Experimental findings presented in this thesis on the metabolic changes in the germinating seeds as affected by water stress which was imposed by osmotic stress, desiccation as well as the low temperature treatment chiefly relate to the following aspects.

I  Effect of osmotic stress on metabolism of Oat and Guar seedlings.

II  Effect of desiccation and pretreatment on the metabolism of Oat seedlings and that of desiccation on Guar seedlings.

III  Effect of low temperature on metabolism of Oat and Guar seedlings.

Effect of Osmotic Stress:

Germination:

Germination is controlled by the external water supply. Any extension growth is accompanied by increasing turgor (CleLand, 1958). Growth of root and shoot also depends upon the availability of water. In any water deficit, seedling growth is arrested and germination is reduced. Availability of water in the germinating medium influences the extension growth of Oat seedlings which is due to uptake of water. All
osmotica used in this experiment have caused a water deficit as evidenced by data on moisture uptake by Oat and Guar seedling (Plate 2.3, 2.4 and 11.3, 11.4).

Considering therefore moisture uptake, it is seen that in the case of embryo axis, moisture content rose to a considerable extent from 24 to 96 hours of germination. Since germination requires water in proper amount in the medium, absorbed water amounts to a several fold increase in water content (Kramer and Kozlowski, 1960). This accounts for a considerable rise in moisture uptake of embryo axis of Oat and guar. But at 96 hours no adverse effect of osmotica on percent moisture of embryo axis of guar is seen. However, in the cotyledon, all osmotica lowered the percent moisture content as in Oat, which is in agreement with the findings of previous workers (Parmar and Moore, 1968; Prisco and O'Leary, 1970 and Pandya et al., 1972). With the imbibition of water or moisture, the seed rapidly increases during the initial period of germination. It is now well established that the elongation of embryonal axis is mainly brought about by the imbibition of water and not by cell division nor due to the addition of dry matter during the early stages of germination (Toole et al., 1956; Brown, 1965). The restricted moisture available to seedlings has certainly had a marked effect on elongation of root and shoot of oat and guar seedling (Plate 1.1, 1.2 and 10.1, 10.2) which was retarded by osmotica as
reported by previous workers (Parmar and Moore, 1968; Pandya et al., 1972).

All -5 osmotica caused reduction of shoot and root growth of oat and guar seedlings. It was enhanced by -1 NaCl, all -5 osmotica arrested root growth. Enhancement by -1 NaCl may be on account of its ionic value. It is known that NaCl causes succulence by favouring uptake of water (Nieman, 1966). -5 PEG caused maximum reduction as reported for corn seedlings by Parmar and Moore (1968). -1 NaCl and -1 mannitol caused least retardation or had a slight promotory effect on oat seedlings, which may be on account of ionic role of former and nutritive role of the latter.

Fresh weights of embryo axis of oat and guar seedlings increased with time (Plate 2.1 and 11.1); those of cotyledon of guar also increased, which is on account of moisture uptake. -1 NaCl and -1 mannitol enhanced them, while those of endosperm of oat declined which may be on account of their nature. Oat being a starchy seed or guar a proteinaceous seed. All osmotica reduced fresh weights (Plate 2.2 and 11.2), which is on account of and can be correlated with moisture uptake mentioned earlier.

Considering dry weights of embryo axis, it is seen that they increased with time, (Plate 1.3 and 10.3) while those of endosperm and cotyledon decreased with time (Plate 1.4 and 10.4). Since embryo axis is a growing organ, increase in dry
weight may be considered as an index of growth; food reserves are being broken down and mobilized to growing embryo axis from endosperm/cotyledons, hence their dry weights declined. Dry weights of embryo axis were lowered by all -5 osmotica, while decline in dry weights of osmotica were less than by D.W.. Such reduction in dry weights of corn seedlings was reported by Parmar and Moore (1963) and in corn by West (1962) and in Brassica by Pandya et al. (1972). The suppressing effects of osmotica on decline in dry weights of endosperm or cotyledon showed the water stress effect, more dry weights of endosperm or cotyledon indicate that under water deficit, they are not properly broken down and mobilized to embryo axis which, therefore, had less dry weight. Consequently, the seedling growth-root and shoot was retarded as reported by several workers (Parmar and Moore, 1968; Collis-George and Sands, 1959, 1962; Mehrotra et al., 1967; Williams and Shaykewich, 1971; Pawloski and Shaykewich, 1972 and Vora et al., 1976).

It may be mentioned here that the retardation in fresh and dry weights was more by all -5 osmotica than -1 osmotica; secondly, the effect NaCl, mannitol and PEG were not always consistent, this may be attributed to their different chemical natures.

The uptake of water (i.e. water content of seeds) by seedlings is primarily responsible for the reaction of the various controlling systems in the cell, which in turn, set up all
physiological processes in the seed (Ferry and Ward, 1959; Woodstock and Feeley, 1965; Woodstock and Grabe, 1967). Due to very low water content (10-20%) in air dry seed Metabolic activity is practically standstill (Street, 1966). Further, the main centre of the enzymic activity is embryo axis and not the endosperm/cotyledon (Brown, 1965). With an increase in water content of the seed, the radicle begins the elongate and at the same time metabolic activity is also accelerated (Street, 1966). During germination, food reserves in the endosperm or cotyledon are hydrolyzed and mobilized to growing embryo axis and synthesis of new and essential cell constituents takes place culminating in growth. The food thus available to embryo axis provide it with energy which is utilized to carryout and continue the processes of metabolits.

(2) Carbohydrate metabolism:

The food reserves in the case of oat seeds is starch in endosperm. Considering the starch content, therefore it is seen that (Plate 3.3) it went on depletion with progress of germination indicating that it is being hydrolyzed. Depletion of starch was enhanced by osmotica compared to D.W. and was maximum by -1 PEG. It is known that under water stress, starch content depletes due to hydrolysis by amylase to provide sugars (Vaadia et al., 1961). All osmotica caused a water stress hence starch depletion was faster. Depletion of starch is mainly due to amylase activity.
Considering the amylase activity of oat, it is seen that (Plate 3.1, 3.2) it was following a rising trend in embryo axis, it was also seen that all -1 PEG stimulated amylase activity during the initial period of germination. -1 NaCl stimulated throughout the germination and which -1 mannitol stimulated in initially. -5 Osmotica stimulated the amylase activity upto 48 hours, and depressed it subsequently. Thus, it was stimulated in the initial period of germination but as the stress was prolonged, it was depressed. Amylase activity of endosperm was depressed by osmotica. In water stressed, barley seedlings Vyas (1971) reported enhanced amylase activity in the embryo axis and reverse in endosperm. Eaton and Ergle (1943), Vieira da Silva (1970) and Wilson (1971) also reported stimulated amylase activity under water stress. But when the stress was prolonged, i.e. during later stages of germination amylase activity was suppressed. It is known that mild stress stimulates enzymic activity and a severe stress depress it (Todd, 1972) which is observed in this study. Vora et al. (1976) reported in maize seedling enhanced amylase activity by NaCl and depressed activity by mannitol and PEG. In the endosperm, -3 osmotica stimulated; -5 mannitol also stimulated but -5 NaCl and -5 PEG depressed it.

The amylase activity was higher in embryo axis than of endosperm inspite of the absence of starch. This finding confirms the finding of Brown (1965); Saxena (1969) and Chiho.
and Saxena (1971) all of whom report that embryo is the major seat of enzymes.

Any energy made available depends on carbohydrates especially sugars. Considering total sugars of oat seedlings it is seen that they rose in embryo axis with advancing germination (Plate 4.2) sugar concentrations were lowered by all osmotica up to 72 hours but at 96 hours they were enhanced by -1 NaCl and -1 and -5 mannitol. PEG lowered them. Endospermic sugars also exhibited a rising trend on account of starch-sugar conversions. Effects of osmotica were not consistent, although they did lower them at 96 hours. Saunier et al. (1968) also found a low level of glucose and sucrose in droughted leaves of Larrea divaricata. However, in maize seedlings Vora et al. (1976) reported enhancement of sugar by osmotica. Lowering of total sugars may be on account of their conversion into reducing sugars and nonreducing sugar or their oxidation. Considering therefore, reducing sugars, it is seen that (Plate 4.2) they increased with time. Effects of osmotica were variable with respect to time and type. Enhancement or depletion of reducing sugar by osmotica would suggest that they were being utilized, oxidized and converted from total sugars. At 96 hours, however, sugars were lowered by -5 osmotics while in guar total sugars of embryo axis (Plate 13.2) increased and decreased during germination indicating their turnover and utilization. However, at 96 hours as the stress
was prolonged, they rose to higher concentrations as in oat embryo axis. Similarly, cotyledonary sugars also rose and fell. Effects of osmotica were not consistent.

Reducing sugars of the embryo axis also did not remain steady. Osmotic effects were also not consistent. This indicates that under stress, sugars were in high demand by growing axis to continue growth. But at 96 hours, they were raised by osmotica while in oat they were lowered. Fluctuating behaviour of reducing sugars in cotyledons also point out their active utilization. Enhancement of reducing sugars at a later period of stress (Plate 14.3) supports the theory that sugars accumulate, wherever there is a stress (Parker, 1972; Marenville and Paulsen, 1970). It is known that under water stress, sugars are oxidized through increased respiration (Gates, 1964).

Thus behaviour of Reducing sugar is different in oat and guar. Since in oat, they were lowered by osmotica, while in guar, they were enhanced.

Non Reducing sugars of embryo axis of oat (Table 1. ) of control seedlings went on increasing. All osmotica lowered them upto 72 hours; however at 96 hours, they were enhanced by -1 NaCl, mannitol and PEG and -5 mannitol they were lowered by -5 NaCl and PEG. Nonreducing sugars of endosperm of control seedlings also increased throughout the germination, but generally they were lowered by osmotica, while in guar, non-reducing sugars of embryo axis and cotyledon also were actively
utilized i.e. rise, fall and rise (Table 2). Osmotic effects were not consistent, although on the whole they were enhanced. Stimulation of sucrose synthesis was reported by Hiller and Greenway (1968). On the whole, therefore, sugars were enhanced by osmotic stress. A number of workers have ascribed sugars a protective role against water deficit and drought. Reduction in the sugar concentration would again indicate that they were being utilized by oxidation (Woodhams and Kozlowski, 1971) or may provide \( \alpha \)-ketoglutarate and NADP(H) for proline synthesis, Stewart et al. (1966) which is known to increase relative hydration of protoplasm under water stress. Reduction in sugar concentration by PEG was also reported by Pandya et al. (1973). Greenway et al. (1972) reported stimulated sucrose synthesis by mannitol and reduced rate of other metabolic processes including starch and proteins; but little effects by ethylene glycol, than mannitol, such differences are also discerned in the data reported in this thesis.

Thus, sugars help in maintaining turgidity and protoplasmic constitute (Maranville and Paulsen, 1972) by replacing water crystal lattice on the protein (Parker, 1968). Further liquid water mixture acts as a solvent as the cell dehydrates and prevents solution out of protein (Parker, 1968, 1972). Thus, the increase or accumulation of sugars during drought has a protective role.
Invertase activity of oat of embryo axis (Plate 4.1) was depressed by -5 osmotica especially at 96 hours when stress was prolonged, depression being more by -5 NaCl followed by -5 PEG and -5 mannitol. While in guar seedlings of embryo axis was also rising with germination. The activity was stimulated and the maximum stimulation was by NaCl. While PEG and mannitol -5 depressed it. In endosperm of oat, the activity was depressed by all osmotica. While in guar the activity in cotyledon also rose with germination and was low compared to that of embryo axis. Except -5 PEG and mannitol depressed it. Thus the behaviour of invertase activity was the same for both embryo axis and cotyledon. Stimulation by -1 osmotica and -5 NaCl and depression by -5 PEG and mannitol. This is one more instant of differential behaviour of enzyme under mild or severe stress (Todd, 1972). Depressed invertase activity resulted into greater accumulation of sugars in the stressed seedlings. Vyas (1971) reported higher invertase activity in water stressed barley embryo axis. Suppression of invertase activity should be more favourable for survival of seedlings under stress since sucrose is not hydrolyzed as observed by Maranville and Paulsen (1970) and this would maintain sucrose level under stress and sucrose is known to exert protective action against water deficit. Although invertase activity was suppressed, yet the reducing sugars were enhanced.
especially at 96 hours possibly by the activation of enzymes like maltase which might be either activated or de novo synthesized. It is known that during stress new enzymes are formed (Kessler, 1959) and this might be considered as a biomechanism for allowing seedlings to grow after providing energy as reported for water-stressed sorghum seedlings by Vora et al. (1974). Generally, osmotica depressed invertase activity which is in conformation of the previous findings of Maranville and Paulson (1970), Todd and Yoo (1964).

(3) Protein metabolism:

Protein content of embryo axis of oat seedlings was lowered by all osmotica and was greater by -5 osmotica. -5 PEG caused more reduction of proteins. While in guar the content of embryo axis rose and fell (Plate 12-3). They were raised by NaCl and lowered by mannitol and PEG. All osmotica also lowered. Protein content of cotyledon which was maximum by PEG. Greenway et al. (1972) reported inhibition of protein synthesis at less than -6 atm. Eren-zioni et al. (1967) also reported severe inhibition of protein synthesis under water stress. Reduction in protein synthesis or content has been reported by West (1962). Maranville and Paulsen (1972). Chen et al. (1964) in citrus seedlings also reported decreased protein. Barnett and Naylor (1966), Petrie and Wood (1938); Nir et al. (1970); Todd et al. (1970) also reported degradation
of protein fractions into aminoacids. Greenway et al. (1972) reported lower protein synthesis in maize root tips by mannitol and PEG, mannitol had greater effect than PEG. However, it is observed here that PEG both -1 and -5 caused a greater reduction of proteins than mannitol. NaCl caused least effect, more recently Thindsa and Cleland (1975) also reported decreased protein synthesis by mannitol and PEG or carbowax 4000, molecular wt. Pandya et al. (1972) and O'Leary (1970) reported lower protein synthesis capacity in Phaseolus seedlings under osmotica. While Pandya et al. (1972) observed no change on crude protein by PEG, ammonical nitrogenous was lowered by PEG.

Protein content of endosperm (Plate 6.4) was on the whole, enhanced by osmotica, during germination protein content decreased, protease activity was showing a rising trend. The activity of embryo axis of oat was depressed while that of endo was stimulated. This differential behaviour of protein content and protease activity of embryo axis and endosperm may be on account of their nature. Considering the protein metabolism in guar, it is seen that the protease activity of embryo axis showed a rising trend indicating active protein aminoacid turnover. NaCl stimulated the protease activity -1 mannitol also stimulated while -5 mannitol and -5 PEG depressed it. This again proves that -1 osmotica causing a milder stress stimulates activity, -5 osmotica causing a
severe stress, suppressed activity (Todd, 1972), Vyas (1971), however, reported greatly enhanced protease activity in water stressed barley seedlings as in the case of -1 osmotica. Bhavsar (1977) in another proteinaceous seed, Cajanus cajan reported suppressed protease activity, by osmotica maximum being by sucrose in embryo axis and mannitol in cotyledon. It is known that the water deficit generally cause an overall decreased enzyme level (Todd, 1972) and the synthesis of macromolecule is reduced (Kozlowski, 1964).

Although hydrolytic enzymes are stimulated under water stress, it was depressed in oat seedlings. This would indicate that lowered protein content may also be on account of the lower protease activity since it does not synthesize proteins from aminoacid. Further, according to Todd (1972) water deficits cause an overall decrease in enzyme level. Thus, amylase, invertase and protease activities were depressed. Depressed status of these enzymes confirm above observation of Todd. In case of guar, the protease activity of cotyledon of the seedlings exhibited a rise and fall trend indicating again an active protein turnover. On the whole, it was suppressed by osmotica, although occasionally -1 osmotica enhanced it. -5 PEG caused maximum suppression unlike in cotyledon of Cajanus where mannitol caused maximum suppression. Suppressed cotyledonary protease activity of osmotically stressed seedlings shows that proteins as resevers are not
adequately broken down, therefore, the dry weights of these cotyledon are more and those of embryo axis less. Thus on account of reduced protease activity, protein content was low in stressed seeds.

Thus, a direct relation between protease activity and protein is seen. Depressed activity indicate that proteins were not synthesized from aminoacids and hence protein content was less. The differential behaviour of protein content and protease activity of embryo axis and endosperm/cotyledon may be on account of their nature. Enhanced protein content of endosperm and suppressed protease activity in oat show that proteins are not broken down to aminoacids and a pool to embryo axis is not maintained, which may also account for the arrested seedling growth retardation on embryo axis of oat and guar (Plate 1.1, 1.2 and 10.1, 10.2) as discussed earlier.

(4) Nucleic acid metabolism:

In case of oat seedlings, considering the nucleic acid metabolism it is seen that DNA content of embryo axis was higher than endosperm (Plate 7.2, 8.2) and both increased with time. Effects of osmotica were more pronounced on embryo axis, where PEG lowered it, -5 NaCl lowered it, while mannitol increased it. In guar seedling DNA content of embryo axis (Plate 15.2) was enhanced by -4 NaCl and -5 NaCl. Otherwise, it
was lowered by osmotica.

Endospermic DNA, however, was not much affected by osmotica while in cotyledon of guar DNA content was lowered by osmotica. It was much more than that of cotyledon.

RNA content of oat of embryo axis (Plate 7.1) went on increasing with germination. On the whole RNA content was lowered by osmotica at 96 hours except -1 NaCl. In guar embryo axis, it is seen that all -1 and -5 NaCl osmotica enhanced RNA content but all -5 mannitol and PEG caused reduction of RNA.

RNA content of endosperm of oat (Plate 8.1) also was lowered by osmotica. PEG caused more reduction of RNA while in the cotyledon of guar the osmotica effects were not conspicuous, although -5 mannitol and PEG reduced RNA content.

RNase activity of embryo axis of oat seedlings and endosperm (Plate 7.3, 8.3) was suppressed by osmotica and suppression was more by PEG. In case of guar, the RNase activity of embryo axis was stimulated by -1 NaCl; otherwise, it was depressed while in cotyledon also it was depressed. Depressed RNase activity affects RNA content which was also, therefore, low.

The findings on nucleic acid metabolism are in agreement with those of previous workers Shah and Loomis (1965), Kessler (1959), Todd and Bashir (1965), Dove (1967), Mareville (1967), Stutte (1968), Tvoros (1970), Vyas (1971).
Enhanced nucleic acids of embryo axis of guar by -1 and -5 NaCl is agreement with the findings of West (1962) who found an increase in RNA content of water stressed corn seedlings. Ghazalch and Handershott (1967) also observed higher RNA and DNA content of leaves of droughted sweet orange plant. Dhinda and Bewley reported that polysomes levels substantially declined in desiccated Tortula moss although there was no stimulation of RNase activity. They also reported that ribosomes in the desiccated moss failed to completed with m-RNA fragments. Thus, under osmotic stress, decreased RNA levels, might be on account of reduced RNA synthesis probably by failure of ribosome- mRNA complex. Endospermic DNA remained more or less unaffected while in embryo axis -1 NaCl enhanced DNA content which might again indicate an ionic role of NaCl or possibly it might have caused a milder stress or moderate stress. Shah and Loomis (1965) reported a decline in RNA and DNA under stress. Maranville (1967) also observed a decline in RNA and DNA and decline in free nucleotide. Thus the overall effect of osmotica was that of lowering of all macromolecule like nucleic acids and proteins. Since nucleic acids are lowered, Nucleic acid directed protein synthesis may also be adversely affected and consequently, embryonal growth was arrested.

Supressed RNase activity under the osmotic stress is in conflict with findings of Dove (1967) and Maranville and
Maranville and Paulsen (1972). Loss of RNA concentration is during water stress has been attributed to increased RNase activity (Kessler and Tischel, 1962). However, in the present study, RNA content was lowered although the RNase activity was depressed. The contradictory found on nucleic acids and RNase activity may be due to the material. Most of the data on nucleic acids are on wilted leaves (Dove, 1967) or whole seedlings (Maranville and Paulsen, 1972) while in the present work, separate embryo axis and endosperm/cotyledon are taken.

Decrease in nucleic acid in the droughted wheat plants and an accumulation of intermediate plants of nucleic acids was found by Ivanova (1965) and Tvorus (1970). Findings on suppressed RNase activity are therefore, in conflict with those of these workers. However, Vyas (1971) observed low RNase activity of water stressed barley seedlings.

(5) Oxidizing enzymes:

Considering osmotic effects on oxidizing enzymes, in case of oat seedling, it is seen that catalase activity of embryo axis and endosperm (Plate 9.1, 9.2) increased up to 72 hours indicating active metabolic status. All osmotica suppressed the catalase activity and was more by -5 osmotica. While in guar seedling, the activity of embryo axis showed a rising trend and was higher than that of cotyledon. The enzymic
activity was depressed by all -5 osmotica, although -1 osmotica occasionally stimulated it - both for embryo axis and cotyledon. -5 PEG caused maximum suppression.

Depressed catalase activity was reported in desiccated wheat seedlings by Acharya (1968), Farkas-Rajathay (1955), Todd and Yoo (1964), Lukicheva (1968), Takaoki (1968), Chinoy et al. (1969). Vora et al. (1974) also reported depressed catalase activity in embryo axis and endosperm of sorghum under low moisture level. The results are in contrast to those of George (1975), who reported increased catalase activity of maize seedlings by osmotica. Catalase activity has been correlated with vigour of germination by Chikasue (1953), Nanda (1950) and Delkov and Makedonoka (1969). Depressed activity of the enzyme therefore can be correlated with lower rate of germination. Galston (1951) and Halevy (1964) have shown inverse relation between growth and catalase activity.

Another oxidizing enzyme, peroxidase of embryo axis of oat also increased with the germination period (Plate 9.3, 9.4). After an initial stimulation was suppressed by osmotica especially at 96 hours, were -5 NaCl caused maximum suppression, while in guar the activity of embryo axis followed a rise and fall pattern. -1 NaCl stimulated, it effect of other osmotica were variable, although at 96 hours and even otherwise, there was a stimulation of enzymic activity by osmotica being maximum by -5 NaCl.
Endospermic peroxidase of oat seedlings also was suppressed, being maximum by -5 PEG, -1 osmotica caused lesser suppression while in guar seedlings cotyledonary activity was enhanced by -1 NaCl, -5 PEG and mannitol depressed the activity. Initial stimulation of peroxidase activity of embryo axis and a later suppression again confirms the observations of Todd (1972), that a milder stress stimulates enzymic activity but a severe stress results into its suppression. A positive correlation respiration rate, catalase and peroxidase in growing roots of citrus was reported by Altman et al. (1966); Depressed catalase and peroxidase activities of embryo axis, therefore, indicates a lowered respiratory activity on account of which also the growth of embryo axis in osmotica was suppressed or arrested. Since, lesser energy may be available is may not be satisfy the need of a growing axis. The energy helps only in continuation of growth under osmotica. Again, peroxidase activity has been shown to be associated with active differentiation. Siegel and Galston (1964) reported that peroxidase has an important role in differentiation and cell regulation. Initial stimulation of the peroxidase activity by osmotica, results into differentiation of the osmotically stressed seedlings through at slower rate. Suppression of peroxidase activity by osmotica at a later period of germination did not allow seedlings to fully differentiate and growth. Both activities were depressed in
endosperm—again endosperm being a storage organ requires a continued supply of energy for breakdown of food and subsequent mobilization to embryo axis. Since oxidizing enzymes are depressed, indicating a lowered respiratory activity enough energy was not made available and hence there was not proper and adequate food breakdown, therefore, the dry weights of endosperm were higher in osmotically stressed seedlings (Plate 2.4).

Stimulated peroxidase activity indicates that respiration and oxidative processes are at higher level under stress. Peroxidase rises wherever there is a stress (Agrios, 1969). The increased oxidative processes under water stress may increase \( \text{H}_2\text{O}_2 \) production and to reduce peroxidative damage, peroxidase activity rises. Bhavsar (1977) also reported stimulated peroxidase activity of Cajanus seedlings by osmotica as in the present study. This would indicate that although all macromoles were at a lower level, yet the growth and differentiation of embryo axis did continue or was increased even under stress as peroxidase stimulation are correlated with growth and differentiation Vora and Vyas (1974).

The depression or inhibition of the catalase activity but a rise in peroxidase activity indicate that the metabolically derived \( \text{H}_2\text{O}_2 \) is spared for the action of peroxidase which may then be used as oxidant for reduced NADPH in the pentose
pathway of glucose as shown by Hendricks and Taylorson (1975). Thus, carbohydrates were used as substrates for respiration or providing protection; they were not, available for polysaccharide synthesis for cell wall formation which may also cause retarded growth of seedlings (Lockhart, 1965) in addition to lower macromolecule contents proteins and nucleic acids.

Effect of pretreatment and desiccation:

Data and discussion on the first experiment were on the effects of osmotica simulating water deficit. Water deficit can also be simulated by desiccating seedlings. Hence, in this experiment oat and guar seedlings were subjected to desiccation treatment of 24 hours and 96 hours duration. Although Livne and Vaadia (1972) have extensively reviewed "water deficits and hormone relations", they have not cited effects of any pretreatment of hormones during water stress. Earlier Vora et al. (1975a) studied effects of pretreatments of GA on water stressed bajra seedlings and reported that pretreatment had a favourable effect. An attempt was made here to study pretreatment effects on carbohydrate during water stressed seedlings of oat.

Considering first the seedling growth, it is seen that GA pretreatment caused enhanced root and shoot growth which is in accordance with previous findings of Vora et al. (1975); Ravi and Laloraya (1967); Katsumi (1970). CCC ppm caused
retardation. Thus, the higher concentration of CCC had a retarding effect. Kinetin retarded root growth. However, all pretreatments caused enhancement of shoot growth. The results are in conflict with those of Panjya and Khan (1973) who reported enhanced germination of CCC treated seeds of Brasicca.

Fresh weights of embryo axis (Plate 18.5) were also promoted by GA, while other pretreatments caused reduction. The fresh weight of endosperm (Plate 18.6) of pretreatment seedlings caused reduction of fresh weight. Effects of pretreatment on dry weights were not conspicuous. Dry weights of endosperm (Plate 18.4) declined, but decline was lower in pretreated seedlings. The % moisture content of embryo axis (Plate 18.7) was not affected by pretreatment; while that of pretreatment lowered it.

Decline in dry weights of endosperm is at the utilization or depletion of starch the reserve food. Considering therefore, the starch content of endosperm, it is seen that it depleted with time and the depletion was faster by pretreatment and GA caused maximum depletion followed by CCC. GA is considered as an enzyme mobilizing hormone, Faleg (1960, 1961) and therefore, it must have stimulated hydrolyzing enzymes and therefore, starch content was depleted faster.

Effect of desiccation treatment was more pronounced during desiccation at 24 hours when starch content depleted faster. All pretreatments caused faster depletion of starch and was more by CCC than by
GA and kinetin. But when the stress was prolonged, GA caused maximum depletion (Plate 19.3). The results are in agreement with those of Vora et al. (1975) who reported more depletion of starch of water stressed GA treated pearl millet seedlings. It is known that under water stress, starch is depleted to provide sugars (Vaadia et al., 1961), Maranville and Paulsen (1970).

Depletion of starch must be due to hydrolytic activity of the amylase enzyme which was inconsistent with respect to treatment. The enzymic activities of control seedlings rose up to 72 hours and then declined. In GA treated seedlings it fluctuated. In kinetin and CCC treated seedlings, it was declining. Although the activity was declining (Plate 19.1), it did speed up hydrolysis of starch during early period of germination, which therefore, was faster depleted. It is worth noting that the desiccation treatment stimulated amylase activity and was greater by 96 hour or increased desiccation period. It is well established that during water stress hydrolytic enzymes are stimulated. Stimulated amylase activity resulted into increased depletion of starch. Stimulation of hydrolytic activity is a common phenomenon of drought stress (Iljin, 1957) and under water stress; stimulated amylase activity under water stress has been reported by Eaton and Eagle (1948) and Vieira da Silva (1970). Wadleigh and Ayers (1945) also reported reduction of starch and enhancement of
sugar due to increased amylase activity. Jani et al. (1968) observed an increase in amylase activity of desiccated barley seedlings and progressing depletion of starch to a greater formation of sugars. CCC treatment caused more stimulation; GA and kinetin lesser than D.W. Chinoy and Acharya (1975) also reported stimulation of amylase activity in desiccated wheat seedlings. Gepstein and Ilan (1970) also reported no promotive effect of GA on amylase activity in cotyledon of Phaseolus vulgaris.

The endospermic amylase activity of seedlings also was variable with pretreatments. Thus in control seedlings, it registered a continuous rise, GA treated seedlings increased up to 72 hours. A continuous decline in kinetin treated seedlings and fluctuation in CCC treated seedlings is seen (Plate 19.2). Endospermic amylase activity was also stimulated by desiccation and more by 96 hours treatment. But the maximum amylase activity was in untreated and control seedlings of the pretreatments. CCC caused a greater stimulation and least by GA. Thus, although GA is known as enzyme mobilizing hormones (Varner and Chandra, 1964) the data presented here prove that CCC caused the stimulation of enzymic activity of both embryo axis and endosperm and may, therefore be considered as EMH.

Total sugars of embryo axis (Plate 20.2) on the whole showed a rise trend concomitant with starch depletion by amylase
activity. Kinetin and CCC enhanced, total sugars, while GA enhanced at 24 and 96 hours. Thus, on the whole, pretreatment caused enhancement of sugars. Sugars were also enhanced by desiccation treatment, more being by 96 hours. CCC treated seedlings had greater sugars, while GA treated had lower sugars during desiccation, lesser than D.W.

Total sugars of endosperm (Plate 21.2) on the whole, followed a rising trend. All pretreatment enhanced them at 24 hours of germination and decreased them at 72 and 96 hours. However, desiccation treatment increased sugars of endosperm. The findings are in agreement with the findings of several workers that sugars are increased during stress (Parker, 1972) and as discussed earlier. During desiccated GA treatment caused maximum enhancement of sugars kinetin and CCC also enhanced them embryo axis of GA treated seedlings showed lesser reducing sugars which is in conflict with findings of Vora et al. (1975) who reported enhanced sugars by GA treatment, however, data on endosperm support these findings of Vora et al. (1975).

Reducing sugars of embryo axis (Plate 20.3) except those GA treated seedlings followed a decline, indicating that they were being used up providing energy. CCC and kinetin treatments enhanced reducing sugar content, while GA treatment lowered them in undesiccated seedlings. Sugar concentrations were increased by desiccation treatment, the increase was more by
96 hours desiccation. All pretreatments caused enhancement of Reducing Sugars.

Reducing sugars of endosperm of all seedlings increased with time (Plate 21.3). All sugars were lowered by pretreatments. Desiccation treatment enhanced Reducing Sugar concentrations. 24 hours desiccation treatment caused more enhancement in all endosperm of seedlings except in GA treated seedlings, where 96 hours desiccation treatment caused more enhancement. GA treatment caused more enhancement of Reducing sugar during desiccation.

Accumulation of Reducing sugars of both embryo axis and endosperm of desiccated seedlings is in agreement with the findings of Amer and Williams (1958), Chinoy et al. (1969), Hodges and Lorio (1969).

Non reducing sugars (NRS) of embryo axis of all seedlings, on the whole, exhibited a rising trend (Table 3). Effects of desiccation were variable. They were increased in control and GA desiccated seedlings. In kinetin treated seedlings, NRS were enhanced by desiccation during early period of germination and lowered during later period of germination. NRS of CCC treated seedlings were enhanced by desiccation of 96 hours, but 24 hours desiccation enhanced them in seedlings during early germination, lowered them at 72 and 96 hours. The rise and fall of stressed seedlings indicate a high turnover of NRS through oxidation by increased respiratory activity (Gates, 1964).
NBS of endosperm of control seedlings rose (Table 4). GA treated seedlings declined, kinetin treated seedlings after a fall increased and remained steady. NBS of CCC treated seedlings were increased during later period of germination. Thus each pretreatment had a different effect on NBS. Desiccation treatment of 96 hours enhanced NBS, although 24 hours treatment lowered them. The enhancement of NBS of desiccated endosperm may then be mobilized to embryo axis to exert either a protective role (Parker, 1972) or to provide substrates for increased oxidation (Gates, 1964).

Invertase activity of embryo axis of (Plate 20.1) all seedlings declined. All pretreatment depressed activity. This is again in disagreement with the theory that pretreatment stimulates activity especially GA (Kaufmann et al., 1971). Desiccation treatment also suppressed enzymic activity which is in agreement with the observation of Maranville and Paulsen (1972) that lowered invertase activity under water stress allow sucrose to accumulate and that sucrose has a protective role as discussed earlier. Kinetin treated seedlings, however, showed stimulated invertase. Invertase activity of endosperm (Plate 21.1) was variable depending on treatment. Desiccation treatment stimulated invertase activity of all seedlings especially by 24 hours. In fact, there was not much difference between 24 and 96 hours of desiccation. Stimulated invertase activity of endosperm (Plate 21.1) results into
larger concentration of Reducing sugars which may be mobilized to embryo axis for providing energy through their oxidation, as discussed earlier. Thus a sink-source is maintained between endosperm and embryo axis. Pretreatment effects were variable.

Considering first the effects of desiccation on Guar seedlings, it is seen that protein content of embryo axis was lowered by desiccation treatment which was more by 24 hours desiccation (Plate 23.3). Protein content of cotyledon (Plate 23.4) was enhanced by desiccation treatment, while 96 hours desiccation treatment enhanced it during earlier germination and decreased it during late period of germination. Reduction of protein content of embryo-axis by desiccation treatment shows that there is either a break down of proteins or that their synthesis is reduced or is impaired as discussed earlier (Petrie and Wood, 1938; Barnett and Naylor, 1966; Marenville and Paulson, 1972). There may be accumulation of amino acids (Chen et al., 1966). Initial desiccation treatment lowered proteins i.e. at 24 hours; more than 96 hours which might be on account of adjustment to desiccation period. A cyclic pattern of increase, decrease and restitution in Citrus leaves was observed by Chen et al. (1964); similarly, here also, similar cyclic pattern could be considered. Genkel (1970) has stated that a high degree of resistance to drought is largely due to plants ability to renew proteins during the stress period.
More proteins by 96 hours desiccation compared to 24 hours desiccation may lend support to this. When stress period was prolonged i.e. from 24 to 96 hours perhaps there might have been a renewal of protein synthesis. But cotyledonary proteins behaved differently; while they were enhanced by 24 hours desiccation, they were lowered by 96 hours indicating a hydrolysis.

Protease activity was stimulated by desiccation at early stages of germination (Plate 23.1) and suppressed during later stages of germination. It is known that sensitivity of drought varies with age of the seedlings (Chinoy et al., 1969). In the cotyledon (Plate 23.2) protease activity was stimulated by desiccation and hence the protein content was lowered by this stimulated enzymic activity. Maranville and Paulson (1972) reported lowered protein content of corn seedlings by reduced protein synthesis and not increased protease activity. They, however, reported lowered protease activity.

Total sugars of embryo axis were lowered by desiccation treatments (Plate 22.3) and more by 96 hours desiccation. In cotyledon (Plate 22.4) 24 hours desiccation or a mild stress increased sugars but 96 hours desiccation lowered them. Reducing sugars of embryo axis were enhanced up to 72 hours germination only at 96 hours they were lowered (Plate 22.5). Non-reducing sugar of embryo axis were lowered by desiccation treatment; and the decrease was more by 96 hours both in
embryo axis and cotyledon (Table 5). Enhancement of Reducing sugars and depletion of NRS indicates that NRS were being converted to Reducing sugar which thus increased. Accumulation of sugar during drought has been reported by Amer and Williams (1958), Chinoy et al. (1969a) and Hodges and Lario (1969). Sugars may accumulate either to provide energy or as discussed earlier, they have a protective role (Parker, 1968). Murty and Srinivasulu (1968) also reported increased FS due to drought. Total sugars and NRS were increased. Increase in total amount of soluble sugars under water stress was also observed by Subbotina (1961); Naidu (1967). Invertase activity of embryo axis was depressed by desiccation (Plate 22.1) and the depression was greater by 24 hours desi treatment. In the cotyledon (Plate 22.2), however, 24 hours desiccation depressed by 96 hours stimulated it. Stimulation of invertase activity of cotyledon results into breakdown of sugars and their subsequent mobilization or translocation to embryo axis. The enzyme activity of embryo axis was suppressed. The lower content of NRS of embryo axis despite suppressed, invertase activity would suggest that they must be have been oxidized through the increased respiratory activity (Gates, 1964) and a rise due to in RS content of embryo axis must be supplied from cotyledon which served as a source.

The catalase activity of embryo axis (Plate 23.5) was much stimulated by desiccation by 96 hours; while in cotyledon
(Plate 23.6), 24 hours desiccation caused more stimulation. The results are in conflict with those of Acharya and Desai (1974) who reported depressed catalase activity of desiccated sesamum seedlings. Stimulated catalase activity by desiccation indicates that the respiratory activities were at a faster rate, that $H_2O_2$ was released and to nullify its toxicity. Parkao and Rajatham (1955) and Lukicheva (1968) and Polimbetova et al. (1964) had also reported higher catalase activity of water stressed wheat plant. Stimulated catalase activity of cotyledon suggests that due to increased respiration, providing energy more and more food must be broken down to mobilize to the embryo axis during germination. Peroxidase activity of embryo axis in the initial stages of germination was depressed (Plate 23.7) but during later stages it was stimulated; that of cotyledon was stimulated (Plate 23.8). Thus both peroxidase and catalase activity were stimulated indicating an increased respiratory activity during desiccation.

**Effect of low temperature treatment:**

A voluminous literature is available covering various aspects of cold hardiness (Alden and Hermann, 1971). Insitve of this, the mechanism involved in cold hardiness of plants remains obscure. But it must involve some physiological and chemical events (Mazur, 1969) and hence an attempt was made to investigate biochemical changes associated during the low temperature of oat and guar seedlings.
Carbohydrates have been ascribed a protective role during freezing or low temperature (Alden and Hermann, 1971). Considering, therefore, the carbohydrate content of tissues subjected to low temperature, it is seen that endospermic starch (Plate 25.3) of oat seedling went on depleting at a faster rate by 24 and 96 hours low temperature treatments and that the depletion was greater by 96 hours low temperature treatment. It is well documented that there is a reduction of carbohydrate reserves under cold and Levitt (1959) cites more than fifty references on starch to sugar conversion. Faster depletion of endospermic starch, therefore, is in agreement of above findings of Levitt (1959). Ogolevets (1964) also observed starch and hemicellulose depletion in the bark of oak, apple and birch at temperature below 0°C.

The amylase activity of embryo axis and endosperm (Plate 25.1 and 25.2) of oat was suppressed by low temperature; the suppression was greater by 24 hours in embryo axis and by 96 hours in the endosperm; although starch depletion was faster. It means that there must have been other enzymes like phosphorylase which might have been activated to hydrolyzed starch in endosperm. It is known that during water stress a 'de novo' enzyme synthesis occurs (Kessler, 1959). Similarly, during cold stress also a new enzyme - i.e. phosphorylase might be activated.

In oat, total sugars of embryo axis and endosperm were
enhanced (Plate 24.3 and 24.4) by low temperature and there was more enhancement by 96 hours while in guar, total sugars of embryo axis (Plate 26.3) were lowered by 24 hours low temperature treatment and enhanced by 96 hours treatment during early stages of germination after which they were lowered. In the cotyledon (Plate 26.4) also, sugars were lowered being more by 96 hours low temperature.

In oat and guar, the reducing sugar content was also enhanced in both in embryo axis as well as endosperm/cotyledon (Plate 24.5, 24.6 and 26.5, 26.6) by low temperature treatment. Non-reducing sugars of embryo axis (Table 6a) of oats were enhanced during later period of germination in endosperm also they enhanced; while in both embryo axis and cotyledon (Table 6b) of guar seedlings they were lowered by low temperature treatment more by 96 hours. Decline in NRS and total sugars of embryo axis of guar seedlings account for enhanced reducing sugars in embryo axis. Thus the faster depletion of starch of endosperm in oat resulted in greater accumulation of all sugars. Enhancement of sugar under low temperature treatment has been reported by several workers (Parker, 1963), Teltscherova (1967) reported that sucrose, polyfructose, raffinose in addition to monosaccharids appeared in shoot apices of winter plants at low temperature of which sucrose and monosaccharids increased. Accumulation and increase of sugar concentration during low temperature treatment
may allow and help the seedlings to survive freezing condition. Protective role of sugars has been ascribed under stress. Thus, Parker (1963, 1972) stated that substances like sucrose were shown to retard growth of ice crystals and alter their pattern without depressing the point of ice nucleation any more than the freezing point and thereby may protect the proteins of membranes and enzymes from sudden loss of water with freezing. According to Ullrich and Heber (1961) sugars protect proteins during frost by replacing some of the water of hydration more firmly through hydrogen bonding in structures sensitive to dehydration as water is removed from ice. According to Parker (1963) sugars may alter the state of hydration of enzymes and protein membranes. Further, Murray and Cooper (1967) believed that carbohydrates may serve as protective substances and as an energy source in development of cold hardiness. This view has also been subscribed by Alekseeva (1969), Khisamutdinova and Vasil' eva (1970) and Pyiklik (1963). It may be mentioned that mechanism and effects of sugars are the same both for low temperature and water stress (Parker, 1972).

Invertase activity of embryo axis and endosperm or cotyledon (Plate 24.1, 24.2 and 26.1, 26.2) was depressed by cold treatment both in oat and guar seedlings. Thus, both enzymes, amylase and invertase were depressed in oat and guar seedlings, which might be on account of either degradation
of proteins or its vitrification, although much lower temperature -10°C to -20°C is reported for vitrification (Sakai, 1966). But most of such studies are on bark or twigs and leaves which may be more resistant than the seedlings as in present stress. Moreover, Ogolovets (1966) also reported decline in amylase and invertase activity from 2°C to -20°C.

Protein content of guar embryo axis was much lowered by low temperature treatment especially of 24 hours (Plate 27.3). The protein content of cotyledon was also lowered by low temperature treatment more by 96 hours (Plate 27.4). All available literature, however refer to increase in proteins especially water soluble ones (Alden and Hermann, 1971). However, this increase in protein content is due to degradation of complex protein. Lowered protein content reported here also indicates a degradation. However, new protein synthesis seems to have occurred in the embryo axis after an initial decline, since proteins were more at 96 hours of low temperature treatment than at 24 hours indicating a rise in protein content from 24 to 96 hours. Thus, data on protein are in conflict with the current theories. However, decline in protein content indicates probably a rise in amino acids which are associated with an increase in cold hardiness (Kohn and Levitt, 1966) and together with nucleic acids these altered proteins affect the physical properties of cell
protoplasm and enables the protoplasm to resist the stress from dehydration which may be caused by intercellular freezing.

Lowered protein content may also be on account of increased protease activity (Plate 27.1 and 27.2). The low temperature treatment enhanced protease activity which in its turn, hydrolyzed protein and, therefore, proteins were lowered. According to Belkin andPerfil'eva (1962) cold resistance involves changes in synthetic and hydrolyzing activities of the entire enzyme system. Stimulated protease activity with a concomitant decline in protein content indicates a shift towards hydrolytic side of protease activity.

Catalase activity of embryo axis of oat was depressed (Plate 25.4) while in guar it was stimulated (Plate 27.5) by low temperature treatment. Stimulation being greater by 96 hours in guar. In endosperm of oat (Plate 25.5) and cotyledon of guar (Plate 27.6) it was stimulated. In oat, lowered catalase activity of embryo axis indicates that the respiratory activity is at a lower state but increased catalase activity of endosperm or cotyledon indicates a faster respiration in endosperm or cotyledon and may offer cold resistance as shown by Korovin and Barskaya (1962). Gerloff et al. (1967) reported an increase in the activity of catalase and peroxidase during cold hardiness of alfalfa roots.
It may be mentioned here that no change in catalase activity, under low temperature was observed by Korovin and Barskaya (1962). Respiratory activity increased in endosperm to provide energy to embryo axis and as a source of energy to embryo axis to continue its survival.

Peroxidase activity of embryo axis of oat was suppressed and the suppression was greater by increased duration of low temperature (Plate 25.6) while in guar, it was stimulated by low temperature treatment (Plate 27.7), stimulation being greater by 96 hours. The endosperm of oat (Plate 25.7) and cotyledon of guar (Plate 27.8), in both the seedlings, it was stimulated by low temperature treatment during early periods of germination during later period, however, it was suppressed in oat. Gerloff et al. (1967) observed stimulated activity of catalase and peroxidase during low temperature treatments. Changes in peroxidase enzymes have been considered to regulate permeability and protect membrane injury at low temperature sub-freezing temperature (McCown et al., 1968). Depressed peroxidase activity of embryo axis again points out a low respiratory activity, just to keep the seedlings only to survive against frost.

Considering the overall effects of desiccation on carbohydrate metabolism, it may be observed that during desiccation treatment, there is a faster depletion of starch of endosperm during desiccation when GA treatment causes
more depletion. Amylase activity of desiccated or stressed seedlings was stimulated both in the case of embryo axis and endosperm. CCC treatment caused a greater stimulation of enzymic activity of embryo axis.

Total sugars were also enhanced by desiccation and CCC caused more increase of sugars of embryo axis. GA caused lesser enhancement. But in endosperm GA caused more enhancement of sugars, followed by CCC and kinetin.

Even Reducing sugars were also enhanced. Enhancement of Reducing sugars must be through the stimulated invertase activity of endosperm which hydrolyzed NRS to Reducing sugar, and thereby augmenting a supply of Reducing sugars for continuation of survival during desiccation.

Non-Reducing sugars were also enhanced by desiccation and CCC treated seedlings had more NRS. Invertase activity was depressed by pretreatment. Desiccation pretreatment also suppressed invertase activity which therefore, maintained NRS concentrations. Accumulation of sugars play a protective role as discussed earlier.

The pretreatment also caused enhancement of sugars and CCC on the whole, proved more effective than GA and kinetin. CCC has been established as presowing drought hardening agent (Humpharies, 1968; Humphris and Bond, 1969; Vora et al., 1974; Appleby et al., 1966 and Phipolts, 1972). GA and kinetin also proved beneficial but not so much as CCC,
GCC also stimulated amylase activity although starch depletion was faster by GA. Kinetin treated seedlings also showed more sugars during desiccation. Thus, all pretreatment caused an enhancement of sugars while depressing invertase activity. Such pretreatment may therefore by providing more sugars to embryo axis may induce desiccation resistance to them.

As mentioned in the introduction, various methods are employed to simulate water deficit. Two methods were employed in this study; (i) use of osmotica and (ii) desiccation to stimulate water deficit. It would be interesting to compare the effects of such water deficit on some metabolic changes.

Considering starch, all osmotica and desiccation treatments depleted it faster than control. But amylase activity of oat embryo axis was stimulated by -1 osmotica but -5 osmotica causing a greater stress stimulated it initially and later suppressed it. Desiccation treatment, on the contrary stimulated it and stimulation was more by longer stress due to 96 hours desiccation. Total sugars of embryo axis were lowered by osmotica up to 72 hours and were, however, enhanced at 96 hours while endospermic sugars were lowered by -5 osmotica at 96 hours. Nonreducing sugars were also lowered by osmotica. Thus, although osmotica and desiccation treatment caused water deficit, behaviour and response of seedlings are quite different. All osmotica lowered reducing and nonreducing sugars while desiccation
treatment enhanced them.

In the case of Guar seedlings, total sugars were increased at 96 hours by osmotic stress while reducing sugars were enhanced by osmotic stress at 96 hours. Sugars of cotyledons were also enhanced by osmotic stress. Total sugars of embryo axis were lowered during desiccation. Reducing sugars were also lowered by 96 hours desiccation. NRS were also lowered by desiccation. NRS were enhanced by osmotic stress while they were decreased by desiccation treatments. Thus, as in oat, guar seedlings also behaved differently during osmotic stress and desiccation stress. While under osmotic stress, sugars were enhanced, during desiccation they were lowered.

Differential behavior is also to be noted between oat and Guar regarding sugars. Sugars were lowered by osmotic stress in oat seedlings while, they were enhanced by osmotic stress in guar seedlings. Sugars were enhanced in desiccated oat seedlings while they were lowered in desiccated oat seedlings. A common trend is seen in invertase activity which exhibited a steady behaviour. It consistently remained suppressed in guar and oat embryo axis during osmotic stress and desiccation stress, although it was stimulated by desiccation in guar cotyledon. Osmotic stress stimulated invertase activity of guar.

Protein content of guar embryo axis was lowered by desiccation. Protein content of cotyledon was enhanced. It was also lowered by osmotic stress. Thus, proteins exhibited a
steady behaviour. Protease activity of embryo axis was promoted by -1 NaCl and mannitol -5 osmotica suppressed it. Similarly desiccation treatment at early stages stimulated but at later stages suppressed protease activity, but the suppression was greater by a mild stress i.e. 24 hours desiccation; all -5 osmotica suppressed protease activity of cotyledon of guar seedlings but desiccation treatment stimulated it. Thus, once again a differential response is manifested. It is therefore concluded that evaluation of water stress effects, depends on methods used to stimulate stress. Further, even the effects of osmotica were not consistent. NaCl, mannitol and PEG at lower levels behaved differently -1 NaCl, on the whole, was stimulatory. All -5 osmotica, however had similar effects.

In guar, catalase activity was suppressed by osmotica, although peroxidase activity was stimulated on the contrary, desiccation, stimulated catalase activity, peroxidase activity after initial depression was stimulated. Thus osmotic and desiccating effects on oxidising enzymes specially catalase are again different.

Starch depletion was also faster during low temperature treatment during cold stress as in the water stress. Likewise, amylase and invertase activities were also suppressed during cold treatment. Accumulation of sugars under cold stress, is also a behaviour of seedlings typical of a stressed
condition. Sugars are known to accumulate under cold and
drought. Desiccation or osmotica lowered protein content
in guar; during cold stress also, proteins were lowered.
Catalase activity of oat seedlings were suppressed under
osmotic stress as well as cold stress. In guar, osmotica
stimulated peroxidase activity of embryo axis, depressed
by desiccation after initial increase and stimulated by
cold stress.

Thus, on the whole, stressed condition—whether
by osmotica and desiccation or cold, there is altered metabolism.
This altered metabolism may be considered as adaptation
especially, sugars and oxidizing enzymes. Uniformly it
to also seen in lowered protein content and hydrolyzing enzyme
activities under all stresses.