

Source of Variation	Sum of Squares (S.S.)	Degrees of Freedom (D.F.)	Means of Squares (M.S.)	F. Values
Inoculum (A)	396.09	1	396.09	38.06^{*}
Replication (R)	9.89	2	4.95	$0.48^{n.s.}$
Error (a) E(a)	20.81	2	10.41	—
Salt Stress (B)	1067.78	3	355.93	13.78^{**}
A X B#	289.70	3	96.57	3.74^{*}
Error (b) E(b)	309.96	12	25.83	—
Age (C)	38497.86	3	12832.62	158.40^{**}
A X C#	424.78	3	141.59	$1.75^{n.s.}$
B X C#	1444.51	9	160.50	$1.98^{n.s.}$
A X B X C#	1142.93	9	126.99	$1.57^{n.s.}$
Error (c) E(c)	3888.67	48	81.01	—

** Significant at P ≤0.01.
* Significant at P ≤0.05.
n.s. Insignificantly different at both levels.
Interaction of relevant factors.

Table No.2 (b)

Significance of difference in the mean values of number of nodes at different NaCl treatments, age intervals and in the absence or presence of inoculum.

Inoculum Means	Non-Inoculated		Inoculated	
	73.23		78.75	
Salt Stress Means	0.00 meq/l	12.50 meq/l	25.00 meq/l	50.00 meq/l
	80.71	74.79[a]	75.33[a]	73.12[a]
Age Means	60 days	70 days	100 days	130 days
	51.50	61.16	93.21	98.08

All the mean values showing common letters are insignificantly different. Otherwise there is a significant difference at $P < 0.05$.

However, all possible interactions but between inoculum and NaCl levels ($P < 0.05$), are insignificant. The mean value for mycorrhizal plants is higher and significantly different. The mean value is significantly highest when NaCl level is minimum. It has also been shown by TAL et al. (1979) that as the amount of NaCl increases in the water culture solution, there is decrease in the total number of nodes and branches alongwith the reduction in stem length in jojoba plants.

Fresh weight

As shown in Table No.3 the fresh weight of stem is influenced by all the three factors significantly ($P < 0.01$). All possible interactions are significant ($P < 0.05$). The interaction between NaCl levels and age is even more significant ($P < 0.01$).

The mean values are significantly different and higher in the presence of inoculum. The mean values for stem fresh weight are directly related to the increase in age and at each interval a significantly different value is obtained. The maximum and significantly different mean value is noted at the 25.0 meq/l NaCl level. It has been observed by RHOZEMA and BLOM (1977) that in Agrostis stolonifera.L. the biomass production, stolon length and internode length were stimulated by the presence of NaCl.

Dry weight

SHERIFF O. SANNI (1975) found that dry weight of root, shoot and total phosphorus content showed a positive relation with infection

of V.A.M. in tomato plants. GRAHAM et al. (1976) tested the different strains of V.A.M. fungus (Glomus fasciculatus G. mosseae) which augmented the dry weights of tops, roots and total mycorrhizal potato plant as compared to those of non-mycorrhizal ones. SAIF (1977) in his two field experiments of winter grown vegetable crops viz: carrot (Daucus carota L.) coriander (Coriandrum Sativum L.) onion (Allium cepa L.) and fenugreek (Trigonella foenumgraecum L.) and summer grown vegetable crops viz: musk melon (Cucurbita mochata L.) tomato (Lycopersicon esculentum Miller Goed.) and bringal (Solanum melongens L.) showed that the mycorrhizal plants produced more dry matter through maximum utilization of available nutrients. LAMBERT et al. (1979) referred to an increase in dry matter of shoot. MANJUNATH and BAGYARAJ (1980) worked out that V.A.M. inoculum influenced the onion plant dry matter and growth positively. However, data analysed for our experiment showed (Table No.4) that inoculation had hardly any significant contribution to the dry weight of tomato stems.

ASLAM et al. (1979) noted that dry matter yield in kallar grass grown in sodic soils remains unaffected which indicates that the plant sbmehow can adapt to salinity. This experiment manifests that NaCl levels have significant effect upon stem dry weight ($P < 0.01$) and minimum mean value is obtained at the highest NaCl level interactions of inoculum and NaCl level and between salinity and age have pronounced contribution ($P < 0.01$) contrary to the effects of interactions between inoculum and age and among inoculum, age and NaCl levels.

The mean values are also significantly different at all age intervals and the stem dry weight increases as plant grows more and

Table No.3 (a)

ANOVA for fresh weight of stem alongwith levels of significance for the factors and their interactions.

Source of Variation	Sum of Squares (S.S.)	Degrees of Freedom (D.F.)	Means of Squares (M.S.)	F. Values
Inoculum (A)	22.20	1	22.20	541.71**
Replication (R)	5.65	2	2.82	68.93*
Error (a) E(a)	0.08	2	0.04	—
Salt Stress (B)	125.86	3	41.95	18.97**
A X B#	29.69	3	9.90	4.47*
Error (b) E(b)	26.54	12	2.21	—
Age (C)	2608.68	3	869.56	377.00**
A X C#	21.60	3	7.20	3.12*
B X C#	90.68	9	10.08	4.37**
A X B X C#	46.61	9	5.18	2.24*
Error (c) E(c)	110.71	48	2.31	—

** Significant at $P < 0.01$.
* Significant at $P < 0.05$.
n.s. Insignificantly different at both levels.
Interaction of relevant factors.

Table No.3 (b)

Significance of difference in the mean values of fresh weight of stem at different NaCl treatments, age intervals and in the absence or presence of inoculum.

Inoculum Means	Non-Inoculated		Inoculated	
	12.31		14.57	
Salt Stress Means	0.00 meq/l	12.50 meq/l	25.00 meq/l	50.00 meq/l
	13.42[a]	13.23[a]	14.42	12.69
Age Means	60 days	70 days	100 days	130 days
	7.14	9.51	17.79	19.32

All the mean values showing common letters are insignificantly different. Otherwise there is a significant difference at $P < 0.05$.

Table No.4 (a)

ANOVA for dry weight of stem alongwith levels of significance for the factors and their interactions.

Source of Variation	Sum of Squares (S.S.)	Degrees of Freedom (D.F.)	Means of Squares (M.S.)	F. Values
Inoculum (A)	1.11	1	1.11	$2.51^{n.s.}$
Replication (R)	0.02	2	0.01	$0.02^{n.s.}$
Error (a) E(a)	0.88	2	0.44	—
Salt Stress (B)	2.25	3	0.75	11.89^{**}
A X B#	1.14	3	0.38	6.01^{**}
Error (b) E(b)	0.76	12	0.06	—
Age (C)	160.43	3	53.48	415.36^{**}
A X C#	1.03	3	0.34	$2.67^{n.s.}$
B X C#	3.77	9	0.42	3.26^{**}
A X B X C#	2.00	9	0.22	$1.73^{n.s.}$
Error (c) E(c)	6.18	48	0.13	—

** Significant at $P < 0.01$.
* Significant at $P < 0.05$.
n.s. Insignificantly different at both levels.
Interaction of relevant factors.

Table No.4 (b)

Significance of difference in the mean values of dry weight of stem at different NaCl treatments, age intervals and in the absence or presence of inoculum.

Inoculum Means	Non-Inoculated		Inoculated	
	1.84[a]		2.08[a]	
Salt Stress Means	0.00 meq/l	12.50 meq/l	25.00 meq/l	50.00 meq/l
	2.05[a]	2.03[a]	2.08[a]	1.68
Age Means	60 days	70 days	100 days	130 days
	0.52	0.88	2.86	3.58

All the mean values showing common letters are insignificantly different. Otherwise there is a significant difference at $P < 0.05$.

more ($P < 0.05$). At highest NaCl status the mean value for stem dry weight decreases and is significantly different ($P < 0.05$). There is an inverse relationship between NaCl and this attribute.

Percent water content

Inoculum affects percent water held in stem insignificantly, (Table No.5.).On the other hand, NaCl treatments affect this parameter in plants significantly ($P < 0.05$) and age affects it more significanlty ($P < 0.01$). However, all possible interactions are insignificant.

The mean value of the percent water content in stem is insignificantly different and higher in mycorrhizal plants. The results of "t" test vary greatly from those of analysis of variance, it is mainly due to different assumptions involved in undertaking these tests. ANOVA involves the assumptions that different treatments add different components of variation in total variance, whereas "t" test assumes that the means being tested come from the samples with equal variance. The mean percent water content is highest and significantly different when plants are growing in soil solution without NaCl treatment. Further more, all mean values significantly differ at various age intervals.

Sodium content

Uptake of sodium is related to the quantity of Na available in the culture solution. Accumulation of Na increased in the presence of high NaCl concentrations both in tops as well as in onion roots (BERNSTEIN and AYERS, 1953,b).In halophytes like Suaeda maritima Dum. the accumulation was maximum in the tops (FLOWERS and YEO, 1977).

Table No.5 (a)

ANOVA for percent water content in stem alongwith levels of significance for the factors and their interactions.

Source of Variation	Sum of Squares (S.S.)	Degrees of Freedom (D.F.)	Means of Squares (M.S.)	F. Values
Inoculum (A)	7.03	1	7.03	$0.34^{n.s.}$
Replication (R)	6.92	2	3.46	$0.17^{n.s}$
Error (a) E(a)	41.02	2	20.51	—
Salt Stress (B)	61.07	3	20.36	5.23^{*}
A X B#	8.07	3	2.69	$0.69^{n.s.}$
Error (b) E(b)	46.63	12	3.88	—
Age (C)	1940.42	3	646.81	129.51^{**}
A X C#	5.62	3	1.87	$0.37^{n.s.}$
B X C#	23.18	9	2.57	$0.51^{n.s}$
A X B X C#	13.53	9	1.50	$0.30^{n.s.}$
Error (c) E(c)	239.71	48	4.99	—

** Significant at $P < 0.01$.
* Significant at $P < 0.05$.
n.s. Insignificantly different at both levels.
Interaction of relevant factors.

Table No.5 (b)

Significance of difference in the mean values of percent water content in stem at different NaCl treatments, age intervals and in the absence or presence of inoculum.

Inoculum	Non-Inoculated		Inoculated	
Means	86.89[a]		87.60[a]	
Salt Stress	0.00 meq/l	12.50 meq/l	25.00 meq/l	50.00 meq/l
Means	97.83	87.06[a]	87.24[a]	87.98[a]
Age Means	60 days	70 days	100 days	130 days
	92.59	90.68	83.86	81.85

All the mean values showing common letters are insignificantly different. Otherwise there is a significant difference at $P < 0.05$.

In the present experiment sodium content of stem is significantly affected ($p < 0.01$) by the higher concentration of NaCl in the culture medium (Table No.6). The plants harvested at budding stage contain maximum Na content in stem than the later stages of growth. This result significantly differs with other age levels ($P < 0.05$). The possible reason could be that it was the most active age of the plants, later plant became more resistant. The inoculation affects significantly in this regard ($P < 0.05$). NaCl status and age contributed significantly ($P < 0.01$). All possible interactions are insignificant.

Potassium content

Looking at Table No.7, it is very clear that the amount of K is minimum in stem at highest NaCl level and it is significantly different from the mean values obtained at all other NaCl levels ($P < 0.05$). Age is also a significant factor for this parameter ($P < 0.01$) and all mean values differ at each age interval ($P < 0.05$). K content is highest in stem at budding stage than the later stages of growth.

Inoculum is an insignificant factor, as it did not contribute in the uptake of K by the plant as its mean values are insignificantly different. These results agree with the conclusions of CHAMBERS et. al. (1980). Where $NaNO_3$ addition increased the concentration of Na^+ ions in the shoots of mycorrhizal plants Trifolium subterraneum. L., while K content decreased in those plants. Addition of $(NH_4)_2SO_4$ had little affect on the Na^+ concentration but it decreased the K^+concentration and Na^+transport to the shoots was greatly increased at the expense of K^+.

Table No.6 (a)

ANOVA for sodium content in stem alongwith levels of significance for the factors and their interactions.

Source of Variation	Sum of Squares (S.S.)	Degrees of Freedom (D.F.)	Means of Squares (M.S.)	F. Values
Inoculum (A)	35.67	1	35.67	51.69^{*}
Replication (R)	0.36	2	0.17	$0.26^{n.s.}$
Error (a) E(a)	1.38	2	0.69	—
Salt Stress (B)	65.97	3	21.99	39.73^{**}
A X B#	4.60	3	1.53	$2.77^{n.s}$
Error (b) E(b)	6.64	12	0.55	—
Age (C)	12.26	3	4.09	7.66^{**}
A X C#	0.74	3	0.25	$0.46^{n.s.}$
B X C#	5.56	9	0.62	$1.16^{n.s.}$
A X B X C#	5.55	9	0.62	$1.15^{n.s.}$
Error (c) E(c)	25.62	48	0.53	—

** Significant at $P < 0.01$.
* Significant at $P < 0.05$.
n.s. Insignificantly different at both levels.
Interaction of relevant factors.

Table No.6 (b)

Significance of difference in the mean values of sodium content in stem at different NaCl treatments, age intervals and in the absence or presence of inoculum.

Inoculum Means	Non-Inoculated		Inoculated	
	1.65^{a}		1.83^{a}	
Salt Stress Means	0.00 meq/l	12.50 meq/l	25.00 meq/l	50.00 meq/l
	0.53	1.31	1.73	3.38
Age Means	60 days	70 days	100 days	130 days
	2.31	1.71^{b}	1.33^{a}	1.61^{ab}

All the mean values showing common letters are insignificantly different. Otherwise there is a significant difference at $P < 0.05$.

Table No.7 (a)

ANOVA for potassium content in stem alongwith levels of significance for the factors and their interactions.

Source of Variation	Sum of Squares (S.S.)	Degrees of Freedom (D.F.)	Means of Squares (M.S.)	F. Values
Inoculum (A)	28.38	1	28.38	$5.45^{n.s.}$
Replication (R)	8.44	2	4.22	$0.81^{n.s}$
Error (a) E(a)	10.42	2	5.21	—
Salt Stress (B)	131.5	3	43.68	4.04^{*}
A X B#	18.05	3	6.02	$0.56^{n.s.}$
Error (b) E(b)	129.83	12	10.82	—
Age (C)	9104.16	3	3034.72	$4.07.20^{**}$
A X C#	45.04	3	15.01	$2.01^{n.s.}$
B X C#	117.11	9	13.01	$1.75^{n.s.}$
A X B X C#	33.46	9	3.72	$0.50^{n.s.}$
Error (c) E(c)	357.73	48	7.45	—

** Significant at P ≤0.01.
* Significant at P ≤0.05.
n.s. Insignificantly different at both levels.
Interaction of relevant factors.

Table No.7 (b)

Significance of difference in the mean values of potassium content in stem at different NaCl treatments age intervals in the absence or presence of inoculum.

Inoculum Means	Non-Inoculated		Inoculated	
	17.95[a]		18.78[a]	
Salt Stress Means	0.00 meq/l	12.50 meq/l	25.00 meq/l	50.00 meq/l
	19.42[a]	18.37[a]	18.4[a]	17.27
Age Means	60 days	70 days	100 days	130 days
	31.73	23.94	10.18	8.01

All the mean values showing common letters are insignificantly different. Otherwise there is a significant difference at $P < 0.05$.

Percent phosphorus content

LAMBERT et al. (1979) found a percent phosphorus increase in shoots of mycorrhizal plants. STRIBLEY et al. (1980) reported that several scientists have shown that plants infected with V.A.M. contain generally higher internal phosphorus concentration than do non-mycorrhizal plants of the same size. The effect occurs in a number of hosts and on sterilized or fresh soils. In a few instances infection increased percent phosphorus but did not alter dry weight even though added fertilizer did increase plant growth.

Although the mean values for percent phosphorus content of stem are higher in mycorrhizal plants ($P < 0.05$), yet inoculum itself is insignificant. In the pasture plant, when given an increasing dose of salinity, phosphorus values for tops were stable but these rose by 100-160 percent in roots, although salinity restricted growth, the nutritive value of these pasture plants as reflected by the nitrogen and phosphorus concentration was little affected (GATES et al., 1966)

In this experiment tomato plants show that NaCl status affects the phosphorus content of the plant at $P < 0.05$ and age at $P < 0.01$ (Table No.8) while the interactions between inoculum and NaCl levels and inoculum and age are not much significant. However, the interactions between salinity and age and among inoculum, age and NaCl status are significantly effective ($P < 0.01$ and < 0.05 respectively). The mean value for percent phosphorus content is significantly different at mature fruit stage as well ($P < 0.05$).

Table No.8 (a)

ANOVA for percent phosphorus content in stem alongwith levels of significance for the factors and their interactions.

Source of Variation	Sum of Squares (S.S.)	Degrees of Freedom (D.F.)	Means of Squares (M.S.)	F. Values
Inoculum (A)	0.00000013	1	0.00000013	$0.0149^{n.s.}$
Replication (R)	0.0000649	2	0.00003248	$4.8955^{n.s.}$
Error (a) E(a)	0.0000134	2	0.0000067	—
Salt Stress (B)	0.0008358	3	0.0002786	4.73^{*}
A X B#	0.000341 7	3	0.0001139	$1.93^{n.s.}$
Error (b) E(b)	0.000707	12	0.0000589	—
Age (C)	0.001996	3	0.000665	11.94^{**}
A X C#	0.0000137	3	0.00000458	$0.08^{n.s.}$
B X C#	0.001979	9	0.0002199	3.94^{**}
A X B X C#	0.0011179	9	0.000124	2.22^{*}
Error (c) E(c)	0.0026778	48	0.0000557	—

** Significant at $P < 0.01$.
* Significant at $P < 0.05$.
n.s. Insignificantly different at both levels.
Interaction of relevant factors.

Table No.8 (b)

Significance of difference in the mean values of percent phospherus content in stem at different NaCl treatments, age intervals and in the absence or presence of inoculum.

Inoculum Means	Non-Inoculated		Inoculated	
	0.0052416		0.0111156	
Salt Stress Means	0.00 meq/l	12.50 meq/l	25.00 meq/l	50.00 meq/l
	0.0067145	0.0091125[a]	0.0095687[a]	0.0073187[a]
Age Means	60 days	70 days	100 days	130 days
	0.005475[a]	0.0053875[a]	0.0057791[a]	0.0160729

All the mean values showing common letters are insignificantly different. Otherwise there is a significant difference at $P < 0.05$.

LEAVES

Chlorosis

POLJAKOFF-MAYBER and GALE (1975) have mentioned that under saline conditions the balance of photosynthetic pigment was upset. In more sensitive plants chlorophyll was destroyed due to salinity, in more tolerant plants chlorophyll content increased. Actually salinity affected the strength of forces binding the complex of pigment-protein-lipid in chloroplast structure. As a result, structural changes in chloroplast were induced by salinity and led to the yellowing of leaf. In Plate No.1 non mycorrhizal plants show chlorosis. It can be assumed that mycorrhizae have positively shared to withstand salt-stress in the inoculated plants even at maximum NaCl regime (50.0 meq/l)

Necrosis

Necrosis is the death of foliar tissue pertaining to salt induced stress. This plastic strain was caused by direct primary salt stress i.e. over accumulation of NaCl or indirect primary salt stress, where Na^+ antagonised K^+ and it became deficient thus nitrogen metabolism was perturbed.Diamines like putrescine $\left[NH_2(CH_2)_4NH_2\right]$ could not be processed to proline etc., resulting in toxicity (STROGONOV, 1964). BERNSTEIN and HAYWARD (1958) singled out that plants which were more sensitive to sodium and exhibited characteristic leaf burn symptom when sodium accumulation in leaves became excessive, leaves might have been injured at still lower concentrations of exchangeable sodium even before the unfavourable physical condition of the soil become evident. Bleaching of chlorophyll near tips of okra (Abelmoschus esculentus (L) Moench.) at

Plate No.1

Comparison of leaf color of mycorrhizal (Right) and non-mycorrhizal (Left) tomato plants in presence of NaCl regime (50 meq/l).

Plate No.2

Foliar necrosis in one of the salt-affected tomato plants.

four days age continued in the presence of equal concentrations of NaCl and Na_2SO_4 until leaves became completely brown (KHAN, 1978). Plate No.2 very clearly manifests obvious strain of NaCl stress and browning and curling of the leaf tissue.

Number of leaves

For this parameter the NaCl treatments and age factors are most significant ($P < 0.01$). While presence of inoculum affects significantly ($P < 0.05$). Interactions of inoculum and NaCl levels and NaCl and age influence significantly ($P < 0.05$) Table No.9. However, the interactions of age and inoculum and inoculum x NaCl levels x age intervals are insignificant.

The mean value for the number of leaves in the absence of NaCl is maximum and significantly different from the values at other three NaCl levels. The mean value for the number of leaves increases directly as age interval increases. The effect of inoculum is significant and its mean value is significantly different and higher for inoculated plants ($P < 0.05$). This result coincides with that of SMITH and SMITH (1981). Where mycorrhizal plants showed positive response on the bases of both leaf numbers and weight.

Fresh Weight

Inoculated plants when grown in the absence of NaCl and in the presence of 50.00 meq/l. NaCl show significantly different mean values for the fresh weight of leaves, ($P < 0.05$) Table No.10. These results are at variance with those of KHAN (1972), Who has shown that mycorrhizal plants have more leaf area increase rate at earlier stages of development

Table No.9 (a)

ANOVA for number of leaves alongwith level of significance for the factors and their interactions.

Source of Variation	Sum of Squares (S.S.)	Degrees of Freedom (D.F.)	Means of Squares (M.S.)	F. Values
Inoculum (A)	677.34	1	677.34	72.01^{*}
Replication (R)	20.68	2	10.34	$1.10^{n.s.}$
Error (a) E(a)	18.81	2	9.41	—
Salt Stress (B)	1016.53	3	338.84	8.41^{**}
A X B#	458.36	3	152.78	3.79^{*}
Error (b) E(b)	483.17	12	40.26	—
Age (C)	45289.83	3	15096.61	153.13^{**}
A X C#	567,86	3	189.29	$1.92^{n.s}$
B X C#	1957.93	9	217.55	2.21^{*}
A X B X C#	1659.59	9	184.40	$1.87^{n.s.}$
Error (c) E(c)	4731.99	48	98.58	—

** Significant at $P \leq 0.01$.
* Significant at $P \leq 0.05$.
n.s. Insignificantly different at both levels.
Interaction of relevant factors.

Table No.9 (b)

Significance of difference in the mean values of number of leaves at different NaCl treatments, age intervals and in the absence or presence of inoculum.

Inoculum	Non-Inoculated		Inoculated	
Means	80.66		85.52	
Salt stress	0.00 meq/l	12.50 meq/l	25.00 meq/l	50.00 meq/l
Means	89.29	81.00[a]	82.21[a]	79.87[a]
Age Means	60 days	70 days	100 days	130 days
	57.00	66.87	102.42[a]	106.50[a]

All the mean values showing common letters are insignificantly different. Otherwise there is a significant difference at $P < 0.05$.

Table No. 10 (a)

ANOVA for fresh weight of leaves alongwith levels of significance for the factors and their interactions.

Source of Variation	Sum of Squares (S.S.)	Degrees of Freedom (D.F.)	Means of Squares (M.S.)	F. Values
Inoculum (A)	18.06	1	18.06	53.21*
Replication (R)	2.01	2	1.00	2.95n.s
Error (a) E(a)	0.68	2	0.34	—
Salt Stress (B)	218.49	3	72.83	11.63**
A X B#	36.02	3	12.01	1.91n.s.
Error (b) E(b)	75.15	12	6.26	—
Age (C)	3123.22	3	1041.07	190.79**
A X C#	33.35	3	11.12	2.04n.s.
B X C#	486.13	9	54.01	9.90**
A X B X C#	136.03	9	15.11	2.77*
Error (c) E(c)	261.91	48	5.46	—

** Significant at $P \leq 0.01$.
* Significant at $P \leq 0.05$.
n.s. Insignificantly different at both levels.
Interaction of relevant factors.

Table No.10 (b)

Significance of difference in the mean values of fresh weight of leaves at different NaCl treatments, age intervals and in the absence or presence of inoculum

Inoculum Means	Non-Inoculated		Inoculated	
	14.84		17.01	
Salt Stress Means	0.00 meq/l	12.50 meq/l	25.00 meq/l	50.00 meq/l
	14.73	15.29[a]	16.28[a]	17.42
Age Means	60 days	70 days	100 days	130 days
	8.93	12.03	23.16	19.62

All the mean values showing common letters are insignificantly different. Otherwise there is a significant difference at $P < 0.05$.

and later on both mycorrhizal and non-mycorrhizal plants grew alike. In the present case inoculum affects this attribute significantly ($P < 0.05$). While age and inoculum affect more significantly ($P < 0.01$). Interactions between NaCl levels and age is significant at $P < 0.01$. While interaction among all three factors is significant at $P < 0.05$.

Dry weight

Sodium chloride and age affect the dry weight of leaves significantly ($P < 0.01$) Table No.11. This result is not in accordance with that of HAYWARD and LONG (1941). Where percent dry matter in leaves of tomato plant increased either very slightly or not at all with the increasing concentrations of sodium chloride (20, 54, 90 and 120 mmoles NaCl in base nutrient solution). However, BLACK (1958) has shown that addition of NaCl to the culture medium did increase the dry weight of Atriplex hastata L. over control values as this salt catalysed the rate of thickening and also extended the period of leaf thickening in this case.

Inoculum affects the increase in dry weight insignificantly but the mean values of leaf dry weight for mycorrhizal plants are higher and significantly different. The results of HOWLER et al. (1979) are in favour that the youngest fully expanded leaf blade of cassava (Manihot esculenta Crantz.) and their leaf dry matter increased as a result of mycorrhizal infection. However, MENGE et al. (1978) found no increase in the dry matter of leaves of troyer citrange (Poncirus spp.) when it was infested with Glomus fasciculatus. The mean values in our experiment, at all salinity levels are insignificantly different (Table No.11.b), while increase in dry weight of leaves is directly

Table No.11 (a)

ANOVA for dry weight of leaves alongwith levels of significance for the factors and their interactions.

Source of Variation	Sum of Squares (S.S.)	Degrees of Freedom (D.F.)	Means of Squares (M.S.)	F. Values
Inoculum (A)	0.03	1	0.03	$1.17^{n.s.}$
Replication (R)	0.07	2	0.03	$1.54^{n.s.}$
Error (a) E(a)	0.04	2	0.02	—
Salt Stress (B)	1.77	3	0.59	8.59^{**}
A X B#	0.55	3	0.18	$2.67^{n.s.}$
Error (b) E(b)	0.82	12	0.07	—
Age (C)	94.78	3	31.59	257.90^{**}
A X C#	0.03	3	0.01	$0.08^{n.s.}$
B X C#	5.09	9	0.056	4.62^{**}
A X B X C#	2.14	9	0.24	$1.94^{n.s.}$
Error (c) E(c)	5.88	48	0.12	—

** Significant at $P < 0.01$.
* Significant at $P < 0.05$.
n.s. Insignificantly different at both levels.
Interaction of relevant factors.

Table No.11 (b)

Significance of difference in the mean values of dry weight of leaves at different NaCl treatments, age intervals and in the absence or presence of inoculum.

Inoculum Means	Non-Inoculated		Inoculated	
	1.91		2.17	
Salt Stress Means	0.00 meq/l	12.50 meq/l	25.00 meq/l	50.00 meq/l
	2.05^{a}	2.01^{a}	2.07^{a}	2.04^{a}
Age Means	60 days	70 days	100 days	130 days
	0.85	1.28	2.89	3.14

All the mean values showing common letters are insignificantly different. Otherwise there is a significant difference at $P < 0.05$.

proportional to the increase in age intervals.

Percent water content

SLATYER (1961) concluded that the internal leaf osmotic pressure in case of tomato plants, growing on osmotic substrates made up of diffusible ions paralleled the osmotic pressure of the growth medium and was generally higher than that of the growth medium. After an initial period of adjustment the water uptake by plants is restored to normal. Growth depression was explained by him on the basis that after the initial ion accumulation the degree of hydration of plasma was affected which inturn affected the growth of the plant. WAISEL (1972) quoted that higher water content per unit of leaf surface area was the product of salt induced succulence. Osmotic stress was most deleterious to tomato plants when applied during early growth and recovery was slow as compared to the condition when plants were exposed during their later growth period (DUMBROFF and COOPER, 1974). Salt stress increased the concentration of harmone abscissic acid, this induces stomatal closure thus reducing transpiration and passive uptake of salts. The lowered rate of transpiration results in an increase of the water content of the tissue which reduces the ionic concentration within the plant (POLJAKOFF-MAYBER and GALE, 1975). The effect of salt treatment on water balance in jojoba leaves was not appreciable while relative water content was practically not affected by salt treatments. A great increase in the succulence was found only in plants exposed to 400-450 or more mmol l^{-1} NaCl. The increase of succulence in salt treated plants was suggested as an adaptive response to salinity by JENNINGS(1968).

In our experiment, all the three factors i.e., inoculum NaCl and age matter significantly ($P < 0.01$) as shown in Table No.12. The interaction between inoculum and NaCl status are as significant as among inoculum, NaCl regime and age. While the interactions of both between inoculum and age and NaCl levels and age intervals are significant respectively ($P < 0.05$ and < 0.01). The mean values are significantly different at all age intervals and are the highest and different at maximum NaCl status ($P < 0.05$).

Sodium content

Chloride and sodium were accumulated in high amounts in leaves of jojoba plants grown in saline media. The accumulation was augmented by increasing salt concentration in root medium (TAL et al., 1979). Na content of leaves and stem increased with increasing soil sodicity. The probable reason was that at higher sodicity the dominant ion in soil solution was Na^+ which resulted in its higher uptake by the plants (SALIM et al., 1978). These reports support this experiment where inoculum and sodium chloride levels affected the Na content of leaves significantly (P 0.01). While the interactions such as NaCl treatments and age and among age, inoculum levels and NaCl levels also influenced significantly at $P < 0.01$ and < 0.05 respectively, (Table No.13). However, there is insignificant effect of interactions between inoculum and sodium chloride levels and inoculum and age. The mean values show significant difference at highest and lowest (50.00 and 0.0 meq/L) NaCl levels and the amount of Na content is enhanced as the NaCl concentrations increase. There is no significant different mean value at all age intervals.

Table No.12 (a)

ANOVA for percent water content in leaves alongwith levels of significance for the factors and their interactions.

Source of Variation	Sum of Squares (S.S.)	Degrees of Freedom (D.F.)	Means of Squares (M.S.)	F. Values
Inoculum (A)	25.05	1	25.05	117.26^{**}
Replication (R)	0.25	2	0.13	$0.59^{n.s.}$
Error (a) E(a)	0.43	2	0.21	—
Salt Stress (B)	32.24	3	10.75	11.64^{**}
A X B#	3.86	3	1.28	$1.39^{n.s.}$
Error (b) E(b)	11.08	12	0.92	—
Age (C)	630.74	3	210.25	131.25^{**}
A X C#	15.14	3	5.05	3.15^{*}
B X C#	31.56	9	3.51	2.19^{**}
A X B X C#	23.29	9	2.59	$1.62^{n.s.}$
Error (c) E(c)	76.89	48	1.60	—

** Significant at $P < 0.01$.
* Significant at $P < 0.05$.
n.s. Insignificantly different at both levels.
Interaction of relevant factors.

Table No.12 (b)

Significance of difference in the mean values of percent water content in leaves at different NaCl treatments, age intervals and in the absence or presence of inoculum.

Inoculum Means	Non-Inoculated		Inoculated	
	87.68[a]		87.76[a]	
Salt Stress Means	0.00 meq/l	12.50 meq/l	25.00 meq/l	50.00 meq/l
	86.66	87.64[a]	87.76[a]	88.82
Age Means	60 days	70 days	100 days	130 days
	90.47	117.18	87.40	83.72

All the mean values showing common letters are insignificantly different. Otherwise there is a significant difference at $P < 0.05$.

Table No.13 (a)

ANOVA for sodium content in leaves alongwith levels of significance for the factors and their interactions.

Source of Variation	Sum of Squares (S.S.)	Degrees of Freedom (D.F.)	Means of Squares (M.S.)	F. Values
Inoculum (A)	21.06	1	21.06	120.96^{**}
Replication (R)	0.56	2	0.28	$1.61^{n.s.}$
Error (a) E(a)	0.35	2	0.17	—
Salt Stress (B)	36.17	3	12.06	36.26^{**}
A X B#	3.24	3	1.08	$3.24^{n.s.}$
Error (b) E(b)	3.99	12	0.33	—
Age (C)	1.48	3	0.49	$1.62^{n.s}$
A X C#	1.98	3	0.66	$2.16^{n.s.}$
B X C#	11.15	9	1.24	36.47^{**}
A X B X C#	7.20	9	0.80	2.62^{*}
Error (c) E(c)	14.67	48	0.30	—

** Significant at $P < 0.01$.
* Significant at $P < 0.05$.
n.s. Insignificantly different at both levels.
Interaction of relevant factors.

Table No.13 (b)

Significance of difference in the mean values of sodium content in leaves at different NaCl treatments, age intervals and in the absence or presence of inoculum.

Inoculum Means	Non-Inoculated		Inoculated	
	1.39^{a}		1.45^{a}	
Salt Stress Means	0.00 meq/l	12.50 meq/l	25.00 meq/l	50.00 meq/l
	0.52	1.09^{a}	1.38^{a}	2.68
Age Means	60 days	70 days	100 days	130 days
	1.34^{a}	1.31^{a}	1.39^{ab}	1.63^{b}

All the mean values showing common letters are insignificantly different. Otherwise there is a significant difference at $P < 0.05$.

Potassium content

Presence of inoculum affects the K content in leaves significantly ($P < 0.05$) (Table No. 14). Even more significant is the influence of NaCl treatments and age ($P < 0.01$)for this parameter. The interaction of inoculum and age is effective too ($P < 0.05$). Mean value of this attribute is significantly different and maxium in the absence of NaCl treatment. This indicates the competion between Na^+ and K^+ ions. All mean values at different age intervals are obviously differing. However, K content decreases as plant growe old and mean value is highest at the time of first harvest.

Percent phosphorus content

MENGE et al.(1978) and HOWLER et al.(1979) tested the leaves of troyer citrange and cassava respectively and observed an increase in percent phosphorus content of leaf as a result of mycorrhizal infection. MAAS AND NIEMAN (1978) reviewed that salinity affects the concentration and utilization of orthophosphate (Pi) in plants. The total P-content may be affected. The effect varies with the plant species and in some cases with the root medium. For example, with low concentration of nutrient Pi (0.1 mM) but still higher than in most soils. Salinity (-4 bars Na and Ca chlorides) decreased the Pi concentration in mature photosynthesising corn (Zea mays L.). The ATP concentration and the adenylate energy charge decreased with Pi indicating a Pi deficit at Posphorylation sites. When nutrient Pi was higher (2mM), salinity increased leaf Pi to toxic concentration, so that greater injury rather than benefit resulted from the increased supply of Pi. This phenomenon was named salinity P-toxicity. With moderate nutrient Pi (0.2mM) sallinity decreased

Table No. 14 (b)

Significance of difference in the mean values of potassium content in leaves at different NaCl treatments, age intervals and in the absence or presence of inoculum.

Inoculum	Non-Inoculated		Inoculated	
Means	12.39^{a}		12.59^{a}	
Salt Stress	0.00 meq/l	12.50 meq/l	25.00 meq/l	50.00 meq/l
Means	14.14	12.06^{ab}	12.43^{b}	11.34^{a}
Age Means	60 days	70 days	100 days	130 days
	16.96	15.56	9.71	7.73

All the mean values showing common letters are insignificantly different. Otherwise there is a significant difference at $P < 0.05$.

Table No.15 (a)

ANOVA for percent phosphorus content in leaves alongwith levels of significance for the factors and their interactions.

Source of Variation	Sum of Squares (S.S.)	Degrees of Freedom (D.F.)	Means of Squares (M.S.)	F. Values
Inoculum (A)	0.0001261	1	0.0001261	$3.52^{n.s}$
Replication (R)	0.00000565	2	0.00000282	$0.08^{n.s.}$
Error (a) E(a)	0.0000716	2	0.0000358	—
Salt Stress (B)	0.0007864	3	0.0002621	6.36^{**}
A X B#	0.00099	3	0.000033	$0.80^{n.s.}$
Error (b) E(b)	0.0004946	12	0.0000412	—
Age (C)	0.0003765	3	0.0001255	4.88^{**}
A X C#	0.00008286	3	0.00002762	$1.07^{n.s}$
B X C#	0.0007491	9	0.00008324	3.23^{**}
A X B X C#	0.000249	9	0.00002766	$1.07^{n.s.}$
Error (c) E(c)	0.001231	48	0.0000257	—

** Significant at $P < 0.01$.
* Significant at $P < 0.05$.
n.s. Insignificantly different at both levels.
Interaction of relevant factors.

Table No.15 (b)

Significance of difference in the mean values of percent phosphorus content in leaves at different NaCl treatments, age intervals and in the absence or presence of inoculum.

Inoculum	Non-Inoculated		Inoculated	
Means	0.0059291		0.010275	
Salt Stress	0.00 meq/l	12.50 meq/l	25.00 meq/l	50.00 meq/l
Means	0.0082041^{ab}	0.0058375^{b}	0.0102916^{a}	0.008077^{ab}
Age Means	60 days	70 days	100 days	130 days
	0.0064904	0.0070625^{a}	0.007375^{a}	0.0114687

All the mean values showing common letters are insignificantly different. Otherwise there is a significant difference at $P < 0.05$.

inorganic phosphate (Pi) in tissues especially mature photosynthesising leaves of tomato (Lycopersicon esculentum Mill.) Kidney bean, safflower (Carthamus tincotorius L.) and mustard (Brassica spp). But even with this moderate nutrient Pi salinity increased Pi in Soyabean (Glycine max (L) Merr.) to lethal concentrations. All these effects indicate that salinity damages mechanism controlling interacellular Pi concentration.

In this experiment (Table No.15) percent phosphorus content of leaves is influenced by NaCl levels and age significantly ($P < 0.01$) but not with inoculum, except the interaction between NaCl regime and age (significant at $P < 0.01$) all other possible interactions are insignificant. The mean value of this parameter is significanlty higher and different for the mycorrhizal plants. There is no significantly different mean value at any NaCl level. However, at maximum maturity, leaves show highest and significantly different mean value ($P < 0.05$).

FLOWERS AND FRUITS

Number of flowers

MOSSE et al. (1969) experimented with wheat and KHAN (1972) with maize plants; almost all mycorrhizal plants with or without phosphat fertilizer and non-mycorrhizal plus phosphate plants grew well reproductively as well as vegetatively. Number of grain per ear and grain weight were increased almost twelve times by the inoculation. But in this experiment inoculation affected flowering insignificantly.

ELGIBALY and GOUMAH (1969) proposed that sprouting of the buds was significantly affected by the soil salinization in sugarcane. Number of buds increased with the age but sprouting was retarded. DUMBROFF and

Table No. 16 (a)

ANOVA for number of flowers alongwith levels of significance for the factors and their interactions.

Source of Variation	Sum of Squares (S.S.)	Degrees of Freedom (D.F.)	Means of Squares (M.S.)	F. Values
Inoculum (A)	18.38	1	18.38	$5.30^{n.s.}$
Replication (R)	4.77	2	2.39	$0.69^{n.s.}$
Error (a) E(a)	6.94	2	3.47	—
Salt Stress (B)	4.79	3	1.60	$0.56^{n.s.}$
A X B#	47.46	3	15.87	5.56^{*}
Error (b) E(b)	34.12	12	2.84	—
Age (C)	491.21	3	163.74	46.00^{**}
A X C#	34.71	3	11.57	3.25^{*}
B X C#	66.29	9	7.37	$2.07^{n.s.}$
A X B X C#	88.46	9	9.83	2.76^{*}
Error (c) E(c)	170.83	48	3.56	—

** Significant at $P < 0.01$.
* Significant at $P < 0.05$.
n.s. Insignificantly different at both levels.
Interaction of relevant factors.

Table No.16 (b)

Significance of difference in the mean values of number of flowers at different NaCl treatments, age intervals and in the absence or presence of inoculum.

Inoculum Means	Non-Inoculated		Inoculated	
	1.92[a]		2.13[a]	
Salt Stress Means	0.00 meq/l	12.50 meq/l	25.00 meq/l	50.00 meq/l
	1.29	2.38[a]	1.88[a]	2.54[a]
Age Means	60 days	70 days	100 days	130 days
	0.58[a]	1.71	5.79	0.0[a]

All the mean values showing common letters are insignificantly different. Otherwise there is a significant difference at $P < 0.05$.

COOPER (1974) found almost a delay in flowering of tomato plants, when stress was applied during the early stages of development. However, reproductive process indicated no effect on it, when salt stress was applied during the time of anthesis or when flower buds were visible.

In this experiment NaCl levels applied have insignificant effect upon flowering. However, except the interaction of NaCl levels and age, all other possible interactions are significant ($P < 0.05$) as shown in Table No.16. The mean number of flowers is lowest and significantly different when NaCl level is lowest. It indicates that NaCl has no negative effect for flowering, at least at this maximum NaCl dose applied.

Number of fruits

MOSSE (1973) quoting the results of ROSS (1971) said that mycorrhizal plants of soyabeans weighed more at harvest and yielded more seeds than non-mycorrhizal plants. However, in this experiment inoculum affect the increase in number of fruits insignificantly, Table No.17.

Sometimes productivity is reduced more than vegetative growth of plants due to salt stress (HOFFMAN et al., 1978). Grain yield of rice (PEARSON & BERNSTEIN, 1959) & corn (KADDAH and GHOWAIL, 1964) were diminished without having any appreciable affect on straw yield. The only agronomically significant criterion for establishing salt tolerance is the commerical crop yield. Too often, vegetative growth response to salinity is not a reliable guide for predicting fruit or seed production (MAAS et al., 1977). The mean values for this attribute fall as NaCl concentration increases in the culture medium (soil) and these results are sustained by the above

Table No.17 (a)

ANOVA for number of fruits alongwith levels of significance for the factors and their interactions.

Source of Variation	Sum of Squares (S.S.)	Degrees of Freedom (D.F.)	Means of Squares (M.S.)	F. Values
Inoculum (A)	0.26	1	0.26	$0.06^{n.s.}$
Replication (R)	4.19	2	2.09	$0.47^{n.s.}$
Error (a) E(a)	8.89	2	4.45	—
Salt Stress (B)	42.28	3	14.09	6.93^{**}
A X B#	1.11	3	0.37	$0.18^{n.s.}$
Error (b) E(b)	24.42	12	2.03	—
Age (C)	1633.11	3	544.37	202.29^{**}
A X C#	0.95	3	0.31	$0.12^{n.s.}$
B X C#	109.84	9	12.20	4.54^{**}
A X B X C#	21.18	9	2.35	$0.87^{n.s.}$
Error (c) E(c)	129.17	48	2.69	—

** Significant at $P < 0.01$.
* Significant at $P < 0.05$.
n.s. Insignificantly different at both levels.
Interaction of relevant factors.

Table No. 17 (b)

Significance of difference in the mean values of number of fruits at different NaCl treatments, age intervals and in the absence or presence of inoculum.

Inoculum Means	Non-Inoculated		Inoculated	
	4.42^{a}		3.94^{a}	
Salt Stress Means	0.00 meq/l	12.50 meq/l	25.00 meq/l	50.00 meq/l
	5.58^{b}	4.42^{ab}	3.87^{ab}	3.83^{a}
Age Means	60 days	70 days	100 days	130 days
	0.0^{a}	0.79^{a}	6.29	10.10

All the mean values showing common letters are insignificantly different. Otherwise there is a significant difference at $P < 0.05$.

cited reports. The mean number offruits is highest at minimum NaCl level ($P < 0.05$). While NaCl treatments significantly affect the yield at $P < 0.01$.

Fresh weight

In the present study inoculum, NaCl levels and their interactions produce no significant impact on fresh weight of fruits (Table No.18).

Dry weight

Table No.19 depicts that dry weight of fruit increases in the non-inoculated plants significanlty ($P < 0.05$). However, NaCl treatments and all possible interactions are insignificant. These result differ with the following reports. Weight of wheat grain decreased in presence of high concentration of NaCl and Na_2SO_4 (ANSARI, 1972). Same results were obtained in corn in presence of NaCl by KADDAH and GHOWAIL (1964) MUHAMMAD and MAKHDOM (1971) and STROGONOV (1964) have recorded 50% inhibition of growth in tomatoes grown in soil containing 0.1% (dry weight) chloride. The weight of fruit per plant was reduced by 90%.

Percent water content

Sodium chloride concetrations affect the percent water held in fruit significanlty ($P < 0.05$). In addition there is significant interaction between NaCl levels and age ($P < 0.01$), as shown in Table No.20.

Sodium content

All factors and their interactions are void of significant effect on the sodium content of fruits. However, mean value is significanlty different at highest NaCl concentration. Sodium content of fruit increases

Table No.18 (a)

ANOVA for fresh weight of fruits alongwith levels of significance for the factors and their interactions.

Source of Variation	Sum of Squares (S.S.)	Degrees of Freedom (D.F.)	Means of Squares (M.S.)	F. Values
Inoculum (A)	4.77	1	4.77	$1.95^{n.s.}$
Replication (R)	22.21	2	11.11	$4.54^{n.s.}$
Error (a) E(a)	4.88	2	2.44	—
Salt Stress (B)	60.34	3	20.11	$1.62^{n.s.}$
A X B#	32.53	3	10.84	$0.87^{n.s.}$
Error (b) E(b)	148.68	12	12.39	—
Age (C)	3800.53	3	1266.84	111.65^{**}
A X C#	25.73	3	0.58	$0.75^{n.s.}$
B X C#	88.48	9	9.83	$0.87^{n.s.}$
A X B X C#	89.96	9	9.99	$0.88^{n.s.}$
Error (c) E(c)	544.63	48	11.35	—

** Significant at $P < 0.01$.
* Significant at $P < 0.05$.
n.s. Insignificantly different at both levels.
Interaction of relevant factors.

Table No. 18 (b)

Significance of difference in the mean values of fresh weight of fruits at different NaCl treatments, age intervals and in the absence or presence of inoculum.

Inoculum Means	Non-Inoculated		Inoculated	
	6.05^a		6.14^a	
Salt Stress Means	0.00 meq/l	12.50 meq/l	25.00 meq/l	50.00 meq/l
	5.18^a	6.20^a	6.55^a	6.43^a
Age Means	60 days	70 days	100 days	130 days
	0.0	0.19	9.39	14.78

All the mean values showing common letters are insignificantly different. Otherwise there is a significant difference at $P < 0.05$.

Table No.19 (a)

ANOVA for dry weight of fruits alongwith levels of significance for the factors and their interactions.

Source of Variation	Sum of Squares (S.S.)	Degrees of Freedom (D.F.)	Means of Squares (M.S.)	F. Values
Inoculum (A)	0.42	1	0.42	28.56^{*}
Replication (R)	0.06	2	0.03	$1.93^{n.s.}$
Error (a) E(a)	0.03	2	0.01	—
Salt Stress (B)	0.39	3	0.13	$0.73^{n.s.}$
A X B#	0.71	3	0.24	$1.30^{n.s.}$
Error (b) E(b)	2.17	12	0.18	—
Age (C)	47.90	3	15.97	112.10^{**}
A X C#	1.13	3	0.37	$2.65^{n.s.}$
B X C#	1.03	9	0.12	$0.80^{n.s.}$
A X B X C#	2.62	9	0.29	$2.05^{n.s.}$
Error (c) E(c)	6.84	48	.014	—

** Significant at $P \leq 0.01$.
* Significant at $P < 0.05$.
n.s. Insignificantly different at both levels.
Interaction of relevant factors.

Table No.19 (b)

Significance of difference in the mean values of dry weight of fruits at different NaCl treatments, age intervals and in the absence or presence of inoculum.

Inoculum Means	Non-Inoculated		Inoculated	
	0.68		0.60	
Salt Stress Means	0.00 meq/l	12.50 meq/l	25.00 meq/l	50.00 meq/l
	0.55^{a}	0.67^{a}	0.60^{a}	0.74^{a}
Age Means	60 days	70 days	100 days	130 days
	0.0	0.02^{a}	0.83	1.61

All the mean values showing common letters are insignificantly different. Otherwise there is a significant difference at $P < 0.05$.

Table No.20 (a)

ANOVA for percent water content in fruits alongwith levels of significance for the factors and their interactions.

Source of Variation	Sum of Squares (S.S.)	Degrees of Freedom (D.F.)	Means of Squares (M.S.)	F. Values
Inoculum (A)	219.48	1	219.48	$0.47^{n.s.}$
Replication (R)	2111.36	2	1055.68	$2.25^{n.s.}$
Error (a) E(a)	939.38	2	469.69	—
Salt Stress (B)	4233.37	3	1411.12	5.16^{*}
A X B#	337.31	3	112.44	$0.41^{n.s.}$
Error (b) E(b)	3284.33	12	273.69	—
Age (C)	138557.06	3	46185.69	118.95^{**}
A X C#	1026.35	3	342.12	$0.88^{n.s.}$
B X C#	14444.57	9	1604.95	4.13^{**}
A X B X C#	1577.90	9	175.32	$0.45^{n.s.}$
Error (c) E(c)	18636.75	48	388.27	—

** Significant at $P < 0.01$.
* Significant at $P < 0.05$.
n.s. Insignificantly different at both levels.
Interaction of relevant factors.

Table No.20 (b)

Significance of difference in the mean values of percent water content in fruits at different NaCl treatments, age intervals and in the absence or presence of inoculum.

Inoculum Means	Non-Inoculated		Inoculated	
	59.73[a]		48.61[a]	
Salt Stress Means	0.00 meq/l	12.50 meq/l	25.00 meq/l	50.00 meq/l
	52.15[a]	55.52[a]	53.17[a]	55.85[a]
Age Means	60 days	70 days	100 days	130 days
	0.0	37.06	91.24[a]	88.39[a]

All the mean values showing common letters are insignificantly different. Otherwise there is a significant difference at $P < 0.05$.

Table No.21 (a)

ANOVA for sodium content in fruits alongwith levels of significance for the factors and their interactions.

Source of Variation	Sum of Squares (S.S.)	Degrees of Freedom (D.F.)	Means of Squares (M.S.)	F. Values
Inoculum (A)	2.2083	1	2.2083	$14.97^{n.s.}$
Replication (R)	0.0112	2	0.0056	$0.03^{n.s.}$
Error (a) E(a)	0.2949	2	0.1475	—
Salt Stress (B)	4.167	3	1.389	$1.60^{n.s.}$
A X B#	0.8541	3	0.2847	$0.32^{n.s.}$
Error (b) E(b)	10.3906	12	0.8659	—

** Significant at $P < 0.01$.
* Significant at $P < 0.05$.
n.s. Insignificantly different at both levels.
Interaction of relevant factors.

Table No.21 (b)

Significance of difference in the mean values of sodium content in fruits at different NaCl treatments and in the absence or presence of inoculum.

Inoculum Means	Non-Inoculated		Inoculated	
	0.786[a]		0.913[a]	
Salt Stress Means	0.00 meq/l	12.50 meq/l	25.00 meq/l	50.00 meq/l
	0.32	0.57[a]	0.77[a]	1.73

All the mean values showing common letters are insignificantly different. Otherwise there is a significant difference at $P<0.05$.

with the increase in the level of NaCl in the growth medium Table No.21.

Potassium content

There is neither any factor nor the interaction of any factor which has contributed significantly in the uptake of potassium in the fruit, however, it is highest when the plants are subjected to 50.0 meq/l sodium chloride stress through root growth medium (Table No.22)and their mean value is also significanlty different.

Percent phosphorus content

Sodium chloride concentrations influence the percent phosphorus content in fruits significanlty ($P < 0.01$). Contrary to it inoculum and its interaction with NaCl levels are not much significant. The mean values are significantly different when inoculum is present and NaCl is absent in soil (Table No.23).

CYTOLOGICAL STUDIES OF ROOTS.

Number of arbuscules

Only age factor is significantly effective ($P < 0.01$), Table No.24. Rest of the factors i.e., inoculation and NaCl levels or the possible interactions of three factors are, however, insignificant. The highest mean value for the number of arbuscules is recorded at 100 days interval. The mean value for number of arbuscules decreases as NaCl level increases in the rhizosphere. Plate No.3 displays the extramatrical infecting hypha passing through the entry point to the arbuscules.

Number of vesicles

It is sifted from Table No.25 that age is a significant factor for influencing number of vesicles ($P < 0.05$). Factors i.e., inoculation

Table No.22 (a)

ANOVA for potasium content in fruits alongwith levels of significance for the factors and their interactions.

Source of Variation	Sum of Squares (S.S.)	Degrees of Freedom (D.F.)	Means of Squares (M.S.)	F. Values
Inoculum (A)	0.0485	1	0.0485	$0.01^{n.s.}$
Replication (R)	6.8399	2	3.4199	$0.52^{n.s.}$
Error (a) E(a)	12.9999	2	6.4999	—
Salt Stress (B)	2.9333	3	0.9777	$1.46^{n.s.}$
A X B#	6.3466	3	2.1155	$3.17^{n.s.}$
Error (b) E(b)	7.9999	12	0.6666	—

** Significant at $P < 0.01$.
* Significant at $P < 0.05$.
n.s. Insignificantly different at both levels.
Interaction of relevant factors.

Table No.22 (b)

Significance of difference in the mean values of potassium content in fruits at different NaCl treatments and in the absence or presence of inoculum.

Inoculum	Non-Inoculated	Inoculated
Means	16.2^{a}	16.6^{a}

Salt Stress	0.00 meq/l	12.50 meq/l	25.00 meq/l	50.00 meq/l
Means	16.53^{a}	15.8^{a}	16.26^{a}	17.00

All the mean values showing common letters are insignificantly different. Otherwise there is a significant difference at $P<0.05$.

Table No.23 (a)

ANOVA for percent phosphorus content in fruits alongwith levels of significance for the factors and their interactions.

Source of Variation	Sum of Squares (S.S.)	Degrees of Freedom (D.F.)	Means of Squares (M.S.)	F. Values
Inoculum (A)	0.3749E-06	1	0.3749E-06	$0.02^{n.s.}$
Replication 'R)	0.129E-04	2	0.0949E-05	$0.41^{n.s.}$
Error (a) E(a)	0.309E-04	2	0.0000155	—
Salt Stress (B)	0.443E-03	3	0.1479E-03	12.32^{**}
A X B#	0.712E-04	3	0.237E-04	$1.97^{n.s.}$
Error (b) E(b)	0.000145	12	0.000012	—

** Significant at $P < 0.01$.
* Significant at $P < 0.05$.
n.s. Insignificantly different at both levels.
Interaction of relevant factors.

Table No.23 (b)

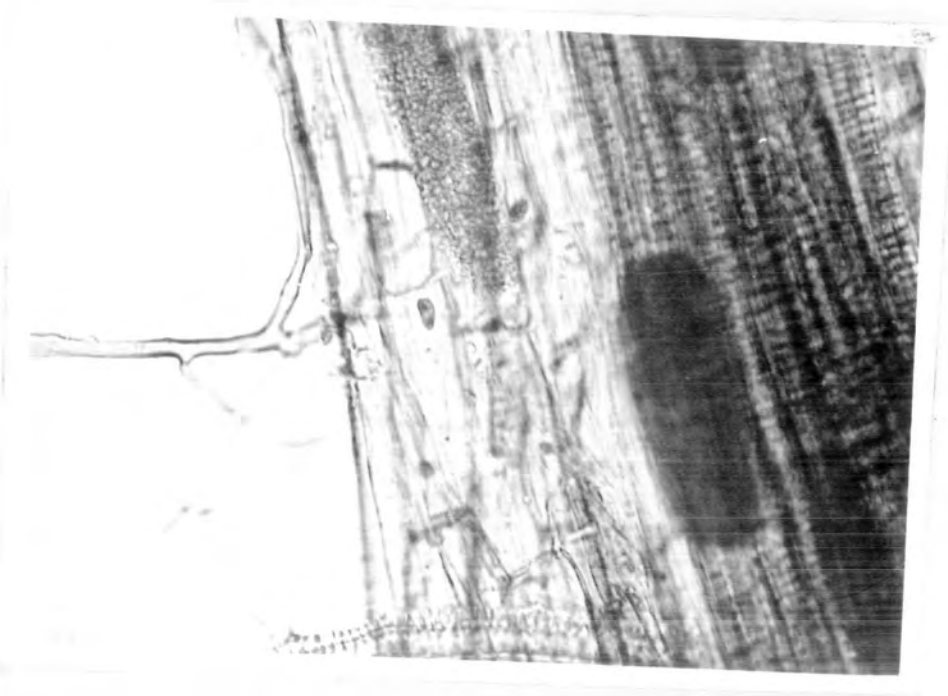
Significance of difference in the mean values of percent phosphorus content in fruits at different NaCl treatments and in the absence or presence of inoculum.

Inoculum Means	Non-Inoculated	Inoculated
	0.00109583	0.0180416

Salt Stress Means	0.00 meq/l	12.50 meq/l	25.00 meq/l	50.00 meq/l
	0.114166	0.0135[a]	0.017833[a]	0.01525[a]

All the mean values showing common letters are insignificantly different. Otherwise there is a significant difference at $P < 0.05$.

Plate No.3



Arbuscules and entry point of infecting hypha into the root of mycorrhizal tomato plant. (400magnification)

Table No.24 (a)

ANOVA for number of arbuscules alongwith levels of significance for the factors and their interactions.

Source of Variation	Sum of Squares (S.S.)	Degrees of Freedom (D.F.)	Means of Squares (M.S.)	F. Values
Inoculum (A)	1785.37	1	1785.37	$0.07^{n.s.}$
Replication (R)	2445.25	2	1222.63	$0.05^{n.s.}$
Error (a) E(a)	48956.22	2	24478.11	—
Salt Stress (B)	59100.25	3	19700.08	$2.89^{n.s.}$
A X B#	22057.37	3	7352.46	$1.08^{n.s.}$
Error (b) E(b)	81661.94	12	6805.16	—
Age (C)	729575.31	3	243191.75	16.34^{**}
A X C#	16612.37	3	5537.46	$0.37^{n.s.}$
B X C#	155907.50	9	17323.05	$1.16^{n.s.}$
A X B X C#	111808.37	9	12423.15	$0.83^{n.s.}$
Error (c) E(c)	714272.11	48	14880.67	—

** Significant at $P < 0.01$.
* Significant at $P < 0.05$.
n.s. Insignificantly different at both levels.
Interaction of relevant factors.

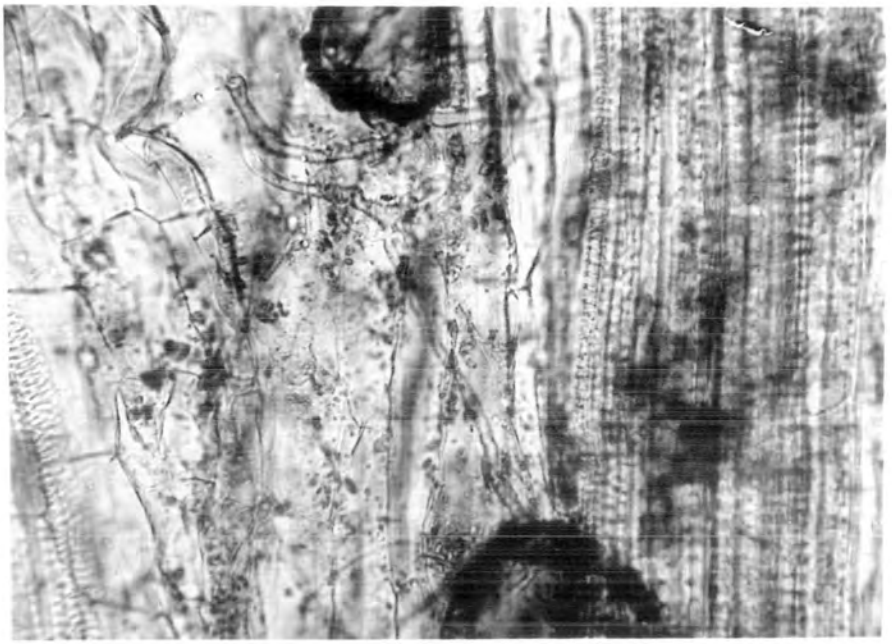
Table No.24 (b)

Significance of difference in the mean values of number of arbuscules at different NaCl treatments, age intervals and in the absence or presence of inoculum.

Inoculum Means	Non-Inoculated		Inoculated	
	152.60^{a}		151.72^{a}	
Salt Stress Means	0.00 meq/l	12.50 meq/l	25.00 meq/l	50.00 meq/l
	186.37^{b}	163.95^{ab}	128.66^{a}	129.66^{a}
Age Means	60 days	70 days	100 days	130 days
	46.42^{b}	92.79^{b}	269.66^{a}	199.79^{a}

All the mean values showing common letters are insignificantly different. Otherwise there is a significant difference at $P < 0.05$.

Plate No.4



Vesicles and intercellular hypha in matrix of infected root of tomato plant (400magnification).

Table No.25 (a)

ANOVA for number of vesicles alongwith levels of significance for the factors and their interactions.

Source of Variation	Sum of Squares (S.S.)	Degrees of Freedom (D.F.)	Means of Squares (M.S.)	F. Values
Inoculum (A)	822.51	1	822.51	$8.53^{n.s.}$
Replication (R)	72.15	2	36.07	$0.37^{n.s.}$
Error (a) E(a)	192.77	2	96.38	—
Salt Stress (B)	1053.70	3	351.23	$0.86^{n.s.}$
A X B#	1470.61	3	490.20	$1.20^{n.s.}$
Error (b) E(b)	4921.25	12	410.10	—
Age (C)	3244.70	3	1081.57	3.56^{*}
A X C#	2398.95	3	799.65	$2.63^{n.s.}$
B X C#	3319.34	9	368.81	$1.21^{n.s.}$
A X B X C#	3875.09	9	430.56	$1.41^{n.s.}$
Error (c) E(c)	14597.13	48	304.11	—

** Significant at $P \leq 0.01$.
* Significant at $P \leq 0.05$.
n.s. Insignificantly different at both levels.
Interaction of relevant factors.

Table No.25 (b)

Significance of difference in the mean values of number of vesicles at different NaCl treatments, age intervals and in the absence or presence of inoculum.

Inoculum Means	Non-Inoculated		Inoculated	
	6.06^{a}		7.33^{a}	
Salt Stress Means	0.00 meq/l	12.50 meq/l	25.00 meq/l	50.00 meq/l
	12.58	7.12^{a}	6.66^{a}	0.42^{a}
Age Means	60 days	70 days	100 days	130 days
	1.46^{b}	0.63^{b}	14.21^{a}	10.50^{a}

All the mean values showing common letters are insignificantly different. Otherwise there is a significant difference at $P < 0.05$.

and NaCl levels and all possible interactions of the three factors influence this parameter insignificantly. The mean values decrease as the NaCl level increases and the only significanlty different mean value is obtained at the lowest level of NaCl. Maximum mean value is calculated at 100 days age interval. Plate No.4 exhibits the vesicles and intercellular hyphae in mycorrhizal plant roots.

Infected length

It has been observed that except the salinity factor ($P < 0.01$) (Table No.26) no other factor influences the infection of roots significantly. All possible interactions are also insignificant.

The mean value is higher for mycorrhizal plants and significantly different. The mean value for the infected root length is highest at maximum NaCl concentration and significanlty different. At the age of 60 days maximum root length is infected.

Percent infection

Age and sodium chloride levels have noteworthy effect upon the percent infection of root ($P < 0.01$) (Table No.27). Whereas inoculum contributes insignificantly. All possible interactions of factors are insignificant. The mean value is higher and significantly different at lower level 12.5 meq/l of NaCl or even in the absence of NaCl ($P < 0.05$). The Table No.26.b, shows that the mean percent infected root increases as the plant grows old.

SAIF (1977,b) has also pointed out the influence of stages of host development on V.A. mycorrhizae. Mycorrhizal crop plants have shown that after four weeks from sowing and transplanting, infection of root

Table No.26 (a)

ANOVA for infected length of roots alongwith levels of significance for the factors and their interactions.

Source of Variation	Sum of Squares (S.S.)	Degrees of Freedom (D.F.)	Means of Squares (M.S.)	F. Values
Inoculum (A)	35519936	1	35519936	$4.54^{n.s}$
Replication (R)	35048000	2	17524000	$2.24^{n.s.}$
Error (a) E(a)	15655573	2	7827786	—
Salt Stress (B)	228310176	3	76103392	6.07^{**}
A X B#	38721968	3	12907322	$1.03^{n.s.}$
Error (b) E(b)	150482832	12	12540236	—
Age (C)	43051888	3	14350629	$1.14^{n.s.}$
A X C#	45853456	3	15284485	$2.17^{n.s.}$
B X C#	106251936	9	11805770	$0.59^{n.s.}$
A X B X C#	116105744	9	12900638	$0.54^{n.s.}$
Error (c) E(c)	337163776	48	7024245	—

** Significant at $P \leq 0.01$.
* Significant at $P \leq 0.05$.
n.s. Insignificantly different at both levels.
Interaction of relevant factors.

Table No.26 (b)

Significance of difference in the mean values of infected length of roots at different NaCl treatments, age intervals and in the absence or presence of inoculum.

Inoculum Means	Non-Inoculated		Inoculated	
	885.06		3653.04	
Salt Stress Means	0.00 meq/l	12.50 meq/l	25.00 meq/l	50.00 meq/l
	760.11	2679.52[a]	2519.78[a]	3116.81
Age Means	60 days	70 days	100 days	130 days
	3186.23[b]	2488.50[ab]	1374.45[a]	1943.66[ab]

All the mean values showing common letters are insignificantly different. Otherwise there is a significant difference at $P < 0.05$.

Table No.27 (a)

ANOVA for percent infection of roots alongwith levels of significance for the factors and their interactions.

Source of Variation	Sum of Squares (S.S.)	Degrees of Freedom (D.F.)	Means of Squares (M.S.)	F. Values
Inoculum (A)	522.62	1	522.62	$0.98^{n.s}$
Replication (R)	197.31	2	98.66	$0.18^{n.s.}$
Error (a) E(a)	1070.17	2	535.08	—
Salt Stress (B)	2134.88	3	711.63	8.47^{**}
A X B#	773.13	3	257.71	$3.07^{n.s.}$
Error (b) E(b)	1008.46	12	84.04	—
Age (C)	19261.55	3	6420.51	14.76^{**}
A X C#	866.16	3	288.72	$0.66^{n.s.}$
B X C#	1383.20	9	153.68	$0.35^{n.s.}$
A X B X C#	1390.10	9	154.45	$0.35^{n.s.}$
Error (c) E(c)	20880.55	48	435.01	—

** Significant at $P < 0.01$.
* Significant at $P < 0.05$.
n.s. Insignificantly different at both levels.
Interaction of relevant factors.

Table No.27 (b)

Significance of difference in the mean values of percent infection of roots at different NaCl treatments, age intervals and in the absence or presence of inoculum.

Inoculum Means	Non-Inoculated		Inoculated	
	40.68^{a}		37.01^{a}	
Salt Stress Means	0.00 meq/l	12.50 meq/l	25.00 meq/l	50.00 meq/l
	39.14	47.21	33.88^{a}	35.14^{a}
Age Means	60 days	70 days	100 days	130 days
	22.91^{b}	26.63^{b}	54.30^{a}	51.52^{a}

All the mean values showing common letters are insignificantly different. Otherwise there is a significant difference at $P < 0.05$.

system by mycorrhizae was generally low and ranged from 12% in fenugreek to 21% in pea. Mycorrhizal infection subsequently increased progressively to maximum between 58% in fenugreek to 88% in lettuce. In most cases 58 to 88% of root system was infected until the fruiting stage of the host plant.

ANALYSIS OF SOIL AND EXTRACTS

Spore count

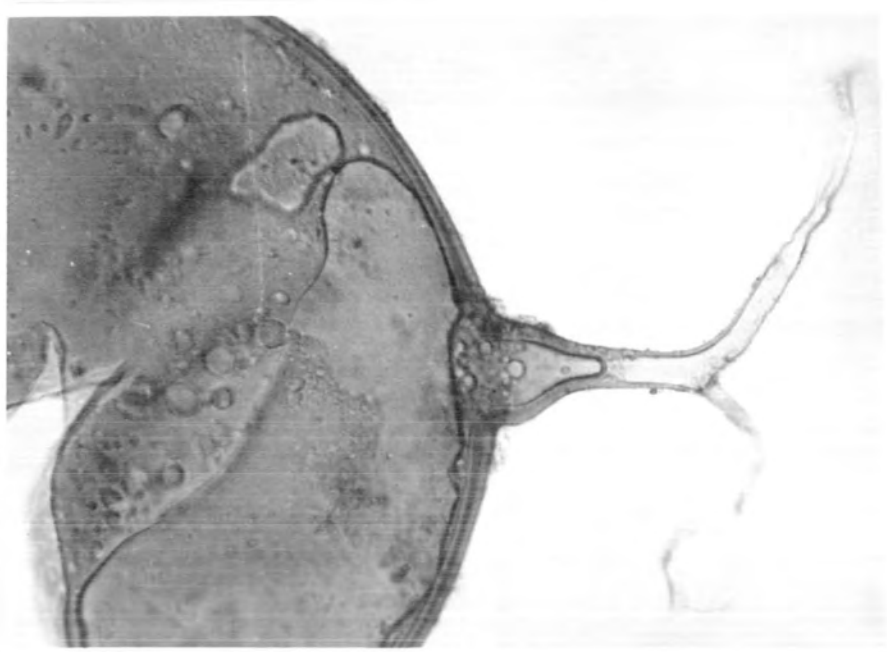
In this experiment(Plate Nos. 5 and 6.) number of spores in soil has been significantly affected by NaCl level ($P < 0.01$) and increase in the mean values of number of spores obtained at different levels of salinity though highest and significanlty different ($P < 0.05$) at the highest NaCl regime shows some-what irregular increasing trend on rest of the salinity levels. HIRREL (1981) concluded that spores could germinate upto a level of 1.28×10^{-1}M or lower amounts of sodium chloride. Whereas in this experiment the highest quantity of NaCl used (50.0 meq/l) is much below than that used by him.

However, mycorrhizal plants show a higher mean value for this parameter and result is supported by DAFT and NICOLSON (1972). He established that the spore number was the measure of infection most closely related to the plant weight. Large tomato plants produced more spores than small ones. On the other hand, REDHEAD (1971) thought that number of spores in soil was not clearly related with root infection. In this case, inoculation interacted with NaCl insignificantly, Table No.28.

Potassium content

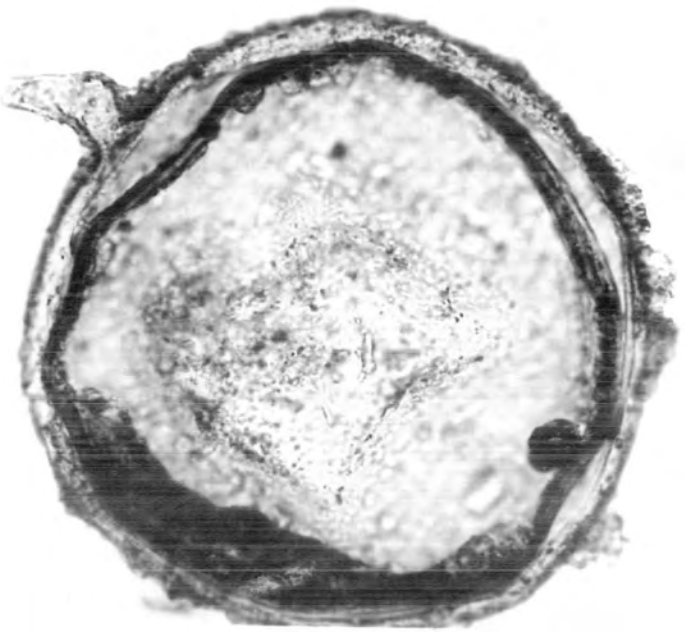
Plants exposed to salt stress exhibit massive reduction for

Plate No.5



Endogonaceous spore from inoculated soil 333 μm diameter (400 magnification).

Plate No.6



Endogonaceous spore from inoculated soil.

250 x 292 μm diameter (400magnification).

Table No.28 (a)

ANOVA for spore count in soil alongwith levels of significance for the factors and their interactions.

Source of Variation	Sum of Squares (S.S.)	Degrees of Freedom (D.F.)	Means of Squares (M.S.)	F. Values
Inoculum (A)	120.125	1	120.125	$1.65^{n.s.}$
Age (C)	936.625	3	312.208	$4.29^{n.s.}$
Error (a) E(a)	218.125	3	72.7083	—
Salt Stress (B)	4168.375	3	1389.4582	10.82^{**}
A X B#	712.375	3	237.458	$1.84^{n.s.}$
Error (b) E(b)	2311.25	18	128.4027	—

** Significant at P <0.01.
* Significant at P <0.05.
n.s. Insignificantly different at both levels.
Interaction of relevant factors.

Table No.28 (b)

Significance of difference in the mean values of spore count in soil at different NaCl treatments, age intervals and in the absence or presence of inoculum.

Inoculum		
	29.25	49.12

NaCl stress				
Means				
	35[a]	32.75[a]	39.5[a]	49.5

	60 days	70 days	100 days	130 days
Age Means				
	39.75[ab]	31.12[a]	39.5[ab]	46.38[b]

All the mean values showing common letters are insignificantly different. Otherwise there is a significant difference at $P < 0.05$.

Table No.29 (a)

ANOVA for potassium content in soil extracts alongwith levels of significance for the factors and their interactions.

Source of Variation	Sum of Squares (S.S.)	Degrees of Freedom (D.F.)	Means of Squares (M.S.)	F. Values
Inoculum (A)	1.0153	1	1.0153	10.81*
Age (C)	1.3043	3	0.4347	4.63n.s.
Error (a) E(a)	0.2815	3	0.0938	—
Salt Stress (B)	6.7243	3	2.2414	8.15**
A X B#	3.4278	3	1.1426	4.15*
Error (b) E(b)	4.9503	18	0.2750	—

** Significant at P <0.01.
* Significant at P <0.05.
n.s. Insignificantly different at both levels.
Interaction of relevant factors.

Table No.29 (b)

Significance of difference in the mean values of potassium content in soil extracts at different NaCl treatments, age intervals and in the absence or presence of inoculum.

Inoculum	Non-Inoculated		Inoculated	
Means	1.39		1.82	
Salt Stress	0.00 meq/l	12.50 meq/l	25.00 meq/l	50.00 meq/l
Means	1.36[a]	1.30[a]	1.50[a]	2.27

Age Means	60 days	70 days	100 days	130 days
	1.94	1.48[a]	1.59[a]	1.41[a]

All the mean values showing common letters are insignificantly different. Otherwise there is a significant difference at $P < 0.05$.

the levels of potassium in the roots. It has been quoted by WAINWRIGHT (1980) that NaCl can cause potassium leakage from plant roots. The potassium leakage from barley and bean roots is salt induced rather than osmotically induced. SMITH (unpublished) found that NaCl treatment can induce potassium leakage at conentrations which cause substantial reduction of root growth. At this stage it is not possible to know whether the observed leakage represents membrane damage or a process of exchange of cellular potassium for sodium. It is possible however, that the salt induced potassium leakage is of significance for salt toxicity or tolerance. In the present experiment inoculation influences the extractable potassium content of soil significantly and mean value is significanlty different ($P < 0.05$) as has been shown in the Table No.29, NaCl status influences this parameter significantly ($P < 0.01$). The mean value is significantly different at the highest NaCl status. These results are in favour of the WAINWRIGHT's description. However, the interaction between NaCl level and inoculum is effective only at $P < 0.05$.

Extractable phosphate (PO_4^{3-}) content

Sodium chloride concentrations have also influenced the extractable phosphate (PO_4^{3-}) of soil extracts significanlty ($P < 0.01$), Table No.30. Inoculation and its interaction with NaCl levels is, however, insignificant. There is a trend of increase in mean values of this parameter as NaCl status increases and the significanlty different values are noted at higher NaCl levels.

The mean extractable phosphate level is higher and significantly different for the extracts of soil where mycorrhizal plants have grown, Table No.30.b.

Table No.30.(a)

ANOVA for extractable phosphate (PO_4^{3-}) content in soil alongwith levels of significance for the factors and their interactions.

Source of Variation	Sum of Squares (S.S.)	Degrees of Freedom (D.F.)	Means of Squares (M.S.)	F. Values
Inoculum (A)	0.32E-05	1	32E-05	$0.01^{n.s.}$
Age (C)	0.00446	3	0.00149	$2.775^{n.s.}$
Error (a) E(a)	0.0016	3	0.00054	—
Salt Stress (B)	0.1029	3	0.0343	14.60^{**}
A X B#	0.0072	3	0.00240	$1.02^{n.s.}$
Error (b) E(b)	0.0423	18	0.00235	—

** Significant at $P < 0.01$.
* Significant at $P < 0.05$.
n.s. Insignificantly different at both levels.
Interaction of relevant factors.

Table No.30 (b)

Significance of difference in the mean values of extractable phosphate (PO_4^{3-}) content in soil at different NaCl treatments, age intervals and in the absence or presence of inoculum.

Inoculum	Non-Inoculated		Inoculated	
Means	0.0881562		0.1546	
Salt Stress	0.00 meq/l	12.50 meq/l	25.00 meq/l	50.00 meq/l
Means	0.0884	0.01022[a]	0.1549	0.1399[a]
Age Means	60 days	70 days	100 days	130 days
	0.1033[a]	0.1312[a]	0.1184[a]	0.1326[a]

All the mean values showing common letters are insignificantly different. Otherwise there is a significant difference at $P < 0.05$.

Here more extractable PO_4^{3-} is not merely due to the fast turn over of nutrient in pot soil but soil samples alongwith fixed P of plant endomycorrhizal roots when digested showed more available P to the plants and consequently there would be more nutrient release. FOGGEL (1979) appreciated the nutrient cycling through mycorrhizal and fine roots of mycorrhizal plants; as their die back, senescence and decomposition increase the nutrient release to the soil.

Water holding capacity

In the present case (Table No.31), not a single factor or their interaction is effective. The mean values for this attribute are also insigificanlty different. It would be just to concluded that W.H.C. is not affected by that much amount of salt present in pot soil.

Table No.31 (a)

ANOVA for water holding capacity of soil alongwith levels of significance for the factors and their interactions.

Source of Variation	Sum of Squares (S.S.)	Degrees of Freedom (D.F.)	Means of Squares (M.S.)	F. Values
Inoculum (A)	511.200	1	511.200	$3.38^{n.s.}$
Age (C)	779.358	3	259.786	$1.71^{n.s.}$
Error (a) E(a)	453.187	3	151.0625	—
Salt Stress (B)	1630.963	3	543.654	$2.97^{n.s.}$
A X B#	464.2077	3	154.7359	$0.84^{n.s.}$
Error (b) E(b)	3290.084	18	182.782	—

** Significant at $P < 0.01$.
* Significant at $P < 0.05$.
n.s. Insignificantly different at both levels.
Interaction of relevant factors.

Table No.31 (b)

Significance of difference in the mean values of water holding capacity of soil at different NaCl treatments, age intervals and in the absence or presence of inoculum.

Inoculum Means	Non-Inoculated		Inoculated	
	90.98[a]		01.66[a]	
Salt Stress Means	0.00 meq/l	12.50 meq/l	25.00 meq/l	50.00 meq/l
	96.33[a]	93.18[a]	89.25[a]	86.54[a]
Age Means	60 days	70 days	100 days	130 days
	90.45[a]	90.56[a]	91.81[a]	92.46[a]

All the mean values showing common letters are insignificantly different. Otherwise there is a significant difference at $P < 0.05$.

CHAPTER 5

CONCLUSIONS

CONCLUSIONS

Inoculation regarding a few aspects was effective in the tomato plants experiment. Mycorrhizal plants have higher mean values, especially for most of the vegetative growth parameters, leaves hardly show any cholorosis(Plate No.1).

Mycorrhizal hyphae as nutrient conduit have taken part effeciently, inturn, higher mean values of infected root length,and spore count in soil corroborate the results. Through increased root absorbing area mycorrhizal plants seem to have enjoyed the privilage to acquisit more PO_4^{3-} from such salt affected soils. Higher mean values of percent phosphorus content in stem, leaves and fruits of inoculated plants favour the fact, simultaneously, higher soluble K^+ and extractable PO_4^{3-} content in soil signifies the higher nutrient turn over by the mycorrhizal plants. Inoculation has influenced invague the K^+ uptake or its content in aerial parts of plants. May it be the antagonistic effect of excessive Na^+ ions at cation exchange complex around hyphae or fine roots.

Inoculation increased percent water content in stem and leaves. The mean values of this attribute are insignificantly higher than those of non-mycorrhizal plants. Contrary to it insignificantly higher values were in the fruits of non-inoculated ones. This opposing result is correlated with that of dry matter content in fruits. Which is significantly higher ($P<0.05$) in fruits of non-mycorrhizal plants.

Sodium chloride treatments have inverse effect on vegetative growth and food synthesising area of the tomato plants.

However leaves dry weight, number of fruits, fresh and dry weights of fruits, have not been affected by NaCl regime. In addition, sodium chloride has positively contributed to increase the fresh and dry weights of stem but this increase is only at 25.0 meq/l. NaCl level.

Fruits seem to be least responsive towards inoculum and NaCl stimuli, whether it is due to the screening systems of plants to save their seeds for further propagation or through development of resistance. However, this fact places the tomato plant in semi-tolerant catagory, at least to this much salt stress condition and insignificantly responding to inoculation. Agronomically, no increase in yield means little positive contribution of these factors.

Number of arbuscules is insignificantly affected at low levels of NaCl. However, arbuscular development has been deranged at 50.0 meq/l. NaCl level.

It is a well known fact that Na^+ content of stem, leaves and fruits is directly related to the increase of NaCl level in the soil which may cause imbalance in the nutrient uptake, such as K^+ and percent phosphorus content have decreased in stem and fruit respectively. However, percent phosphorus content of stem and leaves does not seem to be affected by thesalt used in this experiment.

Stem has highest water content when NaCl is absent in the pot soil. Whereas,stem and fruits of salt-stressed plants visualized insignificantly different means values for this parameter. The rising NaCl level in plant growth medium may have increased the water content of leaves.

Potassium content in the soil saturation extracts is directly related to NaCl concentrations. This K^+ possibly was displaced by Na^+ at the cation exchange complex in the soil and was dissolved in water.

As plant age increased, there was increase in stem height, numbers of nodes, fresh weight of stem, number of leaves and their fresh and dry weights, fresh and dry weights of fruits. Conversely, stem dry weight diminished when plants borne ripe fruits as compared to plants harvested at budding stage.

Percent phosphorus content in stem and leaves increased at K^+ content of the stem increased. This increase shows the synthesis of organic compounds containing P as basic constituent in their skeleton. Potassium content in leaves has decreased as plants grow old. Consequently, fall in rate of photosynthate metabolism has also been observed.

Na content of leaves and number of flowers are the main attributes which do not seem to be affected by the age factor. At the same time more or less all characters of roots viz., number of vesicles, length of infected root and spore count are also unaffected. However, number of arbuscules increased in the infected roots.

Water translocation is a physiological process and it is age dependent. Therefore, plants have highest water content in stem and leaves when they were at the youngest stage of development. Water content decreased as plant becomes old. Age insignificantly

affected the water content of fruits except at 70 days age, at that time the mean value was lowest and significantly different ($P < 0.05$).

Except the K content, rest of the attributes i.e., extractable PO_4^{3-}, number of spores and water holding capacity of soil have been insignificantly affected at various harvest intervals. Soil extracts showed the highest and significantly different mean values of potassium from plants harvested at onset of the budding stage.

CHAPTER 6

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BIBLIOGRAPHY

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