Chapter - I

Review of Literature

CHAPTER - I

-:- REVIEW OF LITERATURE -:-

****

A) Salinity and Plant Metabolism

1) Introduction

2) Growth

3) Mineral nutrition

4) Organic constituents

5) Photosynthesis

6) Nitrogen metabolism

B) Germination

1) Introduction

2) Biochemical changes during germination

3) Factors controlling germination

4) Germination under saline conditions

C) Scope of Present Investigation

=o=o=o=o=o=o=o=o=o=o=o=o=o=o=o=o=o=o=o=o=o=o=o=o=o=o=o=o=o=o=o=o=

1. REVIEW OF LITERATURE :

A) Salinity and Plant Metabolism :

1) Introduction :

Salinity or sodicity of the soil is a serious handicap to successful agriculture in all arid and semi-arid regions of the world which constitute about one third of the total cultivated land. The saline environment is mainly due to excessive presence of sodium salts like chlorides, sulphates and carbonates or salts of magnesium in the environment of a plant. Day by day more and more land is becoming non-productive as a result of poor soil management which results in salt accumulation. In India, this problem is very serious. It is estimated that 10 million hectares of the land in our country is affected by salinity and alkalinity (Sharma and Gupta,1986). The states where this problem is very serious are U.P., Haryana, Gujarat and Rajasthan. In Maharashtra also this problem is becoming serious, especially in agricultural zones dominated by sugarcane cultivation. Irrigated land having a higher watertable also suffers from salinity. Poor drainage and high watertable are the two important factors which lead to the development of salinity. As long as the salts are present in the substrate, exert only osmotic and toxic effects on the plants. Their toxic effect begins only after they are absorbed. Plants growing in such environments for several generations do develop some adaptations. The nature and extent of adaptations is different

in different species or varieties. This adaptive response is of qualitative nature. The process of adaptation includes various morphological, anatomical and metabolic changes and is more rapid in halophytes than in glycophytes. The ability of halophytes to withstand high salt concentrations is due to their thicker cuticle and low permeability to salts which prevents excessive accumulation of toxic ions. Succulence characteristics of halophytes (chloride type) helps in diluting the ions in the cytoplasm.

There is a great variation among plant species with respect to salt tolerance. Halophytes is a group of plants which is fairly suited for saline regime whereas most of the plants cannot thrive because of their glycophytic nature. Most of the crops are glycophytes. According to Stroganov (1964), it is impractical to grow any crop on the soil where the amount of salt in the soil exceeds 0.5% by weight. Saline soils with concentrations of 0.2 to 0.5% are used in agriculture but give very poor yields. The crop plants possess certain potential inspite of glykik for salt tolerance which varies from species to species. The survey of salt tolerance of various crops has been carried out by several workers. According to Bernstein (1964) the economically, important salt tolerant species are Bermuda grass, tall wheat grass, barley, sugarbeet and cotton. The crops like alfalfa, soyabean, rice and tomato belong to the class of moderately salt tolerant types. Clover, bean and onion

are among the salt sensitive ones. Maximum salt resistance was exhibited by sugarbeet while carrots exhibited the minimum in experiments of Strogonov (1964). Maas and Hoffman (1978) have made an assessment of salt tolerance of 76 economically important species. Their survey indicates that barley, Bermuda grass, cotton, datepalm, sugarbeet, wheatgrass and wild rye are the most salt tolerant ones. Almond, apple, apricot, avocado, bean, blackberry, baysenberry, carrot, grape, lemon, okra, onion, orange, peach, plum, rasberry and strawberry belong to the category of most sensitive types. Remaining 52 species that include many important crops show intermediate degrees of salt tolerance. According to Maas and Hoffman (1978) the only agronomically significant criterion for establishing salt tolerance is the commercial crop yield.

Several workers have reported that salinity adversely affects growth and dry matter production in several plants (Taylor et al., 1975; Heikel, 1976; Georjiv and Spasenovski, 1977; Frota and Tuker, 1978; Joolka and Singh, 1979; Ahmed et al., 1980; Ibrahim, 1980; Chavan and Karadge, 1980). However, greater sodium uptake promotes dry matter yield of all parts in case of karley and sugarbeet, indicating that sodium plays a specific role in their metabolism (Hamid and Talibudin, 1976). Differential response by spinach and lettuce has been observed by Matur et al., (1975). They found that with increasing sodium supply, dry matter production was decreased in lettuce while that increased in spinach. Similar observations have been made

by Chavan and Karadge (1983) in Sesbania which behaves like barley, spinach and sugarbeet indicating its well adaptibility to saline conditions.

Greenway and Munns (1980), while reviewing the mechanism of salt tolerance in non-halophytes; have catagorised the plants into three groups. The first group is of halophytes which continue to grow rapidly at 200-500 mM NaCl, including Suaeda martima, Atriplex numularia, A.hastata, Spartima townsendie and sugarbeet. The second group is of both halophytes and non-halophytes which grow very slowly above 200 mM NaCl which includes halophytic monocotyledons, cotton, barley and tomatoes and the third group comprises of very salt sensitive non-halophytes including fruit trees such as citrus, avocado and stone fruit.

Not only the species differ in salt tolerance but varietal difference is also noticed by several workers (Bernstern, 1964; Iyengar et al., 1968; Paliwal et al., 1970) with respect to salt tolerance. Epstein et al., (1979) demonstrated that when resources of germplasm in barley and wheat are screened on an adequate scale, much intraspecific diversity with respect to salt tolerance exists so as to make it possible to select and breed strains adapted to seawater culture. According to Maas and Neiman (1978) such studies help in selection and breeding of crops for salt tolerance.

According to Stroganov (1964) salt tolerance of crops depends on the mechanical composition of the soil, soil moisture

during the vegetational period, climate, micro-relief and other environmental factors. Similarly growth stage of the crop is also one of the most important factors. Nieman and Shannon (1976) postulated that the germination rate could be a useful criterion of tolerance of some crops where tolerance does not diminish at some later growth stage, because the tolerance of many crops seems to be similar during germination and later growth stages.

2) Growth :

At the population, the organismal, the physiological and the molecular level, salinity puts various problems. The overall reflection of all these problems results in the reduction of growth. Salinity causes stunting in glycophytes. On the other hand the growth in halophytes is favoured by certain amount of salts (Stroganov, 1964). According to him the adverse effects of salt on growth is due to a change of the state of protoplasm in the cells. The ability of the halophytes to withstand high salt concentration is due to their thicker cuticle and low permeability to salts, which prevents excessive accumulation of toxic ions. Succulence characteristic of halophytes (chloride types) helps in diluting the ions in the cytoplasm.

Chloride salinization causes changes in the intercellular spaces. The volume occupied by cells is smaller and the intercellular spaces are larger than in the sulphate salinated plants.

Strongly hydrophillic substances like pectins accumulate in the intercellular spaces. Such substances determine the water relations of plants (Strogonov, 1958) and the changes in the properties of the protoplasm occuring during retraction from the cell wall, as the cells enter the quiscent state. During retraction of the protoplasm from the cell wall the intercellular connections (plasmodesmata) are broken (Strogonor,1964).

In chloride dominant salinity, the number of vascular bundles decreases but their diameter increases; while under sulphate dominant salinity conditions, the reverse happens. Combial activity is inhibited more by Cl^- than by SO^{2-} type of salinity. In cereals, thickness of the waxy layer and cuticle increases. The number of stomata per unit area also increases but their length and width decreases.

Chloride type of salinity inhibits cell division and thus the number of cells is lowered, while the linear growth is stimulated which results in increased size of the individual cells. On the other hand, sulphate type of salinity inhibits the extension growth of cells more than cell division. In halophytes, however, salinity decreases both by cell division and extension (Pokrovaskaya,1954,1957). Thus, chloride salinity develops halosucculence while sulphate salinity causes haloxeric characters.

The work for last several decades on salinity has lead to formation of two schools of thoughts regarding the nature of

salt injuries. The Champions of Osmotic School (Bernstein and Hayward,1958) claim that most of the adverse effects of salinity are related to the decreased osmotic potential of saline root media. On the contrary the Champions of Specific Ion School (Eaton,1942; Strogonov,1964) propose that the adverse effects of salinity are caused mostly by the specific effects of individual ions. The work of Strogonov (1964), indicated that each type of soil salinity creates specific conditions for growth of plants and also determines the nature of anatomical and physiological changes which occur in it. According to Maas and Neiman (1978) such specific ion effects seem limited to certain susceptible plant species and rarely are a major cause of growth suppression. Among the two salinities, responses of plants to chloride salinity are extensively investigated.

Bernstein et al.,(1975) investigated the osmotic adjustment of plants to saline media and suggested that there is no apparent corelation between salt tolerance and osmotic pressure of expressed sap of leaves or roots. The reduction in growth under salt stress conditions may be regarded as a consequence of the requirement for osmotic adjustment and the primary mechanism for affecting it.

3) Mineral Nutrition :

The major nutritional effects of salinity are associated with cation nutrition. The regulation of ion concentration is

relevant to salt tolerance of vascular plants (Greenway,1965). Epstein (1968) suggested that halophytes and salt tolerant plants have developed a mechanism for the preferential uptake of potassium from mixtures rich in sodium and is supported by recent findings of Storey and Wyn Jones (1978) in members of Graminae. Stuiver et al.,(1978) found a difference in root membrane structure with respect to lipid composition which could be correlated with differences in membrane permeability to sodium and chloride in sensitive bean, less salt sensitive barley and the salt tolerant sugarbeet. La Haye and Epstein (1969) have shown that calcium ion has an ameliorating effect on plant growth under the conditions of salinity. According to Bernstein and Hayward (1958) a degree of physiological balance between Na^+ and Ca^{2+} must be present if toxicity due to high concentration of Na^+ alone is to be avoided. Wyn Jones and Lunt (1967) has documented the requirement of Ca^{2+} in maintaining membrane integrity and selective transport of other ions. According to Lessani and Marschner (1978) Ca^{2+} regulate membrane properties and it is proposed that Ca and Na probably compete for common uptake sites.

Accumulation of phosphorus in different parts of salt tolerant as well as sensitive plants grown under saline conditions has been reported by many workers (Ansari,1972; Narayanan,1975; Karadge,1981). Syed and Swaify (1973) reported that phosphorus content remained unchanged for sugarcane variety H 50 7209 under

the treatment of NaCl. However, Im (1969) observed no difference in the absorption of phosphorus by cabbage under saline conditions. According to Shimose (1972), Na_2SO_4 has no significant effect on phosphorus content of barley, wheat and asparagus. In citrus seedlings irrigated with saline waters similar observations have been made by Guillen et al.,(1978).

Contrary to the above observations there are several reports where reduced phosphorus uptake due to salt stress has been observed (Udovenko, et al.,1971; Paliwal and Maliwal,1972; Zhukhovskaya,1973; Singh et al.,1974; Kleinkopf et al.,1975; Dahiya and Singh, 1976; Tindel et al.,1979; Starack and Kozinska, 1980). According to Wilson et al.,(1970) the resistance to secondary salt induced stress in Glycine falcata lies in the ability to maintain high phosphorus content in presence of salt stress. The significant nutritional effect of salinity is impaired utilization of orthophosphate and salinity appears to damage plant mechanism, controlling intracellular concentration of it (Nieman and Clark,1976).

Very few attempts have been made to study the effect of salinity on Fe metabolism. Strogonov (1964) found that chloride salinity causes decrease in Fe content in gram and cotton. Similar type of observations have also been made by Rahman et al.,(1972) in Panicum, Oryzopsis, Crotolaria, Medicago and Chloris species. However, Guillen et al.,(1978) observed no effect on Fe content of citrus seedlings irrigated with saline waters. An increase in

Fe content in differant parts of tomato, squash, soyabean and peas have been recorded by Maas et al.,(1972), Dahiya and Singh (1976).

Very little work has been done regarding the role of Mg^{2+} in salt tolerance. According to Atkinson et al.,(1967) Mg^{2+} maintains the salt tolerance in the leaves of Aegialitis; a mangrove species. Bernstein (1975) has claimed that the tolerance of species for particular salts reflects the ability of species to absorb nutritionally adequate levels of Ca^{2+} and Mg^{2+} from the soil.

Many workers (Azizbekova and Babaeva, 1970; Meiri et al., 1971; Lashin and Atansia, 1972; Syed and Swaify, 1973; Guillen et al.,1978) have reported an increase in Mg^{2+} content due to salinity. On the other hand some workers (Im, 1969; Rahman et al.,1972; Cooper and Dumbroff,1973; Shimose,1973; Kleinkopf et al.,1975; Ackerson and Youngner, 1975; Guggenheim and Waisel, 1977; Laszlo and Kuiper,1979) have reported decreased Mg^{2+} uptake due to salinity.

Pearson and Bernstein (1958) and Bains and Fireman (1964) observed an increased uptake of sulphur by oats, rice, safflower and tomatoes but Bains and Fireman (1964) found reverse situation in several other crops and there is no change in the behaviour of barley, wheat, tall fescue and tall wheat grass (Pearson and Bernstein,1958) with increasing ESP of the soil.

Mn is one of the micro-nutrients about which very little information regarding the effects of salinity is available. It plays a vital role in many enzymatic reactions as a co-factor. A positive correlation between soil salinity and Mn content of the plant have shown by Hassan et al.,(1970). Maas et al.,(1972) found that Mn content increased in tomato and soybean tops but decreased in squash. Shimose (1972,73) has studied the effect of salinity on Mn content in several plants and observed a varietal differance in absorption and accumulation of Mn in the plants.

Influence of salinity on uptake of micronutrients like iron, manganese and zinc has been investigated by Maas et al., (1972) Absorption of some other micronutrients is suppressed due to increased uptake of Na. In general, absorption of Fe, Mn, Cu, Zn, B and Cl decreases and that of Mo increases at ESP around 25. But absorption of Mn by Sorghum and rye grass and Fe and Cu by tomato increased which may be due either to excessive accumulation as a result of reduced plant growth or to crop specificity (Bains and Fireman,1964). In saline soils the availability of Zn is low as compared to the sodic soils where availability decreases so low to develop deficiency symptoms. With increasing ESP of the soil in corn, safflower and tomato the Zn obsorption decreased (Bains and Fireman,1969) but in Sorghum it was unaffected or increased.

Leeper (1947) and Jones and Leeper (1951) observed low availability of Mn in mild sodic soils, but it is increased in highly sodic soils to a toxic level. Increased Mn uptake by beans and sweet corn under increasing levels of chloride salinity has been observed by Jackson et al.,(1966).

High salt concentration decreases or lowers the dissociation of nutrients which decreases high osmotic potential and reduction of root growth. The NaCl absorbed, competes with K^+, Ca^{2+}, Fe^{2+}, Mn^{2+}, etc. ions resulting a decrease in uptake of such ions. As a result the Na^+, Cl^-, SO_4^{2-} accumulate in the tissues with the reduction in intake of K^+ and Ca^{2+}.

4) Organic Constituents :

Boiko and Matukin (1966) determined enzymatic transformation of carbohydrates in the leaves of cereals in relation to their adaptation to soil salinization and found that the formation of sucrose was considerably increased with inhibition of its degradation in oats and millets. The starch content decreases with increase in salinity.

Gupta and Kaur (1970) observed that in pea varieties somehow, the hydrogénase activities are closely linked with salt tolerance. Probably dehydrogenase helps to maintain protein synthesis which otherwise is known to decrease under saline conditions. They (Gupta and Kaur,1970) further observed that a pea variety rich in ascorbic acid (a hydrogen acceptor) and also

processing a better mechanism to maintain the ascorbic acid level was more tolerant to salinity than the other poor in ascorbic acid contents and also showing greater variations in the acid content with salt treatment. Large amount of relatively strong organic acids of unknown nature accumulate in plants growing in sodic soils (Tulaikov, 1922). Some halophytes may accumulate organic acids upto 25% or more of their dry wt. These organic acids have an excellent binding ability with mineral elements in plant cells (Strogonov and Ostapenko, 1941; Strogonov, 1946, 1949).

The change is ionic balance in salt stressed plants is the shift in ionic interactions with the enzymes and intermediates of metabolism at several levels. Effect of salt stress on enzyme activities has been studied by several workers (Hasson Porath and Poljakoff-Mayber, 1968; Weimberg, 1970, Waisel, 1972). However, Greenway and Osmcnd (1972) in *in vitro* studies observed that the enzymes from salt sensitive and salt tolerant species do not differ markedly in their response to salinity. ATPase can behave differently in halophytes and glycophytes (Jennings, 1960). According to Flowers (1978) a compartmentalization of enzymes at a distance from salts in halophytic cells may help in keeping normal enzyme activities under saline conditions.

5) Photosynthesis :

A decrease in net photosynthetic rate due to salinity has been shown in the experiments of many workers. However,

Nieman (1962), based on the studies on twelve crop plants, suggested that photosynthetic assimilation of CO_2 is not the growth limiting factor in salinized media. According to Gale et al.,(1967) the adverse effects of salinity on photosynthetic rate are mediated through its influence on light reactions of photosynthesis. Nieman and Clark (1976) suggested that salt stress limits photophosphorylation. According to Strogonov et al.,(1970) salinity affects the strength of the forces binding the complex of pigment-protein-lipid in the chloroplast structure. Further, they have stated that change in the chloroplast content due to salinization is related to salt tolerance capacity of the plant. According to Udovenko et al.,(1971) due to migration of chloroplasts into the lower parts of pallisade and spongy parenchyma cells, photochemical activities are inhibited.

Lapina and Bikhmukhametova (1972) indicated that photosynthetic ability under saline conditions decreases due to the growth retardation and the diminished assimilation area of the leaves. Downtan (1977), based on the work of photosynthesis in salt stressed grapevines, suggested that the salinity induced decrease in photosynthetic rate can be largely attributed to increased residual (mesophyll) resistance to CO_2 fixation. According to Passera and Albuzia (1978), the reduction in $^{14}CO_2$ assimilation rate of higher concentrations of salt may be due to increased rate of photorespiration. Salt stress also brings about

significant changes in the pattern of photosynthetic carbon metabolism. For the first time Bidwell (1958) showed that photosynthetic pattern in marine algae is significantly different from higher plants and is characterized by synthesis of number of organic compounds uncommon in higher plants. NaCl concentrations have marked influence on dark CO_2 fixation (Joshi et al.,1962; Karmarkar and Joshi, 1969). It has been reported in Bryophyllum pinnatum that dark $^{14}CO_2$ fixation and CAM is stimulated due to NaCl salinity (Karamarkar and Joshi, 1969 and Kulkarni, 1975).

A shift in the labelling pattern from organic acids to amino acids in the marine plants has been observed by Joshi et al.,(1962) and Webb and Burley (1965). Winter and Willert (1972) have shown that a C_3 plant Mesembryanthemum crystallinum responds to salinization with the development of crassulacean acid metabolism (CAM). Similarly, C_3 to C_4 shift due to salinity was predicted by Shomer Ilan and Waisel (1973) in a grass Aleuropus litoralis. In Portulaca oleracea subjected to NaCl salinity, Kennedy (1977), Joshi and Karadge (1979) observed an increase in labelling in C_4 acids and suggested the tendency of this plant towards CAM (Karadge and Joshi,1983). A shift from C_3 to C_4 intermediate pathway is recorded by Ghevade and Joshi (1980) in sea grass, Halophila becarii; Karadge and Chavan (1981) in groundnut and Hegde and Patil (1982) in Parthenium hysterophorus. Sankhla and Huber (1974) studied the effect of NaCl salinity on $^{14}CO_2$

SHIVAJI UNIVERSITY LIBRARY KOLHAPUR

fixation in seedlings of Pennisetum typhoides and found that the high concentrations of NaCl (1.7×10^{-2}M) increased $^{14}CO_2$ incorporation in organic acids (especially malate) but less radioactivity was detected in amino acids fraction (alanine). The marine algae and mangroves follow a modified C_4 pathway (Patil,1967; Gowada,1971; Joshi and Karekar,1975; Joshi et al., 1974; Joshi and Shitole,1977).

Thus, it is apparent that photosynthetic carbon metabolism is variously altered in different plant species when are subjected to salt stress.

Both RuBPcase and PEPcase, the key enzymes of photosynthesis are also adversely affected by salinity even at the low levels of salt. Osmond and Greenway (1972) reported that PEPcase from salts tolerant Atriplex is more severely affected than that from salt sensitive Zea mays. Malate dehydrogenase activity is enhanced with decreased activity of PEPcase and RuBPcase in Pennisetum typhoides, a C_4 plant (Sankhla and Huber,1974). On the contrary stimulation of PEPcase in a C_3 halophyte, Cakile maritima and sea grasses is reported by Beer et al.,(1975). They have observed an inhibition of RuBPcase in sea grasses. On the other hand,Heuer and Plaut (1982) reported an increased activity of RuBPcase in salt tolerant sugarbeet and suggested that salinity may induce confirmational changes in the enzyme structure.

Salinity decreases chlorophyll a, b and total chlorophylls, carotenoids, reducing sugars, starch and Hill reaction activity

and increases chlorophyllase and invertase activity (Reddy and Vora, 1986).

6) Nitrogen Metabolism :

Various types of salinities affect the production of amino acids and proteins. According to Strogonov et al., (1956) salinity increases the amino acids content from 10 to 15% in chloride and by 18% in sulphate type of salinity. Similarly Strogonov (1964) and Stewart and Lee (1974) also found that amino acids and amides accumulate in tissues of salt stressed plants. However, Ter-Karapetian (1957), noted disappearance of certain amino acids - lysine, threonine and glycine from plants under saline conditions. Lapina (1966) has noted a sharp decrease in protein nitrogen, increased accumulation of number of amino acids (lysine, proline, aspartic acid, glutamic acid, alanine, tyrosine and valine) and amides. In the salt damaged leaf tissue, total and protein-nitrogen are markedly reduced (Benzoni et al., 1967). However, high amount of total nitrogen in halophytes and Clerodendron inerme under saline conditions has been recorded by Mishra (1967). While, Joshi et al., (1962) have observed stimulation of transaminases in marine algae and terrestrial plants and presented an evidence that salinity diverts carbon flow from organic acid synthesis towards amino acid synthesis. Some results were confirmed by Webb and Burley (1965), Weimberg (1967) and Karekar and Joshi (1973).

According to Reistad (1970) proteins of all the extreme halophytes tested were relatively high in aspartic and glutamic acids and low in lysine and alanine. Decreased protein level in salt treated Lobularia maritima and Bryophyllum crenatum has been recorded (Catarino,1969). In salt tolerant Atriplex polycarpa nitrogen metabolism and growth response were studied by Chatterton et al., (1971) and they found that some non-tolerant species of Atriplex accumulate non-protein nitrogen when grown in saline conditions but no such increase in Atriplex polycarpa was found. According to them adaptability of this plant is due to its high protein content. The growth of Sueda maritima in the upper salt marsh appears to be nitrogen limited (Stewart et al.,1977). However, the overall content of amino acids in the same salt bush was unaffected by the salinity of the growth medium (Flowers and Hall,1978).

The rate of accumulation of non-protein nitrogen decreases sharply with increasing salinity levels, while total nitrogen content increases except at the high salt concentration. The balance between soluble amino acids and proteins is changed by saline habitat. Salt treatment results in decrease in protein content of plant tissue (Neeman,1965; Huber et al.,1977;Pessarakli and Tucker, 1985; Reddy and Vora,1985). According to Reddy and Vora (1985), due to salinity, protein and RNA contents are decreased with the increase in protease and RNAase activity resulting in accumulation of amino acids.

According to Longstreth et al.,(1984) the level of soluble proteins remains constant. On the other hand stimulation of protein synthesis is reported by Singh and Vijaykumar (1975); Helal et al.,(1975); Kumar et al.,(1982) and Parihar and Baijal (1983). However, this stimulation depends upon the degree of salinization.

Karmarkar and Ranganathan (1971) observed that at low salt concentrations glutamate-pyruvate, alanine transaminase system was stimulated. It has been suggested by them that these transaminases might be associated with CAM in Bryophyllum pinnatum and Aloe vera. Under saline conditions, nitrogen and protein metabolism was found to be stimulated in Aloe barbadensis (Bartakke,1977).

Bottacin et al.,(1985) have studied the effect of NaCl salinity on nitrogen absorption and assimilation in salt resistant and sensitive genotypes of Pennisetum. The salt injury occur usually through the influence of salt on nitrogen metabolism of a plant. The amino acids and other soluble nitrogen compounds play an important role in salt tolerance mechanism of plant. Salinity influences nitrate uptake by inhibiting it (Rush and Epstein,1976; Aslam et al.,1984; Bottacin et al.,1985).

According to Strogonov et al.(1970) along with the carbohydrates, organic acids, pigments such as anthocyanins and carotenoids, nucleic acid proteins, some amino acids like proline have protective properties towards salt stress. Free

proline has been found to vary with salt concentrations in halophytic higher plants (Stewart and Lee, 1974; Treichel, 1975). It has been suggested that proline functions as a source of solute for intercellular osmotic adjustments under saline conditions and the capacity to accumulate proline is correlated with salt tolerance. It is known that proline content of glycophytes is normally negligible. However, it increases markedly in plants subjected to salinity (Palfi and Juhasz, 1970; Storey and Wyn Jones, 1975; Chu *et al.*, 1976).

It has been reported in non-saline succulents *Lobularia maritima* and *Bryophyllum crenatum* that NaCl treatment induces proline synthesis (Catarino, 1969). Recently Cavalieri and Huang (1978) have shown that C_4 grasses have higher threshold values for proline at sea water and accumulated 63.6 mM of proline g^{-1} fresh wt, while C_3 plants accumulated 27.4 mM of proline g^{-1} fr. wt at salinities greater than 1%. However, succulents did not accumulate proline until extremely high salinities were applied. From these observations it appears that proline has a little role in salt tolerance in succulents.

In several plant species differing in salt tolerance close relations between betaine levels and salt stress has been reported (Storey and Wyn Jones, 1975). Betaine concentration varied under saline conditions from negligible in salt sensitive tomato to 0.4% fr. wt in the halophytes, *Suaeda manoica*. The hypothesis has been put forth by Flowers *et al.* (1978) and Hall

et al.(1978) that betaine acts as a cytoplasmic osmoticum to balance high vacuolar salt levels in certain levels. These compounds - proline, betaine and putricine whether play a significant osmoregulatory role or not depends upon whether they are confined to cytoplasm or are evenly distributed throughout the cells (Maas and Nieman,1978). However, Chu et al.(1976) observed that proline couldn't exert an osmotic potential below - 0.5 bar, if diluted by the entire cell volume.

B) Germination :

1) Introduction :

Seed germination is the most important event in the life cycle of higher plants. When a viable (i.e.living) seed is wetted, water is taken up, respiration, protein synthesis and other metabolic activities begin and after a certain period of time the embryo emerges from the seed, generally radicle first and the seed is germinated. Though the process of germination is easy to recoganize it is very difficult to define.

It is defined by different workers in different ways. According to Evenari (1961) seed germination is the, sum total of all the physiological process occuring inside the seed which starts with the imbibition of water and ends with the protrusion of embryonic root. Botanists define germination as " the emergence of radicle from seed coat " (Lang,1965). Heydecker (1973) recoganized seed germination as the process of activation of hitherlo

resting embryo.

He is of the opinion that, the germination starts with the first metabolic process during imbibition. However, according to him it is difficult to determine the end point.

Thus, germination differs with the person. From all these, one can say that germination is a very complicated dynamic process involving several biochemical pathways.

Seeds will germinate only if are given appropriate environmental conditions including water, air, temperature, free from high salt concentrations, inhibitors and sometimes some specific spectral quality of light.

Seeds are highly dehydrated and naturally require water before germination. The first phase of seed germination is penetration of water through micropyle and imbibition of various tissues of the seed till a critical level of water is attained. This causes considerable increase in the volume of the seed. The dry seed coats which are impermeable to gases in the dry conditions now become somewhat permeable to oxygen and carbon dioxide. The pressure exerted by the seedling often ruptures the testa.

Once the imbibition is completed seeds begin to germinate and seedling emerges out. Radicle/root penetrates the seed coat and is followed by shoot emergence. This is the phase of emergence. In this phase root and shoot systems develop. Thus, germination is preceded by imbibition and followed by the emergence.

Water also brings about the hydration of the cell walls and protoplasm. Osmotic absorption of water now replaces imbibition. The enzymes claimed in the cotyledonous cells became active and begin to digest the stored food which is then converted into soluble form and transported to the radicle and plumule tips. If the food is stored in the endosperm, the enzymes migrate into the endosperm and digest the food. The digested food then migrates to the cotyledons and from there it is transported to the growing tips. In the process of digestion, the stored carbohydrates are converted into soluble sugars; the fats are digested into glycerol and fatty acids. The β-oxidation of fatty acids and the glyoxalate cycle results in the formation of succinic and malic acids which may be converted into sugars.

The soluble carbohydrates are partly consumed in respiration and partly used in constructing cell wall. The digestion of storage proteins results in the production of amino acids. These are not consumed in respiration but are the starters for the synthesis of structural proteins in the growing regions and of other complex nitrogenous compounds from which new protoplasm is built up in the cells of growing embryo. Respiration in the early stages of germination is mostly anaerobic. As the seed coats become partially permeable to gases / consequent upon their structure, the anaerobic respiration is gradually replaced by aerobic respiration.

2) Biochemical Changes During Germination :

The biochemical changes occuring before and during germination are very important because the breakdown of reserve food material in the cotyledons of seeds takes place in different stages. According to Koller et al.(1962) in all such studies two things should be borne in mind. Firstly it is not always clear whether metabolic events which have been observed are the results of its cause. Secondly, it is quite possible that the extent of given metabolic process may be marked because whole seed or seed extracts are normally used for experiments.

The quiscent state of mature plant seed is characterised by arrested growth, suspended development and a substance level of metabolism (Khan,1977). With the proper environmental stimulus, biochemical processes that were markedly desreased during seed maturation readjust to a state more characteristic of a growing system.

The metabolism of germinating seeds is amphibolic i.e. it is both catabolic in the sense of degrading reserve compounds to provide energy and raw materials for the early growth of the seedling and metabolic in the sense of producing machinery for protein synthesis and kiogenesis of various organelles needed for catabolic activity as well as the true anabolic synthesis of new cells and tissues (Ching,1972). Major catabolic activities are localised in storage tissues such as endosperm and cotyledons while anabolism takes place in the embryo axis. These metabolic

processes are not all stimulated simultaneously but are activated either in series or in parallel depending upon the mechanisms responsible for their control.

Leguminous seeds contain large amount of storage proteins and several polysaccharides are reserve food materials which are utilized during germination of seeds. But the nature of the enzyme involved is not known. An account of work done by Krishnamurthy and his associates (1980) on Cicer arietinum, is given to understand the mechanism regulating the various biochemical process occuring during germination. Quantitative changes in the various reserve materials like proteins, amino acids, starch and activities of several enzymes associated with germination have been studied in this species. Protein reserve of the cotyledons was found to decrease by about 50% in seven days of germination, whereas an axis showed an increase of 30% in the net protein content. Recording the amino acid content, an accumulation occurs in the cotyledons during germination. The net proteolytic activity of the axis was several fold than that of cotyledons. The activity of seedlings may arise from the synthesis of new proteins to sustain a growing tissue. Starch constituted about 50% of the dry weight of the seed. Starch and polyfructosans are found to be depleted during germination to a level of 20% and 47% of the dry wt respectively. Degradation of starch resulted in an increase in the amount of soluble sugars and other easily assimiable sugars. The activation of α-amylase and starch

phosphorylase suggests that degradation of starch occurs both by hydrolytic and phosphoryletic cleavage. Presumably sucrose arising from phosphorylating clearage is transported to the axis from the cotyledons and is converted into reducing sugars like glucose and fructose.

The metabolic activities in seeds under optimum conditions, for germination, show a triphasic pattern of water uptake.

Initial uptake of water in phase I (imbibition) occurs irrespective of whether a seed is a dormant or non-dormant, viable or non-viable. Imbibition is the first phase of seed germination i.e. rehydration of seeds by water i.e. uptake of water by seeds. The imbibition rate and quantity of water imbibed during germination depends upon different factors like nature of seed coat, permeability of seed coat or fruit coat to water, seed size, chemical composition of seed and temperature. This is physical process and during which reduction of macromolecules and cell organelles takes place. In most of the cases cell enlargement rather than cell division occurs.

Three phages of imbibition have been recoganised. The first phase is short phase and is of 10 minutes. The second phase is of longer duration (one hour) of further imbibition and the third phase in which there is continuous uptake of water. This phase coincides with an increase in the rate of respiration and number of mitochondria and crestae are also increased. Mitochondria in dry seeds are not normal, active mitochondria,

although they can probably maintain certain oxidative functions. Low levels of respiration have been reported in 'dry' seeds. Seed and fruit coats can act as barriers to the uptake of water and thus prevent or retard germination. They can also affect respiration by limiting the permeability to oxygen.

As the imbibition starts there is rapid change in mitochondria which increase their activity (Eldan and Mayer, 1972). The activation of mitochondria during the early stages of imbibition of water is therefore very significant in controlling the initial rate of seed germination. In first 15 minutes' imbibition there is reformation of keto acids from amino acids by deamination and transamination reactions and is considered to be a very early metabolic event (Collins and Wilson,1975). Similarly during respiration there is oxidative breakdown of certain organic constituents or available substrate other than that derived from hydrolysis of the major stored reserves which only become available after embryo growth has commenced. Therefore, in germinating seeds, there is always change in the pattern of respirable substrate. During germination in seeds different pathways namely glycolysis, the pentose phosphate pathway and citric acid cycle are assumed to become active. Naturally, these pathways considerably increase the respiration rate and this is the most conspicuous metabolic process taking place in the seeds.

Bewley and Blank (1978) have given four phases that are involved in respiration during germination. These phases are :-

i) Phase I - During this phase of germination there is sharp rise in respiration, progressing the linear swelling of cotyledon tissue. The major respiratory substrate is sucrose and the respiratory quotient (R.Q.) is slightly above 1.0.

ii) Phase II - After the beginning of imbibition there is lag phase between hours 10 and 25 and it may be due to limited supply of oxygen. In this phase hydration is completed and the enzymes in the seeds are activated. There is rise in R.Q. upto 3.0, as compared to the first phase which indicates, anaerobic respiration.

iii) Phase III - This phase is characterised by the fall in R.Q. to about 1.0 indicating predominant aerobic respiration of carbohydrates.

iv) Phase IV - This is the last phase and is marked by the fall in respiration with the disintegration of storage organs followed by depletion of the stored reserves.

Besides these one of the important biochemical events of germinating and growing tissue is protein synthesis. The reserved proteins present in grains and cotyledons of the seeds are hydrolysed by the enzymes proteases and peptidases.

Germination is characterised by a decline or reduction in protein content of the storage tissue and an increase in the soluble nitrogen components in the growing embryonic axis, suggesting that during germination proteins in the reserve tissue are

hydrolysed to amino acids which are translocated to the growing axis (Ingle et al.,1964; Beevers and Guernsey,1966). Proteins are broken down to amino acids and amides during seed germination with rise in the level of amino acids and amides followed by de novo protein synthesis not only in growing parts of embryo (Ota et al.,1953) but also in the endosperm (Young and Varner, 1959; Young et al.,1960). The hydrolysis of reserve proteins is catalysed by enzyme proteases to yield amino acids and units of peptides. An increase in protease activity during germination of pea and squash seeds has been reported by Beevers and Guernsey (1966) and Wiley and Ashton (1967). During germination there is increase as well as decrease in the activity of peptides (Beevers and Splittstoesser, 1968; Prentice et al.,1969). Of the total amino acids liberated during protein hydrolysis, some are utilised for synthesis of proteins in the growing parts of the seedling and deamination of remaining amino acids provide carbon skeletons for various respiratory and carbon cycles.

All seeds contain a certain amount of protein. The breakdown of protein and the appearance of new proteins is followed by the appearance of other nitrogenous compounds as germination proceeds. The presence of proteases and peptidases has been shown in many seeds. Some of the proteins and peptides are present in the dry seeds while other appear during germination. In most cases the enzymes having proteolytic activity are soluble and are present or develop in the storage organs i.e. in the cotyledons or the endosperm.

Starch is the most important and widespread reserve carbohydrate in seeds. Starch is normally broken down by amylases. However, the exact path by which these amylases function is different in different seeds. Usually seeds contain both amylose and amylopectin. Dry seeds contain β-amylase which detaches units of maltose from the starch molecules. In the case of attack on amylopectin, dextrins are formed, while when amylose is attacked the molecule is broken down more or less completely. In most seeds, as germination proceeds, other enzymes attacking starch are liberated. More particularly α-amylase is formed. Phosphorylases are also appear to be present, both in dry seeds and in germinated ones.

The result of the hydrolysis of starch by β-amylase, maltose, rarely accumulates as such in the seeds. Maltose is further broken down to glucose by maltase. Attack on starch by -amylase results in a mixture of sugars, including maltose and glucose. The maltose again is usually broken down further.

<u>Zea mays</u> seeds contain only β-amylase in the seeds. The rise in amylase activity in the seed during germination is primarily in α-amylase which, when amylolytic activity is at its peak, accounts for 90% of total amylolytic activity of the endosperm.

3. <u>Factors Controlling Germination</u> :

The germination of seeds takes place only when conditions are favourable. Environmental factors has marked influence on the

germination of seeds. It is controlled and regulated by different factors like light, temperature, water, soil etc. Besides these factors other factors like fertilizers, herbicides, fungicides and insecticides are equally important, which also affect the germination.

According to Sen (1977) there is an interrelationship between the various environmental factors and the germination of seeds, and which varies from plant to plant and species to species. Fluctuations in the environmental factors are stimulatory as well as inhibitory and they cause certain physiological disorders in germinating seeds, ultimately leading to the disturbances in the developmental processes like development of morphological disorders.

a) Light :

Light has marked effect on germination. It affects the germination in both ways. It has stimulatory as well as inhibitory effects. The necessity of light in the process of germination was recognized for the first time by Cieslar (1883). Some seeds are sensitive to light, some require light for germination and in some others, germination is prevented by light. The phenomenon is known as "photoblastism" (Evehari,1956). Accordingly, seeds may be positively photoblastic (requiring light), may be negatively photoblastic (dark requiring) or they may be non-photoblastic in which germination is neither stimulated nor inhibited but it takes place irrespective of light and this

response depends upon the quality, quantity and duration of light.

According to Mukharjee (1967) light is favourable for germination of seeds of Panicum coloratum, while, the seeds of Panicum turgidum and Cenchrus setigerus comparitively prefer dark conditions for germination. On the other hand the seeds of Cenchrus ciliaris and Panicum antidotale found to be indifferent to light.

Borthwick and associates (1952) working with lettuce seeds germination, showed the red and far red photoreversibility in germination and is regulated by phytochrome - a photoreceptor pigment which is present in two different forms Pr - a red and Pfr - a far red form.

$$Pr \underset{\text{far red light}}{\overset{\text{red light}}{\rightleftharpoons}} Pfr$$

It is clearly established now, that actually phytochrome is a metabolic switch, involving in number of metabolic processes (Smith,1975). However, Pr/Pfr ratio is different in different (+ vely photoblastic and - vely photoblastic) seeds (Malcoste,1967).

In light requiring seeds germination is controlled by a Pfr level. In such seeds phytochrome is in the Pr form. Red light converts Pr into Pfr form which promotes germination. When far red (FR) is given after red (R) irradiation, Pfr is converted to Pr thus inhibiting the germination. The germination in negatively photoblastic seeds may be due to the presence of sufficient

level of Pfr to bring about germination. Macinelli et al.(1967) have demonstrated in dark germinating seeds of tomato that a single short far red (FR) irradiation inhibits germination and red (R) applied after FR repromotes germination indicating the presence of sufficient amount of Pfr in the dark germinating seeds to bring about germination in darkness.

According to Smith (1975) the quality of light is important even during maturation of seeds in deciding the phytochrome state which further determines the germination behaviour.

It has also been shown that the day light affects germination. According to Kovrigo and Krustina (1966), the seeds of weed plants, Dracocephalum thumiflorus and Matricacria discoidea germinate in dark at the rate of 0.3 to 0.7% while in the light the same rate reaches to 69 to 92% depending upon photoperiod. In the seeds of Oryzopsis miliacea, the germination in dark was only 13% but after 1 to 2 minutes of exposure to red light it was elevated to 50% (Negbi and Koller, 1964). The seeds of Asteracantha longifolia are capable of germinating in light (Sen and Chawan,1968). The germination was favoured by blue or red light, whereas, total darkness delayed it. Thus, the spectral zone is also found to affect germination differently. The light having wavelength of 670 nm promotes germination while that of 700 nm inhibits it. However, the exact period of illumination controls the stimulation or inhibition.

According to Sharma et al.(1975) germination percentage of Caesalpinia bonducella in blue red spectrum light was highest, whereas dark and green spectrum of light had adverse effects.

In total darkness, maximum radicle and plumule elongation of the seedlings of Phaseolus radiatus was found, however it was to a lesser extent in continuous light (Jewasi,1965). Red light strongly inhibited germination. While studying the germination of false broom weed (Ericameria austratexana) seed, Mayeux (1982) observed maximum radicle elongation and fresh weight of 14 days old seedlings when germinated at continuous temperature of 15-30°C when 8 hours daily light was provided. Germination was suppressed in the dark.

b) Water :

Water is one of the most important factors, which has profound effect on germination. It is a universal solvent and a medium in which most of the metabolic processes take place. According to Vartapetyan (1966) water is the source of O_2 for aerobic oxidation and not the molecular O_2. With the increase in the hydration level of seed, pre-existing macromolecules and organelles are reactivated during germination.

Water is essential for seed swelling and thereby for the activation of RNA (Marcus and Feeley,1964). For seed germination, absorption of water is the first and the most essential process. In the beginning, water is taken up by imbibition. The seeds like Xanthium, can take up water by the process of imbibition

(Wareing,1969). The availability of water in soil varies and depends upon the nature of the soil, its chemical composition and temperature. Similarly availability of water for germinating seeds, is limited by prolonged drought of arid and semi-arid conditions.

Although, slight positive soil moisture tensions have been reported to have promotive effects (Cavazza,1953), the increasing moisture tension of the medium resulted in slower and reduced germination. According to Haller (1984), difference in the water and air regimes of the germination environment, may cause variations of 30% and over in the yield of barley, wheat and oats. The maximum limit of moisture tension at which seeds can absorb sufficient water for germination differs from species to species (Hunter and Erickson,1952). Cavazza (1953) and Sircar et al.(1955) observed that the rice is insensitive while other species and varieties are sensitive to an excess moisture tension.

Due to evaporation, prolonged drought causes considerable changes in the osmotic potential of the soil water. At the germination stage, varietal difference regarding drought resistance, was evident in some experiments (Richards,1978). Joyce et al.(1985) in their experiments on the radish plants subjected to different water deficit during the expansion of fleshy axis and cell division, observed that water deficit inhibited both cell expansion and cell division in all axis tissues and lignification of parenchyma during deficit period. When water stress was not relieved, cell expansion in pericycle cells out stripped the recovery of cell division.

7572
A

Oizumi et al.(1981) studied the effect of water stress in germinating seeds of seven legume species and observed that the seeds were more susceptible in the advanced stage than in the early stage of germination. They also found increased germination percentage and promoted growth probably due to breaking of the dormancy in case of highly tolerant species to water stress.

c) Temperature :

Temperature is one of the critical factors of the environment which exerts a profound influence on all the metabolic activities, by controlling the rate of chemical reactions. There is variation in germination temperature, called as cardinal temperature, viz. minimum, optimum and maximum, which varies from species to species. Different seeds have different temperature ranges within which they germinate.

The optimal temperature may be taken to be that at which the highest percentage of germination is attained in shortest time. The minimal and maximal temperatures for germination are the highest and the lowest temperatures at which germination will occur. The maximal temperatures at which germination still occurs may be as high as 48°C, e.g. Cucumis sativa (Knapp,1967).

The temperate spp. require minimum temperature than the trophic ones. The germination in the seeds of various alpine plants takes place at the temperatures little above 0°C.

Some germinate at constant temperatures or within a specific range of temperatures depending upon the stage of development. According to Knapp (1966), the optimum germination in mung bean seeds required temperature 24-30°C. Sharma et al.(1975) recorded maximum germination in Caesalpinia ponducella when temperature was elevated from 25°C to 30°C, whereas, no germination occurred at 0 to 20°C. According to Chatterji and Mohnot (1964) the optimum temperature requirement for germination varies from species to species and even it differs from season to season.

Variation in temperature affect the seed metabolism (Maquire,1973) in many ways. According to Come and Tissaoui (1973) higher the temperature, smaller is the quantity of oxygen available to the embryo. Further, they have speculated that the seeds with seed coat rich in substances like phenolic compounds, capable of fixing dissolved O_2 on its way to embryo, become highly sensitive to high temperature. Catabolic activities in the seeds, that require warm temperature to germinate, may be inhibited by low temperatures or may fail to activate and proteins denatured by excessively high temperature upsetting the anaerobic activities involved in producing the seedlings. The relation between enzyme activity and temperature is fairly well established for a number of enzyme systems. Nikolaeva and Yonkuevich (1979) studied the effect of low temperature on the activity of some enzymes and germination of Siberian pea tree seeds and they found increased peroxidase activity due to cold adaptation of the seeds.

According to Raynolds and Thompson (1971) the response of seeds to external conditions can also be modified with regulators. The salt tolerance of sugarbeet under different NaCl levels at various temperatures has been studied by Mahmoud and Hill (1981) and have shown that salinity had little effect on seedling emergence at 10° to 15°C, but was considerably inhibitory at the temperatures from 25° to 35°C. According to Levitt (1956) probably there is some correlation between the storage materials in the seed and their heat resistance, although, seeds may still be viable after treatment at high temperatures; the subsequent development of the seedling is often adversly affected.

The effect of temperature on germination is not independent of other factors. According to Baar (1912) Physalis franchetti seeds germinate well in the dark between 5° and 15°C. Between 15° and 35°C, they require light for their germination and the light requirement increases with the temperature. Similar situation is observed in lettuce. Taylorson and Hendricks (1972) also demonstrated the interaction of temperature and light by work on Rumex crispus. The seeds germinate when exposed to a temperature shift from 20° to 35°C for short periods. High temperature, 30°C, reduces germination. Exposure to 30°C during imbibition, reduces the subsequent response to temperature shifts. This high temperature effect is reversed by exposure to low energies of red light (R). It appears that germination in dark, caused by the temperature shift, is due to an effect of the temperature shift, on pre-existing phytochrome in the seeds in the Pfr form.

d) Soil :

Soil is another most important external factor which markedly affects germination of seeds. Both physical and chemical properties of soil influence the seed germination and seedling growth. Similarly soil composition and soil moisture level also affect the seed germination and helps to establish the seedling in the soil.

In India about 10-11 million hectares of land has become saline (Rammurthy,1968). Saline soil is non-alkali soil which contains soluble salts in large quantities which adversely affect growth of the plant. The pH of such soil is 8.5 having exchangeable sodium percentage less than 35. Sodic soil may be saline or non saline, saline sodic or saline alkali. Saline alkali soil contains exchangeable sodium as well as soluble salts having pH less than 8.5 and exchangeable sodium percentage greater than 15.

Non saline sodic or non-saline alkali soil has exchangeable sodium percentage greater than 15. The pH is also greater than 8.5. Such soil has ppor physical conditions and has low permeability to water and air. When moist, they are sticky and become hard after drying. Soluble organic matter at the upper surface of the soil affects the growth of a plant.

According to Epstein (1972), pH of the soil is a crucial factor governing nutrient availability for the crop. The ionic composition of the soil also affects germination. Some seeds

require calcium rich soil while some others require sodium rich soils.

4) Germination under saline conditions :

The phase of germination and seedling growth is a critical one, as the ability of a crop to germinate and establish the seedlings frequently becomes a limiting factor in crop production. But, there is not always a positive corelation between salt tolerance at germination and during the later stages of growth. Some of the crop species which are very tolerant to salts during later stages of growth are quite sensitive during germination and vice-versa (Bernstein and Hayward,1958). Number of workers have further demonstrated significant varietal differences in salt tolerance of wheat, rice, barley, jute and peas etc. Still the knowledge of salt and sodium tolerance at germination and early seedling growth is of primary importance as the initial stand determines the final production to a large extent.

The first effective increment of salinity for a given crop, generally retards the rate of germination with little or no effect on the ultimate number of seedlings which emerge. At high levels, salinity further delays emergence and also decreases the ultimate germination percentage.

The excess of sodicity depresses germination and emergence of alfalfa more than the yield (Chang,1961). Salt causes delay in germination, because of the reduced availability of water.

Thus, the salinity effects are more severe at lower soil moisture levels than at higher as the soil moisture tension and osmotic pressure exert additively. Germination is either decreased or delayed while at high salt concentration the final germination percentage is decreased. Due to low osmotic pressure of the cell sap than that of the external salt solution, seeds are unable to absorb sufficient water necessary for germination (Novikov,1936). Heerkloss et al.(1980) have observed the species and varietal differences in salt tolerance during germination. The time and rate of germination under high saline conditions are severely affected. Due to toxic effects of Na^+ and Cl^- high salt concentration inhibits germination. Even in halophytes salinity affects germination.

There is an evidence that certain salts or ions may be toxic to the embryo or seedlings, occuring significantly at high concentrations (Hayward and Wadleigh,1949) and may thus limit germination. This toxicity may result in the reduction in germination and which is frequently accompanied by abnormalities in the growth and development of seedlings. These studies indicate that the germination is retarded or inhibited by the presence of soluble salts in the soils.

Buffum (1886 and 1899) showed that " the retarding effect of a salt solution on the germination and seedling growth is directly proportional to its osmotic pressure when the solutions are strong." Similarly many workers (Magistad, 1945; Dewey,1960;

Maliwal and Paliwal,1967) have concluded that high osmotic pressure inhibits germination. Sorour et al.(1977) found that seedling emergence was delayed in T.aestivum with increasing level of salinity. The low and medium salinity levels (3000 and 6000 ppm) exerted suppressing effects on seedling emergence. Reduction in germination of safflower with increased salinity from 0 to 20% of NaCl have shown by Sionitt et al.(1973) and have also shown variations among the safflower varieties during germination. The germination in rice is adversly affected when electrical conductivity of NaCl exceeds 8.9 mS cm^{-1} (Narale, et al.,1969). Sarin and Narayanan (1968) have also shown in wheat that salinity depresses and delays the germination. The germination and growth of Atriplex polycarpa affected by NaCl in water culture have been studied by Chatterton and McKell (1969) and observed that germination was severly reduced by solutions having osmotic pressure of 4.2 atm. or less. It was observed that as the level of salinity increased root/top ratio also increased.

Singh et al.(1971) have reported in P.aureus variety RS-5 that germination was not affected at salinity levels upto 22-5 meq but which was slightly decreased at 50 meq and markedly decreased at 100 meq. Germination retardation under saline conditions is mainly due to a lower mobility of water in salinised medium (Udovenko and Alekseeva,1973).

The salinity injury is often noted at the initial stages of plant growth which could be attributed to an upsetting of the

metabolism of the germinating seed due to accumulation of toxic ions (Cl, SO_4, etc.) in the seedling or an imbalance of the accumulated ions. The salt tolerance of rice diminishes after germination (Pearson et al.,1966). Generally it is believed that the plants are more sensitive to salinity at germination than at later stages of growth (Kling,1954; Bhumbla et al.,1968).

According to Allison (1964) rice quite a tolerant during germination but becomes sensitive during seedling stage. On the other hand, however, Kaddah et al.(1973) observed that salt tolerance of rice continues to increase after the seedling stage with no decrease during flower and seedset. Ayers (1952) and Maliwal and Paliwal (1967) found that barley was more salt and alkali tolerant at germination stage than wheat.

Salinity creates several metabolic disorders in the germinating seeds that can be recoganised immediately by changes in the pattern of key enzymes and metabolites. The disorders ultimately lead to the retardation of growth and failure of emergence of normal seedlings.

Enzyme systems like amylase, catalase, acid phosphatase, protease and transaminase are affected by salt accumulation in seedlings (Bharadwaj,1965; Sarin and Narayanan,1968; El-Fouly and Jung,1972; Huber and Sankhala, 1974; Prisco and Vieira,1976; Sheoran and Garg,1979). Rizk et al.(1979) have observed that

the germination percentage, germination rate index, seedling length and dry wt of seedlings progressively decreased with increase in salt concentration and also the germination responses were different with different salts. NaCl stress inhibits the enzymatic and respiratory activity during germination ultimately resulting in growth reduction (Sung, 1981).

C) Scope of present investigation :

The brief review of literature presented above indicates the spectrum of soil salinity problems as well as the importance of germination process in the life cycle of a plant. It also reveals that most of the studies with respect to salinity tolerance in plants are centered around the cereal crops like rice, wheat, maize, barley etc. Considerable work has been done on pulse crops by various research centers throughout the world. There is extensive work on the legumes like pea, soybean, gram etc. However, most of the legumes have been relatively less investigated for their salt toelerance. The studies in relation to physiology of salt tolerance during germination are quite a few in the legumes.

There are numerous minor grain legumes which are cultivated on smaller scales and inspite of their high nutritive value and wide range of adaptability they have received however, a scant attension from the scientific community. In the present investigation, therefore some of the minor grain legumes have been studied for their salt tolerance during germination.

Following are the legume species selected for the present investigation :

1) Horse gram (D.biflorus Roxb.) :

This legume can be grown over a wide range of soil except the badly alkaline bands. It can be grown as a dry crop under low rainfall. It is extensively grown (around two million hectares with a production of half a million tonnes), particularly in peninsular India. It is grown mainly to provide feed and fodder for cattle and horses. The work done on the improvement of this crop is meager.

2) Lentil (L.esculenta, Moench.) :

It is a cool season crop, can be grown on a wide range of soil. It is raised on light loams, alluvial soils and even black cotton soil. It can stand moderate amount of alkalinity. The area under this pulse in India is around 0.9 million hectares, with a production of 0.45 million tonnes. Unripe pods are used as a green vegetable. The seed contains approximately 25% protein. Only a few improved varieties are available.

3) Moth bean (P.aconitifolius, Jacq.) :

It is the most drought resistant of the kharif pulses, and is largely grown as a dry crop, either alone or subsidiary to millets or cotton. On account of its mat like habit of growth, it is highly useful against wind erosion in sandy areas. Occasionally it is used as green mannure, ripe pods are consumed

as a green vegetable. The whole grain (23% protein) is used as pulse in the main producing regions. In India the area under cultivation of this grain legume is about 2 million hectares and total annual production is about 0.3 million tonnes. No improved varieties of this pulse have been produced so far. Only some selections have been made in Rajasthan.

4) Green gram (P.aureus, Roxb.) :

This pulse is largely grown as a rainfed kharif crop. In some regions of India, it is also cultivated in the Rabi season. The rabi crop is generally grown unmixed, whereas the kharif may be sown alone or mixed with and subsidiary to millet, maize, bajara, ragi and even cotton, sugarcane and red gram. This pulse does best on deep, well-drained loams, in the alluvial tract in the north as well as on the red and black soils of peninsular and southern India. It is also cultivated on light or shallow stoney soils to clayey soils. The grains are used as a pulse or made into flour and into straw and husk as fodder for cattle. Grains are also eaten whole after germinating them, parched, salted, with sugar or boiled with condiments. This crop is spread all over the country covering an area of about 2.5 million hectares with a production of about 0.8 million tonnes.

5) Fenugreek (T.foenum-graecum,'Linn) :

It is a leafy vegetable grown all over India as a pot herb or green. It is very rich in minerals and vitamins A and C.

The leaves of this plant are used as green or vegetable. Seeds of Fenugreek are used in the spices and also have a medicinal importance.

In the present investigation an attempt has been made to test the local cultivars of the above legumes for their salt tolerance during germination. The effect of NaCl salinity at different concentrations on germination percentage, linear growth of seedlings (epicotyle, hypocotyle and root length), biomass (fresh and dry wt) production and the rate of moisture uptake has been investigated. The activities of hydroxyperoxidases i.e. peroxidase and catalase, which are the important enzyme systems playing a vital role in the respiratory activities, under saline conditions have also been determined. The behaviour of acid phosphatase an important enzyme involved in phosphorus metabolism of germinating seeds, under saline conditions has also been studied. Soluble proteins and carbohydrates, the main food reserves in the seeds, have also been determined in the germinating seeds at different stages.