Chapter: IV

SUMMERY & CONCLUSION

Safflower (*Carthamus tinctorius*, L.) is an annual flowering and broad leaved plant, belongs to family Asteraceae, cultivated mainly for its seeds, which yield edible oil. Safflower is an important rabi oilseed crop of spiny and non spiny nature. It is grown in the states of Maharashtra, Karnataka and some extent in Andhra Pradesh. India is in the first place in terms of area and second in terms of production in the world; raised over an area of 3.65 lakh ha with a production of 2.29 lakh tones. Maharashtra and Karnataka are the two most important safflower growing states accounting for 72% and 22% of area and 69% and 26% of production respectively.

Seven percent of about billion hectares of the land's surface and five percent of cultivated land is affected by salinity. Salt stress being one of the most serious environmental factors limiting the productivity of crop plants. Therefore, extensive research into plant salt tolerance has been carried out, with the aim of improving the resistance of crop plants. In India the problem of salinity originated in the mid 70s during the green revolution but its visible impacts began to appear in mid 80s. In India the salinity area occupy nearly 8.6 million hectares and represent a serious threat to its ability to increase food production to meet the expanding needs. Both ecologists and plant physiologists have long been interested in the effect of salinity on plants. However, little extensive research has been carried out to further our understanding of how the different safflower cultivars respond to saline conditions. Drought stress is one of the most important abiotic stresses which play an important role in yield reduction in rain fed conditions. Physiological studies in crops under stress will help to verify effective mechanism/ traits that influence drought tolerance. Although safflower is considered to be a drought resistant crop, irregular distribution of precipitation and limited rain are the main risk factors for growing this crop in fields under dry land agriculture. In the present investigation, an attempt has been made to investigate the physiology of NaCl salinity and water stress tolerance in two varieties (Nira- spiny and Nari- 6- nonspiny) and two hybrids (Nari-H-15- spiny and Nari-NH-1- nonspiny) cultivars of *Carthamus tinctorius* L.

Salt Stress Studies:-

1. The process of germination relatively delayed in all cultivars of *Carthamus tinctorius* L. due to NaCl salinity. Among the cultivars, nonspiny hybrid Nari-NH-1 noted the highest germination percentage at higher salinity level while, spiny hybrid

Nari-H-15 reveals lowest germination percentage under NaCl salinity as compared to spiny variety Nira and nonspiny variety Nari-6.

2. The shoot length and root length decrease in all cultivars of safflower as NaCl concentration increases. Root length is more adversely affected than shoot length. The highest shoot and root length is recoded in nonspiny hybrid Nari-NH-1. The lowest shoot length is reported in spiny variety Nira while, lowest root length is observed in nonspiny variety Nari-6 at higher salinity level. Shoot root ratio is increased consistently with increasing NaCl salinity level in all cultivars. The highest shoot root ratio is recorded in nonspiny variety Nari-6 while, nonspiny hybrid Nari-NH-1 exhibited lowest shoot root ratio as compared to other cultivars at higher salinity level.

3. The significant reduction in fresh weight is observed in all cultivars of *Carthamus tinctorius* L. under NaCl salinity. Highest fresh weight is recorded in nonspiny hybrid Nari-NH-1 while, lowest fresh weight is reported in spiny variety Nira at higher salinity level.

4. The values of dry weight are influenced by different NaCl concentrations in all cultivars of *Carthamus tinctorius* L. Highest dry weight is recorded in nonspiny hybrid Nari-NH-1 while, lowest dry weight is noticed in spiny variety Nira as compared to other cultivars with increased salinity level.

5. Moisture content declines in all cultivars with increasing salt concentrations. The more decline in moisture percentage is recorded in spiny hybrid Nari-H-15 while, least decrease is observed in nonspiny hybrid Nari-NH-1 at higher salinity level over control.

6. Vigour index is decreased with increasing salinity levels in all cultivars of *Carthamus tinctorius* L. Nonspiny hybrid Nari-NH-1 gave the higher vigour index at all salinity levels. However, spiny hybrid Nari-H-15 exhibit lowest vigour index at higher salt concentration.

7. Reducing sugars of all cultivars is decreased as salt stress increased. More reduction of reducing sugars is observed in spiny hybrid Nari–H-15 at higher salinity level. On the other hand, nonspiny hybrid Nari-NH-1 gave the better performance in respect of reducing sugars under high saline conditions.

8. Non reducing sugars increased with increasing NaCl concentration in all cultivars. Highest increase in non reducing sugars is recorded in nonspiny hybrid Nari-NH-1 while, least increase in non reducing sugars is noted in spiny hybrid Nari-H-15 at higher saline conditions over control as compared to other cultivars.

9. The Total Sugars Content increases under NaCl salinity in all cultivars of *Carthamus tinctorius* L. The maximum total sugars is occurred in nonspiny hybrid Nari-NH-1 while, minimum is reported in nonspiny variety Nari-6 at higher salinity as compared to other cultivars.

10. The stimulation in hydrolysis of starch only in the seedlings in control and treated with lower concentrations of salt. The highest percentage of starch is recorded in nonspiny variety Nari-6 and nonspiny hybrid Nari-NH-1 while, lowest starch content is noted in spiny variety Nira at higher salinity level as compared to other cultivars.

11. There are increasing total carbohydrate contents with increasing salinity in all cultivars. Nonspiny hybrid Nari-NH-1 exhibit highest total carbohydrate. On the other hand, spiny variety Nira reported lowest total carbohydrate as compared to other cultivars at higher salinity level.

12. Soluble protein content in the seedlings of all cultivars is significantly increased when concentration of NaCl increased. More increase in soluble protein content is recorded in nonspiny hybrid Nari-NH-1. However, least increase in soluble protein content is noted in spiny hybrid Nari-H-15 at higher NaCl concentration over control as compared to other cultivars.

13. Inorganic constituents of nonspiny hybrid Nari-NH-1 showed different behavioral changes under salt stress. The sodium and chloride accumulation in the seedlings increased linearly with increasing NaCl levels. Potassium accumulation is dramatically increased at 100mM NaCl salinity thereafter; it is again decreased. The Na/K ratio is increased consistently as salinity increased. Calcium content increased up to 100mM NaCl salinity over control and again decreased at higher salinity level. Mg content decreased under NaCl salinity over control. The accumulation of iron is inhibited at all levels of salinity.

14. The activity of lipase is found to decrease as doses of NaCl concentration increases. The highest lipase activity is recorded in nonspiny hybrid Nari-NH-1 in

control and all levels of salinity while, the lowest lipase activity is observed in spiny variety Nira as compared to other cultivars at high salt concentration.

15. Increasing salinity induces conformational changes in the activity of peroxidase in all cultivars. Highest peroxidase activity is observed in spiny variety Nira. However, lowest activity of peroxidase is noted in nonspiny hybrid Nari-NH-1 at higher salinity level as compared to other cultivars.

16. Catalase activity decreases in all cultivars as salinity increases. Among the cultivars, highest catalase activity is recorded in nonspiny hybrid Nari-NH-1. On the other hand, spiny variety Nira, nonspiny variety Nari-6 and spiny hybrid Nari-H-15 noticed lowest catalase activity at 200mM NaCl concentration.

Water Stress Studies:-

1. Plant height reduced significantly under water stress conditions. The rate of the plant height reduction is lowest in spiny variety Nira while, maximum plant height reduction is observed in nonspiny variety Nari-6 as compared to other cultivars under water stress over control.

2. There is not a significant difference between width and length of stomatal aperture among the cultivars. The stomata open at maximum level in between 10.00 a.m. to 4.00 p.m. range during the hours of day. The width and length of stomatal aperture goes on decreasing as the water stress increased in all cultivars of *Carthamus tinctorius* L. It is also found that in spiny variety Nira, nonspiny variety Nari-6 and spiny hybrid Nari-H-15 shows two peak points in the width of stomatal aperture during the hours of day.

3. Relative water content reduced significantly in all cultivars of *Carthamus tinctorius* L. when plants exposed to water stress. Among the cultivars, highest reduction of RWC is recorded in nonspiny hybrid Nari-NH-1 while, spiny hybrid Nari-H-15 showed lowest decrease in RWC at 8 days water stress over control.

4. The water stress caused significant increase in titratable acid number in all cultivars of *Carthamus tinctorius* L. The highest increase in titratable acid number is recorded in spiny variety Nira. However, spiny hybrid Nari-H-15 exhibit lowest increase in titratable acid number at 8 days water stress than control.

5. The accumulation of proline increased as the stress prolonged and attained maximal levels at 8 days water stress in all cultivars. Highest increase in proline accumulation is observed in spiny hybrid Nari-H-15. On the other hand, nonspiny hybrid Nari-NH-1 exhibit lowest increase in proline accumulation at 8 days water stress over control as compared to other cultivars.

6. Reducing sugars in the leaves of water stressed cultivars is increased significantly. Highest increase in reducing sugars is recorded in spiny variety Nira while, lowest percentage is noted in nonspiny hybrid Nari-NH-1 at 8 days water stress over control as compared to other cultivars.

7. Nonreducing sugars reveal different behavioral changes under water stress. Highest increase in nonreducing sugars is recorded in nonspiny hybrid Nari-NH-1 at 8 days water stress over control as compared to other cultivars.

8. Total sugars increase under water stress over control in all cultivars of *Carthamus tinctorius* L. Highest enhancement of total sugars is noted in nonspiny variety Nari-6 while, least increase in total sugars is recorded in spiny hybrid Nari-H-15 at 8 days water stress as compared to other cultivars than control.

9. Starch content in the leaves of water stressed cultivars increased significantly over control. Spiny variety Nira shows highest increase in starch at 8 days water stress over control as compared to other cultivars.

10. Total carbohydrate increases with increasing water stress. Spiny variety Nira shows highest increase of total carbohydrates while, spiny hybrid Nari-H-15 recorded lowest percentage of total carbohydrates at 8 days water stress over control.

11. The chlorophyll 'a' and chlorophyll 'b' are decreased due to water stress in all cultivars of *Carthamus tinctorius* L. The rate of decline is more in chlorophyll 'b' than chlorophyll 'a' in all cultivars under water stress. The highest decrease in chlorophyll 'a' and chlorophyll 'b' is recorded in spiny variety Nira at 8 days water stress over control as compared to other cultivars.

12. Total chlorophyll reduces consistently with increasing water stress in all cultivars. The highest reduction of total chlorophyll is observed in spiny variety Nira than other cultivars.

13. Chlorophyll 'a' and 'b' ratio decreased under water stress and again increased slightly at 8 days water stress in spiny variety Nira, spiny hybrid Nari-H-15 and

nonspiny hybrid Nari-NH-1, while the decline pattern of chlorophyll 'a' and 'b' ratio is more and consistent in nonspiny variety Nari-6.

14. Inorganic constituents of spiny variety Nira showed different behavioral changes under water stress. The sodium accumulation in the leaves increased largely at 8 days water stress. Potassium is dramatically decreased under water stress. Calcium, magnesium, manganese and iron content increased consistently with increasing water stress over control.

15. The nitrate reductase activity decreased in all cultivars as water stress increased. The lowest value of nitrate reductase activity is noted in spiny hybrid Nari-H-15 while, highest one is reported in nonspiny hybrid Nari-NH-1 at severe water stress as compared to other cultivars.

In conclusion, there were differences amongst the cultivars for salt tolerance with regards to germination percentage, seedling growth, organic and inorganic constituents and activities of enzymes viz. lipase, peroxidase and catalase. Nonspiny hybrid Nari-NH-1 is more resistant while, spiny hybrid Nari-H-15 is most susceptible to high salt concentrations than the other cultivars. Moreover, nonspiny variety Nari-6 is moderately tolerant to NaCl salinity. In addition, cultivars of *Carthamus tinctorius* L. also exhibited considerable changes under water stress in respect of plant growth, stomatal behavior, organic and inorganic constituents and activities of enzyme nitrate reductase. Spiny variety Nira is tolerant while, nonspiny hybrid Nari-NH-1 is susceptible to water stress than nonspiny variety Nari-6 and spiny hybrid Nari-H-15.

However, the experimental results suggest that, in salt affected fields or saline soils, the nonspiny hybrid Nari-NH-1 will withstand satisfactorily. It is recommended for cultivation on salinity affected areas. On the other hand, our research results showed that variety Nira is tolerant to water stress. It will withstand better way in semiarid region or dry land area. These investigations can be used in future designing of genetically engineered plants of safflower with enhanced salt stress and water stress resistance properties. In other words, our research data will enable the plant breeders to develop new salt stress resistant and water stress resistant hybrids of *Carthamus tinctorius* L.