CHAPTER III

GROWTH AND PRODUCTIVITY UNDER SALINE CONDITIONS
1) INTRODUCTION

Growth of agricultural crops is studied under natural conditions since long time. Many factors are responsible for alterations in the growth of the plant which may be beneficial or may be hazardous to the plant, for instance, light, temperature, water, chemicals, etc. For centuries man has known that the deleterious effects of heat waves, droughts, mineral deficiency, disease, epidemics, climatic conditions and salinity in soil on crop plants and the development of environmental stress in nature is a natural event (Poljakoff-Mayber, 1982).

The physical and chemical nature of soil affects the plant growth. Various minerals and inorganic elements are essential for normal growth of the plant. Most of the soils of Indo-Gangetic belt are alkaline, while those of the other region are saline. (Yadav, 1980). Saline soils affect the absorption of minerals leading to abnormalities in plant metabolism which affects growth and yield. According to (Abroal et al., 1984) in India, about 7.5 million hectare of productive land has become salty due to heavy use of chemicals, fertilizers, over irrigation and poor drainage. In Maharashtra, about 3.4 lakh hectare of land is saline. The distribution and causes for the development of saline and alkaline soils in Maharashtra has been investigated by several investigators.

The ability of the plant to tolerate high concentrations of salt is salt tolerance. It is expressed with reference to salinity level which causes decline in the yield. Crop plants show greater spectrum of salt tolerance from very sensitive to fairly tolerant. Thus, salt tolerance varies from species to species and within different varieties of same species (Bernstien and Ayers, 1953; Pearson et al., 1966; Torres and Bingham, 1973; Shannon, 1978 and Rathert, 1982 (abc)). Therefore, in the present investigation
attempts have been made to study the effects of sodium chloride and sodium sulphate salts on growth and productivity of safflower Cv. Bhima.

2) MATERIALS AND METHODS

The plants of *Carthamus tinctorius* L. Var. Bhima were grown in cement pots in the research laboratory, Botany Department, University of Pune. An artificially salinized pot culture method was followed for salt stress studies experiment. (USDA handbook No. 60, 1954). The pure certified seeds of Var. Bhima were obtained from the College of Agriculture, Pune-7.

A. Experiment A: - Preparation and maintenance of salinity in pot culture.

a] Preparation of pots: - Forty two square cement pots of 25cm x 30cm were selected and filled with 5 Kg of homogeneously mixed air dried soil and well rotted compost in 3 : 1 proportion. The pots did not have any drainage hole. Three sets were prepared. Each set had fourteen pots.

b] Sowing of seeds:- In each pot, thirty seeds were sown at equal distance and depth. The pots were watered every day on the basis of water holding capacity of soil. After seven days of germination, uniform eight seedlings were maintained by removing others.

c] Salt treatment:- After fifteen days of germination, plants were treated with sodium chloride and sodium sulphate, except for the controls. At the same time, the control pots were irrigated with equal amount of tap water. The treatments were given to the plants according to the description given in the USDA Handbook No. 60 (1954).
i) Sodium chloride treatment: Three sets of pots were treated with sodium chloride and calcium chloride salt solution. The Electrical conductivity of soil in pot was raised from ECe 5.0, 7.5, 10.0, 12.5, 15.0 and 17.5 mScm⁻¹ (USDA Handbook No. 60) by adding required amount of salts.

ii) Sodium sulphate treatment: Three sets of pots were treated with sodium sulphate and calcium chloride salt solution. The Electrical conductivity of soil in pot was raised from ECe 5.0, 7.5, 10.0, 12.5, 15.0 and 17.5 mScm⁻¹ (USDA Handbook No. 60) by adding required amount of salts.

d) Salinity status: The electrical conductivity (of soil saturation extract) level was maintained constant by adjusting salt solutions in the soil from time to time. For this, soil samples from 20 cm depth of the pots were collected after seven days and air dried. Their soil saturation extracts were subjected to ECe tests expressed in terms of mScm⁻¹ at 25 °C (Wadleigh and Gauch, 1944).

All treatments were set in three multiples. 6 X 3 sets for NaCl treatment and 6 X 3 sets for Na₂SO₄ treatments were set with 1 X 3 sets of control pots. The concentrations of salts were calculated according to the water holding capacity of the soil. The Calcium Chloride salt was added to each pot during each treatment for the maintenance of constant pH (USDA Handbook No. 60, 1954). Each pot was treated with salt solution while control was irrigated with equal amounts of tap water. On the basis of water holding capacity of the soil, each pot was irrigated. Required ECe was maintained throughout the experiment by analysing ECe of each pot per week and by adding required amounts of respective salts. Eight plants were grown in each pot.
Growth in terms of height was studied at 30, 60 and 90 days of germination. Productivity per plant was studied at flowering stage as well as at post harvest.

B. Experiment B: Growth Observations

Following growth observations were recorded after 30, 60 and 90 days of germination.

a) Height: -

Height of the main shoot was measured from the soil surface to the base of the uppermost leaf or to the base of capitulum after 30, 60 and 90 days of germination.

b) Total leaf area: -

The total mean leaf area per plant for each salinity treatment and control was calculated after 30 and 90 days of germination by using graph papers (Sestak et al., 1971).

c) Dry matter at flowering: -

The productivity per plant was studied at flowering by following Sestak et al. (1971) method. Plants were uprooted, cleaned with tap water and then with distilled water. With the help of blotting paper, plants were made dry. Each plant organ was separated, its fresh weight was taken and kept for drying in Oven at 60°C till constant weight (Sestak et al., 1971).

d) Yield and Post harvest studies: -

At maturity watering to the crop was stopped and post harvest studies were done when plants were completely dried in the pots. The post harvest studies were done according to Sestak et al. (1971) method.
3) RESULTS

a) Height

The effect of increasing levels of NaCl and Na$_2$SO$_4$ on height, are recorded in the Tables 1, 2 and Figs 1a, 1b, 2a, 2b, after 30, 60 and 90 days of germination. The results indicated that low concentrations (ECe 5.0 to 10.0 mScm$^{-1}$) of NaCl stimulate, while high concentrations (ECe 15.0 to 17.5 mScm$^{-1}$) of it inhibit growth in height at 30 days of germination. However, after 60 days of growth, height was decreased linearly with increasing levels of NaCl, thereby indicating that all the levels of salinity inhibit growth in height of safflower. At 90 days of growth, height was less than the control at all levels of chloride salinization. Plants growing at ECe 12.5 to 17.5 mScm$^{-1}$ died during 60 to 90 days of growth. Thus, at 90 days of growth plants could survive up to ECe 10.0 mScm$^{-1}$ of NaCl while at all higher levels plants died indicating its more susceptibility to NaCl during flowering phase of the life cycle. At ECe 10.0 mScm$^{-1}$ plants died during 90 to 115 days of growth.

With increasing levels of sulphate salt, height increased linearly up to ECe 10.0 mScm$^{-1}$ of Na$_2$SO$_4$ at 30 days of germination. At ECe 10.0 mScm$^{-1}$, it was more than the control but was less than that of ECe 7.5 mScm$^{-1}$. At higher (ECe 12.5 to 17.5 mScm$^{-1}$) levels height was linearly decreased with increasing levels of sulphate salinizations.

At 60 days of growth, height was more than the control up to ECe 10.0 mScm$^{-1}$ while it was less than the control in plants growing at ECe 12.5 to 17.5 mScm$^{-1}$. At 90 days of growth, height was more than the control up to ECe 10.0 mScm$^{-1}$ and was less than the control at ECe 12.5 mScm$^{-1}$. During 60 to 90 days of growth, plants growing at ECe 15.0 to 17.5 mScm$^{-1}$ could not survive, while plants growing at ECe 12.5 mScm$^{-1}$ died.
Table 1. Effect of increasing concentration of NaCl salinity on height of *Carthamus tinctorius* L. Var. Bhima

<table>
<thead>
<tr>
<th>Treatment</th>
<th>ECe mScm⁻¹</th>
<th>Height after 30 days of germination in cm</th>
<th>Height after 60 days of germination in cm</th>
<th>Height after 90 days of germination in cm</th>
</tr>
</thead>
<tbody>
<tr>
<td>Control</td>
<td>0.44</td>
<td>11.480</td>
<td>23.373</td>
<td>54.197</td>
</tr>
<tr>
<td>NaCl</td>
<td>5.00</td>
<td>11.507</td>
<td>22.800</td>
<td>52.377</td>
</tr>
<tr>
<td>NaCl</td>
<td>7.50</td>
<td>13.063</td>
<td>21.463</td>
<td>50.513</td>
</tr>
<tr>
<td>NaCl</td>
<td>10.00</td>
<td>12.017</td>
<td>20.367</td>
<td>49.510</td>
</tr>
<tr>
<td>NaCl</td>
<td>12.50</td>
<td>11.471</td>
<td>19.910</td>
<td>23.41</td>
</tr>
<tr>
<td>NaCl</td>
<td>15.00</td>
<td>11.287</td>
<td>17.833</td>
<td>-</td>
</tr>
<tr>
<td>NaCl</td>
<td>17.50</td>
<td>11.117</td>
<td>17.717</td>
<td>-</td>
</tr>
</tbody>
</table>

SEM 7.47  13.31  36.54
LSD 23.02  41.02  112.61
SD+ ± 0.639  ± 2.019  ± 1.929

LSD at 5% level of significance
- Plants died during 60 to 90 days of growth

Table 2. Effect of increasing concentration of Na₂SO₄ salinity on height of *Carthamus tinctorius* L. Var. Bhima

<table>
<thead>
<tr>
<th>Treatment</th>
<th>ECe mScm⁻¹</th>
<th>Height after 30 days of germination in cm</th>
<th>Height after 60 days of germination in cm</th>
<th>Height after 90 days of germination in cm</th>
</tr>
</thead>
<tbody>
<tr>
<td>Control</td>
<td>0.44</td>
<td>11.480</td>
<td>23.373</td>
<td>54.197</td>
</tr>
<tr>
<td>Na₂SO₄</td>
<td>5.00</td>
<td>14.503</td>
<td>25.290</td>
<td>56.163</td>
</tr>
<tr>
<td>Na₂SO₄</td>
<td>7.50</td>
<td>16.727</td>
<td>24.833</td>
<td>55.150</td>
</tr>
<tr>
<td>Na₂SO₄</td>
<td>10.00</td>
<td>14.283</td>
<td>23.733</td>
<td>54.420</td>
</tr>
<tr>
<td>Na₂SO₄</td>
<td>12.50</td>
<td>11.470</td>
<td>19.967</td>
<td>31.810</td>
</tr>
<tr>
<td>Na₂SO₄</td>
<td>15.00</td>
<td>10.260</td>
<td>14.940</td>
<td>18.31</td>
</tr>
<tr>
<td>Na₂SO₄</td>
<td>17.50</td>
<td>9.837</td>
<td>12.517</td>
<td>-</td>
</tr>
</tbody>
</table>

SEM 8.42  14.00  35.51
LSD 25.97  43.16  109.45
SD+ ± 2.40  ± 3.68  ± 9.422

LSD at 5% level of significance
- Plants died during 60 to 90 days of growth
**Fig. 1a.**

Effect of NaCl on height after 30 and 60 days of germination

![Graph showing effect of NaCl on height after 30 and 60 days of germination.](image)

**Fig. 1b.**

Effect of NaCl on height after 90 days of germination

![Graph showing effect of NaCl on height after 90 days of germination.](image)
Fig. 2a.

Effect of Na$_2$SO$_4$ on height after 30 and 60 days of germination

Fig. 2b.

Effect of Na$_2$SO$_4$ on height after 90 days of germination
after 90 days of growth. Thus, low levels of sulphate stimulate while high levels of it inhibit growth in height in *Carthamus tinctorius* Cv. Bhima.

b) Leaf area

Effect of increasing concentrations of NaCl and Na$_2$SO$_4$ salinity's on leaf area per plant are depicted in Tables 3,4 and Fig. 3,4.

The leaf area of *Carthamus tinctorius* Cv. Bhima was calculated after 30 and 90 days of growth. From the results, it is clear that at 30 days of growth the total leaf area per plant was increased upto ECe 12.5 mScm$^{-1}$ of NaCl over the control. However, at high (ECe 15.0 and 17.5 mScm$^{-1}$) levels of NaCl, it was less than the control. Thus, it was observed that low concentrations of NaCl stimulate formation of leaf area while high concentrations of it inhibit the same in safflower Cv. Bhima. At 90 days of growth leaf area was more than the control upto ECe 7.5 mScm$^{-1}$ of NaCl, while it was less than the control at ECe 10 mScm$^{-1}$.

Under sodium sulphate salinity, at 30 days of growth, leaf area was less than the control which reflects that all levels of Na$_2$SO$_4$ inhibit formation of leaf area in safflower Cv. Bhima. At 90 days of growth, leaf area was also less than the control at all levels of Na$_2$SO$_4$ salinity. Thus, all levels of Na$_2$SO$_4$ inhibit leaf area growth.

c) Productivity at flowering (dry matter)

Effect of increasing levels of NaCl and Na$_2$SO$_4$ salinity's on root, stem and leaves per plant and average total (R+S+L) dry weight per plant is recorded in Tables 5,6. Fig. 5,6.
### Table 3.
Effect of increasing concentrations of NaCl on leaf area of *Carthamus tinctorius* L. Cv. Bhima

<table>
<thead>
<tr>
<th>Treatment</th>
<th>ECe mS cm⁻¹</th>
<th>Leaf area cm² / plant After 30 days of germination</th>
<th>% of control</th>
<th>Leaf area cm² / plant After 90 days of germination</th>
<th>% of control</th>
</tr>
</thead>
<tbody>
<tr>
<td>Control</td>
<td>0.44</td>
<td>273.3</td>
<td>100.00</td>
<td>245.2</td>
<td>100.00</td>
</tr>
<tr>
<td>NaCl 5.0</td>
<td></td>
<td>360.2</td>
<td>131.80</td>
<td>302.2</td>
<td>123.25</td>
</tr>
<tr>
<td>NaCl 7.5</td>
<td></td>
<td>325.8</td>
<td>119.21</td>
<td>269.8</td>
<td>110.03</td>
</tr>
<tr>
<td>NaCl 10.0</td>
<td></td>
<td>368.2</td>
<td>134.72</td>
<td>169.3</td>
<td>69.00</td>
</tr>
<tr>
<td>NaCl 12.5</td>
<td></td>
<td>294.6</td>
<td>107.79</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>NaCl 15.0</td>
<td></td>
<td>265.8</td>
<td>97.26</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>NaCl 17.5</td>
<td></td>
<td>120.5</td>
<td>44.09</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>SEM</td>
<td></td>
<td>200.59</td>
<td></td>
<td>111.61</td>
<td></td>
</tr>
<tr>
<td>LSD</td>
<td></td>
<td>618.15</td>
<td></td>
<td>343.94</td>
<td></td>
</tr>
<tr>
<td>SD±</td>
<td></td>
<td>± 41.08</td>
<td></td>
<td>± 24.75</td>
<td></td>
</tr>
</tbody>
</table>

LSD at 5% level of significance
- Plants died during 60 to 90 days of growth

### Table 4.
Effect of increasing concentrations of Na₂SO₄ on leaf area of *Carthamus tinctorius* L. Cv. Bhima

<table>
<thead>
<tr>
<th>Treatment</th>
<th>ECe mS cm⁻¹</th>
<th>Leaf area cm² / plant After 30 days of germination</th>
<th>% of control</th>
<th>Leaf area cm² / plant After 90 days of germination</th>
<th>% of control</th>
</tr>
</thead>
<tbody>
<tr>
<td>Control</td>
<td>0.44</td>
<td>273.3</td>
<td>100.00</td>
<td>245.2</td>
<td>100.00</td>
</tr>
<tr>
<td>Na₂SO₄ 5.0</td>
<td></td>
<td>225.0</td>
<td>82.3</td>
<td>244.8</td>
<td>99.83</td>
</tr>
<tr>
<td>Na₂SO₄ 7.5</td>
<td></td>
<td>242.2</td>
<td>88.6</td>
<td>235.1</td>
<td>95.88</td>
</tr>
<tr>
<td>Na₂SO₄ 10.0</td>
<td></td>
<td>228.1</td>
<td>83.5</td>
<td>220.8</td>
<td>89.72</td>
</tr>
<tr>
<td>Na₂SO₄ 12.5</td>
<td></td>
<td>234.2</td>
<td>85.7</td>
<td>180.8</td>
<td>73.73</td>
</tr>
<tr>
<td>Na₂SO₄ 15.0</td>
<td></td>
<td>187.0</td>
<td>68.4</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Na₂SO₄ 17.5</td>
<td></td>
<td>124.8</td>
<td>45.7</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>SEM</td>
<td></td>
<td>147.38</td>
<td></td>
<td>114.80</td>
<td></td>
</tr>
<tr>
<td>LSD</td>
<td></td>
<td>454.16</td>
<td></td>
<td>353.78</td>
<td></td>
</tr>
<tr>
<td>SD±</td>
<td></td>
<td>± 26.24</td>
<td></td>
<td>± 10.35</td>
<td></td>
</tr>
</tbody>
</table>

LSD at 5% level of significance
- Plants died during 60 to 90 days of growth
Fig. 3.

Effect of increasing concentrations of NaCl on leaf area after 30 and 90 days of germination

Fig. 4.

Effect of increasing concentrations of Na₂SO₄ on leaf area after 30 and 90 days of germination
### Table 5.

Effect of NaCl salinity on productivity of root, stem, leaf, total plant, days of flowering and maturity in *Carthamus tinctorius* L. Var. Bhima at flowering

<table>
<thead>
<tr>
<th>Treatment</th>
<th>ECe mScm⁻¹</th>
<th>Total root (R) weight/plant (g)</th>
<th>Total stem (S) weight/plant (g)</th>
<th>Total leaf (L) weight/plant (g)</th>
<th>Total plant (g) (R + S + L)</th>
<th>Total as % of the Control</th>
<th>Days for flowering</th>
<th>Days for maturity</th>
</tr>
</thead>
<tbody>
<tr>
<td>Control</td>
<td>0.44</td>
<td>0.20</td>
<td>0.52</td>
<td>0.58</td>
<td>1.30</td>
<td>100.00</td>
<td>88</td>
<td>111</td>
</tr>
<tr>
<td>NaCl 5.0</td>
<td>0.16</td>
<td>0.48</td>
<td>0.61</td>
<td>1.25</td>
<td>96.15</td>
<td>81</td>
<td>109</td>
<td></td>
</tr>
<tr>
<td>NaCl 7.5</td>
<td>0.14</td>
<td>0.42</td>
<td>0.50</td>
<td>1.06</td>
<td>81.53</td>
<td>85</td>
<td>110</td>
<td></td>
</tr>
<tr>
<td>NaCl 10.0</td>
<td>0.13</td>
<td>0.29</td>
<td>0.24</td>
<td>0.66</td>
<td>50.76</td>
<td>83</td>
<td>107</td>
<td></td>
</tr>
<tr>
<td>NaCl 12.5</td>
<td>0.04</td>
<td>0.12</td>
<td>0.10</td>
<td>0.26</td>
<td>20.00</td>
<td>77</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>NaCl 15.0</td>
<td>*</td>
<td>0.01</td>
<td>0.08</td>
<td>0.07</td>
<td>12.30</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
</tbody>
</table>

**SEM** 0.009 0.008 0.006
**LSD** 0.029 0.027 0.020
**SD** ± 0.06 ± 0.17 ± 0.22

*LSD at 5% level of significance

*Plants died during 60 to 90 days of growth.

**Plants died within 15 days after flowering.

### Table 6.

Effect of Na₂SO₄ salinity on productivity of root, stem, leaf, total plant, days of flowering and maturity in *Carthamus tinctorius* L. Var. Bhima at flowering

<table>
<thead>
<tr>
<th>Treatment</th>
<th>ECe mScm⁻¹</th>
<th>Total root (R) weight/plant (g)</th>
<th>Total stem (S) weight/plant (g)</th>
<th>Total leaf (L) weight/plant (g)</th>
<th>Total plant mean in (g) (R + S + L)</th>
<th>Total as % of the Control</th>
<th>Days for flowering</th>
<th>Days for maturity</th>
</tr>
</thead>
<tbody>
<tr>
<td>Control</td>
<td>0.44</td>
<td>0.20</td>
<td>0.52</td>
<td>0.58</td>
<td>1.30</td>
<td>100.00</td>
<td>88</td>
<td>111</td>
</tr>
<tr>
<td>Na₂SO₄ 5.0</td>
<td>0.26</td>
<td>0.72</td>
<td>0.71</td>
<td>1.69</td>
<td>130.00</td>
<td>92</td>
<td>114</td>
<td></td>
</tr>
<tr>
<td>Na₂SO₄ 7.5</td>
<td>0.32</td>
<td>0.75</td>
<td>0.80</td>
<td>1.87</td>
<td>143.84</td>
<td>95</td>
<td>117</td>
<td></td>
</tr>
<tr>
<td>Na₂SO₄ 10.0</td>
<td>0.16</td>
<td>0.53</td>
<td>0.47</td>
<td>1.16</td>
<td>89.23</td>
<td>91</td>
<td>112</td>
<td></td>
</tr>
<tr>
<td>Na₂SO₄ 12.5</td>
<td>0.10</td>
<td>0.22</td>
<td>0.17</td>
<td>0.49</td>
<td>37.69</td>
<td>83</td>
<td>106</td>
<td></td>
</tr>
<tr>
<td>Na₂SO₄ 15.0</td>
<td>*</td>
<td>0.01</td>
<td>0.10</td>
<td>0.08</td>
<td>14.81</td>
<td><strong>75</strong></td>
<td>-</td>
<td>-</td>
</tr>
</tbody>
</table>

**SEM** 0.008 0.006 0.008
**LSD** 0.025 0.021 0.025
**SD** ± 0.10 ± 0.24 ± 0.27

*LSD at 5% level of significance

*Plants died during 60 to 90 days of growth.

**Plants died within 15 days after flowering.
Fig. 5.

Effect of NaCl on productivity of root, stem and leaf

Fig. 6.

Effect of Na2SO4 on productivity of root, stem and leaf
i) Root
From the observations (Tables. 5,6), it is clear that there is decrease in root weight with increasing sodium chloride salinity. However, under sulphate salinity, root weight increased at ECe 5.0 mScm$^{-1}$ and ECe 7.5 mScm$^{-1}$ and decreased at all higher levels. Thus, all levels of chloride inhibit, while low levels of sulphate stimulate and high levels of it inhibit root growth indicating different effect of sulphate and chloride salinity on root growth.

ii) Stem
Reduction in stem weight per plant (Tables.5,6) was observed with increasing concentrations of sodium chloride. On the contrary, under sulphate salinity, the stem weight increased in plants grown up to ECe 10.0 mScm$^{-1}$ and reduced at all higher concentrations of sulphate salinity which reflects that low levels of sulphate stimulate and high levels of it inhibit stem growth.

iii) Leaves
Average leaf weight per plant (Tables.5,6) increased over the control in plants growing at low (ECe 5.0 mScm$^{-1}$) NaCl salinity. However, at high (ECe 7.5 to 15.0 mScm$^{-1}$) levels leaf weight decreased with increasing salinity levels. Under sulphate salinization, leaf weight increased at low (ECe 5.0 and 7.5 mScm$^{-1}$) but decreased at all higher levels. Thus, low levels of both the salts stimulated, while high concentrations of them inhibited growth of leaves in *Carthamus tinctorius* Cv. Bhima.

iv) Total (R+S+L) DM per plant at flowering
It was less than the control at all levels of chloride (Tables. 5,6), whereas, it was increased in plants growing up to ECe 7.5 mScm$^{-1}$ of sulphate and was less than the control at all higher levels. Thus, all high levels of chloride were detrimental to safflower.
while low levels of sulphate stimulate growth and high levels of it inhibit growth in safflower Cv. Bhima. The dry matter per plant was very less at ECe 10.0 to 15.0 mScm$^{-1}$ of NaCl and at ECe 12.5 and 15.0 mScm$^{-1}$ of Na$_2$SO$_4$ because plants growing at ECe 12.5 to 17.5 mScm$^{-1}$ of NaCl died during 60 to 90 days of growth and plants growing at ECe 12.5 to 17.5 mScm$^{-1}$ of sulphate also died during 60 to 90 days of growth.

v) Moisture percentage at flowering
The results of moisture percentage at flowering stage are indicated in Tables 7, 8. Under NaCl salinity in roots, the moisture percentage decreased with increasing salinity. Under sulphate salinity, the moisture percentage increased up to ECe 7.5 mScm$^{-1}$ and decreased further with increasing salinity. In stem, it decreased with increasing NaCl and Na$_2$SO$_4$ salinity. In leaf, the moisture percentage decreased under NaCl salinity but under Na$_2$SO$_4$ salinity moisture percentage increased up to ECe 10.0 mScm$^{-1}$ and decreased further at high salinity levels. However, moisture content of total plant decreased under both the salinity’s.

d) Post harvest studies
Effect of increasing concentrations of NaCl and Na$_2$SO$_4$ on root, stem, leaf, husk and grain weight per plant are given in Tables 9, 10.

The root and stem weight linearly decreased with increasing concentrations of NaCl up to ECe 10.0 mScm$^{-1}$. The leaf and grain weight was slightly more than the control at ECe 5.0 mScm$^{-1}$ of NaCl. The husk weight was less than the control at all levels of NaCl salinity. The average total of plant weight increased at ECe 5.0 mScm$^{-1}$ and decreased linearly with increase in chloride salinizations at higher levels.
Table 7.
Effect of increasing concentrations of NaCl on moisture percentage in root, stem, leaf and total plant in *Carthamus tinctorius* L. Cv. Bhima

<table>
<thead>
<tr>
<th>Treatment ECe mS/cm⁻¹</th>
<th>Root</th>
<th>Stem</th>
<th>Leaf</th>
<th>Total Plant (R + S + L)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Control 0.44</td>
<td>90.47</td>
<td>88.69</td>
<td>94.82</td>
<td>91.32</td>
</tr>
<tr>
<td>NaCl 5.0</td>
<td>88.00</td>
<td>88.70</td>
<td>94.10</td>
<td>90.26</td>
</tr>
<tr>
<td>NaCl 7.5</td>
<td>87.70</td>
<td>85.50</td>
<td>93.10</td>
<td>88.76</td>
</tr>
<tr>
<td>NaCl 10.0</td>
<td>83.69</td>
<td>84.26</td>
<td>90.20</td>
<td>86.03</td>
</tr>
<tr>
<td>NaCl 12.5</td>
<td>78.00</td>
<td>81.30</td>
<td>88.10</td>
<td>82.46</td>
</tr>
<tr>
<td>NaCl 15.0</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
</tbody>
</table>

- Plants died during 60 - 90 days of growth  
  R - root  S - stem  L - leaf

Table 8.
Effect of increasing concentrations of Na₂SO₄ on moisture percentage in root, stem, leaf and total plant in *Carthamus tinctorius* L. Cv. Bhima

<table>
<thead>
<tr>
<th>Treatment ECe mS/cm⁻¹</th>
<th>Root</th>
<th>Stem</th>
<th>Leaf</th>
<th>Total Plant (R + S + L)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Control 0.44</td>
<td>90.47</td>
<td>88.69</td>
<td>94.82</td>
<td>91.32</td>
</tr>
<tr>
<td>Na₂SO₄ 5.0</td>
<td>91.20</td>
<td>87.00</td>
<td>94.90</td>
<td>91.03</td>
</tr>
<tr>
<td>Na₂SO₄ 7.5</td>
<td>91.40</td>
<td>85.60</td>
<td>94.86</td>
<td>90.62</td>
</tr>
<tr>
<td>Na₂SO₄ 10.0</td>
<td>90.10</td>
<td>85.20</td>
<td>94.63</td>
<td>90.03</td>
</tr>
<tr>
<td>Na₂SO₄ 12.5</td>
<td>88.00</td>
<td>84.19</td>
<td>91.71</td>
<td>87.63</td>
</tr>
<tr>
<td>Na₂SO₄ 15.0</td>
<td>85.00</td>
<td>82.66</td>
<td>89.26</td>
<td>84.61</td>
</tr>
</tbody>
</table>

R - root  S - stem  L - leaf
PLATE 1 Photograph showing effect of increasing concentrations of NaCl salinity in *Carthamus tinctorius* L. Cv. Bhima, on growth.

PLATE 2 Photograph showing effect of increasing concentrations of Na$_2$SO$_4$ salinity in *Carthamus tinctorius* L. Cv. Bhima, on growth.
Table 9.
Effect of increasing concentrations of NaCl on root, stem, leaf, husk and grain weight at maturity in Carthamus tinctorius L. Cv. Bhima

<table>
<thead>
<tr>
<th>Treatment</th>
<th>ECE mScm⁻¹</th>
<th>Root</th>
<th>Stem</th>
<th>Leaf</th>
<th>Husk</th>
<th>Grain wt</th>
<th>% of control</th>
<th>Total plant (R+S+L+H+ G)</th>
<th>% of control</th>
</tr>
</thead>
<tbody>
<tr>
<td>Control</td>
<td>0.44</td>
<td>0.25</td>
<td>0.58</td>
<td>0.60</td>
<td>0.7</td>
<td>1.1</td>
<td>100.0</td>
<td>0.646</td>
<td>100.0</td>
</tr>
<tr>
<td>NaCl 5.0</td>
<td></td>
<td>0.20</td>
<td>0.52</td>
<td>0.63</td>
<td>0.6</td>
<td>1.4</td>
<td>127.3</td>
<td>0.670</td>
<td>103.7</td>
</tr>
<tr>
<td>NaCl 7.5</td>
<td></td>
<td>0.16</td>
<td>0.51</td>
<td>0.52</td>
<td>0.6</td>
<td>0.7</td>
<td>63.6</td>
<td>0.498</td>
<td>77.1</td>
</tr>
<tr>
<td>NaCl 10.0</td>
<td>*</td>
<td>0.14</td>
<td>0.38</td>
<td>0.26</td>
<td>0.6</td>
<td>0.5</td>
<td>45.5</td>
<td>0.376</td>
<td>58.2</td>
</tr>
<tr>
<td>NaCl 12.5</td>
<td></td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>NaCl 15.0</td>
<td></td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>SEM</td>
<td></td>
<td>0.135</td>
<td>0.355</td>
<td>0.37</td>
<td>0.44</td>
<td>-</td>
<td>0.700</td>
<td></td>
<td></td>
</tr>
<tr>
<td>LSD</td>
<td></td>
<td>0.418</td>
<td>1.09</td>
<td>1.14</td>
<td>1.36</td>
<td>-</td>
<td>2.15</td>
<td></td>
<td></td>
</tr>
<tr>
<td>SD+</td>
<td></td>
<td>±0.04</td>
<td>±0.07</td>
<td>±0.152</td>
<td>±0.06</td>
<td>±0.36</td>
<td>-</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

LSD at 5% level of significance
*Plants died after 90 days of growth and seeds were not viable.
-Values are given in g / plant (dry wt.)

Table 10.
Effect of increasing concentrations of Na₂SO₄ on root, stem, leaf, husk and grain weight at maturity in Carthamus tinctorius Cv. Bhima

<table>
<thead>
<tr>
<th>Treatment</th>
<th>ECE mScm⁻¹</th>
<th>Root</th>
<th>Stem</th>
<th>Leaf</th>
<th>Husk</th>
<th>Grain wt</th>
<th>% of control</th>
<th>Total plant (R+S+L+H+ G)</th>
<th>% of control</th>
</tr>
</thead>
<tbody>
<tr>
<td>Control</td>
<td>0.25</td>
<td>0.58</td>
<td>0.60</td>
<td>0.7</td>
<td>1.10</td>
<td>1.10</td>
<td>100.0</td>
<td>0.646</td>
<td>100.0</td>
</tr>
<tr>
<td>Na₂SO₄ 5.0</td>
<td></td>
<td>0.28</td>
<td>0.75</td>
<td>0.73</td>
<td>5.2</td>
<td>1.35</td>
<td>122.7</td>
<td>1.602</td>
<td>257.3</td>
</tr>
<tr>
<td>Na₂SO₄ 7.5</td>
<td></td>
<td>0.36</td>
<td>0.78</td>
<td>0.82</td>
<td>5.2</td>
<td>1.56</td>
<td>141.8</td>
<td>1.744</td>
<td>270.0</td>
</tr>
<tr>
<td>Na₂SO₄ 10.0</td>
<td></td>
<td>0.30</td>
<td>0.76</td>
<td>0.61</td>
<td>3.6</td>
<td>1.10</td>
<td>91.8</td>
<td>1.256</td>
<td>194.4</td>
</tr>
<tr>
<td>Na₂SO₄ 12.5</td>
<td>*</td>
<td>0.13</td>
<td>0.28</td>
<td>0.19</td>
<td>0.6</td>
<td>0.40</td>
<td>36.4</td>
<td>0.320</td>
<td>49.5</td>
</tr>
<tr>
<td>Na₂SO₄ 15.0</td>
<td></td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>SEM</td>
<td></td>
<td>0.200</td>
<td>0.46</td>
<td>0.44</td>
<td>2.60</td>
<td>-</td>
<td>0.815</td>
<td></td>
<td></td>
</tr>
<tr>
<td>LSD</td>
<td></td>
<td>0.417</td>
<td>1.43</td>
<td>1.36</td>
<td>0.03</td>
<td>-</td>
<td>2.510.</td>
<td></td>
<td></td>
</tr>
<tr>
<td>SD+</td>
<td></td>
<td>±0.07</td>
<td>±0.19</td>
<td>±0.22</td>
<td>±0.12</td>
<td>±0.4</td>
<td>-</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

LSD at 5% level of significance
*Plants died after 90 days of growth and seeds were not viable.
-Values are given in g / plant (dry wt.)
Under sulphate salinity, the root, stem, leaf and husk weight increased up to ECe 10.0 mScm$^{-1}$ and decreased at ECe 12.5 mScm$^{-1}$. The grain weight was more than the control up to ECe 7.5 mScm$^{-1}$ and decreased at ECe 10.0 and 12.5 mScm$^{-1}$. The average total of the plant was increased up to ECe 10.0 mScm$^{-1}$ and decreased at ECe 12.5 mScm$^{-1}$ of Na$_2$SO$_4$. This fact suggested that plants growing up to ECe 7.5 mScm$^{-1}$ of NaCl and up to ECe 10.0 mScm$^{-1}$ of Na$_2$SO$_4$ become more resistant to both salts after flowering.

4) DISCUSSION

a) Height

Salt stress may reduce plant growth by causing water deficits, ion toxicity, ion imbalance or a combination of any of these adverse factors when plants are exposed to salinity. In glycic plants, reduction in growth occurred due to salinity (Hayward, 1955; Bernstein and Hayward, 1958 and Eaton et al., 1971). The vegetative growth is reduced, with the increase in osmotic potential of the substrate which is proportional to the amount of salt present in the substrate (Bernstein, 1964). The soil containing 0.1% of NaCl showed 50% reduction in growth of tomatoes (Stroganov, 1964). Decrease in height with increasing salinity has been reported in many other crops and plants by several workers like Kaddah et al. (1973) and El-Shouny (1976) in rice; Longnecker (1973); Abdel-Wahab and Al-Juboory (1975) and Malofeev et al. (1979) in cotton; Bhardwaj (1960); Joshi (1976) and Soliman et al. (1978) in wheat and barley; Ansari (1972) in Brassica and Joolka and Singh (1979) in citrus.

Salim and Pitman (1983) reported reduction in growth in Vigna radiata which was due to high Na, and Cl contents in shoots. Gomes et al. (1983) reported delay in seedling
growth in *Vigna unguiculata*. Decrease in growth with increasing levels of salinity upto 350 mmol$^1$ was noted in *Spinacia oleracea* by Kaiser *et al.* (1983). Kawasaki and Moritsugu (1983) had reported inhibitory effect of high concentrations of NaCl and PEG on growth of *Phaseolus vulgaris*, *Zea mays* and *Sorghum vulgare*. In *Pisum sativum*, shoot growth was inhibited at 192 mM NaCl (Hasson and Mayber, 1983).

Growth was reduced by 22% under salt stress in *Trifolium alexandrinum* (Winter, 1984). Abdel-Rahman and Abdel-Hadi (1984) reported consistent reduction in growth in cowpea under saline conditions. Bhatti *et al.* (1983) investigated that upto 150 mM NaCl and KCl in soil had little effect on growth, however, CaCl$_2$ depressed growth strongly in kaller grass. In *Avicennia marina*, decline in growth was due to high concentrations of Na and / or Cl but in *Rhizophora stylosa* growth was poor at high salinity due to water stress (Clough 1984). Sharma *et al.* (1984) reported growth inhibition by NaCl in wheat seedlings, whereas, Poly Ethylene Glycol (PEG) was detrimental to resistant Var. (Karchia - 65). Kent and Lauchli (1985) reported reduction in root growth in 7 - 9 days old seedlings of *Gossypium hirsutum*. Termatt *et al.* (1985) tested the hypothesis of reduced rates by ~20 % in roots of *Triticum aestivum* and *Hordeum vulgare* at 100 mM NaCl, which was due to inadequate turgor in expanding cell of leaves. Robinson *et al.* (1985) reported growth reduction in *Suaeda australis* seedlings at high salinities at 50 to 150 mM NaCl. Decrease in growth in *Cajanus indicus* and *Sesamum indicum* was reported under NaCl salinity by Rao (1985). Sharma and Garg (1985) observed reduction in growth in terms of parameters such as fresh and dry weight, plant height, leaf number and leaf area in wheat under saline conditions. Ashraf and Bradshaw (1986) observed reduction and variation in capacity of salt tolerance in seedlings of *Agrostis stolonifera* L., *A Capillaris* L, *Holeum lanatus*, *Lolium perenne* L., *Dactylis glomerata* L, *Festura rubra* L and *puccinellia distans* L.
According to Cramer et al. (1986), root growth of seedlings of Gossypium hirsutum was inhibited at high NaCl concentrations when supplemented with Ca.


Blits and Gallagher (1990) reported that when Kosteletzya virginia (L) Prest. was grown in nutrient solutions of 0, 85, 170 and 255 mol m$^{-3}$ NaCl, growth was reduced at 170 and 255 mol m$^{-3}$ NaCl progressively. Decrease in relative growth rates was observed at and above 300 mol m$^{-3}$ NaCl that is when plants were subjected to 0-420 molm$^{-3}$ NaCl. However, salinity range 0-200 molm$^{-3}$ NaCl did not affect growth rate in Diplachne fusca L. P.Beav.ex Roemer and Schultes (Myers et al., 1990).

Hatzmann (1991) found suppression in growth by salt treatment at different (50 and 100 mM) concentrations in Opuntia ficus indica (L) Miller. Brugnoli and Lauteri (1991) reported that plant growth was strongly reduced by salinity in cotton and bean plants at different concentrations from 10 day and until mature reproductive structures were formed. Reduction in relative growth rate with increasing salinity levels in growth medium was observed in Phaseolus vulgaris (Abbas et al., 1991). Haddad and Coudret (1991) observed that growth was strongly affected by increased (upto 150 mM) NaCl.
concentrations after 21 days of growth in culture medium which was due to water deficit linked to a drop in water(Ψ) and osmotic (Γ) potentials in *Triticum* cultivars Clercal and Beagle. Growth was however increased by more than 30 % when medium was supplied with KCl or CaCl₂ which suggests that KCl or CaCl₂ decrease toxicity of NaCl. Kalaji and Nalborczyk (1991) reported decrease in growth rate in 8 barley cultivars under salinity stress and on the basis of their tolerance they have classified cultivars into 3 groups that is tolerant (Aksad 60, Rihane, Furat 1); medium (Ars, sth,215, cerice) and sensitive (Arabian black, Beecher). Shitole and Shinde (1991) observed decrease in height with increasing levels of chloride and sulphate salinity in *Carica papaya* Cv. Ranchi.

Grattan and Grieve (1992) found reduction in growth under saline conditions due to low nutrient ion activities and extreme ratios of Na/Ca, Na/K, Ca/Mg and Cl/NO₃, resulting in nutritional disorders. Considerable decrease in growth of the seedlings of *Brassica juncea* at varying concentrations of NaCl (0, 100, 150 and 200 mM) took place (Mohanty and Saradhi, 1992). Ashraf and Naqvi (1992) reported that low amounts of Ca cause growth inhibition in salt affected soils in four *Brassica* species thereby indicating need of sufficient amount of Ca for salt tolerance in *Brassica*.

Blits and Gallagher (1993) reported that growth in cell cultures of *Kosteletzkya virginia* L. was inhibited at high 225 molm⁻³ due to increase in Na content. Tipirdamaz and Karakulluku (1993) observed that 150 mM salt concentration along with 10 mM proline or glycine betaine decreased growth in *in vitro* cultured tomato embryo which indicated that proline or glycine betaine when provided externally could not help in increasing salt tolerance. Growth was inhibited in broad bean and *Triticum vulgaris* plants by NaCl salinity (El-Samad and Abd, 1993). He and Cramer (1993) reported that relative growth
rate in *Brassica napus* and *B. carinata* was reduced due to salinization. Marcar (1993) observed reduction in seedling growth when *Eucalyptus* species were treated with 150 or 100 mol m\(^{-3}\) NaCl with or without waterlogging. At 100 NaCl mol m\(^{-3}\) pretreatment with waterlogging improved growth. *E. camaldulensis* showed least growth reduction with addition of S, W and S X W treatment. Storey et al. (1993) studied in laboratory and reported that, root growth of *Melanthera biflora* (Asteraceae) was inhibited by salt above 50 mol m\(^{-3}\) but survived up to 400 mol m\(^{-3}\) salinity level.

Zakharin (1994) demonstrated that plant growth could be delayed or stopped by high (100 to 200 mM) NaCl concentrations as well as low (10 to 20 mM) NaCl concentrations resulting in substantial organ shortening. Elimination of salt stress led to elongation and original growth due to osmotic pressure. Ortiz (1994) reported retardation of growth and then restored growth to reach steady state growth rate in *Phaseolus vulgaris* plants under saline conditions. Also leaf growth was interrupted due to water storage in roots. Meinzer et al. (1994) observed decline in shoot growth rate as concentration of NaCl (EC 2.0, 4.0, 8.0, 12.0 dSm\(^{-1}\)) of irrigation solution increased above 2 dSm\(^{-1}\) and growth rate was high in sugarcane resistant cultivar (H69-8235) at all salinity levels. Hamada and Enany (1994) reported that increasing salinity up to 80 mM Na showed reduction in growth in broad bean leaves.

El-Samad and Abd (1995) reported that salinity affected growth in *Cucumis sativus*, however Sodium pyruvate ameliorated adverse effects of NaCl. Reinhardt and Rose (1995) observed that salinity stress delayed primary root growth and reduced peak elongation rates, without changing general primary root growth. Lateral root growth of *Gossypium hirsutum* L. Cv. Acala SJ-2 was inhibited by salinity than primary root growth. Elongation of lateral roots was more inhibited by salinity than their initiation and
emergence. Huang and Redmann (1995) investigated the role of Ca under saline conditions in *Hordeum vulgare* and reported that increased Ca in growth medium increased the salt tolerance in barley. Muthuchelian *et al.* (1996) showed significant reduction in growth rate in *Erythrina variegata* Linn seedlings when grown under low (100 mM NaCl) and high (250 mM NaCl) salinity for 10 days. Lin and kao (1996) reported inhibition of root growth in rice seedlings under NaCl stress.

Morabito *et al.* (1996) reported that in *Eucalyptus microtheca* clone 42, growth was delayed while in clone 43 shoot length growth was completely inhibited during salt stress. Zhang *et al.* (1996) showed that germination percentage was reduced and growth was inhibited under NaCl stress in *Eleucine coracana* seedlings. Guerrier (1996) found that after six days of salinization relative growth rates of both, *Lycopersicon pimpinellifolium* and *L. esculentum*, decreased significantly in whole plants. Hamada (1996) reported that growth was retarded with rise in NaCl/ drought or NaCl and drought in wheat plants. Misra *et al.* (1996) found that higher salinity level (200 mM NaCl) reduced seed germination and seeding growth due to reduction in root or shoot elongation and dry mass accumulation. However, 20 mM NaCl increased seedling length and biomass accumulation over the control in 2 *Brassica juncea* L. cultivars Kranti and T-59. Okuba and Utsunomiya (1996) observed suppression in growth when plotted *Ficus carica* L. Cv. Masui Dauphine cuttings were subjected to 0-50 mM NaCl solution for four weeks.

Botella *et al.* (1997) reported that salinity significantly decreased shoot growth when *Zea mays* L. plants were grown in ½ Hoagland nutrient solution which was 0.1 m mol/L which was probably due to salinity induced K deficiency. Lechno and E-Telor (1997) reported reduced growth in cucumber seedlings grown in hydroponic solution for 1 to 2
weeks to a final concentration of 100 mmol/L for 4 days. According to Gucci et al. (1997) growth parameters were completely inhibited at 300 mM external NaCl for 64 days in Phillyrea species.

Misra et al. (1997) reported that leaf growth of resistant Oryza sativa Cv. Damodar was less affected than susceptible Cv. Jaya under NaCl stress. Ai-Yemeny and Basahy (1997) found marked growth reduction at 16 and 20 mmhos/cm upto 40% in root, 73% in shoot and 54% in stem and 58% in root dry weight in Cyamopsis tetragonoloba (L) Taubert. Garg et al. (1997) observed that increasing NaCl concentration (0, 50, 100 and 150 mM) progressively decreased growth of Cyamopsis tetragonoloba (L)Taubert. However, supplemental Ca (2.5 and 5.0mM) which ameliorated adverse effect of NaCl. Muthukumaraswamy and Pannerselvam (1997) found marked reduction in growth over the control in root, stem and leaf of green gram at 100 and 150 mM NaCl treatment. According to Wang and Zhao Ke-Fu (1997) root growth decreases in com due to NaCl stress. Converso et al. (1997) observed inhibition of growth in stems of wheat plants under salt stress. Sharma (1997) observed that plant growth declined with increasing levels of salinity in CSG 8890 and CSG 8927 genotypes of chickpea.

There are few reports of increase in height under saline conditions in glycophytes. Nieman (1962) suggested stimulation of growth in garden beet and spinach by 0.2 % NaCl. Das and Mehrotra (1971) reported that salinity accelerated growth in barley, oat, rice, maize, Sorghum and cotton. However, 0.6% salinity proved to be critical salinity level for barley, oat, maize and Sorghum and 0.8% for rice and cotton. Growth stimulation by low concentration of NaCl (0.01 and 0.05 M ) and inhibition by high concentrations was reported in sugarcane Var. Co 740 by Nimbalkar and Joshi (1975). Similar results were reported in cowpea plants by Imamil Huq and Larher (1984).
Jeschke et al. (1983) found an increase in growth at 10 and 50 mM Na salts due to efficient K uptake under NaCl and Na$_2$SO$_4$ salinity's in Atriplex hortensis. Clough (1984) observed stimulation in growth in seedlings of Avicennia marina and Rhizophora stylosa in 25% of sea water. According to Huq et al. (1985) at low salinities (10 mM) relative growth rate of Vigna sinensis was greater than Phaseolus aureus and at 100 mM relative growth rate was same for both species indicating that both the plants were more resistant at younger stage. Eshel (1985) observed 90% acceleration in growth in presence of Na, tested at all concentrations of NaCl and Na$_2$SO$_4$ at 125 (eq) m$^{-3}$ indicating more resistance to NaCl at younger stage.

Waisel (1985) reported stimulation of growth at low levels of salinity's in halophytic rhodes grass (Chloris gayana Kunth Cv.). Harvey (1985) observed considerable growth in Zea mays under 100 mol m$^{-3}$ NaCl. According to Cramer et al. (1986) root growth of Gossypium hirsutum was stimulated by low NaCl (25 mM) concentration.

Clipson (1987) reported that growth rates increased in presence of salt in Suaeda maritima L. Dunn seedlings in 0 - 200 mol m$^{-3}$ salinity. Abdel Rahman (1987) observed acceleration of main stem growth in dwarf bean varieties in Var. Balady (upto 20 m eq) while in variety black valentine the concentration of NaCl was higher (60 m eq). Abdel-Rahman (1987) found that salinity promoted growth in cowpea while in calabrese, effect was promotive or depressive depending on the concentration of NaCl. Results of Larher et al. (1987) revealed that 10 mM NaCl promoted growth in Vigna unguiculata, Vigna faba and Trigonella foenum graceum. Results of Blits and Gallagher (1990) suggested that when Kosteletzky virgina L. Prest were grown in nutrient solutions of 0, 85, 170, 255 mol m$^{-3}$ NaCl then the growth was stimulated by 85 mol m$^{-3}$ NaCl.
Reinhardt and Rose (1995) reported daily primary root elongation gradually increased to maximum then declined close to zero in dark grown seedlings in *Gossypium hirsutum* L. Cv. Acala SJ-2. Guerrier (1996) observed that short term salt exposure (4-6 days) of salinization enhanced relative growth rates of *Lycopersicon pimpinellifolium* and not in *L. esculentum*. Kohl (1997) reported growth enhancement by NaCl in inland population upto 200 mM NaCl in *Armeria maritima* (Mill). Venkatesan et al. (1997) reported that growth was promoted by exogenous addition of NaCl upto 200 mM in *Ipomoea pes-caprae* sweet plants. Khan et al. (1997) reported that plant height, shoot and root growth was increased with increasing salinity (0, 50, 100, 150 and 200 mM NaCl concentration in 3 cultivars of rice. Saha and Gupta (1997) found that 5 mhos/cm NaCl promoted growth in sunflower seedlings. From all these results it is clear that many glykic plants need Na and Cl in small amounts for their growth which is clear from the observations that low concentrations of NaCl stimulate growth in many glykic plants.

Tyerman et al. (1984) reported that leaf growth was unaffected by 13 % to 15 % of salinity in *Posidonia australis*. Results of Yeo and Flowers (1985) suggested no effect on growth at a range of Na / Ca (5.25), but reported marginal increase in NaCl entry to shoot in *Oryza sativa*. Aslam et al. (1986) observed that growth of *Atriplex amnicola* at 400 mol m$^{-3}$ NaCl was not limited by availability of photosynthate in the plant as a whole. However, there is no growth limitation due to inadequate organic solutes for osmotic regulations. Ohta et al. (1987) observed that Na is required for normal growth of *Amaranthus tricolor* L. seedlings. Flowers et al. (1990) reported that in *Oryza* members salt concentrations upto 20 % did not affect growth adversely.
Marcar (1993) reported that salt and water logging alone did not affect seedling growth of *Eucalyptus* species. Sadek (1993) observed that growth was not affected by salinity in *Atriplex halimus* var. Schweinfurthii. Fernandez et al. (1996) reported that plant growth was unaffected up to NaCl 150 mol m\(^{-3}\) in *Lupinus albus* L. studied over six day period. Thus in many plants salinity does not affect growth.

Kaavari - Nejad and Najafi (1990) reported that in *Helianthus annus* Cv. Record growth was adversely affected by NaCl salinity at 25 and 50 mM. Salt solutions with or without CaCl\(_2\) at 17 h light period 100 \(\text{wm}^{-2}\) PAR day / night and temperature of 24 / 18 °C. Zallag et al. (1990) suggested that shoot mean relative growth rates were similar for both control and plants growing at 300 mol m\(^{-3}\) NaCl. Matoh and Murata (1990) found the beneficial effect of sodium on growth of *Panicum coloratum* walt Cv. Kabulabula. Zhao and Munns (1992) provided evidence that plant growth of barley and salt brush is controlled by a message given from roots under increasing NaCl concentration. Amzallag and Lerner (1994) observed that 150 and 300mM NaCl inhibit growth in *Sorghum bicolor* L. Moench genotypes.

Thus among glykic plants the effect of salt is not uniform. In some plants all the concentrations of NaCl are toxic while in some plants low concentrations of NaCl stimulate while high concentrations of it, inhibit growth.

Results of the present investigation (Table.1 ; Fig.1a,b) revealed that growth in height was stimulated up to ECe 10 mScm\(^{-1}\) of NaCl at 30 days of germination. However, it was less than the control at 60 and 90 days of germination which clearly indicated that all levels of NaCl salt were toxic for growth in height in this plant. Further plants could
survive and complete life cycle up to ECe 7.5 mScm$^{-1}$ of NaCl. Plants growing at ECe 12.5 to 17.5 mScm$^{-1}$ of NaCl died during 60 to 90 days of growth.

Under sulphate salinization (Table. 2; Fig. 2a, b), height was more than the control up to ECe 10.0 mScm$^{-1}$ at 30 days of growth and up to ECe 7.5 mScm$^{-1}$ at 60 and up to ECe 10.0 mScm$^{-1}$ at 90 days of growth which clearly indicated that low concentrations of Na$_2$SO$_4$ are required for growth and development of this crop. However, higher concentrations of it are detrimental. Plants could survive and complete life cycle up to ECe 10.0 mScm$^{-1}$ of Na$_2$SO$_4$. Plants growing at ECe 15.0 and 17.5 mScm$^{-1}$ of Na$_2$SO$_4$ died during 60 to 90 days of growth. Thus survival range is wider under sulphate salt rather than chloride salt in Carthamus tinctorius Var. Bhima.

Reduction in height at all levels of chloride and at all higher levels of sulphate must be due to combination of osmotic and specific ion effect because moisture content (Tables. 7, 8) was less than the control and Na and Cl content (Tables. 11 - 16) was more than the control. At low concentrations of sulphate increase in height must be due to stimulatory effect of Na and SO$_4$ on growth because content of both the minerals was more than the control and moisture content of leaf was also more than the control (Table. 8).

b) Leaf Area

It has been observed that efficiency of energy conversion is less in young leaves as they have less leaf area to carry out high rates of photosynthesis and other leaves which are senescent. The rates of important physiological processes such as photosynthesis, transpiration and final yield of the plant depends on area of green leaves exposed to radiant energy (Date et al., 1980).
With an increase in salinity, leaf area and number decreases (Kale, 1962; Ahmed, 1965; Sharma et al., 1977 and St. Omer and William, 1980). Reduction in growth due to reduced leaf area by 20 to 40% in bean plants under saline conditions was observed by Meiri and Poljakoff-Mayber (1970). Productivity in corn, bean and sunflower is affected as a result of decreased leaf area due to salinity (Ch'Yung and Lapina, 1974). Decreased leaf area, leaf number and fresh and dry weight in kidney bean (Heikal, 1976); in rice (El-keredy and El-Showry, 1976); in citrus (Joolka and Singh, 1979) in cotton (Malofeev et al., 1979), under saline conditions have been reported. Chavan (1980) observed considerable decrease in leaf area in ragi at 100 mM NaCl. Robinson et al. (1983) subjected Spinacea oleracea to 25 mM to 200 mM NaCl salinity and observed decrease in leaf area.

Longstreth et al. (1984) showed that when alligator weed, Alternanthera philoxeroides was grown at different concentrations of NaCl, then plants produced less leaf area / unit dry weight with increase in salinity (to conserve water). Yasseen et al. (1987) observed decrease in leaf area by salinity in two barley cultivars (Black local and Arivat) by reducing number and volume of cells. Schubert and Lauchli (1986) in wheat and Blits and Gallagher (1989) in a dicot halophyte made similar observations as Chavan (1980). Blits and Gallagher (1990) observed decrease in leaf production and leaf area in Kosteletzkya virginia (L) Prest, a dicot halophyte subjected to nutrient of 0, 85, 170, 255 mol m⁻³ NaCl. Myers et al. (1990) reported decrease in leaf area in Diplachne fusca L. (beetle grass) when subjected to NaCl (0-420 mol m⁻³). Brugnoli and Lauteri (1991) reported reduction in leaf area development in Gossypium hirsutum L. and Phaseolus vulgaris L. at different NaCl concentrations from 10 day old seedling till mature reproductive structure formation. Kalagi and Nalborczyk (1991) observed reduction in
leaf area under salinity stress which classified 8 barley cultivars into 3 groups. Tolerant
(Aksad 60, Rihane, Furat 1), medium (Ars, sth, 215 cerice) and sensitive (Arabian lack,
Beecher). Zhao and Munns (1992) found decrease in leaf area and relative leaf
expansion rate in barley and salt brush under increasing NaCl saline conditions where
this rate is suggested to be controlled by factor originating from roots associated with
concentrations of water status of roots. Alarcon et al. (1993) reported that salinity of 0,
40, 70 and 210 mM NaCl reduced leaf area in Lycopersicon esculentum. Sharma
(1996) observed reduced leaf area and number of litters in Triticum durum L. Cv. HD
4502 under steady state NaCl salinities (1.6, 12.0, and 16.0 dsm⁻¹) for 8 weeks. Salinity
reduced leaf area by 35-75 per cent in different sugarcane varieties (Sharma, 1997).

Nunes et al. (1984) demonstrated that low Na concentration in root medium of intact
and decapitate young sugar beet (Beta vulgaris) cultivar Kaueply grown under
controlled conditions modified leaf water relations and increased leaf area. Jeschke et
al. (1984) observed that leaf size was stimulated at 10 mM and 50 mm of (NaCl,
Na₂SO₄) salts in Atriplex hortensis. Kayani and Mujeeb-ur-Rehman (1988) reported in
crease in leaf area with increasing salinity in Zea mays L. Cv. Sunahry. Hwang and
Chen (1995) studied histology of leaves and roots of Kandelia candel seedlings and
reported greater leaf area and thickness at 50 and 100 mM NaCl. According to
Venkatesan et al (1997) leaf area increases in plants (Ipomea pes- caprae sweet)
grown upto 20 mM of NaCl.

Our results of present investigations indicate that (Table. 3 ; Fig.3) at 30 days of growth
total leaf area per plant was increased upto ECE 12.5 mScm⁻¹ of NaCl, however, it was
less than control at higher salinity level (ECE 15.0 and 17.5 mScm⁻¹). At 90 days, leaf
area was more than the control upto ECE 7.5 mScm⁻¹. Under sulphate salinity (Table. 4;
Fig. 4), at 30 days of growth, leaf area was less than the control and at 90 days of
growth, leaf area was more than the control at ECe 5 mScm⁻¹ and less than the control
at all higher levels of Na₂SO₄ salinity. Thus, all concentrations of NaCl inhibit while low
concentrations of Na₂SO₄ stimulate and high concentrations of it inhibit leaf

c) Productivity (Dry matter)

The total area of photosynthetic organs and their efficiency to receive solar energy
gave an idea about total dry matter production (biomass) which gives the idea about
carbon budget and productivity of the plant (Sestak et al., 1971).

To study the effect of salinity on plants, it is necessary to consider parameters such as
total dry matter production and yield per plant.

Results of several workers (Ayers et al., 1943; Gauch and Wadleigh, 1944, 1945;
Bernstein and Hayward, 1958; Lunt et al., 1961; Lunin et al., 1961; Greenway et al.,
1966; Nieman and Poulsen, 1967; Meire and Poljakoff-Mayber, 1969; Lahaye and
Epstein, 1971; Meire et al., 1971; Neiman and Poulsen, 1971; Ayoub, 1974; Heikel,
1976; Lessani and Marschner, 1978; El-Kurouri, 1979; Sameni et al., 1980) suggested
that salinity reduces growth and dry matter production per plant in many crop plants.

A decrease in dry matter production due to increased salinity was reported by Kale
(1962) in rice; Heikal (1975, 1976) in safflower, sunflower and Kidney bean; (Paliwal et
observed decrease in dry matter with increasing salinity where the effect was more
hazardous under chloride compared to sulphate salinity. Wagnet et al. (1980) reported
similar results. With increase in NaCl from 0 to 18 mM, a decrease in shoot dry weight took place in barley (Dale et al., 1980).

Robinson et al. (1983) observed that in Spinacia oleracea there was decrease in fresh and dry weight (more than 50%) under salt (0 to 200 mM) stress. Mehta and Bharti (1983) reported that chloride salinity reduced fresh and dry weight of cotyledons whereas sulphate salinity had opposite effect. Karadge and Chavan (1983) found 40% reduction in dry matter in Sesbania aculeata. Winter (1984) observed 70% reduction in dry matter production in Trifolium alexandrinum at 50 mM NaCl stress.

Bhatti et al. (1983) reported decrease in dry weight of Diplachne fusca (Kaller grass) at 150 mM NaCl/ KCl. Noble et al. (1984) observed decrease in stem biomass in seedlings of cactus (Cereus validus). Haworth, when treated with NaCl 400 mM. Clough (1984) found fall in dry matter production between 25 and 50% seawater in Rhizophora stylosa. Great reduction in fresh weight was observed at 200 mol m\(^{-3}\) NaCl in Gossypium hirsutum (Kent and Lauchli, 1985); in tomato (Raymond, 1985); in tobacco (Flower et al., 1986); in grapes (Arbabzadeh and Dutt, 1987); in cowpea Kannan and Ramani, (1988) and in Pistachio cultivars (sepaskhan and Maftown, 1988) under saline conditions.

Seemann and Critchley (1985) showed that dry and fresh weight decreased with increasing external NaCl concentration ranging from 0 to 150 mM in Phaseolus vulgaris. Robinson et al. (1985) reported decrease in growth on basis of fresh/ dry weight in halophyte Suaeda australis at 50-150 mM NaCl. Jeschke et al. (1986) observed linear decrease in dry matter of shoots and root with increasing (1, 5, 10, 25 and 40 mol m\(^{-3}\)) external NaCl in nodulated Lupinus albus. According to Naidoo (1986) decrease in root
mass at low external osmotic potential in *Rhizophora macronata* occurred. Safaraliev *et al.* (1987) found significant decrease in dry matter at 0.6% salinity in maize seedlings. Younis *et al.* (1987) subjected seeds of flax, cotton and castor beans to 0.5 and 1% NaCl for 12 days and observed continued decrease in dry matter.

Pessarakli *et al.* (1989) reported that increasing pressure of culture solution decreased total dry matter production when grown under control and NaCl salinized (3, 6 and 9 bars osmotic pressures) in *Zea mays*. Cv. "Florida stay sweet". According to Khan and Ashraf (1988) depression in dry matter yield in 4 varieties of sorghum took place when subjected to tolerant, moderately tolerant and sensitive NaCl salinity. In *Cicer arietinum*, NaCl significantly decreased shoot and root dry weight; total nodule number per plant, nodule weight and average nodule weight (El-Sheikh and Wood, 1990). Myers *et al.* (1990) reported decrease in plant dry weight at and above 300 molm$^{-3}$ NaCl when plants were subjected to 0-420 molm$^{-3}$ NaCl in *Diplachne fusca* L.P.Beave-ex Roemer and Schultes. Kalaji and Nalborczyk (1991) observed decrease in dry mass under salinity stress which classified 8 barley cultivars into 3 groups; Tolerant (Aksad 60, Rihane, Furat 1); medium (Ars, sth, 215 Cerice) and sensitive (Arabian Black, Beecher). Hatzmann (1991) added 50 and 100mM NaCl to nutrient solutions and reported suppression in dry matter in *Opuntia ficus indica*. Shitole and Shinde (1991) reported decrease in dry matter production with increasing levels of NaCl and Na$_2$SO$_4$ salinities in *Carica papaya* cv. Ranchi. Zhao and Munns (1992) found decrease in dry weight in barley and saltbrush with increasing NaCl concentrations while Ashraf and Naqvi (1992) reported lowest plant dry biomass in 4 species of *Brassica napus* at varying Na/Ca ratios of NaCl (15, 30, 60, 120 and 150 mM) concentrations. Wilson *et al.* (1992) reported low overall fresh weight in 25 days old plants of *Phaseolus vulgaris*. Cv. Stringless green pod with full salt treatment for 7 days by 33% compared to control.
Shoot fresh weight decreased by 40% compared with 22% for roots thus increasing root:shoot ratio from 0.7 to 0.9. Banulis and Millo (1992) reported decrease in dry matter in Citrus sinensis Osbeck Cv. Hamlin due to accumulation of Cl ions under salinity stress. Mirza and Tariq (1992) found decrease in dry weight of shoots and roots of Sesbania sesban with increasing salinity levels (0 to 2 %) of NaCl in sandy clay loam soil (ECe 1 dSm⁻¹). A decrease in fresh and dry weight of root and coleoptile with increasing levels of NaCl was reported by Chippa et al. (1992) in Pearl millet. In Apium graveolus, total shoot weight and root growth was severely reduced at all salt concentrations (Everard et al., 1992).

Storey et al. (1993) reported decrease in fresh weight / dry weight ratio in Melanthera biflora (Asteraceae) with increasing salt stress (50 mol m⁻³) to (400 mol m⁻³) due to increase in onium compound (quaternary ammonium and/or tertiary sulphonium). Cachorro et al. (1993) observed decrease in plant weight at 25 mM NaCl concentration in Phaseolus vulgaris.

According to Alarcon et al. (1994), reduction in leaf and shoot dry weight in Lycopersicon esculentum at 0, 70, 140 and 210 mM NaCl occurred. Mansour (1994) reported more pronounced decrease in fresh mass of sensitive cultivar of 10-d-old wheat seedlings in presence of 100 mM NaCl for 7 days. Gouia et al. (1994), observed reduction in dry mass after 20 days at 50 and 100 mM NaCl by 48% and 55% in bean and 6% and 14% in cotton in culture solution. According to Sharma (1995) biomass declined with increasing salinity in salt sensitivity variety of wheat. Zhao et al. (1995) reported inhibition of dry weight production by 100-500 mmol/L KCl in Suaeda salsa, Atriplex centralasiatica and Limonium bicolor. Cayuela et al. (1996) reported low reduction in shoot and root dry weights in primed seed of tomato with 6M NaCl at
different harvests (30, 45, and 60 days after sowing). Lopez and Satti (1996) observed reduction in root volume and fresh weight in 5 cultivars of tomato at 150 molm$^{-3}$ NaCl. Misra et al. (1996) reported reduced fresh mass with increasing NaCl salinity (0.0, 0.5, 1.0, 2.0, 3.0 percent m/v) in 2 cultivars, Sujata and Cv.K851 of *Vigna radiata*. Muthuchelian et al. (1996) showed reduction in biomass production in *Erythrina variegata* seedlings grown under low (100 mM NaCl) and high (250 mM NaCl) salinity for 10 days. Ai-Yemeny and Basahy (1997) found reduction by 58% in dry weight in *Cyamopsis tetragonoloba* Taubert at 16 and 20 mmhos/cm salinity levels. Converse et al. (1997) observed decrease in fresh weight of stems and leaves under salt stress in wheat plants. According to Maliwal (1997), dry mass decreased with increasing salt concentrations in 5 varieties of wheat. Saha and Gupta (1997) reported decline in dry matter production with increasing NaCl salinity in sunflower seedlings.

On the other hand, increased dry matter production at low and moderate salinity concentrations was reported by Nimbalkar and Joshi (1975) in sugarcane; St. Omer et al. (1980) in *Jaumea carnosa*; Nukaya (1983) in musk melon; Matoh et al. (1986) in *Atriplex gmelini*; Mahmood and Malik (1987) in *Atriplex rhagodioides*; Weimberg and Shannon (1988) in tall wheat grass and Alka et al. (1982) in barley.

Jeschke and Stelter (1983) observed substantial stimulation in dry matter production at 10 mM and 50 mM Na salts under mild conditions of NaCl and Na$_2$SO$_4$ in *Atriplex hortensis*. Nunes et al. (1984) demonstrated increased dry weight at low Na concentrations in young *Beta vulgaris* Cultivar Kauepdy. Seemann and Critchley (1985) found that at 0 - 150 mM NaCl concentrations, root / shoot ratio increased in *Phaseolus vulgaris* Cv. Hawkesbury Wonder. Eshel (1985) suggested that fresh weight of *Suaeda monoica* and *Suaeda aegyptica* was raised by NaCl, 5 to 10 times respectively. In these
plants, NaCl stimulated growth and plants stored more amount of water. In seedlings of coastal halophyte Atriplex gmelini, maximum dry weight yield was obtained at both low and high NaCl concentrations. Matoh et al., (1986) and Kunth et al. (1986) observed increase in both length and weight of primary root at 25 - 100 mM NaCl in presence of 10 mM Ca in Gossypium hirsutum L. (Cv Acala SI - 2) grown hydroponically.

NG and BH (1987) reported increase in dry weight of nodules, shoots and roots and nitrogen content of shoots at 50-100 mM NaCl in Casuarina equisitifolia. Stiborova et al. (1987) observed increase in root/shoot ratio at 0-100 mM NaCl concentration in Hordeum vulgare and Zea mays, indicating that shoot growth was more affected than root growth. Tirmizi et al. (1991) found that increasing NaCl treatments increased dry matter production in Hippophae rhamnoides L.

Ashraf and Naqvi (1991) observed that in Leptochloa fusca L. Kunth highest fresh and dry biomass production at varying Na/Ca ratio under different salt treatment of 24, 49, 99 and 199 at constant concentrations of 200 molm^-3 NaCl. Further, Ashraf and Naqvi (1992) reported that in Brassica carinata plant dry biomass was greater than other species at varying Na/Ca ratios in 150 NaCl solutions of 15, 30, 60 and 120. Khan et al. (1992) observed that Sorghum Var. IS-1347 yielded more biomass than IS-4807 when grown in series of NaCl concentration in nutrient culture solution. Reddy et al. (1992) reported increase in biomass production, % moisture and succulence in different tissues of Salicornia branchiata, Roxb. under saline conditions (seawater irrigation).

Tipirdamaz and Karakullukcu (1993) observed increase in stem weight at 150 mM NaCl concentration along with application of 10 mM proline/ Glycinebetaine in invitro cultured tomato embryo. Everard et al. (1994) reported increase in shoot fresh weight at low NaCl concentration of root zone salinity (25mM NaCl) compared to control and growth
continued at further higher salinity’s in celery *Apium graveolus*. Ashraf (1994) reported increase in dry matter production in oil seed salt tolerant (*Eruca sativa*) at 0, 100, 200 or 300 mol m$^{-3}$ NaCl. Ashraf and Fatima (1995) observed that two tolerant accessions (260622 and 305167) of safflower (*Carthamus tinctorius* L.) when grown in soil salinized with 0, 70, 140 and 210 mol m$^{-3}$ NaCl produced greater fresh and dry biomass. Reiman and Breckle (1995) reported increase in dry weight by 50 mmol$^{-1}$ NaCl in ssp tragus (L.) and not in ssp ruthenica of *Salsola Kali* L. when subjected to 200 mmol$^{-1}$ NaCl.

Studies of Cayuela *et al.* (1996) indicated positive effect of seed priming with 6M NaCl on shoot and dry weight at different harvests (30, 45 and 60 days) after sowing at 140mM NaCl in *Lycopersicon esculentum* Mill. Cv. Pera. According to Muthuchelian *et al.* (1996) increase in biomass was partially ameliorated by triacontanol (1 mg/ kg) in *Erythrina variegata* Linn. seedlings grown under low (100 mM NaCl) and high (250 mM NaCl) salinity for 10 days. Kohl (1997) reported increase in shoot root dry weight in *Armeria maritima* (Mill) upto 200 mM NaCl in Inland populations, which grew better upto 40 mM NaCl compared to control. Venkatesan *et al.* (1997) reported increased fresh weight upto 200 mM NaCl in *Ipomoea pes caprae* sweet. Mohanty and Saradhi (1992) reported no significant change in dry weight at varying concentrations of NaCl (0, 100, 150 and 200 mM) in *Brassica juncea* Cv. DlIRA 367.

Thus in several glykic plants, salinity inhibits growth. However, there are many glykic plants in which dry matter production per plant increases by low levels of salts which is clear from the results of several workers cited above. This fact indicated that, for many glykic plants, Na and Cl are essential for growth but their high concentrations are inhibitory.
Results of the present investigation (Tables. 9,10) revealed that all concentrations of NaCl inhibit total dry matter production per plant. However, total dry matter production per plant increased in plants grown upto ECe 7.5 mScm\(^{-1}\) of Na\(_2\)SO\(_4\) and at higher (ECe 10.0 to 15.0 mScm\(^{-1}\)) levels of sulphate, dry matter per plant was less than the control. Further, this cultivar Carthamus could survive and complete its life cycle upto ECe 7.5 mScm\(^{-1}\) of chloride and upto ECe 10.0 mScm\(^{-1}\) of sulphate. Thus, higher levels of NaCl are more toxic than higher levels of sulphate.

d) Post harvest

Salinity affects plant growth (Epstein, 1962; Greenway, 1973 and Rai, 1977) and induces changes in anatomy and morphology of stems and leaves (Poljakoff-Mayber et al., 1975; Strogonov, 1962; Waisel, 1972 and Hayward and Long, 1941). Bhardwaj (1960) observed that yield was reduced from 7.2 to 2.1 g per plant in wheat and gram under saline conditions. Asana and Kale (1965) reported that grain yield /1000 grain weight were reduced but grain number was not affected. Jadhav (1969) mentioned that yield of jowar was reduced at ECe 2.6 to ECe 4.4 levels but the grain number was stable. Shalhevet et al. (1969) observed 50 % reduction in the yield of Arachis hypogea, under artificially salinized conditions (4.7 ECe). Venkateswarlu et al. (1972) stated that at ECe 4.5 mScm\(^{-1}\) the yield was reduced by 25 to 30 % in rice. Longneckar (1973) noted reduction in total number of fruiting forms, total number of matured balls, weight of both, seed and lint per ball and fiber length in cotton due to salt stress. Ch'Yung and Lapina (1974) have traced the effect of salinization in corn, sunflower and bean and recorded reduced productivity. Starck et al. (1975) and Udovenko (1973, 1975 and 1977) suggested that reduction in economic yield is related to greater reduction of translocation of photosynthate in bean plants due to NaCl treatment.
Paliwal et al. (1976) reported reduction in dry weight of tops and grain yield in barley due to increased salt concentration of irrigation water. Seed yield per plant and 1000 grain weight of barley were decreased when grown with sea water (Iyengar et al., 1977). Ayoub (1977) found 50 % reduction in the seed yield at soil salinity of about 3.9 mmhos / cm in lentil. A decrease in seed yield and seed weight and soybean due to salt stress was evident in the experiments of Sepaskhan (1977). Sourour et al. (1975) reported that the negative effect of salinity resulted in reduction of average number of tillers and spikes per plant, total yield (grain + straw) and also grain size of cotton. Dhir et al. (1977) and Ansari et al. (1977) reported decrease in grain yield due to salinity. Murthy et al. (1979) reported that Na of 23.49 meq 100^-1 g in leaf reduced the grain yield by 61 % of the control while 50 % decrement in grain yield was associated with 19.2 meq 100^-1 g of Na and K/Na ratio 5 in the leaves of wheat. They attributed the reduction in the yield at high concentration of Na in wheat leaves induced by salinity.

The grain yield was more seriously affected than other morphological characteristics in barley when grown under salinization (Kumar et al., 1981). Hassan (1981) observed that spraying of rice plant with NaCl solution during flowering reduced flower growth, pod and seed growth. Cerda et al. (1982) and Sharma et al. (1997) registered reduction in seed yield due to salt stress in pea and chick pea respectively. Nukaya et al. (1982) reported reduction in pod and seed yield of soybean. West and Francios (1982) and Wagnet et al. (1983) reported marked reduction in pod and seed yield in pea and Phaseolus sp. under saline conditions. Ioneva and Spiridonov (1985) found change in total length of main root and lateral roots (wheat and corn) in 14 days exposed young plants of wheat Var. Bezostaya 1, Corn hybrid KVS-701 at 25, 50, 100 and 200 mmol NaCl in Hoagland's mixture. Jeschke et al. (1986) observed that at 1, 5, 10, 25 and 40 mol m^-3 NaCl the relative growth rate of roots was affected more than in shoots of nodulated Lupines albus Cv. Ultra. Tirmizi et al. (1991) reported reduction in root
length, increased root to shoot ratio relative to control in *Hippophae rhamnoides* L. under NaCl stress. Khan et al. (1995) observed decrease in biological yield at high levels of NaCl salt (0-100 mmol\(^{-1}\)) and was more suppressive than Na\(_2\)SO\(_4\) (0-50 mmol\(^{-1}\)). Khan et al. (1995) reported reduction in biological yield after 4 weeks of growth at high level of NaCl in *Sorghum bicolor* L. Moench Cv. IS-4807.

According to Siddiqui and Krishnamoorthy (1995), salinity inhibited flowering and yield of cowpea and gram. However, when salinity exceeded 15 meq salts/l, plants either did not survive or failed to flower or yield. Application of B9 alleviated deleterious effects of salinity. Misra et al. (1996) found that due to reduced root and shoot elongation, growth and dry mass accumulation was reduced at high salinity level (200 mM NaCl) in *Brassica juncea* L. cultivars Kranti and T-59. However, at low salinity level (20 mM NaCl), reverse effect was observed. Savvas and Lenz (1996) studied effects of 20, 40 and 60 mM NaCl on eggplants and reported reduction in yield when grown in closed sand culture system for 6 months. Misra et al. (1996) reported reduced shoot and root length at 0, 0.5, 1.0, 2.0, 3.0 % w/v NaCl salinity in cultivars, Sujata and Cv. K-851 of *Vigna radiata* L. seedlings.

According to Patil et al. (1996) irrigating the maize crop with saline water significantly reduced grain yield at high (4 ds/m) levels of salinity. Okubo and Utsunomya (1996) reported that stem elongation was suppressed by increasing concentration from 0-50 mM NaCl in *Ficus carica* L. Cv. Masui Dauphine cuttings. According to Gucci et al. (1997), increasing salinity levels inhibited shoot elongation by 50% at 123 and 135 mM external NaCl after 31 and 123 days of salt treatment in *Phillyrea* species. Garg et al. (1997) reported that increasing NaCl concentration (0, 50, 100 and 150 mM) decreased seed yield in *Cyamopsis tetragonoloba* Taub. Gadallah and Ramadan (1997) observed
that shoot and root length decreased in salt stress plants compared to unstressed plants in *Carthamus tinctorius* L. Maliwal (1997) reported low reduction in grain yield in Karchia-65 and highest reduction in grain yield in J-405. Var. of wheat and observed that chloride salinity reduced yield more than sulphate salinity. Salinity decreased yield of sugarcane crops (Sharma, 1997). Reeve et al. (1948) found that yield of wheat was increased from 0.7 to 42.6 bushels per acre as ECe was reduced from 40 mmhos/cm to 4 mmhos/cm. Hamid and Talibudeen (1976) noted that Na salt in the soil benefits the yield in barley and sugar beet. Singh and Chandra (1980) observed that hybrids of *Pennisetum typhoides* survived and yielded better at ECe 20.0 than ECe 10.0 and 15.0 and grain yield increased over the control at ECe 5.0. Hussain (1981) suggested that ECe 4.0 mmhos/cm may be utilized without excessive loss of yield for barley crop. Ashraf and Fatima (1995) reported greater seed yield in two tolerant accessions of safflower at salinity levels of 0, 70, 140 and 210 mol m⁻³ NaCl.

Results of the present investigation (Tables. 5, 6) indicate that safflower plants flower earlier (77 to 88 days) under NaCl salinity than sulphate salinity (88 to 75 days). However, the plants mature within 95 to 115 days under both the salinity's. At maturity, under both salinizations, the content of root, stem and leaf weight increased slightly than at flowering. The husk weight was less than the control under chloride and sulphate salinizations. Under NaCl salinity the grain weight increased at low (ECe 5.0 mScm⁻¹ (Table. 9) and decreased at high (upto 10.0 mScm⁻¹) whereas, under Na₂SO₄ salinity the grain weight was increased upto ECe 7.5 mScm⁻¹ (Table 10) and decreased at high (ECe 10.0 and 12.5 mScm⁻¹) salinity. Under NaCl salinity the total DM per plant (Root + Stem + Leaf + Husk + Grain) (Table. 9) was increased at ECe 5.0 mScm⁻¹ and decreased at high (upto ECe 10.0 mScm⁻¹) levels. The plants died after 90 days of growth and their seeds were not viable (Table. 9) at ECe 10.0 mScm⁻¹. Under Na₂SO₄
salinity, the total DM per plant (Root + Stem + Leaf + Husk + Grain) was increased upto
\( \text{ECE} 10.0 \text{ mScm}^{-1} \) and decreased at \( \text{ECE} 12.5 \text{ mScm}^{-1} \) (Table. 10). The plants died after
90 days of growth and their seeds were not viable at \( \text{ECE} 12.5 \text{ mScm}^{-1} \) (Table.10).
Thus, this plant can be grown upto \( \text{ECE} 7.5 \text{ mScm}^{-1} \) of \( \text{NaCl} \) with 77% overall
productivity and 63.6% of grain productivity. While under sulphate salinity, this plant
can be grown profitably upto \( \text{ECE} 10.0 \text{ mScm}^{-1} \) of \( \text{Na}_2\text{SO}_4 \), where overall productivity
was 194.4% of the control and the grain productivity was 91.8% of the control. This
plant can grown upto \( \text{ECE} 10.0 \text{ mScm}^{-1} \), where its grain productivity was 91.8% of the
control. Highest (141.8% of the control) grain productivity was at \( \text{ECE} 7.5\text{mScm}^{-1} \) of
\( \text{Na}_2\text{SO}_4 \).

Thus, low levels of sulphate are essential for growth of this plant and this plant
\textit{Carthamus tinctorius} L. Cv.Bhima is moderately salt tolerant.