PHYSIOLOGY OF TARAMIRA (Eruca stiva) Mill UNDER SALINITY STRESS

THESIS

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BY

KAILASH CHAND SHARMA

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This is to certify that this thesis entitled **"Physiology of taramira (*Eruca sativa* Mill.) under salinity stress"** submitted for the degree of Master of Science in Agriculture in the subject of Plant Physiology embodies bonafide research work carried out by **Mr. Kailash Chand Sharma** under my guidance and supervision and that no part of this thesis has been submitted for any other degree. The assistance and help received during the course of investigation have been fully acknowledged. The draft of the thesis was also approved by the advisory committee on ……..2005.

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This is to certify that **Mr. Kailash Chand Sharma** of the Department of Plant Physiology, S.K.N. College of Agriculture, Jobner has made all corrections/modifications in the thesis **"Physiology of taramira (*Eruca sativa* Mill.) under salinity stress"** which were suggested by the external examiner and the advisory committee in the oral examination held on ……2005. The final copies of the thesis duly bound and corrected were submitted on ……..2005, are enclosed herewith for approval.

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CONTENTS

LIST OF TABLES

Contd…

LIST OF FIGURES

LIST OF PLATES

Physiology of taramira (*Eruca sativa* Mill.) under salinity stress

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ABSTRACT

An investigation on "Physiology of taramira (*Eruca sativa* Mill.) under salinity stress" was conducted in Department of Plant Physiology, S.K.N. College of Agriculture, Jobner during the *rabi* season, 2004-05. The objectives of the study were (i) to study the effect of cycocel on photosynthetic efficiency and plant water relationship of taramira genotypes under saline and non-saline conditions, (ii) to find out the effect of both salinity and cycocel on morpho-physiological attributes and yield in genotypes of taramira and (iii) to study the role of cycocel in mitigating the adverse effect of salinity stress in taramira genotypes.

The experiment consisted two levels of salinity [normal field (ECe = 2.1 dSm^{-1}) and saline field (ECe = 7.5 dSm^{-1})], three genotypes of taramira (RTM-314, RTM-2002 and RTM-969) and three levels of cycocel (0, 50 and 100 ppm) results revealed that genotype RTM-969 obtained significantly higher number of siliqua per plant, number of seeds per siliqua, test weight, grain yield and biological yield as compared to genotypes RTM-2002 and RTM-314. However, above yield and yield attributing parameters were found statistically at par in genotypes RTM-2002 and RTM-314.

Salinity stress decreased significantly the seedling emergence percentage, root-shoot and seedling length, seedling vigour index, leaf area and leaf area index, plant height, yield attributes such as number of siliqua per plant, number of seeds per siliqua, test weight, grain and biological yield. Photosynthetic and plant water relation parameters *viz.*, photosynthetic rate, leaf transpiration rate, water use efficiency, relative water content, water potential and osmotic potential, physiological attributes such as Na/K ratio in root and shoot decreased significantly at all three growth stages. Quality parameters of seed such as protein content and oil content also decreased significantly.

Soaking of seeds prior to sowing with 100 ppm cycocel concentration increased significantly the seedling emergence percentage, root length, seedling vigour index, leaf area and leaf area index but decreased significantly shoot length, seedling length and plant height. It also increased significantly the number of siliqua per plant, number of seeds per siliqua, test weight, grain yield, biological yield, protein content and oil content. 100 ppm cycocel increased significantly the photosynthetic rate, water use efficiency, relative water content, water potential and osmotic potential, while decreased significantly the leaf transpiration rate and Na/K ratio in root and shoot at all three growth stages.

Based on this study it may be concluded that the effect of salinity can be mitigate by treatment of taramira seeds prior to sowing with cycocel 100 ppm concentration which may give higher yield of taramira.

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** Thesis submitted in partial fulfilment of the requirement for M.Sc. (Ag.) degree in Plant Physiology under the supervision of **Dr. B.L. Kakralya**, Assistant Professor and Incharge Department of Plant Physiology, S.K.N. College of Agriculture, Jobner (RAU, Bikaner).

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Place – Jobner
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LIST OF ABBREVIATIONS

ABA	Abscisic Acid
AICRP	All India Co-ordinated Research Project
CCC	Cycocel
cv	Cultivars
cm	Centimeter
DAS	Days after sowing
EC	Electrical conductivity
ESP	Exchangeable sodium per cent
ET	Evapo-transpiration
fr.wt.	Fresh Weight
GA	Gibberellic acid
HI	Harvest Index
LAI	Leaf area index
LDR	Leaf Diffusive Resistance
LT	Leaf Temperature
LTR	Leaf Transpiration Rate
NS	Non-Significant
OP	Osmotic Potential
PGRs	Plant Growth Regulators
PNUE	Photosynthetic nitrogen use efficiency
ppm	Part per million
RWC	Relative Water Content
SLW	Specific leaf weight
SVI	Seedling vigour index
TR	Transpiration Rate
WUE	Water use efficiency
ψ	Leaf water potential

Ψ_s	Leaf osmotic potential

1. INTRODUCTION

India is a major oilseed producing country, having about 19 % area and 10 % production at global level. Among them Brassicas are the 3rd most important oilseed crops next after groundnut and soybean both in terms of area and production (Anonymous, 2001-02). Oilseed crops occupy an important position in the agricultural and industrial economy. These crops are rich source of energy for majority of Indian population.

Rajasthan is the leading state both in area and production of rapeseed and mustard followed by Haryana and Uttar Pradesh. It produces 1.18 million tonnes from an area of 1.19 million ha with the productivity of 989 kg/ha. Among them, taramira (*Eruca sativa* Mill.) occupies an area of 3.26 lakh ha with annual production of 1.40 lakh t with productivity 428 kg/ ha (Anonymous, 2002-03).

Taramira is an important *rabi* herb, native to South Europe and is now grown mainly in north India. It is highly drought tolerant crop owing to its efficient root system. The oil content of taramira ranges from 32 to 37 per cent and is used for burning purposes. Oil cakes serve as cattle feed and powdered seeds are reported to possess antibacterial activity (Jakhar *et al.*, 2002). The tender leaves are used as salad and plant is also feed to cattle.

Soil salinity is one of the major problem of the world which reduces production potential of the crops. The problem of soil salinity are very old in agricultural production system and attaining serious status in recent time. The area of salt affected soils in India is about 7.5 million hectare out of which, Rajasthan comprises more than 0.728 million ha and this area is increasing year after year because of the poor quality (brakish) irrigation

water as well as poor drainage system. It is a serious problem in arid and semi-arid regions where rainfall is insufficient to leach down the salts from the rhizosphere to lower depths. The under ground saline irrigation water contains dissolved salts that are concentrated as the water evaporates and build up in the soil over time. It is the major factor for soil salinity particularly, in arid and semi-arid regions of the state (Gupta, 1990).

Saline conditions drastically change the environment of the root, osmotic potential of the soil solution and the normal equilibrium of the dissolved ions. Among various edaphic factors, the salt stress and sodicity are important factors limiting the growth and development of plant and result in premature termination of plant cycle.

The detrimental effects of salinity are due to the influence of ions on the water activity of the external solution which affects the water status of plant and biochemical functions of the soils (Munns *et al.*, 1982). These effects can result in turgor reduction, inhibition of membrane functions or enzyme activity (Wyn Jones and Gorham, 1983), inhibition of photosynthesis (Walker *et al.,* 1981) or increased use of metabolic energy for non-growth processes involved in the maintenance of tolerance (Yeo, 1983). The reduction in growth under salinity has been described either due to osmotic or ionic effects and/or the combination of both (Levitt, 1980).

The problem of salinity due to the use of saline water for irrigation has covered vast area in Jaipur, Pali, Jodhpur, Churu, Bikaner, Sikar, Barmer and Jaisalmer districts of Rajasthan because wells having saline water are the main source of irrigation in these areas. The saline alkali soils have the maximum area in Jaipur, Bharatpur, Bhilwara and Pali districts.

In some areas with agricultural potential two approaches may be taken, one approach is to try to find inexpensive and cost-efficient ways of desalting sea water to be used for irrigation purposes. Another approach is to select plants that can grow and survive under highly saline conditions. In many cases reclamation of salts by the common practices, such as leaching

and drainage are not only expensive but also impracticable. A possible approach to raise the productivity of such areas is to improve salt tolerance of plants. Some growth substances have been good promised in the amelioration of salt stress. Cycocel have been tested in this regard because of its dwarfing effect on plant growth. It antiagonizes gibberellic acid biosynthesis by inhibiting cyclization (conversion) of geranyl-geranoid pyrophosphate to copylpyrophosphate resulting inhibition of synthesis of kaurene and other such compounds (*i.e.* GA). It exhibits low toxicity and excerts its influence on many crop plants (Roberts and Hooley, 1988). CCC also stimulates photosynthetic activity, protein synthesis, action of nitriate reductase, uptake of nitrogen, increasing chlorophyll content and leaf thickness.

Growth retardants are reported to increase the resistance of plants to drought and salinity (Halevy and Kessler, 1963). The known mechanism of action of cycocel as inhibitor of gibberellin biosynthesis (Corcoran, 1975) is sufficient to explain its effect on countracted salinity. These inhibitors add to the aesthetic qualities of the plants by retarding vegetative growth (Sachs and Kofrnek, 1963).

The present work was therefore carried out to evaluate the performance of different cultivars through cycocel in improving the tolerance of taramira plants to salinity during germination as well as at vegetative and reproductive growth stages.

In view of the above-mentioned perspective of physiological attributes of salt tolerance and plant growth regulator for increased crop production, the study entitled “Physiology of taramira (*Eruca sativa* Mill.) under salinity stress” was undertaken with the following objectives : -

(i) To study the effect of cycocel on photosynthetic efficiency and plant water relationship of taramira genotypes under saline and non-saline conditions.

(ii) To find out the effect of both salinity and cycocel on morpho-physiological attributes and yield in genotypes of taramira.

(iii) To study the role of cycocel in mitigating the adverse effect of salinity stress in taramira genotypes.

2. REVIEW OF LITERATURE

2.1 INTRODUCTION

Taramira (*Eruca sativa* Mill.) is an important *rabi* herb native to South Europe and is now grown mainly in north India. It is highly drought tolerant crop owing to its efficient root system. In this chapter the literature has been reviewed relating to the work on “Physiology of taramira (*Eruca sativa* Mill.) under salinity stress” since the literature on the different aspects of the research work on taramira is very merge, therefore related research finding on cereals, pulses and other oil seed crops etc. have also been incorporated in the review.

Salt accumulation in soil is one of the limiting factors for physical properties as well as fertility of soils and has been considered as major constraint for world agricultural production system. The detrimental effects of salinity on plant growth are attributed to osmotic as well as specific ion effects. The extent of injury to plant by salt stress varies with the type and concentration of predominant ions, physiological stage of plant species and the surrounding environments. The excessive accumulation of salts increases the osmotic pressure of soil, which creates unfavorable conditions for the plant growth by disturbing the physical conditions of the soil. The excessive accumulation of salt thus becomes toxic to plants due to disturbance in metabolism. Losses in crop and plant productivity due to soil salinity at national and global levels are well documented. However, the use of PGRs for ameliorating such adversities has attracted the attention of Agricultural Scientists, Environmentalists and Plant Biologists (King *et al*., 1992; Hatfield and Stewart, 1994, Nathawat and Srivastava, 1996).

2.2 SALT STRESS IN RELATION TO GERMINATION

Germination under saline conditions differs from one crop to another and even a significant variation was recorded among the different cultivars of the same crop (Asana and Kale, 1965; Kumar and Bhardwaj, 1981).

Uprety and Sarin (1973) reported that soil salinity (ECe 8 dSm^{-1}) significantly decreased the germination in two varieties of pea. The effect was attributed to inhibition of sprouting seeds, slower rate of germination and mortality of seedlings.

Balki and Padole (1982) reported that the germination of wheat seed decreased with the increasing level of salinity while seed soaking treatments with different growth regulators increased the germination under different levels of salinity. Pre-soaking treatments of seeds with GA_3, IAA or ethrel mitigated the inhibitory effects of salinity (4-16 dSm^{-1}) on germination and coleoptile growth in pearlmillet (Madan and Kumar, 1983).

Yadav *et al*. (1985) reported that the increasing levels of soil salinity decreased the percent seed germination significantly at and above 4.91 and 6.23 dSm^{-1} in green gram and cowpea, respectively. Significant reduction in dry matter and yield was also observed.

Salinity tolerance of crops varies from germination to later stages of plant growth and development. The increase in salinity levels leads to decrease in germination in wheat (Lal *et al*., 1985), barley (Bliss *et al*., 1986), guar (Gabar and Mahmood, 1986) and *Vigna radiata* (Ashraf and Rasul, 1988).

Chhipa *et al*. (1992) conducted a petridish experiment with pearlmillet to study different physiological indices of salt tolerance at

different salt concentrations. They found that germination percentage, length of roots, coleoptile length and osmotic potential coleoptile decreased as compared to control, but reduction was less in tolerant genotype. Verma (1994) observed that salinity delays as well as decreases germination of most of the crops. In peralmillet, a number of studies indicated the depressive effects of salinity and sodicity on seed germination and early seedling growth.

Kumar *et al.* (1992) conducted an experiment on several genotypes under saline conditions. The most promising order under saline conditions were *B. juncea and B. carinata*, followed in descending order of salt tolerance by *Eurca sativa* (*E. vesicaria*) > *B. tournefortii* > *B. napus* > *B. campestris* (types toria > brown sarson > yellow sarson) > *B. alba* (*Singapis alba*).

Sharma *et al.* (1994) conducted an experiment on determental effects of salinity on germination and early seedling growth of wheat. In wheat, both chloride and sulphate types of salinity did not affect germination significantly upto 6 dSm^{-1} but beyond this limit both the salinities adversely affected the germination. However, chloride salinity was more deterious than sulphate salinity for germination and early seedling growth.

Farida Begum (1996) reported that germination of wheat seed cv. Kanchan and Triticale cv. Naib decreased with increase in salinity from 100 to 400mm NaCl particularly in wheat. No wheat seeds germinated at 400 NaCl under high salinity. A reduction in growth and an accumulation of Na and Cl in plumules and radicles was observed. Triticle seedlings were more tolerant to salinity than wheat.

Rathore *et al.* (1977) determined the effect of 4 salinity levels of 0, 24, 32 and 40 m mhos/cm on seed germination of 22 varieties of barley and revealed that increased salinity levels delayed and decreased germination %. However, Chandra D. (1979) concluded that taramira and

mustard can be grown successfully even with the water having ECe 10.0 m mhos/cm and SAR 30.

Soil salinity affects the every plant process at variable magnitude depending upon the crop variety and stage. Gupta *et al.* (1999) studied the germination behaviour of wheat under sodium chloride (NaCl) salinity and reported that salinity reduced the length and weight of radicle and plumule differentially in the five wheat strains categorized them.

Baroncelli (2001) discussed the trends in oilseed production including a predicted decline in rape and sunflower production over the next two seasons. This is caused by declining acreages for rape production in Canada, the problem of genetically modified crops (especially soybeans) in the USA, the decreasing sunflower production in central Europe. Given the anticipated increase in demand for plant proteins for livestock feeds, it is suggested that Italian growers might profitably increase the areas devoted to oilseed crops.

Yadava *et al*. (2001) conducted an experiment on seven important oilseeds crops belonging to the Brassicaceae in India under the names rapeseed and mustard *viz*. Indian mustard (*B. napus),* three genotypes of *B. campestris* sub sp. Oleifera, toria [*B. campestris* var. toria], *B. napus, B. carinata and Eruca sativa* and brown and yellow sarson [Both *B. campestris* var. sarson]. Information is presented on trends in production of the rapeseed-mustard crop over the last 5 decades, and in recent years in relation to different environmental conditions and states in India. Major cropping system involving rapeseed-mustard crops are described. Available technologies, including crop protection and crop management strategies, are assessed with a view to doubling the production of these crops. The constraints to rapeseed-mustard crop productivity are outlined.

Lallu and Dixit (2003) reported that the salinity tolerance of different genotypes was assessed by their overall reduction in germination per cent, speed of germination, root and shoot length. On the basis of study it was

found that germination per cent, root length, shoot length and speed of germination were reduced significantly with increasing salinity levels.

2.3 SALT STRESS IN RELATION TO GROWTH, YIELD AND YIELD ATTRIBUTES

Pearson and Bernstein (1958) reported that growth is adversely affected by increasing level of salinity, but the effect being less pronounced on vegetative growth than on reproductive growth. Salinity affects plant growth and yield ability by differential absorption of ions, toxic effects of ions and reduced growth because of the reduced uptake of nutrients (Levitt, 1972).

Salinity is known to affect several morphological and metabolic aspects of plant life. In glycophytes, stunted growth, reduction in leaf area and inhibition of shoot growth are the characteristics effects (Strogonov, 1964; Poljakoff-Mayber and gale, 1975).

Gupta and Abichandani (1975) reported that height of main shoot, total number of tillers per plant, length of the ear and test weight of wheat decreased with increased salinity of irrigation water. This was attributed to the concept that continuous addition of salts to the field increased osmotic pressure of soil solution and resulted in the restricted availability of water to the plants, which adversely affected various yield attributes.

Promila and Kumar (1982) studied the effects of salinity on flowering and yield characters in pigeon pea. They reported that increasing salinity delayed 50 per cent flowering by a week to a fortnight and prolonged the peak period of flower production. Number and weight of the pods were reduced with increasing salinity. The number of seeds per pod and 1000 seed weight were also reduced by salinity.

Salinity restricts the growth and development of plants and even results premature termination of life cycle, while altering their morphological, physiological and biochemical processes. Different views, hypothesis and theories are given for the effect of salt on growth processes in plants. For instances, two different views have been advanced. According to one, the harmful effects of salts on the plants are due to the osmotic potential of the external salt laden soil solution and according to second, it is due to toxic action of the ions of the salts. As yet, no single factor or group of factors has been identified as promoting salinity tolerance rather; it is a complex whole plant phenomenons (Yeo and Flowers, 1984; Munnsdisl, 1990; Kumar, 1993). In general, the prospects of further improvement in any species rests o the variability available for various traits. Salinity is simply defined as the presence of excessive concentrations of soluble salts, which suppressed plant growth (Mass and Hillman, 1978).

Ashraf and Rasul (1988) working on *Vigna radiata* reported that increasing salt concentration significantly reduced the fresh and dry weight, leaf area, shoot and root length, and shoot root ratio.

Sudhakar *et al*. (1990) reported that dry weight of shoot and root of salt stressed green gram decreased and there was significant increase in the levels of Na^+, Ca^+ and Cl in shoot and root of the plant. On the other hand in horse gram, which did not decrease the dry weight of its seedling. Besides growth suppression due to salinity, chickpea plants also showed necrosis and salt injury on the main or primary stem, its lower leaves being first to suffer (Sharma, 1990).

Lal (1991) reported that salt stress induced decrease seed yield per plant through the smaller number of grain per ear. Grieve and Poss (2000) studied on wheat response combined effects of boron and salinity on biomass production and found reduction in yield components and final grain yield. The

effect of salinity decrease root length and shoot length dry weight (Shafqat *et al.*, 1998). Increasing salinity reduced plant height and grain yield (Ehsan *et al.*, 1986).

Qadar, 1994, reported that, huskless (cv. IB65) barley was more sensitive than husked (cv. Ratna) to irrigation with saline water in terms of growth parameters and grain yield. Hebbar *et al*. (2000) at Central Cotton Research Institute, Nagpur, observed that salinity did not affect plant height, leaf area, boll number and plant biomass up to 10 dSm^{-1} beyond which *i.e.* 15 and 20 dSm^{-1} they were drastically reduced. At these levels plant height were reduced 47 % and 60 %, respectively.

Kausik *et al.* (2003) conducted an experiment on 73 taramira [*Eruca sativa* (*Eruca vesicaria*)] cultivars were evaluated along with the control cultivars, RMT-314 and T-27 in Rajasthan India. The number of siliqua per plant had the highest positive effects on seed yield per plant, followed by plant height, days to 50 % flowering, number of seeds per siliqua, siliqua length and biological yield per plant. At the phenotypic level, the number of siliqua per plant had the highest positive direct effect on seed yield per plant, followed by siliqua length, number of seeds per siliqua and plant height. Results indicate that seed yield per plant can be improved through direct selection for a higher number of siliqua per plant because of this has a direct positive effect on seed yield.

Sharma *et al*. (2003) reported that soil significantly reduced protein content in the grain while proline accumulation was stimulated in the leaves. The increase in leaf proline was relative greater in the tolerant genotypes than the susceptible once. Per cent decrease in grain yield showed significant positive association with per cent decrease in nitrogen content as well as protein content while significant negative association was recorded in per cent decrease in proline accumulation.

Verma *et al.* (2003) conducted a field experiment during the *rabi* season of 1994-95 to 1996-97 in Bikaner (Rajasthan, India) to study the yield and yield contributing characters of mustard cultivars Pusa contributing characters of mustard cultivars Pusa Bold, T-59, PCR-7, Kranti, Bio-902 and Rs-30 under different salinity level (0.25, 2.50, 5.00, 7.50 and 10.00 dSm^{-1}) of irrigation water. The highest seed yield was recorded in Kranti, T-59 showed the highest mean salinity index and high EC in value for 50 % yield reduction.

Humaira and Rafiq Ahmad (2004) conducted an experiment on effect of different irrigation intervals on the growth of rape cv. oscar under saline water irrigation of different sea salt concentrations. Plants were subjected to control (non-saline), over 0.4 (ECe 4.5 dSm^{-1}), and 0.6 (ECe 6.5 dSm^{-1}) of sea salt concentration. Vegetative growth was recorded in terms plant plants highest, number of leaves and branches and fresh and dry shoot biomass per plant, while reproductive growth was noted in terms of numbers of flowers and siliqua per plant, siliqua weight, number and weight of seed per plant, plant growth at vegetative and reproductive phases was proportionately inhibited by increasing salinity of irrigation water. The vegetative and reproductive growth of the plants was much reduced under 6-days irrigation interval compared 2 to 4 days irrigation intervals under non-saline and water irrigation.

Enferad *et al.* (2004) conducted a pot experiment, on the growth (dry matter) responses of 10 rapeseed *B. napus* var. *oleifera* cultivars to three levels of NaCl salinity induced by 1.2, 6.0 and 12.0 dSm^{-1} were investigated. The result indicated that salinity reduced total dry matter, Na concentration, K: Na ratio, ion selectivity of K versus Na and leaf water potential while it increased K concentration. However, the leaf water potential of plant had the highest and a significantly negative correlation with total dry matter accumulation. Therefore, it seemed that leaf water content of the peanut could explain the tolerance or sensitivity responses to salinity. The rapeseed cultivars were accordingly ranked in to different groups.

Cultivars Alice, fonax, DP. 94.8 and licord were classified as the saline tolerant group and cultivars such as Okapi, Akamer and Eurol as the saline sensitive group. The remaining 8 rapeseed cultivars were moderately tolerant. Meanwhile the response of rapeseed cultivars consul, VDH 8003-98 and orient were different such that the above explanation could not be applied to them. Therefore halophytic strategies for these cultivars might be worth further investigation.

2.4 SALT STRESS IN RELATION TO WATER RELATION PARAMETERS

Effects of water status on osmotic potential and pressure potential is also well documented (Sinha, 1972; Morgan, 1977, 1984). Osmotic potential has been viewed as an important mechanism of dehydration avoidance (Levitt, 1980; Morgan, 1984 and Munns, 1990).

An increase in cell solute content causing a decreased solute an osmotic potential is one way which turgor potential is maintained despite a reduced total water potential by maintain in high turgor is through that osmotic adjustment enables processes such as stomatal opening photosynthesis and cell expansion to continue at otherwise inhibitory water potentials (Acevedo *et al.*, 1979).

Water potential has been regarded as the most suitable index of water status of plant and it consists of three components namely, osmotic potential, pressure potential and metric potential (Kramer, 1983). Due to stress water potential in cowpea is reduced (Biswas *et al.*1989).

Kumar *et al.* (1994) studied *B. juncea* cv. Prakash in large containers. Plants were subjected to six watering treatments: no watering after crop establishment; dry up to floral bud appearance and irrigated thereafter; dry up to full flowering and irrigated thereafter; early irrigation, dry during the flowering period and irrigated during pod formation; irrigated upto

flowering and dry afterwards; and irrigated control. Diurnally canopy photosynthetic rate (P_N) followed photon flux density (PAR) and transpiration (T) followed air temperature (Ta). At higher PAR, P_N in dry treatments was greater during the 1st than the IInd half of the day. Photosynthesis attained compensation point at-4.0 MPa Ψ_{leaf}. Similarly, T during the 1st half of the day was greater than in the IInd half of the day at similar Ta. WUE was quite low at high PAR during the IInd half of the day. Photosynthesis and WUE peaks were observed during the full flowering period while, T gradually increased towards maturity. Seed yield was primarily reduced by water stress because of a decrease in the number of pods/plant and number of seeds/pod. The number of pods/plant and number of seeds/pod were linearly related to seed yield and cumulativeΨ_{leaf} and P_N related to both seed yield and total biomass.

Sharma and Singh (1993) conducted a field experiment on partially reclaimed sodic soils with pH 8.8 and ESP 23 in 1987-89 at Karnal (Haryana). *B. juncea* cv. Pusa Bold was not irrigated, irrigated at the rossette stage (28-30 DAS), pod formation stage (55 DAS) or rossette + pod formation stages. One irrigation at the rossette stage gave significantly greater relative growth rate, branches and pods/plant and seed and straw yields compared with one irrigation at pod formation stage and unirrigated treatments. Most of the evapotranspiration (ET) of the crop removed water from the 0-15 cm soil layer. The total water removed from all the layers was always greatest under higher irrigation frequency. Maximum WUE was recorded when one irrigation was given at the rossette stage compared with other treatments. The crop ET peaked from 30-60 DAS. Abdel *et al*. (1994) reported that increasing salinity levels, decreased the root length, shoot length, coleoptiles length and seedling length significantly in wheat cultivars.

Gangopadhyay *et al*. (1995) made a comparative study on the effect of water, salt and freezing stresses on relative water content (RWC), viability and banding patterns of some isozymes (esterase, peroxidase and

acid phosphatase) in *B. juncea* callus. RWC in different stress affected tissues was more or less similar though, effect on viability was different. Salt stress, in particular, was most injurious to the tissue. Different kind of stresses also affected the banding patterns of the isozymes. In isoenzymic profile of esterase, intensity of one specific band got diminished while another showed a gradual decline under salt stress conditions.

Panwar *et al.* (2003) reported that the genotypes responded differently in different soil types. The water potential and osmotic potential decreased due to accumulation of salts in these soils. The lower osmotic potential enabled the genotypes in different ways to maintain turgor and due to this the differential water balance was recorded in different genotypes. Accumulation of ions such as sodium potassium and calcium with proline could explain such osmotic adjustment.

Sairam and Srivastava (2002) reported the effect of long term and medium level of sodium salinity on two genotypes tolerant K-65 and susceptible HD-2687 of wheat. Salinity caused decrease in relative water content (RWC), chlorophyll and membrane stability index.

Srivastava (2002) conducted an experiment on three wheat cv. in lysimeter trials, effects of three soil salinity (2.8, 8.6 and 13.5 m mhos/cm) and two alkalinity (SAR 18.7 and 35.9) levels on leaf area, development and xylem water potential of three wheat genotypes were studied. Higher salt tolerance of Kharchia-65 than of other cultivars were described to the higher values for leaf area and lower xylem water potential.

Ashraf *et al.* (2002) conducted a field experiment at Faisalabad, Pakistan, during 1997-98. The salt tolerance potential of *Brassica carinata* cv. Brown raya and Peela raya, *B. juncea* cv. Raya anmol, Chackwali raya and RL-18, *B. napus* (*B. napus* var. Oleifera) cv. Sheiralle and *Eruca sativa* (*E. vesicaria*) cv. Taramira was assessed under 4 salinity levels (3.3, 11, 20 and 27 dSm^{-1}). Cultivars Sheiralle, Peela raya,

Chakwali raya and RL-18 produced significantly greater plant height, higher number of pods on the main branch and yield per plot than other cultivars under all salinity treatments. These plants produced more than 50 % seed yield up to 11 dSm^{-1} and appropriately 50 % seed yield up to 20 dSm^{-1} salt treatment. The experiment was continued during 1998-99 with 2 salt-tolerant (RL-18 and Sheiralle) and 2 salt sensitive (Brown raya and Raya Anoml) under the same conditions. The result showed that the tolerant cultivars had less Na^{+} content, water potential, osmotic potential while they had greater K^{+}, Ca^{++} and Mg^{++} content and turgor potential than the sensitive cultivars. The effects of salinity on P content was not much pronounced in all brassica cultivars.

2.5 SALT STRESS IN RELATION TO PHOTOSYNTHETIC PARAMETERS

Meiri *et al*. (1970) reported that salinity reduced transpiration rate in *Phaseolus vulgaris*.

Sharma and Ghildiyal (1992) reported in *B. juncea* cv. Pusa Bold, photosynthetic activity of the leaves decreased to a very low value by 110 DAS and leaves showed increased senescence and shedding beyond this stage. In spite of this, the plant produced more than 70% of the total seed yields between 110 d and maturity. The shedding of pods decreased the seed yield by 95% as compared with the control by decreasing seed number/pod and seed size. Defoliation decreased seed yield by decreasing the number of pods with a lesser effect on seed number/pod and seed size. These results indicated that there was a complementary role of leaf and pod photosynthesis in determining seed yield in mustard.

Suresh *et al.* (1996) examined the relationship between leaf nitrogen content (N) versus photosynthetic rate (P_N) and other associated parameters in *B. juncea* cv. Pusa Bold and *B. campestris* cv. Pusa Kalyani. Leaf N, specific leaf weight (SLW), leaf area and P_N were significantly higher

in *B. juncea,* while the chlorophyll content was significantly lower compared to *B. campestris.*A significant positive correlation was obtained between leaf N content and photosynthetic rate in both spp. Similarly, SLW was also positively related with leaf N content. *B. juncea* showed higher photosynthetic nitrogen use efficiency than *B. campestris.* Leaf N and PNUE were negatively associated. This was attributed to a low investment of N in photosynthesis related reactions and/or partitioning of N towards compounds functionally unrelated to photosynthesis. This attribution is further supported by the negative relationship obtained between SLW and PNUE.

Net photosynthetic rate, transpiration rate and stomatal conductance were the highest in the flag in the middle and fully expanded leaves and were minimum in the oldest leaves (Sharam, 1996a and Strains and Agenbag, 2000).

It has been reported that with the enhancement of sodium chloride concentration growth was retarded, the chlorophyll and carotenoid content were increased in plants subjected to the salinity only high salinity level induced a considerable decrease in net photosynthesis rate and dark respiration rate (Kumar, 1992; Hamda, 1996 and Meena *et al.*, 2003).

Rahman *et al.* (2000) and Ahmed (2002) reported that total biomass, harvest index, crop growth rate and net assimilation rate decreased with increase in salinity level. Salt progressively reduced germination, plant height, root length, fresh shoot weight, fresh root weight and cumulative reduction for the parameter were maximum at salinity level of 30 dSm^{-1} when compared with other treatment.

Salinity affects the various physiological processes of plants which is called to reduce the yield and quality produce. Mittova and Iganberbien (2000) reported the influence of salt stress on respiration metabolism in higher plants and found that the activity of glycolsis decreases significantly in susceptible wheat genotypes.

Net photosynthesis rate decreased as salt stress increased and salt stress developed at various phenological stage affects the yield and yield attributes differentially by manipulating various plant process (Jenson and Megenson, 1984; Chippa *et al.*, 1992 and Chongo and Mc vetty, 2001).

The effect of salinity applied at different stages of the life cycle of wheat plant growth, yield, translocation of photosynthetes and dry biomass production and grain yield were reduced when salinity was applied at the beginning of the vegetative stage. Whereas, no effects were observed when applied at later stages (Gupta *et al.*, 2001).

Chongo and Mc vetty (2001) observed that the physiological basis of seed yield in oilseed rape still remains unclear, and conclusions on the contribution of various traits to seed yield are difficult to make. Leaf chlorophyll content, net photosynthetic rate/unit leaf area (P_A), per unit leaf dry matter (P_{DM}) and per unit leaf chlorophyll (Pc), transpiration rate (T_R) and WUE were investigated on fully expanded leaf number of the main stem and related to seed yield, total dry matter (TDM) and HI of each yield group. Difference among yield groups for seed yield, TDM and HI were significant. Chlorophyll content was lowest on leaf 4, but increased with leaf age. In general, the results indicate that the largest contribution to net photosynthesis by oilseed rape leaves occured during the vegetative and early flowering stages compared with the early pod-filling stage.

Uprety *et al*. (2001) evaluated the effect of elevated CO_2 concentration on the leaf structure of *B. juncea* cv. BIO-141 under water stress conditions. Moisture stress reduced the length of epidermal cells, palisade parenchyma cells, chloroplasts and starch granules by 26, 58, 23 and 27%, respectively, under ambient CO_2 concentration. However, under elevated CO_2 (600µmol/mol) the reduction significantly decreased and remained only at 6% in epidermal cells, 25% in palisade cells, 5% in chloroplasts and 10.5 % in starch granules. The increase in structural sink size helped in controlling feed back inhibition by excessive photoassimilate which was subsequently used to compensate the adverse effect of moisture stress in *B. juncea* leaves.

Singh *et al.* (2003) conducted an experiment on *Brassica juncea* and concluded that soil sodicity decreased chlorophyll content, nitrate reductase activity yield and yield components *viz.*, length of siliqua, number of siliqua and test weight in all genotypes. Whereas free proline and total soluble sugar were increased with increasing levels of sodicity. Genotypes CSR-50, CSR-15 and CSR-12 showed tolerance to sodicity upto 30 ESP. In these genotypes there was lesser reduction in chlorophyll content, nitrate reductase activity, yield and yield component and also had the potential to accumulate the organic osmotica under stressful environment.

Yadav *et al*. (2003) reported that salinity caused significant decrease in leaf transpiration rate of mothbean genotypes.

2.6 SALT STRESS IN RELATION TO QUALITY PARAMETERS

Malik *et al*. (1977) studied on peas and reported reduced protein content at higher salinity levels (3.1-1.2 dSm^{-1}).

Garg *et al.* (1983) observed maximum adverse effects on growth, yield and metabolism of wheat under Na_2CO_3 and $NaHCO_3$ while Na_2SO_4 and KCl caused negligible effects. $CaCl_2$ and $MgCl_2$ decreased dry matter but not grain yield. They also observed specific ion effect on levels of leaf metabolites and activities of certain enzymes like nitrate and ATPase.

Leiboviten and Smith (1994) observed in a field experiment with spring barely and wheat conducted in Canada applied CCC solution (5.8 x 10^3 mm) after anthesis CCC increased protein content in grain.

Gill and Dutt (1987) found that barley had higher concentrations of Na^+ than wheat and contained more Na^+ than K^+ in roots over other aerial parts while much more Na was transported to aerial parts in wheat thus distributing the Na : K ratio more in wheat than in barley.

Pessarakh *et al*. (1989) studied on green gram and reported that protein content of plants decreased with increasing salinity.

Morales *et al*. (1992) subjected barley cv Igri and Albacete grown hydroponically to conductivity of 2, 6, 12, 19 and 26 dSm^{-1} induced by adding equal weights of NaCl and $CaCl_2$ to the nutrient solutions. Plant growth was significantly decreased by salinity. Shoot fresh weight/pot (04 plant/pot) at 19 dSm^{-1} was 20 and 2 per cent of control yield in Igri and Albacete, respectively. Leaf water potential and osmotic potential were decreased by salinity. Further, salinity did not induce significant change in the relative photosynthetic pigment composition of the leaves.

Chendeminjng and Yurempel (1995) conducted a pot experiment in which wheat and barley were grown in soil salinised to increase the osmotic potential by 0, -0.4, -0.8 and –1.6 Mpa. Increasing salinity levels increased the uptake of Na and decreased K uptake greatly and Ca uptake slightly. K/Na and Ca/Na ratio in leaves were decreased by salinity.

Misra *et al*. (1995) conducted a pot experiment with *B. juncea* cv. Pusa Bold which was exposed to salinity levels of 0-3% NaCl. Chlorophyll and carotenoid contents increased at 0.5 and 1.0% NaCl levels, but decreased significantly over control values at 3 % NaCl level. Protein content of 15 days old cotyledons was decreased by salinity. The leaf protein content increased to three fold that of the control value at 0.5 % NaCl level at 25 days but at higher salinity levels there was no significant change over control values.

Kwon *et al*. (1999) grown *B. juncea* cv. Common Green (salt tolerant) and *B. rapa* (*B. campestris)* cv. Sani (salt sensitive) in a green house with or without NaCl (125 m). Distribution of biomass, and contents of Na^+, K^+, proline, TSS and water were determined in relation to salinity tolerance. NaCl treated plant preferentially accumulated K^+, proline and TSS

in expanding leaves and Na^+ in expanded leaves. The result suggested that the salt induced growth inhibition in both species may be caused by a water deficit effect of salinity in expanding leaves and by excess Na^+ accumulation and or K^+ deficiency in fully expanded mature leaves. The two species differed in their ion accumulation pattern but not in water content, or proline and TSS accumulation in response to salinity, indicating that the relative salinity tolerance was related to an ion effect rather than a water deficit effect. It was concluded that salinity tolerance was associated with Na^+ exclusion, the selective uptake of K^+ over Na^+ and the maintenance of higher K : Na ratios in growing leaves and stems.

Thakral *et al.* (1998) evaluated four *B. juncea* genotypes (2 tolerant and 2 susceptible to salinity) and 3 crosses between them for 4 physiological traits under salt stress (125 meq/litre) and found that K : Na ratio decreased, while chlorophyll, proline and protein contents increased in parents and hybrids under salt stress compared to controls. Thakral *et al.* (1998) further studied leaf samples of 4 genotypes of *B. juncea* and three crosses between them, grown in saline (125 meq/litter) and control environments were collected at flower initiation and analysed for chemical composition. Yield and seedling vigour were also monitored. Seed yield was positively correlated with chlorophyll content and seedling vigour was negatively correlated with proline content in the control environment. Positive non-significant correlations with seed yield were found for RWC, K : Na ratio and proline content in both environments and for seedling vigour and chlorophyll content in the saline environment. Chlorophyll had significant positive correlations with proline content in the saline environment.

Sureena *et al*. (1999) grown *Brassica juncea* cv. Varuna and RH-7846 at 0-150 meq/litre salinity. Oil and erucic acid content decreased with increased salinity, while linolenic acid and linolenic + eicosenoic acids generally increased.

Parti *et al.* (2000) reported that increasing salinity levels increased free proline content but decreased chlorophyll content in leaf, seed and siliqua wall of *B. juncea.*

Pathan *et al*. (2000) reported that plant height, seed index, seed and straw yield and content of P and K in seed and straw of clusterbean decreased with increasing salinity and sodicity, while the content of N and Na increased**.**

The content of sodium ions (Na^+) in the straw and root of wheat plants increased with increasing salinity (Dravid and Goswani, 1986 and Hamada, 2001).

Essa (2002) worked on different levels of salinities 0.5, 2.5, 4.5, 6.5 and 8.5 dSm^{-1} on soybean and found a significant increase in Na^+ and decrease in the accumulation of K^+ and Ca^{2+} in the leaves of plant.

Parti *et al.* (2002) conducted an experiment on *Brassica juncea* cv. RH-30 was grown in earthen pots lined with polyethylene bags and filled with sandy soil (ECe 1.8 dSm^{-1}) salinity level of 4, 8 and 12 dSm^{-1} were obtained by adding chloride and sulphate salts of sodium, calcium and magnesium. All salinity treatments affected plant growth considerably. The dry weight of plant tissue, seeds and siliqua wall was maximum at 4 dSm^{-1}, after which a consistent decrease in dry weight was observed as salinity levels increased. There was also a decrease in plant height and siliqua/plants with increasing salinity. The lipid composition of the seed was also affected by the different salinity levels above 4 dSm^{-1}, total and non-polar lipids showed a reduction with increasing salinity, with polar lipids showing the reverse trend. As salinity increased the nitrogen, phosphorus and potassium content of *B. juncea* plant, seed and siliqua wall samples decreased. The crop in phosphorus content was smaller than that seen with the other two elements. In

contrast, the sodium content of all plants, seed and siliquae wall samples increased with increasing salinity.

Ismail and Moradi (2003) reported that salinity substantially reduces yield of sensitive cultivars by affecting most yield attributes. Tolerant cultivars had significantly lower (Na) and Na/K ratios in younger leaves during the vegetative stage and in the flag leaf and reproductive structures during reproduction, low lipid peroxidation, elevated levels of reduced ascorbic acid and increased activities of enzymes, involved in the antioxidant system, both during vegetative and reproductive stages. They also showed faster reduction in stomatal conductance and transpiration during the initial period of salt stress, whereas, susceptible lines showed a delay of 1 to 2 d before their gas exchange was significantly reduced.

Karadge and Gaikwad (2003) working at Kolhapur reported that NaCl salinity reduced the overall growth of *Catharanthus roseus*, which was highly significant at higher salinity levels only.

Rao *et al.* (2003) concluded that the roots *S. persica* act as accumulator of Na^+ and Cl^- and the flux of these ions to the whole plant increased with increase in salinity of the medium. Among the ions Cl^- was found to be more than Na^+. While ion partitioning at organ level showed more Na^+ and Cl^- accumulation in bark, root and senescing leaves, K^+ was found to be more in young and immature leaves. The flux of these ions from the root to the shoot was only a fraction of that to the whole plant, which indicated that the roots accumulation more toxic ions that of the shoot.

Parihar and Singh (2003) conducted an experiment on five varieties of wheat were grown in different salinity levels of irrigation water at ECe of 3, 6, 9 and 12 dSm^{-1} along with control. Germination percentage and seed yield enhanced upto 3 dSm^{-1} beyond this level showed decrease in trend. Variety KRL 1-4 and K 9006 produced highest seed yield at higher levels of

saline irrigation water in comparison to other. Chlorophyll and potassium content increased at 3 dSm^{-1} ECe while decrease in trend was noted at higher levels of saline irrigation water. Variety K 9006 showed better response in comparison to others. Sodium content increased with increase in salinity levels of irrigation water and was maximum at 12 dSm^{-1} while lowest was recorded in control. Na/K ratio enhanced with increase in salinity of irrigation water. Lowest Na/K ratio was recorded in tolerant variety KRL 1-4 while highest in sensitive K 9644.

Abraham (2003) reported the effect of supplemental calcium supply and sodium chloride on proline accumulation and the ion contents in the roots of *Azolla pinnata* plants. Forty eight hours of exposure to 20 mM NaCl resulted in a 2-fold increase in proline level in the root tips supplemented with 0.5 mM Ca^{2+}. In contrast, a 4-fold increase in proline accumulation was noted in the roots supplemented with 2 mM Ca^{2+}. The K^+ to Na^+ ratio of the roots also varied significantly due to Ca^{2+} supplemented of salinized roots. Thus, Ca^{2+} may ameliorate the NaCl induced inhibition of root growth by proline accumulation and maintaining favourable K^+ to Na^+ ratio.

Pandey and Lal (2003) showed that yielding contributing characters of wheat varieties *viz.*, K-65, K-5262, K-9006 and K-7903 were studied under different concentrations of saline irrigation water *viz.*, control 300 ppm, 6000 ppm and 9000 ppm. Yield contributing characters decreased markedly with increasing levels of salinity. Nitrate reducates activity (NRA) in leaf tissues and concentration of total nitrogen and grain protein showed significant reduction with increase in the concentrations of salinity. Increasing levels of salinity significantly reduced the chlorophyll content in the leaves while proline accumulation was stimulated. Per cent decrease in grain yield at higher salinity level showed positive association with per cent decrease of

NR-activity, chlorophyll and total nitrogen content while proline accumulation showed negative association.

2.7 PLANT GROWTH REGULATORS IN RELATION TO GERMINATION

Application of GA_3 (10 ppm), kinetin (0.5 ppm) and GA_3 + kinetin on wheat seed under saline environment increased the germination upto 58.7, 53.3 and 59.0 per cent, respectively (Kabar and Kocacaliskan, 1990). Strack (1991) found that a cytokinin analogue, Mc Mu TTB (1-methoxy carbonyl 1-3-n-butyl-1, 2 3, 4- tetrahydro-1, 3, 5- Triazino (1, 2-Alfa) benzimidazole) significantly reduced the inhibitory effect of salinity on leaf turgor and germination of cotton.

Ozturk *et al*. (1993) studied *Brassica campestris* seed collected from wild populations in Turkey were germinated in 0-5 % NaCl solutions with 10 ppm aqueous solutions of GA_3, kinetin and IAA and all combinations of the growth regulators, or were soaked in 50 or 100 ppm solutions of the growth regulators for 2 hours and then germinated in the NaCl solutions. In all treatments germination decreased with increasing salinity, while growth regulators significantly increased germination under salt stress compared with controls receiving no growth regulators. GA_3 was more effective than kinetin or IAA.

Ozturk *et al.* (1997) observed that *E. sativa* (*E. vesucaria* Subsp. *sativa*) seeds were germinated at 25^0C under normal daylight conditions in solutions containing 0.5 or 1.08 NaCl with 0, 10 or 50 ppm gibberellic acid (GA_3) or IAA. Germination was significantly decreased by 1.08 NaCl, but was alleviated by 50 ppm GA_3 or 10 ppp IAA.

Anamica and Dhaka (2004) conducted an experiment on seeds of pea cultivars T-163 and Bonneville were soaked in 100, 200, 300 or 400 ppm cycocel (chlormequat) and germinated in petridishes to determine the

effects of the growth retardant on the germination and redicle length of pea seed germination and redicle length decreased with increasing rates of cycocel.

Anamica and Dhaka (2004) conducted an experiment on seeds of *V. faba* were soaked in 50, 100, 150, 200, 250, 350 and 400 ppm cycocel and germinated in petridishes to determine the effect of the growth retardant germination and redicle and shoot length of crop. Seed germination was highest with seed soaking at 50 ppm cycocel whereas redicle and shoot length decreased with increasing cycocel concentrations.

2.8 PLANT GROWTH REGULATORS IN RELATION TO GROWTH, YIELD AND YIELD ATTRIBUTES

Application of cycocel reduced stem growth but increased the root growth, lateral branching, tillering, fruitification and accumulation reserve in stem and other organs. Its use increases the number of stomata per unit area and reduced their size, strength of vascular system and made wilting to be more difficult (Damethy *et al*., 1964).

Growth retradants like CCC and phosphon-D has reported to increase seed yield in barley, berseem and bajra (Yadav and Patil, 1980).

Soaking seeds in CCC solution increased germination percentage, growth and survival of plants in some of the treatments on saline and saline alkaline soils (Gabar and Mahmood, 1986).

Foliar application of cycocel increased the test weight, size of the seed and oil content in sunflower seed (Pando and Srivastava, 1987).

Singh *et al*. (1991) reported that application of a foliar spray of 50mg/l chlormequat (CCC) at preflowering stage increased flower and fruit

formation, protein retention, seed setting, seed yield and 1000 seed weight in chickpea.

Shah and Pratapsen (1991) reported that foliar spray of chlormequat on moong bean (*Vigna radiata*) applied at 14 days after emergence reduced stem length, increased shoot dry weight, leaf area, leaf thickness, number of pod per plant, seeds per pod and seed yield but had no effect on 1000 seed weight.

Singh and Kakralya (1993) reported that infusion of plant growth substances like IBA and GA via acetone and benzene in cultivars of some arid legumes produced advantageous results mediated through different seed technological parameters. However, the physiological and biochemical mechanism underlying such responses are yet to be understood.

Rajput *et al*. (1996) conducted a field experiment in 1991-93 at Morena (M.P.), the application of 500 ml/ha of Cycocel [chlormequat] or 1.25 litres per ha of mepiquat chloride at flower initiation stage, significantly reduced plant height and increased seed yield of mustard (*B. juncea*) cv. Pusa Bold by 38 and 32%, respectively, compared with the untreated control.

Yadav *et al.* (1997) reported that BA partially alleviated the adverse effect of water stress on *Cicer arietinum* by stimulating the accumulation of metabolites in the leaves. Such stress induced increase in metabolites is responsible for osmotica adjustment. The BA also increased the content of cytokinin and lowered the level of ABA in the leaves and spikes of wheat. As a result, photosynthetic activity in leaves increased leading to an increase in grain mass and productivity (Elagina and Yakushkina, 1997).

Mehriya and Khangarot (2000) observed that in a field study in winter 1993-94 in Jobner, Raj., India. *B. juncea* was given 0, 50, 100 or 150 kg S/ha and was sprayed with water, Vipul [triacontanol] Paras [a mixture of triacontanol-based long chain alcohols] or Cycocel [chlormequat]. Seed yield and S and N uptakes increased with increasing S rate, and were increased

by growth regulators, with Vipul giving the best results and Cycocel having the least effect.

Annadurai *et al.* (2003) conducted a pot experiment on the effects of chlormequat on the growth of *C. esculenta*. Chlormequat at 250 and 500 ppm was sprayed to plants at 15 days intervals for 5 months, chlormequat application for 1 month up to 5 months significantly reduced the number of leaves, length of leaves, petiole length and leaf area and increased the content of reducing and non-reducing sugar and starch. The variation between the rates was not significant. The results confirm the efficiency of chlormequat in controlling the vegetative growth of *C. esculenta*.

Reddy *et al.* (2003) reported that seed germination was decreased significantly (89%) with 100 mM NaCl, whereas 50 mM was not that effective (6.3%). The magnitude of reduction in seedling root length due to NaCl stress was not marked compared to that of shoot length. Thus. Root/shoot ratio was increased significantly with increase in NaCl concentration. Significant and drastic reduction of vigour index was noticed with increase in NaCl concentrations. Based on these results, NaCl (100 mM) medium was supplemented with different concentrations of BA and NAA to improve the seed quality parameters in groundnut. BA (2 ppm) and NAA (25 ppm) enhanced the root length significantly indicating the possible dilution effect, probable due to faster cell division, more membrane integrity and the area and volume of root.

2.9 PLANT GROWTH REGULATORS IN RELATION TO QUALITY PARAMETERS

Several reports indicate that salt tolerance of wheat can be increased by sowing of seeds pre-soaked in hormones like gibberellic acid (GA), indole acetic acid (IAA) or kinetin (Darra *et al.*, 1973 and Chippa and Lal, 1986). “Pre-sowing seed soaking with kinetin (10 ppm), Gibberellin (100 and 200 ppm) and to a lesser extent with IAA (50 ppm) significantly

alleviated salt stress effects on seedling dry mass and helped in more ethylene evolution".

Robertson and Greenway (1973) reported that application of CCC reduced transpiration and increased drought resistant of young maize plants by delaying the onset of severe internal water deficit.

Arnon (1975) found beneficial effect of CCC on water use efficiency probably due to reduction in transpiration rate of treated plants. Arnon (1984) reported that CCC treated barley plants resulted increased plant height, dry matter accumulation and photochemical activity of chloroplast but decreased a) chlorophyll content per unit area, leaf fresh weight, b) chlorophyll index and c) chlorophyll photosynthetic potential. Treatment with 1 g CCC/litre slowed down the stem growth, produced significant change in dry matter accumulation and increased a), b) and c) in activated chloroplast and decreased their photochemical activity.

Sairam *et al*. (1991) worked on the effect of chlormequat chloride (CCC) on the two drought tolerant (C-306 and Pissi local) and two drought susceptible (WL-711 and WH-147) wheat genotype under moisture stress. Results showed an increase in leaf water potential, nitrate reductase activity, photosynthesis and cholorophyll content in the leaf by foliar application of CCC under moisture condition at tillering and anthesis stages. There was also an increase in grain yield. The effect of CCC was more pronounced in drought tolerant genotypes over to susceptible ones.

Meera Shravastava (2003) conducted an experiment on effect of the foliar application of cycocel (1000 or 2000 ppm), Alar (daminozide) (100, 200 or 300 ppm) and ABA (10, 20 or 30 ppm) on the performance of Indian mustard cv. Varuna under irrigated (2 irrigations) and non-irrigated conditions were studied in Kanpur in India. The number of leaves per plant was higher under irrigation than under non-irrigated conditions. Alar at 300 ppm was more effective increasing the number of leaves under irrigated conditions, whereas cycocel at 1000 ppm was more effective under non-irrigated

conditions. The growth regulators except 20 and 30 ppm ABA increased leaf area. Alar under irrigated and cycocel under non-irrigated conditions resulted in the highest number of branches. The growth regulators reduced the length of the inflorescence, thus reducing the distance between the source and sink. The reduction in inflorescence length was most pronounced with Alar. The relative growth rate of leaves was generally reduced during the second period due to the application of growth regulators, however, the reduction was less marked with cycocel under irrigated conditions. The growth regulators 20 and 30 ppm ABA significantly enhanced yield and yield compounds. Alar at 300 ppm resulted in the highest yield, cycocel at 1000 ppm and Alar at 3000 ppm resulted in the least variation between irrigated and non-irrigated conditions in terms of yield and yield compounds.

Yadav (2004) reported that the increasing concentrations of CCC decreased Na content but decreased K content both in seed and stover.

3. MATERIALS AND METHODS

All the experiments were conducted on three genotypes of taramira *viz.,* RTM-314, RTM-2002 and RTM-969 were used as experimental material at Department of Plant Physiology, S.K.N. College of Agriculture, Jobner.

3.1 CHARACTERISTICS OF TARAMIRA GENOTYPES

(i) RTM-314

RTM-314 was developed by AICRP-Taramira unit, S.K.N. College of Agriculture, Jobner in 1995. The plant height 100-105 cm, profusely branched, leaves serrated with hairy surface. Seeds containing 35.5 % oil. It takes about 135 days to mature and on an average produces 13.0 q/ha seed yield.

(ii) RTM-2002

RTM-2002 was developed by AICRP-Taramira unit, S.K.N. College of Agriculture, Jobner in 2001. Plants are 114 cm tall containing 37.0 % oil. It takes about 140 days to mature and on an average produces 13.5 q/ha seed yield.

(iii) RTM-969

RTM-969 was developed by AICRP-Taramira unit, S.K.N. College of Agriculture, Jobner in 2001. Plant height 107 cm containing 37.5 % oil. It takes about 138 days to mature and on an average produces 13.5 q/ha seed yield.

3.2 EXPERIMENTAL SITE

The experimental work was carried out under field and laboratory conditions. The field experiment was conducted on the saline (ECe= 7.5 dSm^{-1}) and normal (ECe = 2.1 dSm^{-1}) soils and laboratory experiment was carried out in Post Graduate Laboratory, Department of Plant Physiology, S.K.N. College of Agriculture, Jobner which is situated 45 kms west of Jaipur at 26^0 05' latitude and 75^0 28' east longitude at an elevation of 427 meters above mean sea level.

3.2.1 Field experiment

To study the response of the experimental plant species, saline soil was developed by standard procedure. The pH and ECe of the normal soil were recorded to be 7.8 and 2.1 dSm^{-1}, respectively, indicating that the soil was light saline. As well as the pH and ECe of the saline soil were also recorded to be 8.4 and 7.5 dSm^{-1}, respectively, indicating that the soil was highly saline.

The seeds of taramira genotypes were soaked in cycocel solution of 0, 50 and 100 ppm concentrations for 6 hours with 2-3 drops tipol. The treated seeds of taramira genotypes were sown both in normal and saline soils. The net plot size in both conditions were kept equal *i.e.* 2 x 1.2 sq m. Recommended R x R and P x P distance were kept at the time of sowing *i.e.* 30 cm and 10 cm, respectively. Recommended irrigations were applied at critical stages of taramira crop.

3.2.1.1 Determination of germination, growth and yield responses

The following germination, growth and yield attributing characters were measured and recorded at different crop growth stages.

3.2.1.1.1 Seedling emergence (%)

Seedling emergence percentage recorded at 10 DAS. The counted seeds were sown in two rows of each plot. The emergence per cent was determined by counting the number of emerged seedlings in each rows on the basis of normal seedling by using following formula :

$$\text{Emergence (\%)} = \frac{\text{Number of emerged seedlings}}{\text{Total number of seeds sown}} \times 100$$

3.2.1.1.2 Root-shoot and seedling length (cm)

Length of root-shoot and seedlings (cm) were measured with scale at 21 days after sowing.

3.2.1.1.3 Seedling vigour index

The seedling vigour index was computed by the formula given by Singh and Singh, 1983.

$$\text{Seedling vigour index} = \frac{\text{Emergence (\%) x Seedling length (cm)}}{100}$$

3.2.1.1.4 Leaf area (cm^2) per plant

The leaf area per plant of randomly selected plants was measured directly in sq cm with the help of LI-3100, area meter in the Department of Horticulture, S.K.N. College of Agriculture, Jobner. The average was recorded as mean leaf area per plant in sq cm of five randomly selected plants out of plantation in each plot.

3.2.1.1.5 Leaf area index :

The LAI was calculated by the following relationship :

$$\text{Leaf area index (LAI)} = \frac{\text{Leaf area } (cm^2)}{\text{Ground area } (cm^2)}$$

3.2.1.1.6 Plant height (cm) at harvest

The height of randomly selected plants was measured from base to the top of the plant with the help of meter scale and recorded as plant height in cm, at harvest. The average was recorded as mean plant height in cm of five randomly selected plants out of plantation in each plot.

3.2.1.1.7 Number of siliqua per plant

At harvest, the total number of siliqua per plant of randomly selected plants were counted and average was taken.

3.2.1.1.8 Number of seeds per siliqua

At harvest, the number of seeds per siliqua of randomly selected siliquas were recorded and average values were calculated.

3.2.1.1.9 Test weight (g)

1000-seeds from the samples of each treatment were counted and their average weight was recorded.

3.2.1.1.10 Biological yield (q ha^{-1})

At harvest, the shoot portion of each plot was removed and kept in sunlight for sundrying. After complete drying the material was weighted on balance and weight was recorded. The weight of the thoroughly sun dried total harvested produce on each net plot (2 x 1.2 sq m) was recorded separately as the total biological yield gm per plot. It was then converted in q ha^{-1}.

3.2.1.1.11 Economic yield (q ha^{-1})

After harvesting and threshing, the seed yield for each of the plot was recorded and converted into per hectare by multiplying with a constant factor. Seed yield was expressed as economic yield in kg ha^{-1} or q ha^{-1}.

3.2.1.1.12 Harvest index

Harvest index is the percent of the economic yield to the biological yield produced.

$$\text{Harvest index (\%)} = \frac{\text{Economic yield (q ha}^{-1}\text{)}}{\text{Biological yield (q ha}^{-1}\text{)}} \times 100$$

3.2.1.2 Photosynthetic efficiency and plant water relation parameters at pre-flowreing, flowering and maturity stages

3.2.1.2.1 Photosynthetic rate (µ Mol Co_2 $m^{-2}s^{-1}$)

Photosynthetic rate was taken at pre-flowering, flowering and maturity stages in both normal and salt stress in between 10-12 A.M. on the fully expanded leaf of the randomly selected plants.

Photosynthetic rate (µ Mol Co_2 $m^{-2}s^{-1}$) was measured directly by using infrared gas analyzer (LI- 6200, LICOR, USA).

3.2.1.2.2 Transpiration rate (µ Mol H_2O $m^{-2}s^{-1}$)

Leaf transpiration rate (µMol H_2O $m^{-2}s^{-1}$) was measured directly by using infrared gas analyzer (LI -6200,LICOR,USA).

3.2.1.2.3 Water use efficency

Water use efficiency was calculated by using following formula :

$$\text{Water use efficiency (WUE)} = \frac{\text{Photosynthetic rate}}{\text{Transpiration rate}}$$

3.2.1.2.4 Relative water content (%)

1 gm leaf sample was initially weighed and floated over the distilled water for 24 hours and the turgid weight was recorded. Dry weight was obtained after drying the leaf sample at 80 ^{0}C for 48 hours. The relative water content was calculated by given following formula (Slavik, 1974).

$$RWC = \frac{\text{Fresh weight} - \text{Dry weight}}{\text{Turgid weight} - \text{Dry weight}} \times 100$$

3.2.1.2.5 Water potential (MPa)

The water potential was determined with the help of pressure chember method (Scholander *et al.*, 1964). The pressure chamber was carried to the experimental site. Leaf bearing branch was cut with a sharf kinfe quickly inserted into rubber gasket of pressure chamber with the cut surface protruding outside. Dry compressed air was gradually forced into hermetically sealed chamber through a regulator from a tank of comparessed gas, until xylem sap exuded at the cut surface.

The amount of pressure that must be applied to force water out of the leaf cell in to the xylem untill it is refilled, is equal to the tension

originally existing in the xylem sap, *i.e.* pure water will be exuded by reversed osmosis. Thus the applied pressure is eual to the water potential of the cells.

3.2.1.2.6 Osmotic potential (MPa)

The osmotic potential was determined with the direct reading conductivity meter method as reported by Singh and Singh, (1983).

One gram leaf sample was homogenized in distilled water and squeeze filtered through a double layered muslin cloth. Total volume of extract was made upto 25ml and the ECe of this extract was determined with a direct reading conductivity meter. At the same time the another one gram leaf sample was oven dried at 80 ^{0}C for 48 hours and its dry weight was measured and with the help of following formula dilution factor (D.F.) was calculated.

$$D.F. = \frac{\text{Fresh weight} \times \text{Volume made}}{\text{Fresh weight} - \text{Dry weight}}$$

The osmotic potential of extract was calculated using following formula:

$$OPext\ (bar) = \frac{ECe \times 0.36 \times D.F.}{0.987}$$

where,

OPext = Osmotic potential of extract (bar)

ECe = Electrical conductivity of extract

D.F. = Dilution factor

It was then converted into SI unit MPa. This formula was given by Janardhan *et al.*, 1975.

3.2.2 LABORATORY EXPERIMENT

3.2.2.1 Quality parameters

3.2.2.1.1 Ionic concentration

To estimate ionic concentration of Na and K in plant samples, 1.0 g of powdered material each of root and shoot was digested in a di-acid mixture consisting 9: 4 of HNO_3: $HClO_4$ and then volume of digested material was made up to 100 ml with distilled water. The ionic concentrations were determined in this extract using flame photometer (Bhargava and Raghupathi, 1993).

3.2.2.1.2 Protein content (%)

For extraction of protein content of seed was obtained by multiplying the nitrogen content (in %) with a constant 6.25 (AOAC, 1960).

The nitrogen content was estimated by wet digestion of plant sample with H_2SO_4 and H_2O_2 and estimation on colorimeter after development of colour with Nesseler's reagent in presence of NaOH and sodium silicate (Snell and Snell, 1939).

3.2.2.1.3 Oil content (%)

For the estimation of oil content, 1 gm seeds were weighed and grinded vigorously. The grinded material being pouched in filter paper, previously weighed and then dipped into the petroleum ether (spirit) for 48 hrs. Oil dissolved in petroleum ether and reduction in weight of pouch was estmiated into mg g^{-1} seed wt. oil content and was converted into per cent oil content.

3.6 STATISTICAL ANALSYSIS

The observations were taken in triplicates and data were statistically analysed using randomized block design (RBD).

The comparision of the treatment mean was made with the help of critical difference calculated as under :

$$\sqrt{2 \times MSE}$$

$$\text{CD for salinity} = \frac{}{\sqrt{c \times g \times r}} \times t \text{ value at } 5\%$$

$$\text{CD for cycocel} = \sqrt{\frac{2 \times MSE}{s \times g \times r}} \times t \text{ value at } 5\%$$

$$\text{CD for genotype} = \sqrt{\frac{2 \times MSE}{s \times c \times r}} \times t \text{ value at } 5\%$$

Where,

c = CCC levels (3)

r = replication (3)

s = salinity levels (2)

g = genotypes (3)

MSE = Means squares error

4. EXPERIMENTAL RESULTS

The experimental work was carried out under field and laboratory conditions. A field experiment was conducted on saline and normal soils and laboratory experiment was carried out in Post Graduate Laboratory, Department of Plant Physiology, S.K.N. College of Agriculture, Jobner during the *rabi* season, 2004-05 have shown following features of special interest in experimental results.

4.1 FIELD EXPERIMENTS

As reported in materials and methods, the experimental species of taramira *viz.*, RTM-314, RTM-2002 and RTM-969 were grown on specially prepared saline and normal soils. The germination percentage, growth and yield attributing characteristics of all the three genotypes of taramira along with certain parameters of photosynthetic efficiency, plant water relationship and other biochemical parameters and seed quality parameters of all the three genotypes of taramira were recorded and summarized as below:

4.1.1 Germination

4.1.1.1 Seedling emergence (%) under field condition

Table 4.1 and Fig. 4.1 showed the effect of salinity genotypes and cycocel concentrations on seedling emergence percentage under field conditions. The perusal of data showed that seedling emergence percentage significantly decreased under saline condition as compared to normal condition. Whereas genotypic effect on seedling emergence percentage was found non-significant. The RTM-969 genotype of taramira showed maximum

seedling emergence percentage both under saline and normal conditions. Cycocel gave higher seedling emergence percentage under both the soil conditions. The cycocel 100 ppm concentration showed the highest seedling emergence and significantly more over cycocel 50 ppm concentration and control.

4.1.2 Growth, yield and yield attributes

4.1.2.1 Root and shoot length at 21 DAS

A perusal of data (Table 4.1 and Fig. 4.1) indicated that root and shoot length of taramira genotypes at 21 DAS significantly decreased under salinity stress condition as compared to normal condition. Whereas, genotypic difference with respect to root and shoot length of taramira genotypes at 21 DAS did not attain the level of significance. A critical examination of data indicated that genotype RTM-969 showed maximum root and shoot length, but it was statistically at par with rest of the genotypes. Data further revealed that soaking of seeds in cycocel at 50 ppm and 100 ppm concentrations significantly increased root length over untreated seeds. Unlike root, the shoot length decreased significantly with increasing level of cycocel. The 100 ppm concentration of cycocel showed highest effect on increase in root length and decrease in shoot length.

4.1.2.2 Seedling length (cm) at 21 DAS

The presented data (Table 4.2) indicated that seedling length decreased significantly under saline condition as compared to normal condition. The genotypic difference with respect to seedling length was found non-significant. However, RTM-969 showed higher seedlings length at 21 DAS as compared to other genotypes. A further reference to data showed that seedling length was non-significantly decreased with increasing concentrations of cycocel.

4.1.2.3 Seedling vigour index

The computation of data (Table 4.2) showed the effect of salinity, genotypes and cycocel concentrations on seedling vigour index at 21 DAS. The examination of data showed that seedling vigour index decreased significantly under saline condition as compared to normal condition. Further look to data revealed that the genotype RTM-969 showed maximum seedling vigour index both under saline and normal conditions of soil, and remained at par with rest of the genotypes. The 100 ppm concentration of cycocel also increased significantly to the seedling vigour index, whereas, cycocel 50 ppm concentration remained statistically at par with control.

4.1.2.4 Leaf area (cm^2)

Data (Table 4.3) indicated that salinity of the soil significantly reduced the leaf area over normal soil. The genotypic effect on leaf area was found non-significant. However, RTM-969 showed maximum leaf area but remained statistically at par with rest of the genotypes both under normal and saline conditions. The soaking of seeds with increasing concentration of cycocel 50 and 100 ppm significantly increased the leaf area over control. The highest increase in leaf area was recorded under cycocel 100 ppm.

4.1.2.5 Leaf area index

The perusal of data (Table 4.3) showed that leaf area index significantly decreased under saline condition. Data further indicated that of all three genotypes of taramira remained statistically at par with respect to leaf area index. Among the genotypes RTM-314 showed minimum leaf area index, whereas, RTM-969 showed maximum leaf area index. Treatment of taramira seeds with cycocel 50 ppm and 100 ppm concentration significantly increased the leaf area index. The more pronounced effect of cycocel on leaf area index was recorded at 100 ppm cycocel concentration.

4.1.2.6 Plant height (cm) at harvest

Data (Table 4.3) showed the effect of salinity, genotypes and cycocel concentrations on plant height. The examination of data indicated that plant height decreased significantly under saline condition. The genotypic effect on plant height was found statistically at par. However, RTM-969 showed maximum plant height over rest of the genotypes both under saline and normal conditions of the soil. Data further revealed that seed soaking with cycocel 100 ppm concentration significantly reduced the plant height over cycocel 50 ppm concentration. Cycocel 50 ppm concentration also significantly reduced plant height over untreated seeds.

4.1.2.7 Number of siliqua per plant

The examination of data (Table 4.4 and Fig. 4.2) showed that number of siliqua per plat decreased significantly under saline condition as compared to normal condition. It is further apparent from the same table that genotypic difference with respect to number of siliqua per plant was found significantly higher in genotype RTM-969. However, the genotype RTM-314 and RTM-2002 were found statistically at par in number of siliqua per plant. Seed treatment with cycocel 100 ppm concentration showed the maximum number of siliqua per plant and also significantly more over cycocel 50 ppm and control.

4.1.2.8 Number of seeds per siliqua

The computation of data (Table 4.4 and Fig. 4.2) showed that number of seed per siliqua decreased significantly under saline condition. Further examination of data indicated that genotype RTM-969 showed significantly higher number of seeds per siliqua and significantly more over rest of the genotypes. However, genotype RTM-2002 and RTM-314 were found statistically at par with respect to number of seeds per siliqua. The seed

soaking with cycocel significantly increased the number of seeds with increasing level of cycocel. Whereas, maximum number of seeds were found at seed soaking with 100 ppm cycocel concentration over 50 ppm and control.

4.1.2.9 Test weight (gm)

Data (Table 4.4 and Fig. 4.2) showed the effect of salinity, genotypes and cycocel concentrations on test weight. The examination of data showed that test weight significantly decreased under saline condition as compared to normal condition. Further look to data reflected that the genotypic effect on test weight was found statistically at par. However, RTM-969 showed higher test weight over rest of the genotypes. The cycocel 100 ppm concentration showed the maximum test weight and significantly more over cycocel 50 ppm concentration and control both under saline and normal conditions of the soil.

4.1.2.10 Biological yield (q/ha)

The perusal of data (Table 4.5 and Fig. 4.3) showed that biological yield significantly decreased under saline condition over normal condition. It is further apparent form the same table that genotype RTM-969 gave significantly higher biological yield over rest of the genotypes. Whereas, genotype RTM-314 and RTM-2002 were found statistically at par both under saline and normal conditions. Data further indicated that cycocel mitigated the adverse effect of salinity by increasing biological yield. Sowing of seeds treated with cycocel 50 ppm and 100 ppm concentrations significantly increased biological yield over untreated seeds both under normal and saline conditions.

4.1.2.11 Grain yield (q/ha)

Table 4.5 and Fig. 4.3 showed the effect of salinity, genotypes and cycocel concentrations on grain yield of taramira genotypes. The

examination of data showed that grain yield decreased significantly under saline condition as compared to normal condition of soil. Table also indicated that genotype RTM-969 showed significantly higher grain yield over rest of the genotypes, while genotype RTM-314 and RTM-2002 were found statistically at par with respect to grain yield both under saline and control conditions. Data in Table 4.5 also indicated that soaking of seeds with cycocel gave higher grain yield by ameliorating the adverse effect of salinity. Sowing of seeds with 50 and 100 ppm cycocel concentrations significantly increased grain yield over untreated seeds under both the soil conditions.

4.1.2.12 Harvest index

Data (Table 4.5 and Fig. 4.3) reflected that salinity decreased harvest index as compared to control but it was statistically at par with normal condition. Further perusal of data showed that genotypic difference was also found non-significant in respect to harvest index. The genotype RTM-969 showed maximum harvest index and genotype RTM-314 showed minimum harvest index both under normal and saline conditions. It is further apparent from the same table that cycocel declined the harvest index with increasing level of cycocel. 100 ppm cycocel concentration decreased maximum harvest index but remained statistically at par with cycocel 50 ppm concentration and control both under normal and saline conditions.

4.1.3 Photosynthetic rate (μ Mol CO_2 m^{-2} s^{-1})

Table 4.6 showed the effect of salinity, genotypes and cycocel concentrations on photosynthetic rate at three growth stages. The perusal of data showed that photosynthetic rate decreased significantly under saline condition as compared to normal condition at pre-flowering, flowering and maturity stages. Data presented in Table 4.6 reflected that genotypic difference with respect to photosynthetic rate was found non-significant at all three growth stages. However, RTM-969 showed maximum photosynthetic

rate both under normal and saline conditions at all three growth stages. Sowing of pre-soaked seeds with cycocel significantly increased the photosynthetic rate. The cycocel 100 ppm concentration showed the highest photosynthetic rate at all the three growth stages over cycocel 50 ppm concentration and control. A critical examination of data indicated that photosynthetic rate decreased with growth stages. While maximum photosynthetic rate was recorded at pre-flowering stage followed by flowering and maturity stages.

4.1.3.2 Transpiration rate (µ Mol H_2O m^{-2} s^{-1})

Table 4.7 showed the effect of salinity, genotypes and cycocel concentrations on transpiration rate at three growth stages. The photosynthetic rate decreased with growth stages. The higher transpiration rate was found at pre-flowering stage, while lower at maturity stage. Data given in Table 4.7 showed that transpiration rate was significantly decreased at all three growth stages under saline condition as compared to normal condition. The further examination of data showed that genotypic difference in relation to transpiration rate at pre-flowering, flowering and maturity stages was found non-significant. The higher transpiration rate was found in genotype RTM-314, whereas, minimum in RTM-969. The seed soaking with cycocel significantly decreased transpiration rate with increasing concentrations of cycocel. While maximum reduction was recorded with cycocel 100 ppm concentration over 50 ppm and control at pre-flowering stage. The similar results were also observed at flowering and maturity stages.

4.1.3.3 Water use efficiency

Table 4.8 showed the effect of salinity, genotypes and cycocel concentrations on water use efficiency at three growth stages. A close scruting of data indicated that water use efficiency decreased with growth stages. The higher water use efficiency was found at pre-flowering stage and minimum at

maturity stage. The examination of data (Table 4.8) showed that salinity decreased water use efficiency, but it was statistically at par with normal condition at pre-flowering stage. The similar trend was observed at flowering and maturity stages. Data further indicated that genotypic difference was also found non-significant with respect to water use efficiency. Whereas, genotypes RTM-969 showed maximum water use efficiency but remained at par with rest of the genotypes at all three growth stages both under saline and normal conditions. It is further apparent form the same table that cycocel significantly increased water use efficiency. Cycocel 100 ppm concentration significantly increased the water use efficiency at pre-flowering, flowering and maturity stages over cycocel 50 ppm and control under both the conditions of soil.

4.1.3.4 Relative water content

Data (Table 4.9) showed the effect of salinity, genotypes and cycocel concentrations on the relative water content at pre-flowering, flowering and maturity stages. The perusal of data showed that relative water content of taramira genotypes decreased with growth stages both under normal and saline conditions. However, the maximum relative water content was reported at pre-flowering stage followed by flowering and maturity stage. The critical examination of data revealed that relative water content significantly decreased at all three growth stages under saline condition as compared to normal condition. The genotypic effect on RWC was found non-significant at pre-flowering, flowering and maturity stages. While, genotype RTM-969 showed maximum relative water content as compared to rest of the genotypes. A close scrutiny of data in Table 4.9 showed that cycocel significantly increased the relative water content. Cycocel 100 ppm concentration showed maximum RWC and significantly more over cycocel 50 ppm concentration and control at all three growth stages.

4.1.3.5 Water potential

Data presented in Table 4.10 indicated that water potential decreased with growth stages. However, higher water potential was observed at pre-flowering stage followed by flowering and maturity stages both under normal and saline conditions. Data reflected that water potential decreased significantly under saline condition as compared to normal conditions at pre-flowering, flowering and maturity stages. Data also indicated that genotype RTM-969 showed maximum water potential but remained at par with rest of the genotypes at all three growth stages under both the soil conditions. Sowing of seeds pre-soaked with 100 ppm cycocel significantly increase the leaf water potential. 50 ppm cycocel also significantly increased water potential over untreated seeds at pre-flowering stage. The similar results were also reported at flowering and maturity stages.

4.1.3.6 Osmotic potential

Data presented in Table 4.11 showed the effect of salinity, genotypes and cycocel concentrations on osmotic potential. A critical examination of data showed that osmotic potential decreased with growth stages. However, higher osmotic potential was recorded at pre-flowering stage followed by flowering and maturity stages both under saline and normal conditions. Data also revealed that osmotic potential decreased significantly under saline condition as compared to normal condition at pre-flowering, flowering and maturity stages. The genotypic difference with respect to osmotic potential was found non-significant. However, genotype RTM-314 showed minimum osmotic potential and RTM-969 showed maximum osmotic potential at all three growth stages both under control and saline conditions. Cycocel significantly increased the osmotic potential. Cycocel 50 ppm and 100 ppm concentrations significantly increased the osmotic potential over control at pre-flowering, flowering and maturity stages.

4.2 LABORATORY EXPERIMENTS

4.2.1 Quality parameters

4.2.1.1 Sodium/potassium ratio in root

The perusal of data (Table 4.12 and Fig. 4.4) indicated that Na/K ratio in root increased with growth stages. However, lowest Na/K ratio was found at pre-flowering stage followed by flowering and maturity stages. It is further apparent from the same table that Na/K ratio significantly increased under saline condition as compared to normal condition at pre-flowering, flowering and maturity stages. Data also revealed that there was non-significant difference among genotypes. However, higher Na/K ratio was recorded in genotype RTM-2002 and lowest in RTM-969 at all three growth stages. A close scrutiny of data indicated that cycocel significantly decreased the Na/K ratio in root. Cycocel 100 ppm concentration showed significant decrease in Na/K ratio as compared to cycocel 50 ppm and control at pre-flowering, flowering and maturity stages. A critical examination of Table 4.12 and 4.13 indicated that higher Na/K ratio was recorded in root than shoot at all three growth stages.

4.2.1.2 Sodium/potassium ratio in shoot

The examination of data (Table 4.13 and Fig. 4.5) revealed that Na/K ratio in shoot increased with growth stages. The lowest Na/K ratio was recorded at pre-flowering stage, while highest at maturity stage. Data further showed that salinity significantly increased the Na/K ratio in shoot over normal condition at all the three growth stages. The genotypic effect on Na/K ratio in shoot was found non-significant. However, higher Na/K ratio was recorded in genotype RTM-2002 and lower in RTM-969 at pre flowering, flowering and maturity stages. Data also indicated that cycocel significantly decreased Na/K ratio in shoot. Cycocel 100 ppm concentration significantly

decreased the Na/K ratio over cycocel 50 ppm concentation and control at all three growth stages. A close scruting of data in Table 4.12 and 4.13 revealed that lower Na/K ratio was recorded in shoot than root at all three growth stages.

4.2.1.3 Protien content (%)

Table 4.14 showed the effect of salinity, genotypes and cyccoel concentrations on protein content of taramira genotypes both under control and saline conditions. The persual of data showed that protein content decreased significantly under saline conditions as compared to normal condition. The genotype RTM-969 showed maximum protein content but remained at par with rest of the genotypes under both the conditions of soil The soaking of seeds with cycocel 100 ppm concentation showed highest protein content and significantly more over cycocel 50 ppm and control both under normal and saline conditions.

4.2.1.4 Oil content (%)

Data presented in Table 4.14 indicated that oil content of taramira genotypes decreased significantly under saline condition as compared to normal condition. Further examination of data showed that there was non-significant difference among genotypes. However, RTM-969 showed maximum oil content than other genotypes both under normal and saline conditions. The cycocel significantly increased the oil content. Cycocel 100 ppm concentration showed higher oil content and significantly more over cycocel 50 ppm concentration and control both under normal and saline conditions.

5. DISCUSSION

It is well known fact that environmental stresses limits plant growth, development and productivity (Lange *et al.*, 1976 and Abrol, 1986). Salinity is the major environmental stress limiting plant productivity in arid and semi-arid regions (Abrol, 1986). Salinity has emerged as a great problem in recent past. It becomes more acute due to the irrigation with saline water and uses of uncultivable saline/sodic soils owing to the increasing population, particularly in India. Dealing the mechanism of action, some proposed that salt stress influences plant growth and development in the same way as water stress (Poljakoff-Mayber and Gale, 1975). The higher plants respond differentially to salinity and other stresses via physiological and morphological adjustments (Turner *et al.*, 1986 and Gupta *et al.*, 2002). Under saline condition injurious effect of Na on plant processes are well known (Abrol, 1986).

The detrimental effects of salinity are due to the influence of ions on the water activity of the external solution which affects the water status of the plant and biochemical functions of the soils (Munns *et al.*, 1982). These effects can result in turgor reduction, inhibition of membrane function or enzyme activity (Wyn Jones and Gorham, 1983) inhibition of photosynthesis (Walker *et al.*, 1981) induction of ion deficiency due to inadequate transport/selectivity mechanism (Jescheke, 1984) or increased use of metabolic energy for non growth processes involved in the maintenance of

tolerance (Yeo, 1983), reduction in plant height drying and ultimately death of leaf and then whole plant (Hamada, 2001 and Gupta *et al.*, 2002).

The degree of salt tolerance varies not only with the plant species but different varieties of the same species may show variation in salinity and alkalinity tolerance (Richards, 1954 and Lal *et al.*, 1985). The reduction in growth under salinity has been described either due to osmotic or ionic effects and/or the combination of both (Levitt, 1980).

Keeping these aspects in view the experiment was conducted to observe the effect of salt stress on some physiological processes of taramira genotypes. The findings of present investigation entitled "Physiology of taramira (*Eruca sativa* Mill.) under salinity stress" have already been presented in the preceding chapters. In this chapter, it is contemplated to discuss the significant variations in different criterion used for evaluating the treatment differences. Significant variations in the results have also been compared with the findings of other workers.

5.1 EFFECT OF VARIETIES

Taramira genotypes under study differed significantly in number of siliqua per plant, Number of seeds per siliqua (Table 4.4 and Fig. 4.2), grain yield, biological yield (Table 4.5 and Fig. 4.3). The above parameters were recorded significantly higher in genotype RTM-969 as compared to rest of the genotypes, but genotype RTM-314 remained statistically at par to genotype RTM-2002. Among taramira genotypes there was non-significant differences were recorded in seedling emergence percentage, root-shoot and seedling length, SVI, leaf area and leaf area index, plant height, photosynthetic and plant water relation parameters, Na/K ratio in root and shoot, protein content and oil content in seeds.

These genotypic differences may be ascribed to a complex interaction of inherent genetic make-up to that of environmental conditions prevailing during *Rabi* season at Jobner, jaipur (Rajasthan). These results corroborate with the findings of Gill and Sharma (1993) in pigeonpea, Kakralya and Singh (1994) in peanut and Kumari *et al.* (1994) in rapeseed.

5.2 EFFECT OF SALINITY

Under field conditions salinity significantly reduced the seedling emergence percentage, root length, shoot length (Table 4.1 and Fig. 4.1), seedling length and seedling vigour index (Table 4.2). Lower germination under salinity is due to inhibition of sprouting seeds (Uprety and Sarin, 1973), while root-shoot and seedling length decreased owing to accumulation of ions near the root surface (Singh and Singh, 1970). The similar results were also obtained by Gupta *et al.* (1999), Farida Begum (1996), Singh and Singh (1999), Yadav *et al.* (1985), Sudhakar *et al.* (1990), Malik *et al.* (1977), Abdel *et al.* (1994), Reddy *et al.* (2003), and Lallu and Dixit (2003). The reduction in seedling emergence percentage ultimately resulted in reduction in seedling vigour index. Similar results have also been reported by Chhipa *et al.* (1992) in pearlmillet and Singh (2002) in brassicas. The high NaCl salinity showed more detrimental effect on all seed physiological parameters (Garg and Gupta (1999) in wheat. In the present investigation salinity significantly reduced the leaf area, leaf area index and plant height (Table 4.3). Salinity might be lead to osmotic inhibition, toxic effect of ions and nutritional imbalance of elements by lowering down the uptake of essential nutrient elements and finally culminates in decreased growth (Levitt, 1972). The results are also in conformation with the findings of Strogonov (1964), Poljakoff-Mayber and Gale (1975), Ashraf and Rasul (1988). The sowing of seeds under saline condition significantly decreased the number of siliqua per plant, number of seeds per siliqua, test weight

(Table 4.4), biological yield and grain yield (Table 4.5) as compared to normal condition. Whereas, harvest index decreased non-significantly as compared to control. The decrease in number of siliqua per plant, number of seeds per siliqua and test weight owing to less number of fruiting nodes, flowers, comparatively poor setting and less decomposition of metabolites in seed. Similar results have also been reported by Kumar and Rathore (2002) in Indian mustard, Murmukar and Chavan (1986) and Lal (1991).

Reduction in yield attributing characteristics resulted in decline the grain and biological yield. The possible reasons for decline in seed yield due to salinity are delay in flowering, reduced number of siliqua per plant, number of seeds per siliqua and decreased test weight. The adverse effect on growth attributes *viz.*, plant height, leaf area, number of branches per plant and above ground phytomass productivity per plant ultimately resulted in reduction of biological yield. As harvest index is directly related to seed : straw ratio and under salinity it becomes wider and decreased harvest index. These results have also been supported by Singh *et al.* (2003) in brassica, Kumar and Rathore (2002) in Indian mustard, Lal (1985) in legumes Kausic *et al.* (2003) and Verma *et al.* (2003).

The reduction in photosynthetic rate in taramira genotypes under the influence of salt stress was reported by number of authors. However, the level of reduction in photosynthetic rate differed in different genotypes. The results of present investigation showed that photosynthetic rate higher at pre-flowering stage followed by flowering and maturity stages. But maturity stage was more adversely affected by salt stress condition (Table 4.6). Similar results have also been reported by Chhipa *et al.* (1992), Gupta *et al.* (2001), Congo and Mc Vetty (2001), Meena *et al.* (2003) and Kumar *et al.* (1994). Salinity reduced chlorophyll content which destroyed due to loosened binding of chlorophyll and chloroplast protein (Ashraf, 1989) depends upon

ion content of the cell (Strogonov, 1964), which ultimately reduced photosynthetic area. The inhibition of photosynthetic capacity under salinity is due, in part, to the closure of the stomatal resistance. In recent years, the over production of activated oxygen species in chloroplast of plants under drought stress has been described (Sairam *et al.*, 2001) and it is hypothesized that a similar mechanism may also operate under salt stress. As soon as the CO_2 concentration decreased inside the chloroplast, as a result of stomata closure, there is a reduced availability of NADP to accept electrons from PS-I, thus initiating oxygen reduction with concomitant generation of activated oxygen species.

Transpiration viewed as a necessary avil which based on the fact that evaporative cooling is essential and advantageous to maintain favorable leaf to air temperature gradient (Gupta *et al.*, 2001). In present investigation the transpiration rate was significantly decreased at pre-flowering, flowering and maturity stages on account of salt stress (Table 4.7). This is attributed due to partil closure of stomata, decreased stomatal conductance and reduced stomatal frequency owing to osmotic stress, thereby lowering the transpiration rate (Plaut *et al.*,1980). These results corroborates with those of Yadav *et al.* (2003), Ismail and Moradi (2003), Meiri *et al.* (1970), Poljakoff-Mayber and Gale (1975), Sharma and Singh (1993), Straus and Agenbag (2000).

It is evident from the observed data (Table 4.8) that the salinity decreased the water use efficiency of taramira genotypes at all three growth stages, which was statistically at par with normal conditions. Since WUE is directly related to photosynthetic rate and transpiration rate ratio, under salinity it reduced the water use efficiency (Sharma and Singh, 1993, Chongo and Mc Vetty, 2001).

Maintenance of a favourable water status is crucial for metabolic activities of the plant. In our study, the relative water content (RWC) decreased significantly under saline condition at pre-flowering, flowering and maturity stages. However, higher RWC was reported at pre-flowering stage over maturity stage. Relative water content has been attributed as an important parameter under salt stress conditions which indicated the ability of leaf to more available water for physio-biochemical processes. Similar findings were also been reported by Gangopadhyay *et al.* (1995), Thakral *et al.* (1998), Gupta *et al.* (2001) and Meena *et al.* (2003). Sufficient literature is available to indicate a decrease in water potential and osmotic potential under salt stress conditions. In present investigation Table 4.10 and 4.11 showed a significant decrease in water potential and osmotic potential under saline condition as compared to normal condition (Panwar *et al.*, 2003). The decrease in water potential is also a well documented phenomenon (Morales *et al.*, 1992, Gupta, 1993, Srivastava, 2002 and Garg *et al.*, 2002). The decrease in water potential has been attributed to accumulation of ions at root zone in soil solution, which lowers the water potential of soil solution resulted decrease in water potential of plant. Osmotic potential is an important component of water potential which directly linked with water status of the plant. The decrease in osmotic potential on account of salinity is a well documented response of glycophytes and halophytes (Morgan, 1984 and Munns, 1990).

It may be concluded that reduction in osmotic potential has been attributed to increase in osmoticum (Jones *et al.*, 1980) and the major osmoticum in plants are inorganic ions, organic acids and soluble sugars (Munns *et al.*, 1982). This is accepted because plant accumulate ions against concentration gradient and the lowering of osmotic potential then that of

water potential under salinity conditions leads to maintenance a positive turgor through osmotic adjustment (Levitt, 1980, Gupta, 1983).

It is crystal clear from data presented in Table 4.14 that salinity decreased significantly protein and oil content in seeds of taramira genotypes. Significant decrease in protein content in seed under saline condition could be due to decrease in amino acid content and metabolites. Similar results were also reported by Malik *et al.* (1977), Murmukar and Chavan (1986). Ashraf and Rasul (1988), Pessarakh *et al.* (1989), Leibovitch and Smith (1994) and Afria *et al.* (1998). Salinity significantly decreased oil content in seeds. Sureena *et al.* (1999) also reported that oil and erucic acid decreased on account of salt stress.

Present investigation showed that salinity increased significantly Na/K ratio in root and shoot at all three growth stages. However, higher Na/K ratio was found in root than shoot. NaCl is the major soluble salt which contribute to the soil salinity. It is generally accepted that adverse effects of salinity are medicated through an excessive uptake of Na and Cl at the cost of K. As K and Ca are required for several important plant cell functions e.g. selectivity and integrity of membrane, stomatal movement, photosynthesis, formulation of starch and activator of a number of enzymes (Gupta *et al.*, 2002 and Meena *et al.*, 2003). The highest Na/K ratio and impare the selectivity of root membrane and result in passive accumulation of Na in root and shoot (Gupta *et al.*, 1999). Tolerant genotype accumulated lesser amount of Na than K and restricted its translocation from root to shoot. Salinity increased the Na/K ratio in root and shoot. This is due to fact that salinity used in the experiment was sodium dominant, which increased the concentration of sodium in soil solution, besides increasing the proportion of sodium to other divalent cations. Sodium dominant salinity resulted in the lower uptake of potassium than Na due to antagonism between Na and K. The increased concentration of sodium in soil solution cause more absorption of

sodium by plants and decrease the absorption of potassium as sodium competes with potassium on absorbing sites. The Na/K ratio higher in root than shoot due to restricted translocation of Na from root to shoot. The results get supported from the findings of Pathan *et al.* (2000), Essa (2002), Ismail and Moradi (2003), Abraham (2003), Parihar and Singh (2003) and Rao *et al.* (2003).

5.3 EFFECT OF CYCOCEL (CCC)

Treatment of taramira seeds with cycocel prior to sowing significantly improved seedling emergence percentage, root length (Table 4.1 and Fig. 4.1) and seedling vigour index (Table 4.2), but decreased shoot length and non-significantly decreased seedling length (Table 4.1 and 4.2). Increase in seedling emergence, root length and seedling vigour index might be due to its stimulatory effect in alleviating the hormones responsible for germination and root growth. Reduction in shoot length and seedling length might be due to dwarfing character induced by cycocel. These results corroborates with those of Damethy *et al.* (1964), Singh and Singh (1970), Gabar and Mahmood (1986), Anamika and Dhaka, (2004). Promontory action of physiologically active concentration of PGR's on seed germination and related parameters have also been reported by Singh and Kumar (1984), Singh and Afria (1986), Singh and Rathore (1987), Singh and Afria (1990), Singh *et al.* (1994) and Anamika and Dhaka (2004).

Soaking of seeds with cycocel significantly increased leaf area and leaf area index (Table 4.3), which is similar to the findings of Annadurai *et al.* (2003), Yadav (2004) and Meera Shravastava (2003). Whereas, significantly decrease of plant height as compared to untreated seeds (Table 4.3). This decrease in plant height could be due to dwarfing characters induced by cycocel. The results are in agreement with those of Demathy *et al.* (1964), Tozani *et al.* (1976) and Rajput *et al.* (1996).

Application of cycocel as seed treatment significantly increased the number of siliqua per plant, number of seeds per siliqua, test weight (Table 4.4 and Fig. 4.2), grain yield and biological yield (Table 4.5 and Fig. 4.3), while decreased non-significantly harvest index. Increase in number of siliqua per plant and number of seeds per siliqua might be due to that cycocel checked luxuriant/excessive vegetative growth and abscission of flowers. Besides, this action of CCC on promoting flower initiation is supposed to depend on its ability to inhibit biosynthesis of endogenous gibberellins and CCC diverted more photosynthates towards the grain development by reducing vegetative growth and hence increase grain yield. These findings get support from those of Corcoran (1975) and Tozani *et al.* (1976). Significant increase in grain and biological yield might be due to significant improvement in yield attributing characters. Similar results have also been reported by Yadav and Patil (1980), Pando and Srivastava (1987) and Singh *et al.* (1991).

Seed treatment with cycocel significantly increased the photosynthetic rate at pre-flowering, flowering and maturity stages (Table 4.6). Increase in photosynthetic rate might be due to increase in photosynthetic area by increasing leaf area and due to increase in chlorophyll content. The increase in chlorophyll content may be ascribed to probably due to its property to accelerate the rate of photosynthesis. The similar results have also been reported by Arnon (1984), Peter and Hradecka (1987), Shah and Prathapasenan (1991) and Sairam *et al.* (1991).

Seed soaking with cycocel significantly decreased transpiration rate at pre-flowering, flowering and maturity stages (Table 4.7). Reduction in transpiration rate might attributed to that CCC decreased stomatal conductivity and stomatal frequency, maintained low level of proline content and relatively low stomatal opening, there by lowering the transpiration rate.

Similar findings were reported by Robertson and Greenway (1973), Arnon (1975), Plaut *et al.* (1980) and Afria *et al.* (1998).

Cycocel increased significantly water use efficiency (Table 4.8) at all three growth stages. Significant increase in water use efficiency might be due to CCC induced increase in photosynthetic rate and decrease transpiration rate thereby increased WUE. Results also supported by Arnon (1975), Arnon (1984) and Peter and Hradecka (1987). Data showed a significant increase in relative water content (Table 4.9), leaf water potential (Table 4.10) and osmotic potential (Table 4.11) with increased CCC concentration. This might be due to that CCC maintained high relative water content, low levels of free proline, low relative stomata opening during stress with partial closure of stomata, decreased stomatal conductance and stomatal frequency and increased resistance in plants against dehydration in leaves. The similar results have also been reported by Plaut *et al.* (1980), Vaid *et al.* (1983), Arnon (1984), Sairam *et al.* (1991) and Agarwal (2002).

Sowing of pre-soaked seeds with cycocel significantly decreased Na/K ratio in root and shoot at all three growth stages (Table 4.12 and 4.13 & Fig. 4.4 and 4.5). Reduction in Na/K ratio might be due to that CCC reduced the uptake of sodium than potassium by decreasing the proportion of Na to other divalent cations. The results corroborates with those of Gill and Sharma (1993), Pathan *et al.* (2000), Essa (2002) and Yadav (2004).

The known mechanism of action of CCC as an inhibitor of gibberelline biosynthesis (Corcoran, 1975), which adequately explains its counter acting effects to salinity. The increased resistance to salt by CCC application might be due to some chemical processes involving the intermolecular hydrogen bond in ribonuclease, giving protection to break down of proteins. Sowing of pre-soaked seeds with CCC gave significantly

higher protein and oil content (Table 4.14). This might be attributed to that cycocel increase amino acid concentration and other metabolites. These results are in agreement with Singh and Rajput (1988), Uprety and Sarin (1973), Pando and Srivastava (1987), Afria *et al.* (1998) and Agarwal (2002).

6. SUMMARY AND CONCLUSION

The present investigation on "Physiology of taramira (*Eruca sativa* Mill.) under salinity stress" was carried out under filed and laboratory conditions at Department of Plant Physiology, S.K.N. College of Agriculture, Jobner during *rabi* season, 2004-05 with the following objectives :

(iv) To study the effect of cycocel on photosynthetic efficiency and plant water relationship of taramira genotypes under saline and non-saline conditions.

(v) To find out the effect of both salinity and cycocel on morpho-physiological attributes and yield in genotypes of taramira.

(vi) To study the role of cycocel in mitigating the adverse effect of salinity stress in taramira genotypes.

The results of investigation presented and discussed in the preceding chapters are summarized and concluded below :-

6.1 GENOTYPE RESPONSE

In present investigation three genotypes of taramira *viz.*, RTM-314, RTM-2002 and RTM-969 were grown both under normal and saline soils. The ECe of normal and saline soils were recorded to be 2.1 and 7.5 dSm^{-1} (pH = 7.8 and 8.4) respectively.

6.1.1 Under field conditions, genotypes of taramira did not showed any significant variations with respect to seedling emergence percentage, root-shoot and seedling length, seedling vigour index, leaf area, leaf area index and plant height.

6.1.2 On account of yield and yield attributes *viz.*, number of siliqua per plant, number of seeds per siliqua and test weight, there was

significant differences existed among the genotypes of taramira. These yield attributing characters of genotype RTM-969 were found significantly higher over rest of the genotypes. However, genotype RTM-2002 and RTM-314 remained statistically at par. Genotype RTM-969 gave significantly higher grain yield and biological yield. Whereas, genotype RTM-2002 remained at par to RTM-314 under both non-stess and salt stress conditions.

6.1.3 Under field conditions the genotypic differences did not attain any significant variations in photosynthetic and plant water relationship parameters. Photosynthetic rate decreased with growth stages. Highest photosynthetic rate was recorded in genotype RTM-969 at pre-flowering, flowering and maturity stages, which was statistically at par with rest of the genotypes both under non-stress and salt stress conditions. Transpiration rate was also decreased with growth stages. Highest transpiration rate was recorded in genotype RTM-314 at all three growth stages, which was statisticallly at par with genotype RTM-2002 and RTM-969. However, water relation parameters were found non-significantly higher in genotype RTM-969.

6.1.4 With respect to qualtiy parameters *viz.*, Na/K ratio in root and shoot, protien content in seeds and oil content in seeds there was no significant variations among the taramira genotypes. However RTM-969 showed lower Na/K ratio in root and shoot at all three growth stages but higher protien content and oil content in seeds, which was statistically at par with other taramira genotypes.

6.2 EFFECT OF SALINITY

6.2.1 Under field studies, it was observed that salt stress significantly reduced seedling emergence percentage, root-shoot and seedling length, seedling vigour index, leaf area, leaf area index and plant height as comapred to non-stress condition.

6.2.2 Yield and yield attributing characters *viz.*, number of saliqua per plant, number of seeds per siliqua, test weight, grain yield and biological yield decreased significantly on account of salt stress. However, harvest index was found to be non-significantly decreased under salt stress condition.

6.2.3 Photosynthesitic and plant water relation parameters *viz.*, photosynthetic rate, transpiration rate, water use efficiency, relative water content, water potential and osmotic potential decreased significantly under saline condition as compared to normal condition at pre-flowering, flowering and maturity stages. Above parameters were also decreased with growth stages.

6.2.4 Na/K ratio in root and shoot at pre flowering, flowering and maturity stages significantly increased on account of salinity. Na/K ratio in root and shoot was found minimum at pre-flowering and maximum at maturity stage. With respect to salinity protein and oil content in seeds decreased significantly as compared to normal condition.

6.3 EFFECT OF CYCOCEL

6.3.1 Sowing of pre-soaked seeds with cycocel under field condition, mean seedling emergence percentage, root length seedling vigour index, leaf area and leaf area index significantly increase. Cycocel 100 ppm concentration showed higher beneficial effect in mitigating the adverse effect of salinity. Unlike, above germination and growth parameters shoot length, seedling length and plant height decreased significantly with increasing level of cycocel both under saline and non-saline conditions. Minimum shoot length, seedling length and plant height were found with cycocel 100 ppm concentration over untreated seeds.

6.3.2 Soaking of seeds with cycocel significantly increased the yield and yield attributing characters. Seed treatment with cycocel 100 ppm gave significantly higher number of siliqua per plant, number of seeds per

siliqua and test weight both under saline and normal conditions. Grain yield and biological yield increased significantly with cycocel 100 ppm concentrations as compared to control.

6.3.3 Photosynthetic rate and plant water relation parameters except transpiration rate increased significantly with increasing level of cycocel at pre-flowering, flowering and maturity stages both under saline and non-saline conditions. Whereas, transpiration rate decreased with increasing cycocel concentration. Cycocel 100 ppm concentration showed more pronounced effect on photosynthetic and water relation parameters against no treatment with cycocel both under saline and control conditions.

6.3.4 Seed soaking with cycocel decreased significantly Na/K ratio in root and shoot at all three growth stages. Cycocel 100 ppm concentration showed minimum Na/K ratio in root and shoot at pre-flowering stage followed by flowering and maturity stages against cycocel 50 ppm concentration and control. Protein content and oil content in seeds of taramira genotypes significantly increased with increasing level of cycocel both under saline and normal conditions. Cycocel 100 ppm concentration showed higher protein content and oil content as compared to control.

Based on this experiment, it could be concluded that genotype RTM-969 have higher seed production potential than rest of the genotypes both under saline and non-saline conditions. The adverse effect of salinity can be mitigate by soaking of seeds prior to sowing with cycocel 100 ppm concentration, which may give significantly higher yield of taramira genotypes. However, these results are only indicative and require further experimentation to arrive at more consistent and final conclusion.

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Table 4.1 : Effect of salinity, genotypes and cycocel concentrations (ppm) on seedling emergence (%), root length (cm) and shoot length (cm) under field conditions

TREATMENT	Seedling emergence	Root length at 21 DAS	Shoot length at 21 DAS
Salinity			
Normal	73.12	7.96	9.76
Saline	67.63	7.38	9.04
SEm±	1.19	0.14	0.16
CD (P=0.05)	3.42	0.40	0.45
GENOTYPE			
RTM-314	68.62	7.54	9.17

RTM-2002	69.73	7.60	9.31
RTM-969	72.78	7.88	9.72
SEm±	1.46	0.17	0.19
CD (P=0.05)	NS	NS	NS
Cycocel			
Control	63.45	5.51	11.73
C_{50}	69.01	7.71	9.35
C_{100}	78.67	9.80	7.11
SEm±	1.46	0.17	0.19
CD (P=0.05)	4.18	0.48	0.56

Table 4.2 : Effect of salinity, genotypes and cycocel concentrations (ppm) on seedling length (cm) and seedling vigour index

TREATMENT	Seedling length at 21 DAS	Seedling vigour index
Salinity		
Normal	17.72	13.04
Saline	16.42	11.15
SEm±	0.29	0.42
CD (P=0.05)	0.82	1.20

GENOTYPE		
RTM-314	16.71	11.54
RTM-2002	16.91	11.87
RTM-969	17.59	12.88
SEm+	0.35	0.51
CD (P=0.05)	NS	NS
Cycocel		
Control	17.24	11.02
C_{50}	17.06	11.89
C_{100}	16.91	13.38
SEm+	0.35	0.51
CD (P=0.05)	NS	1.46

Table 4.3 : Effect of salinity, genotypes and cycocel concentrations (ppm) on leaf area (cm^2), leaf area index and plant height (cm)

TREATMENT	Leaf area	Leaf area index	Plant height at harvest
Salinity			
Normal	315.59	1.05	79.63
Saline	292.41	0.97	64.71

SEm±	4.405	0.02	1.27
CD (P=0.05)	12.66	0.04	3.65
GENOTYPE			
RTM-314	297.22	0.98	70.29
RTM-2002	302.79	1.02	71.49
RTM-969	311.98	1.04	74.73
SEm±	5.395	0.02	1.55
CD (P=0.05)	NS	NS	NS
Cycocel			
Control	225.00	0.75	82.65
C_{50}	303.00	1.01	72.21
C_{100}	384.00	1.28	61.65
SEm±	5.395	0.02	1.55
CD (P=0.05)	15.50	0.05	4.47

Table 4.4 : Effect of salinity, genotypes and cycocel concentrations (ppm) on number of siliqua per plant, number of seeds per siliqua and test weight (gm)

TREATMENT	**No. of siliqua per plant**	**No. of seeds per siliqua**	**Test weight**
Salinity			

Normal	65.42	21.94	3.15
Saline	53.94	18.09	2.91
SEm±	1.16	0.34	0.04
CD (P=0.05)	3.33	0.97	0.11
GENOTYPE			
RTM-314	57.48	19.32	2.99
RTM-2002	58.57	19.75	3.01
RTM-969	62.98	20.97	3.11
SEm±	1.42	0.41	0.05
CD (P=0.05)	3.72	0.85	NS
Cycocel			
Control	54.65	18.75	2.88
C_{50}	59.26	19.96	3.02
C_{100}	65.12	21.33	3.20
SEm±	1.42	0.41	0.05
CD (P=0.05)	4.07	1.19	0.14

Table 4.5 : Effect of salinity, genotypes and cycocel concentrations (ppm) on biological yield (q ha^{-1}), grain yield (q ha^{-1}) and harvest index

TREATMENT	Biological yield	Grain yield	Harvest index
Salinity			
Normal	53.76	13.01	24.22
Saline	40.29	9.68	24.06
SEm±	0.82	0.21	0.33
CD (P=0.05)	2.35	0.60	NS
GENOTYPE			
RTM-314	45.06	10.82	24.04
RTM-2002	46.29	11.17	24.18
RTM-969	49.71	12.04	24.21
SEm±	1.00	0.25	0.41
CD (P=0.05)	2.88	0.73	NS
Cycocel			
Control	41.53	10.02	24.18
C_{50}	47.81	11.56	24.19
C_{100}	51.73	12.45	24.05
SEm±	1.00	0.25	0.41
CD (P=0.05)	2.88	0.73	NS

Table 4.6: Effect of salinity, genotypes and cycocel concentrations (ppm) on photosynthetic rate (µ mol CO_2 m^{-2} s^{-1}) at three growth stages

TREATMENT	Pre-flowering stage	Flowering stage	Maturity stage
Salinity			
Normal	47.40	37.02	26.09
Saline	42.81	33.31	23.56
SEm±	0.75	0.61	0.45
CD (P=0.05)	2.16	1.77	1.31
GENOTYPE			
RTM-314	44.18	34.63	24.23
RTM-2002	45.21	35.06	24.74
RTM-969	45.92	35.81	25.51
SEm±	0.92	0.75	0.56
CD (P=0.05)	NS	NS	NS
Cycocel			
Control	32.75	26.86	17.37
C_{50}	46.34	35.45	25.23
C_{100}	56.22	43.19	31.88
SEm±	0.92	0.75	0.56
CD (P=0.05)	2.64	2.16	1.60

Table 4.7: Effect of salinity, genotypes and cycocel concentrations (ppm) on transpiration rate (µ mol H_2O m^{-2} s^{-1}) at three growth stages

TREATMENT	Pre-flowering stage	Flowering stage	Maturity stage
Salinity			
Normal	2.86	2.50	1.97
Saline	2.69	2.34	1.83
SEm±	0.05	0.04	0.03
CD (P=0.05)	0.13	0.13	0.10
GENOTYPE			
RTM-314	2.83	2.48	1.96
RTM-2002	2.75	2.40	1.88
RTM-969	2.74	2.38	1.86
SEm±	0.06	0.05	0.04
CD (P=0.05)	NS	NS	NS
Cycocel			
Control	3.44	3.18	2.55
C_{50}	2.81	2.47	1.95
C_{100}	2.07	1.61	1.20
SEm±	0.06	0.05	0.04
CD (P=0.05)	0.16	0.15	0.11

Table 4.8: Effect of salinity, genotypes and cycocel concentrations (ppm) on water use efficiency at three growth stages

TREATMENT	Pre-flowering stage	Flowering stage	Maturity stage
Salinity			
Normal	16.57	14.81	13.24
Saline	15.91	14.24	12.87
SEm±	0.29	0.29	0.25
CD (P=0.05)	NS	NS	NS
GENOTYPE			
RTM-314	15.61	13.96	12.36
RTM-2002	16.44	14.61	13.16
RTM-969	16.75	15.05	13.72
SEm±	0.36	0.37	0.31
CD (P=0.05)	NS	NS	NS
Cycocel			
Control	9.52	8.45	6.81
C_{50}	16.49	14.35	12.94
C_{100}	27.16	26.83	26.57

SEm±	0.36	0.37	0.31
CD (P=0.05)	1.03	1.05	0.89

Table 4.9: Effect of salinity, genotypes and cycocel concentrations (ppm) on relative water content (%) at three growth stages

TREATMENT	Pre-flowering stage	Flowering stage	Maturity stage
Salinity			
Normal	75.67	66.70	53.11
Saline	70.27	61.69	49.46
SEm±	1.23	1.09	0.88
CD (P=0.05)	3.53	3.14	2.53
GENOTYPE			
RTM-314	71.50	62.70	50.07
RTM-2002	72.30	64.08	51.20
RTM-969	75.46	65.80	52.59
SEm±	1.51	1.34	1.08
CD (P=0.05)	NS	NS	NS
Cycocel			

Control	66.18	58.07	45.61
C_{50}	72.50	63.82	50.83
C_{100}	80.23	70.69	57.42
SEm±	1.50	1.34	1.08
CD (P=0.05)	4.33	3.85	3.09

Table 4.10 : Effect of salinity, genotypes and cycocel concentrations (ppm) on water potential (MPa) at three growth stages

TREATMENT	Pre-flowering stage	Flowering stage	Maturity stage
Salinity			
Normal	-0.69	-0.80	-0.94
Saline	-0.74	-0.87	-1.01
SEm±	0.01	0.02	0.02
CD (P=0.05)	0.03	0.04	0.05
GENOTYPE			
RTM-314	-0.73	-0.86	-1.01
RTM-2002	-0.71	-0.83	-0.96
RTM-969	-0.70	-0.82	-0.96
SEm±	0.02	0.02	0.02

CD (P=0.05)	NS	NS	NS
Cycocel			
Control	-0.81	-0.95	-1.11
C_{50}	-0.72	-0.84	-0.98
C_{100}	-0.62	-0.72	-0.84
SEm±	0.02	0.02	0.02
CD (P=0.05)	0.04	0.05	0.06

Table 4.11: Effect of salinity, genotypes and cycocel concentrations (ppm) on osmotic potential (MPa) at three growth stages

TREATMENT	Pre-flowering stage	Flowering stage	Maturity stage
Salinity			
Normal	-1.00	-1.07	-1.15
Saline	-1.24	-1.30	-1.39
SEm±	0.02	0.02	0.02
CD (P=0.05)	0.06	0.06	0.06
GENOTYPE			
RTM-314	-1.15	-1.23	-1.30
RTM-2002	-1.13	-1.18	-1.28

RTM-969	-1.09	-1.16	-1.24
SEm±	0.02	0.03	0.03
CD (P=0.05)	NS	NS	NS
Cycocel			
Control	-1.20	-1.28	-1.38
C_{50}	-1.12	-1.19	-1.28
C_{100}	-1.04	-1.09	-1.16
SEm±	0.02	0.03	0.03
CD (P=0.05)	0.07	0.08	0.08

Table 4.12: Effect of salinity, genotypes and cycocel concentrations (ppm) on sodium/ potassium ratio in root at three growth stages

TREATMENT	Pre-flowering stage	Flowering stage	Maturity stage
Salinity			
Normal	0.79	0.90	0.99
Saline	0.86	1.16	1.49
SEm±	0.01	0.01	0.02
CD (P=0.05)	0.03	0.04	0.05

GENOTYPE			
RTM-314	0.83	1.03	1.24
RTM-2002	0.84	1.04	1.25
RTM-969	0.82	1.01	1.22
SEm±	0.01	0.02	0.02
CD (P=0.05)	NS	NS	NS
Cycocel			
Control	0.90	1.18	1.43
C_{50}	0.83	1.03	1.24
C_{100}	0.75	0.87	1.04
SEm±	0.01	0.02	0.02
CD (P=0.05)	0.04	0.05	0.06

Table 4.13: Effect of salinity, genotypes and cycocel concentrations (ppm) on sodium/ potassium ratio in shoot at three growth stages

TREATMENT	Pre-flowering stage	Flowering stage	Maturity stage
Salinity			
Normal	0.53	0.57	0.59
Saline	0.58	0.68	0.76

SEm±	0.007	0.008	0.009
CD (P=0.05)	0.021	0.024	0.027
GENOTYPE			
RTM-314	0.55	0.62	0.67
RTM-2002	0.56	0.63	0.69
RTM-969	0.54	0.61	0.66
SEm±	0.009	0.010	0.011
CD (P=0.05)	NS	NS	NS
Cycocel			
Control	0.59	0.66	0.72
C_{50}	0.56	0.63	0.67
C_{100}	0.51	0.58	0.63
SEm±	0.009	0.010	0.011
CD (P=0.05)	0.026	0.029	0.033

Table 4.14 : Effect of salinity, genotypes and cycocel concentrations (ppm) on protein and oil content (%) in seeds

TREATMENT	Protein content	Oil content
Salinity		
Normal	16.06	31.38
Saline	13.02	29.02
SEm±	0.15	0.31
CD (P=0.05)	0.43	0.88
GENOTYPE		
RTM-314	14.29	29.76
RTM-2002	14.63	30.08
RTM-969	14.71	30.77
SEm±	0.18	0.37
CD (P=0.05)	NS	NS
Cycocel		
Control	12.56	26.24
C_{50}	14.52	30.15
C_{100}	16.54	34.21
SEm±	0.18	0.37
CD (P=0.05)	0.53	1.07