INTRODUCTION

"The response of plants to saline environment is of interest to people of many disciplines. In agriculture the problem of salinity becomes more severe every year as the non-saline waters become more intensively and more extensively exploited. Further expansion of agriculture must consider the cultivation of saline soils and the use of water with a relatively high content of soluble salts. Moreover, industrial development of many countries is causing severe water pollution, especially of rivers, and mismanagement in agriculture often induces secondary salinization of soils and sources of irrigation water. From the point of view of agriculture it is, therefore, of the utmost importance to know the various responses of plants to salinity and to understand the nature of agricultural crops". (Poljakoff-Mayber and Gale, 1975).

Strogonov (1962) has reviewed the research carried out on the effect of salinity on plants, mainly in U.S.S.R., for the period 1920-1960. He emphasised the importance of combined anatomical-physiological studies for a better understanding of the effect of salinity on plants. Salinity affects many aspects of the metabolism of plants and induces changes in their anatomy and morphology (Poljakoff-Mayber, 1975).

The adverse effect of salinity on the plant is first expressed during the germination phenophase as observed in the wheat varieties by Asana (1965) and Bernstein and Hayward (1958). Germination of wheat and barley was delayed and decreased with increase of salinity (Maliwal and Paliwal, 1967). A reduction in germination under saline condition was observed in soybean (Abel and Mackenzie, 1964); sunflower (Karami, 1974); wheat (Singh and Dastane, 1970) and species of medicago (Rizk et al., 1978). Salinity has been found to affect the time and rate of germination and size of plants (Poljakoff-Mayber, 1975). Morphologically the most typical symptom of saline injury to the plant is stunted growth (Nieman, 1962). The depressing effect of high concentrations of salt on height of wheat varieties was observed by Bhatnagar (1960).

The influence of salinity on germination of halophytes and glycophytes has been studied by Feekes (1936). Chapman (1974) has reported the germination of Salicornia stricta under 10 per cent NaCl. Some of the crop varieties although they are salt tolerant, during later stages of growth may be quite sensitive to salinity during germination (Richards, 1954).

Salinity is known to affect many aspects of the metabolism of plants and to induce changes in their anatomy and morphology. These changes are often considered to be adaptations which increase the chances of the plant to endure the stress imposed by salinity; alternately, they may be considered to be signs of damage and disruption of the normal equilibrium of life processes (Poljakoff-Mayber, 1975). Salinity has been shown to affect the time and rate of germination, the size of plants, branching and leaf size, and overall plant anatomy. Waisel (1972) reviewed the various effects of salinity on plants including morphological and anatomical changes occurring in response to salinity, or typical for halophytes.

The morphological changes are correlated with different metabolic abnormalities in salt affected plants (Weimberg, 1970 and 1975; Sheoran, 1975; Ramana and Ramadas, 1978; Sheoran and Garg, 1978 and Sheoran and Sihag, 1978). Salinity is known to reduce synthesis of RNA, DNA and proteins (Nieman, 1965; Rauser and Hanson, 1966). Sodium chloride is reported to be causing reduction in total nitrogen and protein nitrogen in soybean (Abdel-Salam and Khalaf, 1979).

Correlations between the salinity of irrigation water and the lipids of cotton have been found by Twersky and

Felhendler (1973). Several plants have been reported to accumulate free proline during period of salt stress (Goas, 1965 and 1967). The balance between soluble amino acids and protein is changed by salinization (Strogonov, 1964) and is reminiscent of the events occurring during drought (Vaadia et al., 1961). Joshi et al. (1962) showed that marine plants produce much more amino acids and less organic acids than terrestrial plants, when they fix carbon dioxide in the dark.

The hydration and the conformational state of proteins and of the other cytoplasmic constituents are affected by the osmotic potential and by the specific composition of the medium (Kylin and Quatrano, 1975). Weimberg (1970) did not find any significant difference in the levels of 18 different enzymes from pea seedlings in liquid medium with and without salts. Porath and Poljakoff-Mayber (1964 and 1968) could notice an increase in the pentose phosphate pathway under salinity caused by NaCl. Weimberg (1967) explained the interaction of sodium with malic dehydrogenase for the production of amino acids from organic acids.

There is a lack of agreement among various workers on the effect of salinity on enzyme levels in plants. Some investigators believe that levels of several key enzymes are lowered in salt damaged plants than their control plants (Hanson-Porath and Poljakoff-Mayber, 1969; Khan and Begum, 1972; Plaut, 1974) while others have reported either increase (El-Fouly and Jung, 1972; Arad and Richmond, 1973) or no differences in activity of enzymes (Greenway and Osmund, 1972 and Weimberg, 1970 and 1975). Salinity caused inhibition of RNase activity in cotyledons and roots; but increased in embryo axis and leaves of mung bean (Sheoran and Garg, 1978). The stimulatory effect of NaCl on ATPase of Beta and Salicornia has been reported by Flowers (1972). High concentrations of NaCl have often been reported to increase respiration of roots and other tissues (Nieman, 1962).

[illegible] Gale (1975) suggests that growth hormones may be involved in the responses of plants to salinity. The level of endogenous kinetin is lowered while that of abscissic acid (ABA) is raised under conditions of salinity. Ungar and Boucaud (1975) and Boucaud and Ungar (1976) have found that NaCl concentration of 0.85 M strongly reduced the endogenous cytokinin concentration in Suaeda. Considerable interest has been aroused on the use of growth regulators in the induction of salt tolerance in plants. Gibberellins have been successfully employed in overcoming growth suppression in plants resulting from diverse factors. Kahn et al. (1957) have reported that gibberellin was able to overcome an osmotic inhibition in the germination of lettuce seed. Interactive effects of gibberellic acid and salinity in increasing stem growth of beans was reported by Nieman and Bernstein (1959). Plant growth hormones, particularly the root synthesised cytokinins have been shown to be reduced under salinized conditions and that they could be active in overcoming the salinity caused growth reduction in plants (O'Leary, 1971; Prisco and O'Leary, 1973 and Porath and Mayber, 1965).

Ramesh and Sunil (1979) have found that kinetin and GA_3 are effective in promoting the germination of seeds of Cicer arietinum, Cajanus cajan, Phaseolus aureus and Phaseolus mungo. They also observed that these growth regulators influence the survival of seeds under severe saline conditions. Kawasaki et al. (1978) has reported that GA and NaCl synergistically enhanced hypocotyl elongation when both were given simultaneously and IAA and kinetin were found to be ineffective in promoting hypocotyl elongation. Studies with Hordeum jabatum by Benner (unpublished data) also indicate that GA_3 is stimulatory to germination under salinity stress, and that GA_3 apparently alleviates a portion of the dormancy induced by low water potentials. Levitt (1972) reported that GA_3 is not generally able to overcome salt stress induced retardation of growth.

Relationship between indol acetic acid (IAA) and salinity interactions on plant growth has been investigated by Sarin (1961 and 1962). He found that treatments with 5 ppm IAA spray increased plant yields 100%. IAA was found to stimulate growth of Guar varieties under saline conditions while kinetin proved to be inhibitory for growth and elongation of plants at higher salinity level (Varshney, 1980). Odegbaro and Smith (1969) found that treating *Lactuca sativa* seeds with kinetin caused increase in germination in NaCl treated seeds. In studies with various halophytic species Ungar and Binet (1975), Boucaud and Ungar (1976) and Ungar (1977) could not obtain stimulatory responses with kinetin treatments at high salinities, however, GA_3 was found to overcome salt stress induced dormancy in several taxa of *Suaeda* and in *Spergularia* and in *Salicornia*.

GA_3 and phosphon-D are shown to ameliorate the toxic effect of salinity on germination and seedling growth of peas (Uprety and Sarin, 1973). GA_3 also overcomes the inhibitory effects of high osmotic pressure (e.g. on rice and lettuce seeds), of high salt concentration and of water-imposed dormancy (e.g. in barley grains) (Thomas, 1973). The stimulatory effect of GA_3 on the germination of both dormant and nondormant seeds has been widely reported (Lang, 1965; Stokes, 1965; Villiers, 1972).

A number of studies are indicative of the effectiveness of bioactive chemicals in improving seed performance under field conditions (Khan and Tao, 1977). Succinic acid has been shown as one of the most important growth regulators by Russian scientists like Artemova (1968) and Maurina et al. (1969). Treatment of seeds with succinic acid enhanced the rate of germination of seeds of corn (Gertsuskii, 1959 and Maurina et al., 1969) of cereal seeds (Blagoveshchenshii and Rakhmanov, 1964). These are various reports on increase in percentage of germination of seeds as a result of their treatment with succinic acid (Lagutina, 1966; Siuliauskas, 1967; Kudinov, 1967). It was reported that the growth of Cucumber was promoted when seeds were treated with succinic acid (Artemova, 1968). Shevchenko (1967) and Koroleva (1964) have observed increase in dry matter production in Potato and Corn respectively under the influence of succinic acid. Maurina et al. (1969) has observed an increase in yield in corn as a result of seed treatment with succinic acid.

Pretreatment of seeds with 2-chloroethanol was found to increase salt resistance of wheat (Miyamoto, 1962). Treatment of wheat seeds with IAA could reverse the depression of root growth by salt (Sarin, 1961).

Plant growth retardants are a diverse group of chemicals which reduce stem elongation without causing malformation. Tolbert (1960) reported a new group of quarternary ammonium compounds to be effective as growth retardants. The most active substance (2-chloroethyl) trimethyl ammonium chloride (cycocel) was found to limit growth of many species of plants. Shrivastava et al. (1965) have found that cycocel (CCC) failed to reduce plant height in wheat. Solanum plants emerged from seeds treated with cycocel when sprayed with nitrogen showed an increase in the height and also a high percentage of fruit set (Halem, 1978). Cerans et al. (1970) and Furrer and Stauffer (1978) have reported an increase in the yield of wheat and Triticum spelta under the influence of CCC. Treatment of maize with CCC greatly reduced the growth of plants under saline conditions (Hegazi and Kausch, 1978). Devay et al. (1970) examined the effect of CCC on some physiological processes in Phaseolus vulgaris and found that the treatment increased the photosynthetic activity of leaves. Studies by Imbamba (1973) on cowpeas indicated that CCC treated plants were more tolerant to NaCl than non-treated ones. CCC is known to increase drought tolerance in bean plants (Halevy and Kessler, 1963).

Accumulation of proline following NaCl stress has been reported by Storey & Jones (1977) and Chu et al. (1976).

Treatment of rice seeds with 0.02% proline increased their germination under saline conditions (Bal, 1976).

Studies on the action of plant hormones suggest that primary reactions induced by the hormones in the cell are at the level of nucleic acid and protein metabolism (Key, 1969). Interrelationships between exogenous growth regulator treatments and alleviation of dormancy induced by salt stress have been demonstrated by several workers with both glycophytes and halophytes (Ungar, 1978). Various metabolites such as sugars, fatty acids, carboxylic acids and amino acids seem to have regulatory roles in controlling the synthesis and activity of enzymes during germination (Mayer, 1977). The enzymes in a plant cell may be separated from its substrate by cell compartmentation. Phytohormones could cause the release of enzyme and then allow it to act on its substrate (Tao and Khan, 1977). After GA_3 treatment, barley aleurones release a number of enzymes including protease (Jacobsen and Varner, 1967), phosphatases (Briggs, 1963), ribonuclease (Chrispeels and Varner, 1967 a) and α-amylase (Chrispeels and Varner, 1967 b). Hydrolases such as lipase (Black and Altschul, 1965) and invertase (Edelman and Hall, 1964) have also been shown to be induced by gibberellin. All phytohormones appear to have an effect on the membrane permeability.

Many evidences indicate that GA_3 regulates seed germination and subsequent growth by its effect on various metabolic activities (Key, 1969). The most relevant enzymes which are synthesised *de novo* are amylase and protease (Briggs, 1963; McLeod, *et al.*, 1964; Bennet and Chrispeel, 1972 and Jacobsen and Varner, 1967). A diversity in the GA_3 induced protease activity was observed in the rice varieties by Goyal and Baijal (1978).

Exogenous supply of GA_3 counteracted the adverse effect of salt on amylase and release of reducing sugar but not on early seedling growth (Sarin and Narayanan, 1968). Jarvis et al. (1968 a and b) reported that GA treatment enhanced the DNA availability for transcription in hazel seed system. GA increased levels of DNA and RNA in etiolated dwarf pea seedlings (Key, 1969). The effect of pretreatment of seeds with GA_3 on seedling length, non-reducing sugars and amylase activity of water stressed plants of bajra has been reported by Vora *et al.* (1975). GA_3 is also known to influence other enzymes of carbohydrate metabolism like β -amylase, 1,6-β -dextrinase, maltase, invertase and glucosidase (Briggs, 1963; Curtis and Cantlon, 1965; Paleg, 1960 a and b).

In many seeds phosphorus is present in the form of salts of phytic acid (mainly inositol-hexa-phosphate). The level of inorganic phosphorus is very low in dry seed and it may be the limiting factor in phosphate-requiring metabolic reactions. A decrease in the content of phytic acid and an increase in the activity of phytase have been reported during germination of seeds of lettuce (Mayer, 1958), cotton (Ergle and Guinn, 1959), cereals (Peers, 1953) and mung bean (Mandal and Biswas, 1970). The activity of phytase may be of fundamental importance because the inorganic ions viz. Ca, Mg, K liberated from phytin may activate a number of essential enzymes. Mayer (1958) has correlated the levels of various phosphorus fractions with levels of enzyme activity, particularly phytase. A rapid depletion of phytin along with a parallel increase in the level of inorganic phosphorus was observed during the germination of cotton under the influence of GA_3 (Dave, 1976). Stimulation of phytase in barley by GA_3 has been reported by Srivastava (1964). Kathju et al. (1971) have shown that GA_3 stimulates the activity of phosphatases during germination of seeds. Increase in the activity of phytase and RNase was observed in barley when seeds were treated with GA_3(Srivastava, 1964). Application of GA_3 markedly stimulated phytate degradation in germinating barley seeds (Katayama, et al., 1980). Pollard (1969) has investigated the sequence in which a variety of enzymes and metabolites are affected by GA_3 after the application of hormones to aleurone layers of wheat and barley seeds.

A number of studies show hormonal interactions at the level of synthesis and activation of enzymes in seed systems (Khan, 1975; Khan and Tao, 1977). Two enzymes associated with the process of starch degradation are synthesised de novo in the aleurone cells of barley grain in response to GA - there are limit dextrinase and α-glucosidase (Hardie, 1975). Besides stimulating the production and release of certain hydrolases, GA, can also retard enzyme activity (Bewley and Black, 1978).

One of the methods for maximization of agricultural production is to bring more area of land under cultivation. In Gujarat large area of land is not under cultivation especially due to its high content of sodium chloride. In agriculture, ready germination of seeds and the establishment of healthy seedlings are two most important features as the final yield producing value of plants much depends on the said processes. Poor yield of crops under saline conditions are often due to unsatisfactory stand of crop resulting from poor germination of seeds. Paddy is one of the most widely cultivated cereal crops of India and it accounts for 40% of the total food grain production. It has often been observed that seeds of paddy failed to germinate in saline soils and if at all they germinate the percentage of germination is very low. The present studies were, therefore, taken up with a view to finding out various factors responsible for the failure of paddy seeds to germinate under saline conditions and also to evolve some chemical treatments which would render the seeds readily germinable under the said conditions.

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