INTRODUCTION

Safflower (*Carthamus tinctorius*, L.) 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 (Padmavathi, 2005). Safflower is grown mostly in black soils in southern (deccan) plateau region of India during the post rainy (Rabi) season, primarily as a rainfed oilseed crop. It is often grown as a mixture with wheat, barley, gram and *Sorghum* and, as a pure crop; it is rotated with wheat, gram, and cotton and post rainy *Sorghum*. The world production of safflower went up from 6.2 lakh tonnes in 1991 to 9.5 lakh tonnes in 1998 because of an increase in productivity from 535 to 845 kg/ha, the area under its cultivation in the world is now on decline (FAO, 2000). India became self-sufficient in edible oils by 1991 as a result of launching a technology mission on oilseeds in 1986 (Prasad *et al.* 1994) by the central government. The enhanced oilseed production came largely from rapeseed and mustard, soybean and sunflower (Virupakshappa and Kiresur, 1997 and Rama Rao *et al.* 2000). However, amongst different oilseed crops, safflower could not register significant gains, and the area and production under this crop has not shown an adequate growth rate, with the yield levels becoming stagnant (Singh *et al.* 1997 and Paroda, 2000).

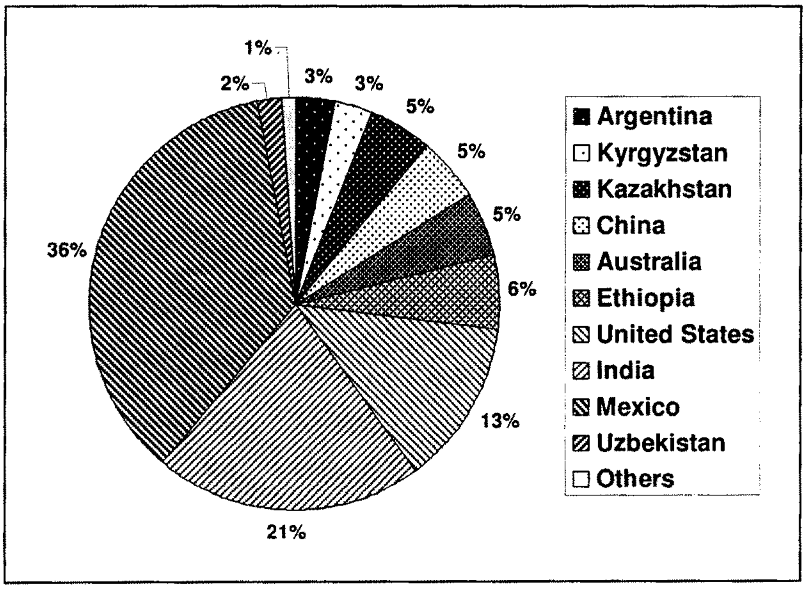
India is one of the major safflower producers in the world. Most of the current safflower acreage in this country comes from border and/or inter strip crop with other rabi crops. India is one of the world's largest growers of safflower (*Carthamus tinctorius* L.) with a cultivated area, of around 9 lakh ha (world = 13 lakh ha) with its total annual production, fluctuating between 3.5 to 5 lakh tonnes (world = 9 lakh tones). Safflower cultivation is mainly confined to Deccan peninsula with Maharashtra (6.5 lakh/ha and 3.59 lakh tonnes) followed by Karnataka (2.15 lakh ha and 1.23 lakh tonnes) and Andhra Pradesh (22 thousand ha and 6.1 thousand tonnes) accounting for almost all of its area and production in the country. Except a negligible portion, most of the current safflower acreage in India comes form either border crops with other principal rabi crops, like *Sorghum*, wheat, chickpea, coriander, and/or as inter/strip crop with them. Based on the encouraging results obtained from experimental farms in the traditional safflower growing areas of the country and the promise the crop displayed as a sole/entire crop under receding moisture conditions as well as life saving irrigation in moisture retentive and deep black soils/clay loams, a

Table 1. World safflower production Historical.

Year	Production in metric tons
1995	877,064
1996	903,870
1997	930,091
1998	653,036
1999	869,181
2000	689,556
2001	607,620
2002	601,332
2003	671,485
2004	604,157

(Data was obtained from the FAOSTAT database of the Food and Agriculture Organization of the United Nations).

Figure 1. Percentage of World Safflower Production by Country: 2004.



(Source: - Smith and Jimmerson, 2005)

demonstration project organized 50 whole package demonstrations, 40 under rainfed and 10 under limited irrigation, in two out of the three principal safflower growing states, namely Maharashtra and Andhra Pradesh (Patil, 2003).

In 2004, world safflower production was about 604,157 metric tons. Safflower is produced in over 15 different countries. Mexico, India, and the United States typically combine to produce about 70 % of total world safflower output (Figure 1). World safflower production increased steadily during the 1990's, but decreased from a high of over 930,000 metric tons in 1997 to only 604,157 metric tons in 2004. Current world production of safflower is approximately 35 percent lower from the record production in 1997 (Table 1).

Soil salinity refers to the state of accumulation of the soluble salts in the soil. It can be determined by measuring the electrical conductivity of a solution extracted from a water saturated soil paste. The EC with units of DeciSiemens per meter (dS m-1) or millimhos per centimeter (mmhos cm-1) is an expression for the anions and cations in the soil. From the agricultural point of view, saline soils are those, which contain substantial neutral soluble salts in the root zone, adversely affecting the growth of most crops. Saline soils are defined as those having an EC more than 4 dS m-1 at 25 °C temperature (Richards, 1954). The chlorides and sulphates of calcium and magnesium are the predominant soluble salts. Sodium Absorption Ratio (SAR) of saline soils is usually less than 15. However, presence of neutral soluble salts of sodium in saline soils invariably results in SAR greater than 15 (MPKV Research Bulletin No 68) (Deosthali and Akmanchi, 2005). As salinity level increases, soil water extraction by plants slows down inducing water stress conditions. High soil salinity causes nutrient imbalance, which results in the accumulation of toxic elements to plants, and reduce water infiltration.

Soil is one of the crucial national resources and, therefore, no country can afford to neglect or waste it. There are extensive saline areas on all the continents, but their extent and distribution has not been studied in detail. Estimates are in general close to 1 billion hectares, which represent about 7% of the earth's continental extent. In addition to these naturally salt affected areas, about 77 mha have become saline as a consequence of human activities, with 58% of these concentrated in irrigated areas.

Table 2. Extent and distribution of salt affected soil in India.

State	Salt affected area			Total
	Canal Command	Outside Canal	Coastal	
A.P	139.4	390.6	283.3	813.3
Bihar	224.0	176.0	Nil	400.0
Gujarat	540.0	327.1	302.3	1214.4
Haryana	455.0	NA	Nil	455.0
Karnataka	51.4	266.6	86.0	404.0
Kerala	NA	NA	26.0	26.0
M.P	220.0	22.0	Nil	242.0
MS& Goa	446.0	NA	88.0	534.0
Orissa	NA	NA	400.0	400.0
Punjab	392.6	126.9	Nil	519.5
Rajasthan	138.2	983.8	Nil	1122.0
Tamil Nadu	256.5	NA	83.5	340.0
U.P	606.0	689.0	Nil	1295.0
West Bengal	Nil	NA	800.0	800.0
Total	3469.1	3027.0	2069.1	8565.2

Note: NA refers to data not available.

(Source: - WWW. alterra.war.nl/ Internet/webdocs/IILRI publicaties/special reports)

Table 3. Talukawise salt affected area of Satara district.

Taluka	Total area affected due to salinization (ha)	Partially affected Area Out of total affected area(ha)	Fully affected area Out of total affected area(ha)
Satara	0.00	0.00	0.00
Koregaon	293.40	293.40	0.00
Khatav	0.00	0.00	0.00
Karad	1248.00	1060.80	187.20
Patan	0.00	0.00	0.00
Wai	0.00	0.00	0.00
Jawali	93.62	93.62	0.00
M'shwar	0.00	0.00	0.00
Khandala	0.00	0.00	0.00
Phaltan	1219.88	1061.30	158.58
Man	0.00	0.00	0.00
Total	2854.90	2509.12	345.78

(Source: - District Superintending Agriculture Office Report, Satara, 2008).

According to estimates by FAO and UNESCO, as much as half of the world's existing irrigation schemes is more or less under the influence of secondary salinization and water logging. About 10 mha of irrigated land are abandoned each year because of the adverse effects of irrigation, (Szabolcs, 1989).

Salt affected soils are an important ecological entity in the landscape in most arid and semi-arid regions. 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. Gupta and Abrol (1990) reported that in spite of the availability of many sources of information, accurate data concerning salt affected lands of the world are rather scarce. It is estimated that saline land extends over 8.6 mha in the country while in Maharashtra it is 6.0 lakh hectares with the increase of 10% every year due to water logging. In India they occupy nearly 8.6 million hectares and represent a serious threat to its ability to increase food production to meet the expanding needs. The establishment of CSSRI in 1969 gave a real impetus to the reclamation of salt affected soils in the country.

Salinity problems are occurred through out the Satara district. The Koregaon, Karad and Phaltan Tahsil of Satara district is mostly affected by salinity as compared to other Tahsil (Table.3). The cultivation of safflower is more at Phaltan and adjoining areas. The safflower production of Satara district is declining day by day due to salinity problem. In the present investigation, the attempt has been made to evaluate the salt tolerant cultivar of safflower, which would be recommended for cultivation at salinity-affected area of Satara district. This investigation enables the agriculturists or farmers to raise the production of safflower in salinized soils or salt fed condition.

Safflower (*Carthamus tinctorius* L.) is an important oilseed crop that owes its importance not only to the premium quality oil but also to the multipurpose uses of the entire plant system. In addition to this, safflower with its deep tap root system has proved more remunerative than most of the *rabi* crops in drought-prone and salinized soils. In India, an estimated 8.2 million hectares of soils are affected by soil-related problems (Singh, 1992).

Seven percent of the land's surface and five percent of cultivated lands are affected by salinity. Salt stress being one of the most serious environmental factors limiting the productivity of crop plants (Ashraf, 1999). Therefore, extensive research into plant salt tolerance has been carried out, with the aim of improving the resistance of crop plants. With a large majority of the world's population relying on crops such as barley, maize and rice to survive, crop salt tolerance is globally important (Ashraf, 1999). Despite advances in increasing plant productivity and resistance to a number of pests and diseases, improving salt tolerance in crop plants remains elusive, mainly because salinity simultaneously affects several aspects of plant physiology. Saline conditions reduce the ability of plants to absorb water, causing rapid reductions in growth rate, and induce many metabolic changes, similar to those caused by water stress. If tolerance cannot be improved then vast amounts of soils may be left uncultivated (Epstein, 1980). 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. Water deficit more than other stresses limits the growth and productivity of crops. Under severe water stress conditions caused by high salinity or drought; plant stop growing completely and accumulate solutes in cells in order to maintain the cell volume and turgor against dehydration. This phenomenon is known as osmotic adjustment. Osmotic adjustment has been observed in stems, leaves, roots and fruits (Nomani, 1998 and Patakas, 2002).

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 (Uslu, 2002). It needs suitable soil moisture levels to ensure a high yield. In general, 600 mm of rainfall during the growing season (the major portion falling before flowering) seems to be sufficient in obtaining high yields. Water shortage during the normal period of maximum growth, i.e. from rosetting until flowering, will cause a marked reduction in growth and delay maturity (Weiss, 1983). An economical crop can be raised without supplementary irrigation when the rains in the months of spring are sufficient. When there is a drought, supplementary irrigation in the dry months at elongation and/or flowering is needed (Agasimani, 1997).

Many agronomists have been working with breeding programmes at various research centers in India to release high yielding varieties of safflower. Their performance at various climatic conditions is also studied. All these attempts have been made with respect to yield studies. It is of almost importance to understand the performance and physiological aspects of plant species under salt stress and water stress conditions.

To achieve the purpose, 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. The different growth parameters as well as various biochemical aspects are studied at the germination stage under saline conditions. The effect of water stress on plant growth, stomatal behaviour and various biochemical changes have been investigated. The plants were raised from seeds in soil culture pots and water stress was induced by with holding water from the pots.

For convenience and presentation, the dissertation has been divided into different chapters. A general account of safflower and the brief review of salt stress and water stress physiology of safflower have been given in chapter I of the dissertation. Various methods were used for the present study are described in chapter II i.e. material and methods. It is followed the presentation of results obtained and discussion with reference to the available literature in chapter III. The chapter IV summarises the main points of the present work. The Literature cited in the dissertation is systematically presented in the last part of the dissertation i.e. Bibliography.