CHAPTER II

SAFFLOWER AT A GLANCE AND SCOPE
OF PRESENT INVESTIGATION
A) SAFFLOWER

Safflower is known by different names that is kusumbha in sanskrit, kusum or kusumphuli in Bengali, kardai or Kurdi in Marathi, kusumbo in Gujarati, Sendurakam in Tamil, kushumba in Telgu, kusumbe or kusum in Kannada and kasumba in Punjabi. It is also known as false saffron, bastard saffron, thistle saffron, dyers saffron, ksahirak. Ghurtum and suff.

a) Geographic origin

Carthamus tinctorius L., safflower belongs to family Asteraceae. There are approximately 25 valid species in the genus and they are distributed across Spain, North Africa, West Asia and India. Many species are indigenous to the Mediterranean region. The probable origin of cultivated safflower is a region bounded by eastern Mediterranean and the Persian Gulf (Knowles, 1969). Cultivated safflower is supposed to have originated either from saffron thistle or from wild safflower in the mountainous regions of Abyssinia and Afghanistan (Chavan, 1960). According to Vaviloe, the three centres of origin of safflower are India, Afghanistan and Ethiopia. Decandale was of the opinion that Arabia was the most probable centre of origin (ICAR, 1980).

Fragments of safflower plants and safflower seeds have been found in some of the ancient Egyptian tombs. Safflower has been domesticated for the orange dye which can be obtained from its florets and the clothes of mummies found in Egyptian tombs have been dyed saffron using this dye. Safflower was probably introduced to Egypt from the Euphrates. A bundle of single safflower flowers was found with the Eighteenth Dynasty mummy of Amenophis I (BC 1600) and was so well preserved that it could be accurately identified (Schweinfurth, 1887). An accurately dated revenue papyrus of
Ptolemy II (BC 259 - BC 258) states that the king had a complete monopoly on the production and marketing of certain vegetable oils including safflower (Keimer, 1924). Hasselquist (1762) while on a visit to Egypt, noted that the dye was exported to Italy, France and England where it was used for colouring and in the preparation of cheese.

Safflower is the latinized version of the Arab word quartum or qurtum which alludes to the colour of the dye obtained from flower. ‘Usfar’ is probably the origin of the English name ‘Safflower via various written forms of usfar, affore, asflore, saffire. Safflower is mentioned as a medicinal plant in De Materia Medica written by a Greek physician, Pedanius (60 AD).

Safflower was introduced to England via Egypt (The Botanical Register) and was used as a food colouring and dye. Safflower has been used as a source of a dye from ancient times by carpet weavers of Iran and Afganistan and was probably introduced into southern Russian regions from here. In ancient Indian Sanskrit, safflower has been described as kusumbha, from which the word ‘kusum’ is derived. Safflower oil was regarded as a purgative and it was used in a manner similar to castor oil. Florets of safflower are added to rice, bread and pickles to give them an attractive orange colour. The tubular florets are commonly used as an adulterant for true saffron or as a less costly substitute.

Safflower is considered to have been introduced to China around 200 - 300 AD as a dye. From China it was introduced to Japan. An early reference to safflower in USA is a research report of the University of California early this century (Weiss, 1983).
b) Distribution, Area and Production

Around 50% of the world’s production of safflower is in India. An area of about 0.9 million hectare annually produces a safflower crop fluctuating between 0.35 to 0.50 million tonnes (Virender Malik, 1995). Besides India, USA, Mexico, Ethiopia, Russia and Australia also cultivate safflower.

In India the states of Maharashtra, Karnataka and Andhra Pradesh are the dominant safflower producers (74% of the area and 69% of the production). In Maharashtra, safflower is cultivated mainly in the districts of Ahmednagar, Aurangabad, Beed, Latur, Osmanabad, Parbhani, Pune and Solapur (Vaidya et al., 1978).

In India when seed oil is the object, yields are about 90 - 130 kg florets / hectare and 440 to 660 kg of seed / hectare (C.S.I.R., 1948-1976). In Maharashtra state 310,000 hectares of land is under safflower cultivation from which 47,000 tonnes of seeds are harvested.

c) Climate, soils, season and rotations

In Maharashtra, Gujarat and southern India safflower is cultivated as a rain fed crop, but in other parts of the country, it is generally cultivated as an irrigated crop. It’s rainfall requirement is between 62.5 to 100 cm.

Safflower is considered to be drought resistant as it is capable of tapping subsoil moisture or seepage not normally available to the majority of other crops. This may be because of its deep and efficient rooting system. Fully grown plants are extremely wind resistant and even after the seeds are mature, there is little loss from lodging and
shattering. It is a day neutral plant. However, varieties may show adaptation to specific photo periods and short photo period can prolong the rosette stage. From an assessment of available data, growing plants are damaged by temperature approaching freezing and even when there is little visual effect the yield can be drastically reduced by a fall in temperature. Frost on maturing crops affects yield and oil content of seeds. Thus, growth period from stem elongation to maturity should be frost free (Weiss, 1983). There could be an interaction between high temperature and soil moisture and the shortage of the moisture exacerbating effects of high temperature. There could be an interaction between high temperature and high humidity resulting in reduction of seed yield (Zimmermann, 1978).

Safflower can be grown in soils with pH values between 5 to 8. For commercial production safflower highest yields can be obtained on fairly deep, well drained and somewhat sandy loams of neutral reaction. Irrespective of their fertility shallow soils seldom produce high yields and this is invariably due to insufficient moisture. Dense soils retards soil growth. Acid soil can increase possibility of attack by Fusarium root rot. The major production, in India, is on typical black cotton soils with the rest of the production being grown on loams and light alluvial soils under dry and irrigated conditions. The crop shows a good response to nitrogenous fertilizers. Excessive rainfall or humidity increases possibility from fungal diseases and water logging due to poor drainage, even for short periods of time, drastically reduces seed yield.

Safflower, mixed with another crop, is grown as a single rabi crop of the year, following the kharif cotton crop taken during the previous year and followed by the kharif jowar during the next year. On heavy soils it is taken after an early kharif crop such as green
gram, black gram, coriander or early groundnut. On lighter soils safflower is usually rotated with jowar, wheat, bajra or even rice.

d) Cultivation of safflower

Being an oil seed crop, it is grown with rabi crop like jowar, wheat, barley or gram. Because of its spiny nature it is also grown as a border crop to protect the main crops against cattle trespass. Three rows of safflower are planted after nine to twelve or more rows of main crop. For the production of dye it is cultivated as an entire crop.

i) Pre cultivation :

It is sown in October to November and harvested in March to April. Late varieties are harvested by the end of April. The land is ploughed once or twice after rains and the clods are crushed. Manure is applied as per the requirement of main crop.

ii) Sowing :-

Healthy, plump and improved seeds are selected. It is sown in moist soil at a depth of 3-5 cm in one to three rows 45 - 55 cm apart alternately with 6 to 12 or more rows of the main crop. Planking is necessary after sowing to ensure proper germination. The seed rate varies from 5 - 12 kg / hectare depending on soil fertility and the nature of the crop. Plants growing very close to each other have a tendency to develop thinner stem or a superficial root system and less number of flowers.

iii) After care :-

Interculturing is done two to three times at fortnightly intervals when the plant is 7.5 cm high. Pure crop is given one or two weeding on 20th and 45th day after sowing. An application of 20 to 45 kg of nitrogen per hectare results in a substantial increase in the yield. Mixed crop shares the preparatory tillage, manuring and cultivation given to the main crop. The young crop is nipped at the top after two months which encourages
branching which is meant for inducing more flowering which results in greater 
production of seed.

iv) Harvesting :-

The safflower crop ripens in 110 to 120 days after sowing. The crop is harvested after 
the main crop by pulling out the plant when there is dew on the drop.

v) Yield :

Average yield of seed for entire crop is 200 - 300 kg per acre while that of the mixed 
crop is 50 kg per acre. An irrigated crop to which 5000 kg of manure is added yields 
750 - 1000 kg of seed per acre. The oil content of seed varies from 20 - 30 %. 41 kg of 
seed yields about 8 kg of oil, 14 kg oil cake and 19 kg husk.

e) Morphology :-

Safflower is highly branched, herbaceous, annual, varying in height from 30 - 60 cm in 
dwarf types and 90 - 150 cm in tall types. It has fleshy trap roots producing thin 
horizontal laterals. The stem is stiff, cylindrical, smooth, glabrous, grey, green to white 
in colour. The stem has fine longitudinal grooves and becomes brittle when mature. 
The leaves are alternate, large, lanceolate, deeply serrated on lower stem. The lower 
leaves are spineless while upper leaves have spiny tips. The leaf size and shape varies 
between varieties from 2.5 - 5.0 cm broad and 10 - 15 cm long.

The inflorescence consists of numerous florets collected together on flattened 
receptacle which is covered by several layers of involucral bracts, outer ring being 
heavily spined. It protects the developing inflorescence. Individual florets have bracts 
in form of hairs. Flowers are yellow to orange red. Each capitulum contains 100 florets, 
outer sterile ray florets and inner fertile bisexual disc florets. Pollination is carried out by
honey bees at the time of flowering. The fruit is achene. The fruits are smooth, angular, glabrous, obovoid truncate at the top with four bosses. The number of seeds per capitulum varies from 18 - 23.

f) Varieties under cultivation:-

Safflower plants are grouped into two broad varieties - those having spiny leaves and those with spineless or sparingly spiny leaves. The spiny varieties are oil yielding forms having yellow flowers while the spineless varieties are the dye yielding types having orange flowers or yellow flowers tinged with scarlet.

Various varieties recommended for different states of India are as follows (Rajan, 1974):-

<table>
<thead>
<tr>
<th>State</th>
<th>Improved variety</th>
</tr>
</thead>
<tbody>
<tr>
<td>Andhra Pradesh</td>
<td>'7-13-3'</td>
</tr>
<tr>
<td>Gujarat</td>
<td>'N.62-3'</td>
</tr>
<tr>
<td>Haryana</td>
<td>'A 300', 'N. 62-8'</td>
</tr>
<tr>
<td>Karnataka</td>
<td>'17-3-3'</td>
</tr>
<tr>
<td>Madhya Pradesh</td>
<td>N. 62-8'</td>
</tr>
<tr>
<td>Maharashtra</td>
<td>'N. 62-8', '116-42'</td>
</tr>
<tr>
<td>Rajasthan</td>
<td>'A. 300', 'N. 62-8'</td>
</tr>
<tr>
<td>Tamil Nadu</td>
<td>'K 1', '6503'</td>
</tr>
<tr>
<td>Uttar Pradesh (Eastern)</td>
<td>'S 2-27', 'N. 62-8', '6503'</td>
</tr>
<tr>
<td>West Bengal</td>
<td>'N. 62-8'</td>
</tr>
</tbody>
</table>
Some promising varieties of safflower along with days for maturity, yield and oil content are given in the table below:

<table>
<thead>
<tr>
<th>State</th>
<th>Variety</th>
<th>Days to maturity</th>
<th>Yield (kg per hectare)</th>
<th>Oil content</th>
</tr>
</thead>
<tbody>
<tr>
<td>Andhra Pradesh</td>
<td>'Manjra' (C 438)</td>
<td>110</td>
<td>1200</td>
<td>32.0 %</td>
</tr>
<tr>
<td>Karnataka</td>
<td>'A - 1'</td>
<td>125</td>
<td>800 - 850</td>
<td>30.8 %</td>
</tr>
<tr>
<td></td>
<td>'A - 300'</td>
<td>125</td>
<td>750 - 800</td>
<td>31.9 %</td>
</tr>
<tr>
<td>Madhya Pradesh</td>
<td>'N0, 7'</td>
<td>140</td>
<td>700 - 850</td>
<td>30.3 %</td>
</tr>
<tr>
<td>Maharashtra</td>
<td>'Tara'</td>
<td>120 - 125</td>
<td>1200 - 1400</td>
<td>32.5 %</td>
</tr>
<tr>
<td></td>
<td>'N. 62-8'</td>
<td>130 - 135</td>
<td>1400 - 1600</td>
<td>30.0 %</td>
</tr>
<tr>
<td></td>
<td>'Bhima'</td>
<td>110-120</td>
<td>1400 - 1500</td>
<td>30.0 %</td>
</tr>
<tr>
<td></td>
<td>'Nag-7'</td>
<td>135 - 140</td>
<td>1000 - 1250</td>
<td>30.0 %</td>
</tr>
<tr>
<td>Tamil Nadu</td>
<td>'K- 1'</td>
<td>120</td>
<td>600 - 800</td>
<td>30.5 %</td>
</tr>
</tbody>
</table>

'Bhima' is the second highest yielding variety and is recommended for cultivation in Ahmednagar, Pune, Sangli, Satara, Solapur districts and Marathwada regions.

g) Economic importance

Safflower crop is an economically important crop since many centuries. It yields the following commercial products such as safflower oil, safflower dye, oil cake, green vegetable, fodder, medicinal uses and other uses.
i) Safflower oil :-

Safflower oil is an important industrial product. It is cultivated for edible oil obtained from its seed. It contains higher percentage of essential unsaturated fatty acids and a lower percentage of saturated fatty acids than other vegetable seed oils. The oil is light coloured and easily clarified. Safflower oil lowers blood cholesterol levels and is used to treat heart diseases. The highest yielding variety is Tara and Bhima yields 30 %. The oil content of the seed depends on the nature of the soil and climate. The component fatty acids of oil are myristic acid (with lauric and lower acids) 1.5%, palmitic 3.0%, stearic 1.0%, arachidic 0.5%, oleic 33.0% and linoleic acid 61.8%.

The safflower oil is mainly used for culinary purpose, burning of lamps and manufacture of soap. It is used as an adulterant of sesame oil and ghee. It is an ingredient of macassr hair oil. The ‘sweet oil’ of Mumbai is obtained by crushing groundnut, sesame and safflower seeds. Under certain conditions the oil develops an unpleasant flavour which is corrected by using extract of turmeric, clove, nutmeg fruit, pepper, red chillies, cinnamon leaves, betel leaves and dry ginger. It is used in paints, varnishes and linoleum. A gelatinous roghan is prepared by heating the safflower oil to high temperature of 150 °C for two hours and then pouring into cold water. This product is used as glass cement and is a substitute for plaster of Paris. The safflower oil is also used for making waterproof cloth.

ii) Safflower dye :-

The florets contain two colouring materials, carthamidin, cartharmin and iso-carthmin, of which carthamidin is yellow and water soluble while cartharmin is orange-red dye, insoluble in water, but soluble in alkaline solution. Cartharmin is found in florets and
ranges from 0.3 - 0.6 % and imparts bright red colour to cotton and silk fabrics. The yellow colouring matter is present in the range of 26 - 36 % in the florets. Safflower dye is used in India to dye clothing used for ceremonial purposes, toys, cosmetics, artificial decorations, food and confectionery, etc. Along with starch and talc it is used for preparing rouge.

iii) Safflower cake :-

The oil cake obtained from decorticated seeds is used as cattle feed while the cake obtained from un-decorticated seeds is used as manure. The oil cake contains fats, proteins, carbohydrates, fibres, ash, nitrogen, potash and phosphoric acid. If used as an organic fertilizer, it improves the physical condition of heavy soils. The cake from decorticated seeds is fed to lambs and poultry.

iv) Green vegetable :-

The tender shoots of the plant are eaten as pot herb and salad. Young leaves contain iron and carotene.

v) Fodder :-

The green safflower yields a fodder of 20 tonnes per acre, which is relished by cattle. Fresh safflower hay, cut before flowering, is relished by sheep. Safflower is also made into silage and fed to hogs in foreign countries.

vi) Medicinal uses :-

Safflower is used as a folk medicine for treating various diseases especially inflammatory tumours of the liver (Hartwell, 1967-1971). Flowers are diaphoretic, emmenagogue, laxative, sedative, stimulant, and in large doses laxative; used as a substitute for adulterant for saffron, in treating measles, scarlatina and other exanthematous diseases. Charred safflower oil is used for rheumatism and sores; seeds, diuretic and tonic (C.S.I.R. 1948-1976). In China, it is prescribed as uterne
astringent in dysmenorrhea (Keys, 1976). In Iran, the oil is used as a salve for sprains and rheumatism. (James A. Duke 1984, Handbook of Energy crops unpublished updated on 9.8.97)

The dye obtained from the flower is also used as a cathartic, antioxidant, anti-inflammatory, analgesic, anticonvulsant, antithrombosis and diuretic (Verma et al., 1997).

vii) Other uses :-

It is suggested that hull may be used in the manufacture of cellulose, insulation, abrasives, etc. The seeds are eaten by several wild birds, fowls, parrots, pheasants and turkeys. Seeds, both edible and nutritious, are eaten roasted or fried and used in chutney in India. A brew made from foliage is said to prevent abortion. Powder of dried safflower leaves is used for curdling milk (Weiss, 1983).

B) SCOPE OF THE PRESENT INVESTIGATION AND WORK DONE ON SAFFLOWER UNDER SALINE CONDITIONS.

According to Ghorashy et al. 1972, in three varieties ‘Ute’, Iranian local 3151 and Iranian local 2811 of safflower, germination reduced with increasing salinity from 0 to 1 % NaCl. However, Iranian local 3151 showed least reduction in percent germination as compared with the other two of NaCl concentrations greater than 1 %. Francois and Bernstein (1964), observed that yield decline of safflower was 10 % at 7 mmhos per cm and 20 - 25 % at 11 mmhos per cm, thus, categorising safflower under tolerant group.

Salt tolerance during germination was half that of later stages of growth. According to Yermanos et al. (1964), soil salinity depressed oil content, seed weight, protein content in seed which contributed to total yield of the tertiary heads. It increased percent hull
content of the seed but did not affect the fatty acid composition of the oil. These results indicated varietal difference in salt tolerance capacity of safflower. Iyengar et al. (1977) observed that, in safflower, plumule growth was more affected than radicle, when subjected to various dilutions of sea water during germination stage.

Darra et al. (1978) reported that safflower, when treated with NaCl, Na₂SO₄ and CaCl₂ 2:1:1 ratio gave 100% germination up to 12.0 mmhos/cm and at 16.0 mmhos/cm germination, percentage was reduced by 10% and at 25.0 mmhos/cm germination percentage was reduced by 90.0%. These observations are similar to those given by Francois and Bernstein (1964). Similar results were given by Janardhan et al. (1986), where the reduction in yield in safflower ranged from 0.2 to 31.4 % at 8 mmhos/cm and 9.1 to 68.1% at 12 mmhos/cm. Also, they reported that the varieties (A-300, 7-13-3, US-10) of safflower which exhibited less reduction in yield under saline conditions accumulated relatively lower amounts of Na and maintained higher K and higher K:Na ratios in leaves. The yield reduction of safflower under salinity is caused by a decrease in number of heads and yield of seed per head, the latter being affected by seed weight and not by seed number (Francois and Bernstein, 1964, Yemonas et al., 1964). Based on the observations of Mass and Hoffmann (1977) and Bresler et al. (1982), safflower was categorised under moderately salt tolerant plant with salinity threshold at ECe of 6.5 mmhos/cm and 50% reduction at ECe 12.0 mScm⁻¹.

According to Nieman et al. (1988), when Carthamus tinctorius L. Cv. Gila was subjected to salt stress (51.0 mol m⁻³ NaCl plus 25.5 mol m⁻³ CaCl₂) and analysed for nucleotide by HPLC, it was found that safflower had switched to flower bud formation and salt stress reduced fresh shoot yield by half. Salt also reduced ATP pool and ATP/ADP ratios in source leaves. It had little or no effect on ATP or other nucleotide
pools in safflower buds. The UDPG pool was not affected in source leaves of safflower buds. Salt stress had little or no effect on UDPG, hexose or ester phosphate in source leaves or buds. Stress did not affect assimilation of photosynthate in more tolerant safflower. Irving et al. (1988), reported that increasing salinity in irrigation water decreased seed yield, plant height, oil content and increased growth rate in salt stressed plants. Fatty acid composition of high linoleate safflower oil was not altered with increasing salinity. Fatty acid composition was altered in the high oleate cultivar, resulting in depressed oleic acid content in the oil. Cl, Ca and Na increased while P and Mg decreased in leaf tissues with increasing salinity levels.

According to Goswami et al. (1978) variety Nagpur-7 proved to be highly salt tolerant followed by 319-12 at higher levels of salt content. The germination percentage of Nagpur-7 was 53.3% at (20 mmhos/cm) while N-62-8 and safflower 6503 were found to be least salt tolerant and were of 23.3% and 25% respectively at salinity level of 20 mmhos/cm. Results of Kole and Gupta (1982) revealed that high concentration of NaCl (50 and 200 mM) inhibited germination percent, shoot / root length, whereas, low concentrations (5 mM) promoted same in safflower Cv. N-140. Soluble carbohydrates decreased at 200 mM and increased at 5 mM in embryo axis and cotyledons and amino acids increased significantly. Nakhlawy and Fawal (1989) indicated that growth of safflower seedlings was affected severely by NaCl than Na2SO4.

Application of saline water of electrical conductivity 4, 8, 12, 16 and 24 ds/m reduced seed yield by 9, 25.4, 34.6 and 45.0 % in vertic ustochrept soil and by 2.8, 6.2, 11.8, 23.7 and 37.8 % in Fluventic Eutrochrept soil with significant yield reduction with 8 ds/m in 'Bhima' Cv. of safflower (Carthamus tinctorius L.) (Singh et al., 1995).
From all these above mentioned references, it is clear that work done on safflower under saline conditions is scanty or meagre. This fact prompted us to select work on physiological studies in safflower Cv. Bhima under saline conditions. Cultivar Bhima is a recent promising cultivar. This cultivar is recommended for the state of Maharashtra. More than 7.5 million hectares of land is saline in India. In the state of Maharashtra, about 60,000 hectares of land has gone out of cultivation due to salinity (Abroal, 1984). Major saline lands of Maharashtra have become salty either due to NaCl or Na₂SO₄ or both. Therefore, it was proposed to study effect of chloride and sulphate salinizations on growth and yield of safflower Cv. Bhima. In order to explain adaptations to salinity, several physiological processes such as mineral nutrition, organic metabolism, photosynthesis, photosynthetic and oxidative enzymes and protein profile were proposed to investigate under saline and control conditions with the hope that such studies will be useful in choosing cultivars by farmers to grow under saline conditions as well as it will be useful in understanding adaptive mechanisms in Cv. Bhima of safflower in response to NaCl and Na₂SO₄ salinizations.