CHAPTER–I

REVIEW OF LITERATURE

SAFFLOWER : A REVIEW

A) General Account of Safflower

i) Introduction :

Among the oil seed crops, Safflower (Carthamus tinctorius L.) occupies middle position in the cultivation. Besides India, U.S.A., Mexico, Ethiopia, Spain, USSR and Australia are the safflower growing countries. The safflower is cultivated for various purposes such as food, fodder, oil and dyes. This crop has been grossly neglected in India and its cultivation is confined to marginal lands of either assured rain fall or drought prone areas, purely under rain-fed conditions with no fertilizers and plant protection measures. The crop is grown in rabi season despite its reputation of being a drought tolerant and hardy crop. However, it gives good response to irrigation, nutrients and management. The crop is fairly resistant to saline conditions in India. Many plant breeders and physiologists are working to improve the quality of this crop.

Safflower has been recognised as a crop of economic importance since many centuries as it is a source of oil, food, fodder and dyes. The safflower is known by different names in different languages :

Sanskrit - Kusumbha, Arabian - Kurtum, Persian - Kazhirah, Hindi - Kusum or Barre, Bengali - Kusum, Kusumphuli,

Gujarathi - Kusumbo, Marathi - Kardai, Kurdi, Tamil - Sendurakam, Telugu - Kushumba or Kusuma, Kannada - Kusumbe, Punjabi - Kasumba, Sindhi - Pavani, Oriya - Kusum and in Assamese - Jafran(Watt, ✓ 1908).

Now-a-days in the wake of a shortage of vegetable oil seed production in India, it is heartening that renewed interest is being shown in this crop especially in irrigated safflower. It is very well realized that the safflower is more stable, productive and profitable than any other irrigated rabi crop. Therefore to understanding physiology, of this crop is not only a pre-requisite for plant breeder to develop a promising variety, but also for an agronomist to examine the performance during cultivation.

ii) Origin and History :

The cultivated forms of safflower are supposed to have originated either from Carthamus lanatus Linn. (Saffron thistle) or Carthamus oxyacantha, Bieb. (wild safflower). In India, the cultivation of safflower in ancient either for its dye or oil. Originally the dye was the main reason for its cultivation, but the introduction of cheap aniline dyes have replaced the natural product and this industry is greatly affected. The crop is now grown for its oil, although a small amount of dye is still produced.

Vavilov (1951) has suggested three centres of origin for safflower. These are - i) India 2) Irano Afghanistan,

3) Ethiopia. This also supports the view of Kupsow (1932). De Candolle (1890) is of the opinion that the undoubted ancient cultivation had been established for both India and Africa. Probably Carthamus tinctorius might be found wild in the intermediate country Arabia. In China, safflower (Hung-hua or red flower) was introduced in the second century B.C. (CF. Breitschneider, 1870). According to Beech (1969) the primary centres of origin are Abyssinia and Afghanistan.

iii) Distribution :

The cultivation of safflower is spread over various parts of the world from tropics to temperate zones. It extends from India, China, and East Indies to Persia, Caucasus, Egypt, Italy, Germany and Spain. It was lately introduced in Australia and U.S.A. Now-a-days besides India, the important safflower growing countries are U.S.A., Mexico, Ethiopia, Spain, USSR and Australia. India is the largest safflower producer and grows well over 75 per cent of the total world acerage.

iv) Area and Production :

In India, the major safflower production is found in the states of Maharashtra (about 64.4%), Karnataka (26%), and Andhra Pradesh (8%). It is also cultivated in Madhya Pradesh, Tamil nadu and Bihar. However Maharashtra ranks first in India both in area (77%) and production (72 %) of safflower. The total area, production and average yield of

Table 1 : Total area, total production and average yield of oil seed crops in Maharashtra and India (1978-79 to 1983-84)

Year	Maharashtra			India		
	Area	Production	Yield	Area	Production	Yield
1978-79	18.34	7.85	428	177.08	101.00	570
1979-80	18.59	8.93	480	169.41	87.39	516
1980-81	19.67	10.05	511	176.02	93.72	532
1981-82	20.50	12.28	599	190.55	121.94	640
1982-83	19.97	10.60	531	177.55	99.95	560
1983-84	22.47	14.30	636	186.95	128.14	685

Area = Lakh Hectares, Production = Lakh tonnes, Yield = Kilograms/hectare.

Table 2 : Area, production and yield of different oil seed crops in Maharashtra and India (1983-84).

Crop	Maharashtra			India		
	Area	Production	Yield	Area	Production	Yield
Groundnut	6.13	5.26	859	-	-	-
Sesamum	2.05	0.51	249	21.8	6.2	284
Rapeseed	0.06	0.02	379	38.9	25.6	658
Sunflower	3.00	1.09	364	6.7	2.7	403
Niger	0.95	0.20	213	6.0	1.8	300
Linseed	2.57	0.65	258	14.7	4.4	299
Safflower	5.68	3.73	657	8.0	4.7	587
Others	0.06	0.03	-	14.5	9.9	-
Total oil seeds	22.47	14.30	636	186.95	128.1	685

Area = Lakh hectares, Production = Lakh million tonnes, Yield = Kilograms/hectare.

Table 3 : Area, production and yield of different oil seed crops in India (1980-81 and 1984-85)

Crop	Area		Production		Yield	
	1980-81	1984-85	1980-81	1984-85	1980-81	1984-85
Groundnut	6801	7754	5006	6744	736	870
Rapeseed	4113	4403	2304	3030	560	686
Sesamum	2472	2156	446	525	180	243
Niger	599	572	146	147	244	257
Sunflower	199	689	66	365	555	529
Castor	498	674	204	469	411	696
Linseed	1673	1546	423	388	253	251
Soyabean	608	1192	442	934	728	783
Safflower	720	870	335	497	465	572

Area = Thousand hectares, Production = Hundred million tonnes,

Yield = Kilograms/hectare.

oil seed crops of Maharashtra during the year 1983-84 was 22.47 lakh hectares, 14.30 lakh tonnes and 636 kg/ha respectively (See Table 1). The total area, production and yield of safflower during the same year in Maharashtra was 5.68 lakh hectares, 3.73 lakh tonnes and 657 kg/ha. respectively (See Table 2). The rate of productivity of safflower in Maharashtra is higher (657 kg/ha) as compared to average productivity rate in India (527 kg/ha.) during the year 1983-84. In India this rate is very slow as compared with other countries. The area, production and yield of different oil seed crops in the year 1980-81 and 1984-85 is depicted in Table 3. As compared to different oil seed crops, the area, production and yield of safflower has increased considerably in the year 1984-85 than the year 1980-81.

It is grown mainly on neglected land and in two agro-climatic zones viz. scarcity zone having rainfall below 700 mm and assured rainfall zone having rainfall from 700 to 900 mm. It is mainly grown in Ahmednagar, Aurangbad, Sholapur, Pune, Satara, Bhir, Osmanabad, Parabhani and Buldhana districts of Maharashtra.

v) Cultivation Practices :

Safflower is mainly grown in India for its oil. It is cultivated as a rainfed as well as irrigated crop. It is mostly grown with wheat, barley, gram and rabi jowar as three rows of safflower after every nine, twelve or more rows of

main crop. Sometimes due to its spiny nature, it is sown as border rows to protect the crops of wheat, rabi jowar etc. from cattle trespass. Occasionally it is grown as a second crop after early maturing Kharif crop e.g. green gram (moong); black gram (Mash), groundnut, coriander etc. According to Veeranna et al., (1980) and Nikam et al., (1985) hybrid jowar in kharif followed by safflower in rabi is profitable under rainfed conditions. However, Veeranna et al., (1977) and Ranga Rao (1982) suggested to include a legume crop in this rotation which improves soil productivity and nitrogen economy. Recently Nikam et al., (1987) concluded, after a two years field study, that safflower suppressed intercropping. But a practice of sole cropping of chickpea with 'Bhima' a safflower variety in a ratio of 3:1 gives maximum monetary returns (Rs. 8265/ha.).

a) Soil :

Being a drought resistant crop safflower can be grown on various types of soils. Generally well drained deep ploughed and fertile soil with a firm sub soil (pH - 7) is used. Any soil will be suitable for its cultivation if irrigation facilities are available. The clay soil is used in dry land under irrigation. In California residual moisture in rice growing clay soil is used for safflower, while medium textured soil used for surface irrigation. Shallow soil is not beneficial. The saline soil and basic or acidic soil are not useful

to safflower (Scheibe, 1939). The soil containing lime is beneficial (Rabak, 1935). On heavy soil it may be followed an early kharif crop such as green gram, black gram, coriander or early groundnut. On lighter soil, it is taken as entirely irrigated crop rotated with jowar, wheat, bajara or even rice (Aiyer and Yegnanarayan, 1944). Soil rich in nitrogen gives only profuse vegetative growth.

b) Climate :

The safflower is mainly grown during rabi, primarily as a rainfed crop. In some areas it is raised under irrigation, but does not favour extremes of either heat or cold. The excess of rain fall or humidity causes fungal diseases. Waterlogging causes substantial fall in seed-yield. Heavy rain during flowering seriously affects pollination and the rain after flowering may discolour the seed and reduces oil content. Eventhough it is a drought resistant crop, it require adequate amount of moisture during sowing period. The soil temperature is also important as it must be between 5°C to 16°C (Scheibe, 1939). Morey et al., (1984) studied cultivation practices for ten years and they concluded that the base temperature needed for safflower is 6°C.

c) Land preparation :

The land is prepared according to the requirements of the main rabi crop. One or two ploughings after rains,

followed by crushing, removal of stubbles, and then repeated harrowing during early rains for the conservation of moisture and removal of weeds are done prior to sowing. Generally a firm subsoil with moisture at about 2.5 cm below the free soil surface is the best under rainfed conditions. According to Deshmukh (1988) one deep ploughing and two harrowings should be done on 90 cm wide ridge furrow system or flat beds.

d) Sowing :

The seed rate, sowing method and sowing period are very important so far the yield is concerned in safflower. In India safflower is sown in September and October, however the late or early sowing reduces the yield considerably. This sowing period also varies with country. In East Pakistan first week of November is the best sowing period (Rahman et al., 1969). In northern California sowing is done in early February, but under rainfed conditions planting is done in early April. In Western plains and near Canadian region, the sowing in early spring is favoured (Claassen and Hoffman, 1950). The spacing is very important in safflower. Generally seeds are drilled in closely spaced rows than broadcasting. According to Sheelvantar et al. (1978) 30 cm space gives higher yield. But recently Deshmukh (1988) showed that 45 cm spacing gives maximum yield in safflower var, NRS-209, while plant to plant spacing should be 20 cm.

The seed rate varies according to the nature of soil fertility and the nature of the crop (pure or mixed) and it is about 5-12 kg/ha.

e) Water requirement :

The scheduling of irrigation has been studied extensively (Randhawa et al.,1986). The pre-planting irrigation is necessary and depth of 5 cm is also important for higher yield (Dauley et al., 1975 and Veeranna et al.,1976). Eventhough safflower is grown as rainfed rabi crop, it requires atleast 3 irrigations (Deshmukh, 1988)

First - Pre-planting

Second- 35 days after planting (early elongation stage)

Third - 65-70 days after planting (bud stage or flower initiation stage).

Sometimes four irrigations are given at Delhi and Rajasthan on light soil and two irrigation under wet and mild climate of Uttar Pradesh (Mahapatra and Singh, 1975). Recently Sondge et al., (1987) reported that two irrigation gives more yield. Generally 16 to 18 inches of available water needed for a satisfactory crop in California (Knowles and Miller, 1960). Stern (1965) calculated the evapotranspiration ratio (Et/Eo) of safflower which is 1.57 during elongation and 1.25 during elongation and flowering.

f) Fertilizer requirements :

The crop responds to various fertilizers but a fair good response is observed to nitrogen fertilizer to increase height, number of seeds per plant, seed weight, yield etc. (Jones and Tucker, 1968). The amount varies with cultivation practices. According to Mahapatra et al., (1975) safflower crop under irrigated area gives profitable yield with 60-80 Kg. N/ha.

The application of N with P_2O_5 is very effective in increasing the seed yield as well as total output of oil (Dhote and Ballal, 1964 and Werkhoven and Massantini, 1967). Under dry land conditions the safflower c.v. A-300 gave maximum yield of 402 Kg/ha with application of 20 Kg of N + 20 Kg. P_2O_5/ha (Ramanath et al., 1974). According to Kamel and Mohamed (1973) the application of NPK shows various effects as N reduces the oil content in seed while P and K applications increased it. But later on Rahman et al., (1978) studied the effect of NPK and concluded that seed yield increases upto 624 g per pot with the application of 40 lb. N + 30 lb P_2O_5 + 30 lb K_2O per hectare. There is positive correlation between seed oil and carbohydrates while negative correlation between seed oil and protein.

g) Yield :

The yield of safflower depends on many factors. The

maturity period is 120 days which also differ with variety. Generally the average yield is 400-500 Kg/ha but in mixed crop it is 100 Kg/ha. The late planting decreases yield and oil content (Luebs et al., 1965). According to Stern and Beech (1965) the highest yield is obtained when the crop planted at the rate of 100 plants/m^2.

h) Crop Protection :

i) Diseases :

Safflower is known to suffer from a number of diseases e.g. rust, Cercospora leaf spot, Alternaria leaf spot, root rot and wilt. They cause considerable damage to the crop.

Safflower crop is reported to be attacked by three rusts viz. (i) Puccinia carthami (ii) Puccinia verruca and (iii) Aecidium carthami. The symptoms appear from January to March. This may be controlled by seed treatment with Agrosan G.N. or by burning infected parts or by growing disease resistant varieties. Singh (1986) reported that rust can be controlled by 3 sprays of 0.05 % tridemorph or 0.15 % thiophanate methyl or 0.1% triadimefon. Cercospora leaf spot caused by Cercospora carthamii is controlled by seed treatment with 2% copper sulphate or by spraying 1% Bordeaux mixture. Alternaria leaf spot caused by Alternaria carthami can be controlled by spraying Bordeaux mixture (4:4:50). Wilt of safflower caused by Sclerotinia sclerotiorum is serious under

high rainfall areas and it can be controlled by clean cultivation practices. Recently Diaz et al., (1985) reported that wilt of safflower is caused by Verticillium dahliae in Andalusia (Spain). Root rot of safflower caused by Phytophthora drechsleri can be controlled by growing disease resistant varieties.

ii) Pest :

Pests are more dangerous than the diseases and cause considerable losses and damage to safflower. Different safflower aphids were reported in India. According to Jagtap et al., (1985) safflower aphid 'Uroleucon carthami, H.R.L. is the most notorious pest causing loss in yield about 20-25% in Andhra Pradesh and 35% in Madhya Pradesh and complete loss in yield if no measures were taken in case of late sowing crop in November in Maharashtra. Pruthi and Bhatia (1940) recorded a maggot Acanthiophilus helianthii, Rossi on safflower. Aphid Macrostatum, Dactynolus corthami, H.R.L. is also a major pest of safflower in Maharashtra.

Recently Ghule et al., (1987) showed that sowing time affects aphid attack and yield. Rathore (1983) reported that late sowing safflower damaged more due to aphid attack. Jagtap et al., (1986) observed that aphid - 'Uroleucon carthami, H.R.L. preferred top plant parts of main stem and branches for their feeding and breeding.

Aphids can be controlled by sparying the crop with

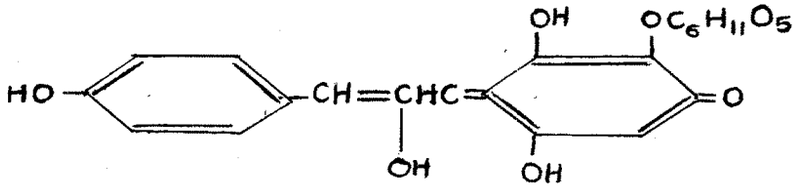
0.03 % Dimethoate, 0.03% Endrin, 0.04% Manazoan, 0.01% Fenithion, 0.05% Malathion, 0.05% Monocrotphon and 0.07% Endosulphon. However recently Pawar et al., (1987) have shown that 0.01 % cypermethrin was the most effective treatment for the control of safflower aphid. Naik et al., (1987) reported that aphid Uroleucon carthami, H.R.L. controlled by Carbofuran 35 STD. It was found suitable without adverse effect on germination and with a significant increase in the plant height and the number of leaves per plant.

vi) Economic Importance :

The safflower at present cultivated for oil, but in the past it was grown for the extraction of dye. Besides these safflower oil cake, vegetable, fodder and hull are also economically important. The seeds are used to manufacture the alkyd resin or eaten after roasting.

Safflower contains 24-36% oil which varies with variety and cultivation practices. The cold pressed oil is golden yellow and used for culinary purposes or for making soaps. The oil obtained by dry hot distillation is black and sticky used for coating ropes and leather goods exposed to water. Due to drying properties it is used for manufacturing paints, varnishes and linoleum. The safflower oil is mixed with white paint to reduce yellowing effect. Charred safflower oil is used for healing sores and in rheumatism.

Safflower dye is very important. The florets contain two colouring substances, a safflower yellow and Carthamin orange red pigment. According to Wada (1953) carthamin, a orange dye, is insoluble in water but soluble in alkaline solutions. Kametaka and Perkins (1910) first obtained Carthamin or Carthomic acid ($C_{21}H_{22}O_{11}$, H_2O, having mol.wt. 450.38, melting point 228° - 230°C) from the florets of safflower. The structural formula of it is as follows :



It is used for colouring clothes, for ceremonial purposes, toys, cosmetics, artificial decorations as well as food and confectionery. This dye is medically used as stimulant sedative and in large doses as laxative.

Safflower oil cake of decorticated seed is used as cattle feed, while undecorticated seed is used for manuring purposes. It is also used as organic fertilizer for improving the conditions of heavy soil. The protein value is high in both oil cakes.

The young seedlings of safflower are commonly sold as green vegetable. Safflower seed hull is used to manufacture cellulose, insulations, abrasives etc.

B) Physiological Studies in Safflower :

Crop physiologists have a greater role to play in fulfilling the world's demand for food than a general biologists, researching on crops have made more progress during the past decade. The physiological studies on safflower are very scanty as compared to other oilseed crops. Many scientists working on safflower are interested only on the cultivation practices and yield. Very few attempts have been made to grow the safflower under water stress conditions and salinity.

Seed germination of safflower was first studied by Tamhane (1923) and reported that upto radicle initiation there is no change in oil, proteins and nitrogen content of the seed. But in further development the oil disappears and nitrogen free extract increases, while non-reducing sugars gradually increase. The proteins are converted into soluble form during initiation of lateral roots. Dorozhkin and Blagodyr (1976) have shown that moisture content of 7.9% during storage affect seed germination. Leininger and Urie (1964) have reported that maximum percentage of germination attained in seed about 14 days after flowering. Sawant (1983) has reported chromatographycally that safflower seeds are richer in free amino acids such as aspargine, glycine, aspartate, glutamate and prolines, while cystein and methionine are produced in later stage of germination. Tamhane (1923) has shown that lipase activity increases very little in the early

stage but enhanced in later stages of germination i.e. plant is not dependent on oil in the early stages of germination and utilizes other materials present. Sawant (1983) studied the particular period of enzyme activation i.e. enzyme was very active till 4 days of germination. During this period of 96 hours possibly most of the reserve food (lipids) in the seeds is hydrolysed resulting in lowering the enzyme activity in the later stages due to lowering the substrate concentration. Germination under the effect of salinity was studied by Ghorashy et al. (1972), Goswami et al., (1978) and Jadhav (1985).

Narkhede et al., (1985) have studied different growth parameters in different 35 Indian and 20 exotic genotypes of safflower. The parameters include plant height, number of primary branches per plant, number of days of first flower, number of capitula per plant, number of seeds per capitulum, seed yield per plant, 1000 seed weight and hull content. Subbiah and Swaram (1965) have recommended nipping of the central shoot of safflower to induce branching and thereby increasing the number of inflorescences to increase the yield. Recently Ahmed et al., (1986) have reported that spraying of growth regulator (N,N-dimethylaminosuccinamic acid) after 15 to 16 days of sowing gives significant effect on plant height and number of heads per plant. The leaf area is the most important which denotes the photosynthetic area. Nar (1971) have given the different methods to determine leaf area in

safflower. The methods include 1) The Planimetric Method, 2) The Punch borer method and 3) The product of leaf length x breadth x factor. According to him the last two methods are simple, precise and less time consuming. Sepaskhan (1977) and Mehrotra et al., (1978) have reported the same method for leaf area determination.

According to Beech (1964) the defoliation from the base of irrigated safflower at the elongation stage, decreased seed yield and oil content. Urie et al., (1968) found that total defoliation reduces yield by 23%, 100 seed weight by 7.7%, test weight by 2.6 %, hull by 6% and oil by 6.9%. The leaf physiology was studied by Aslamy (1972) in two safflower varieties, cv. Rio and Pacific - 1, grown in a glass house and a growth chamber at TULSON (USA). The stomatal density was similar on abaxial and adaxial surface of the cotyledons in both cultivars. Stomata were denser on the abaxial surface of true leaves than on the adaxial surfaces, but differences between cultivars were not significant. Floral bracts of Pacific -1 had a higher stomatal density on both surfaces than those of cv. Rio. Stomatal density (SD) was always higher on the lower surface than the upper surface of bracts. Floral bracts of both cultivars contain more chlorophylls per unit fresh weight than true leaves. Leaves and bracts of Pacific -1 contain more chlorophylls than those of cv. Rio. The rate of CO_2 assimilation was similar in both cultivars during early vegetative growth, but significant differences were noted

between cultivars and between leaves and bracts at flowering. Floral bracts showed a higher rate of CO_2 assimilation than true leaves regardless of cultivars at flowering.

The seeds of safflower were studied by many physiologists. Applewhite (1966) studied the composition of safflower seed and found hull 40%, Oil 37 %, Meal 23 %, Linoleic acid type oils 78%, Oleic 11%, Stearic 3 %, and Palmitic 6%. Saunders (1970) reported that hull and kernal of safflower seed mainly consists of sucrose and raffinose. There were smaller amounts of D-glucose and D-fructose, galactions and other carbohydrate material which appeared to contain uronic acid, glucose, fructose and arabinose. Waliszewski (1987) have found the highest concentrations of poly unsaturated fatty acid in the safflower oil and also in their soapstocks (Generally soapstocks have lower values of poly unsaturated fatty acid than oils). Ahmed et al., (1988) have studied the effect of N,N-dimethylamino succinamic acid (Growth regulator)on biochemical changes in seed and reported the increase in the seed oil content and hydrocarbons in safflower seed. Leininger and Urie (1964) have studied the development of safflower seed from flowering to maturity and found that the maximum oil content in safflower seed after 28 days of flowering. Yermanos and Francois (1963) have shown that the seeds from primary branches possess the highest seed lot and the lowest oil content.

The mineral nutrition in safflower was also worked out by many workers. The majority of them have studied the effect of fertilizers on yield. The safflower gives good response to nitrogen because it increases height, number of seeds per head, number of heads per plant, seed weight, seed yield per head, head weight in secondary and tertiary heads but the oil content is little affected (Jones and Tucker, 1968). Ramchandram and Rao (1980) have studied the response of nitrogen on different growth parameters and found significant response during elongation and flower initiation. The application of nitrogen led to the translocation of reserve food materials from stem and leaves into fruiting parts during post flowering period. Yermanos et al., (1964) have shown that yield is increased due to nitrogen application but iodine value of oil content is depressed. Dhote and Ballal (1964) reported that application of nitrogen with P_2O_5 is very effective in increasing the seed yield and oil output.

The potassium deficiency resulted in reducing growth and development and exhibited visible symptoms of brown necrotic spots in the middle of leaves (Bisht et al., 1987). Sawant (1983) has studied sodium, potassium and potassium: sodium ratio in 4 cultivars of safflower and concluded that potassium is highly mobile cation which accumulates in the shoot while sodium accumulates in root as sodium is restricted in translocation. Werkhoven et al., (1966) reported that with the increase in levels of exchangeable sodium upto 30%

resulted in large increase in dry weight and the high level of sodium affect adversely seed yield and growth. Yermonas et al., (1964) showed the effect of iron chelates on seed oil content and iodine number and reported that application of iron chelate did not affect oil content and iodine numbers. The presence of fair amount of iron in young leaves was initially reported by Aykroyd (1951). Aslam (1975) studied the interrelations of sodium and potassium in growth of safflower. The increased potassium in solution culture, decrease calcium and magnesium content, while added sodium significantly increase magnesium content of stem and leaves but had no effect on calcium content (Yermonas et al., 1964).

Recently the effects of different micronurtients on safflower yield were studied. According to Sangale et al., (1981) foliar sprays of 0.2 % borax, 0.4 % ferrous sulphate, 0.5 % zinc sulphate to safflower at 60 and 90 days after sowing gave seed yields of 880, 753 and 695 Kg./ha, respectively against 765 Kg/ha. with two water sprays and 635 Kg/ha. untreated control. The seed yield can be increased with the application of foliar spray of manganese (Lewis and Mcfralane, 1986). Tavora (1973) has pointed out that under extreme sulphur deficiency reproductive yield was more restricted than vegetative yield. The seeds of tertiary head suffered more in protein content due to high or low sulphur level. It also increases aspartic acid in seed protein. Kurian and Iyengar (1972) showed that irrigation with sea water and

Hoagland solution in safflower reduced sodium uptake and increased the content of nitrogen, potassium and calcium in the plant.

The organic content of the safflower was studied in different plant parts. The organic matter (Chemical Composition) of seed was already discussed in the beginning of this chapter. The organic matters from the leaves were first studied by Aykroyd (1951) and reported the presence of appreciable amount of carotene, carbohydrates, protein, fats etc. The amount of soluble carbohydrates was investigated by Sahasrabuddhe (1921) in safflower and other vegetables. The nitrogen and proline contents was also studied by Sawant (1983). The chlorophylls are rich in safflower while chlorophyll 'a' and chlorophyll 'b' and their ratio signifies C_3 nature of safflower.

Eventhough safflower is a rainfed crop, the attempts were made to study the physiology of safflower under water deficit condition. Gupta et al., (1985) have shown the effect of change in water potential on the growth parameters of safflowers. Increased soil water stress caused more depression of safflower root growth than shoot growth as indicated by a linear increase in shoot : root ratio. However, relative plant height and leaf area of safflower remained almost unaffected upto - 3 bars soil water stress and then declined rapidly. While relative dry weight of root and shoot decreased rapidly from field capacity moisture content (- 0.3 bar) to - 6 bars

caused a slow decrease. Seydlitz (1962) reported that drought (30 % of the capillary potentials) during emergence to the foliar rosette stage did not adversely affect growth and yield of safflower. While drought during rapid growth hindered growth and further prolonged drought adversely affect ripening which reduces yield and percentage of oil and vegetative grwoth period. The comparative study of commercial safflower (Carthamus tinctorius L.) and wild ecotype (Carthamus oxycantha), by Bassiri et al., (1977) under the effect of artificial drought (Polyethylene glycol 6000 mannitol), showed that increase in osmotic potential progressively delayed and reduced seed germination, shoot length and fresh and dry weight of seedlings. They further reported that shoots were more adverasely affected than roots, in contrast to recent view of Gupta et al., (1985). Zimmermann (1972) studied the effect of temperature and humidity stress during flowering in glass house experiment with three safflower varieties and reported that heads were more sensitive to temperature during and before anthesis, while at low humidity seed yield decreased. Sawant (1983) showed that water stress induces stomatal closure during day time except 10.00 to 11.00 a.m. The chlorophyll content and chlorophyll 'a' to chlorophyll 'b' ratio reduced, except in Tara variety, under water deficit conditions. The proline content increases with severe water stress.

The attempts have been made to study the salt tolerance in safflower. Salt tolerance of safflower varieties during

germination was studied by Ghorashy et al., (1972), Goswami et al., (1978) and Jadhav (1985).Francois and Bernstein (1964) recorded that increasing salinity reduced seed yields by decreasing the number of heads and weight of individual seeds, however they have particularly studied the decline in yield by 10% and only 20-25% at 7 mm hos/cm, 11 mm hos/cm respectively and thus categorising safflower under tolerant group. Mass and Hoffmann (1977), Bresler et al., (1982), Janardhan et al., (1986) categorised safflower under moderately salt tolerant plant. Safflower is salt tolerant particularly during later stage of growth. Kurian and Iyengar (1972) reported that the seedlings of safflower irrigated with sea water reduce plant height, number of leaves per plants, seed yield, and 100 seed weight, but did not significantly affect the seed oil content. It reduced sodium uptake and increases potassium, nitrogen and calcium content in plant. Tesu et al., (1975) have grown safflower in various soils with salinities ranging from 26.33 to 639.33 mg salts per 100 g soil and found that yield decreased with increasing salinity. The seed germination was reduced with 0.2 % NaCl in three cultivars of safflower (Ghorashy et al., 1972). The four cultivars of safflower showed 100 % germination at salt concentration upto 6 mm hos/cm and the germination percentage decreased with increasing salt concentration (Rai, 1977 and Goswami et al., 1978).

Kole and Gupta (1982) reported that low concentration of NaCl (5 mM) promotes shoot:root ratio, while further

increase in NaCl reduced germination and shoot:root ratio (Jadhav, 1985). Janardhan et al., (1986) showed that the yield decline per unit increase in salinity by 3.81 per cent in safflower. The reduction in yield was mainly due to decrease in number of heads on secondary branches, 100 seed weight and seed yield per head. Comparatively low accumulation of sodium and relatively high contents of potassium in the leaves was associated with salt tolerance of safflower.

The photosynthesis under saline condition in safflower was studied by some workers. Ahmed et al., (1977) reported that pigment content and photosynthetic activity increased with NaCl concentration, however at higher concentration it declines. Radioactive carbon tracing technique indicated that at high salinity level, carbon was incorporated into malic acid at the expense of aspartic acid; more carbon was incorporated in organic acids than in amino acids. Devi et al., (1980) reported that $^{14}CO_2$ incorporation was higher in the treated plants than control because of sodium which increases the metabolic activity of plant.

C) Scope of the present Investigation :

Generally crops are studied with respect to their productivity which mainly depends upon the physiological aspects of the crop. A number of oil seed crops have been investigated for their physiological behaviour. There are reports of Woodman (1945) in ground nut, Howard and Khan

(1924) in soyabean, linseed, Krishnamurthy et al., (1960) and Brar (1980) in sesamum, Pasha and Salehuzeaman (1978) in niger seed, Elmore and Paul (1980) in cotton seed and Magdum (1984) in sunflower. However, the safflower though an important oil seed crop, its physiology is not studied well as compared to other oil seed crops. In the present investigation an attempt has been made to study the different growth parameters, inorganic constituents like sodium, potassium, calcium, magnesium, iron, copper, zinc, manganese and chloride, organic constituents such as moisture, TAN, polyphenols, chlorophylls, carotenoids and the activity of some enzymes like peroxidase and acid phosphatase. In addition to this, the effect of water stress and sodium chloride on the physiology of safflower is also attempted in the two cultivars of safflower as Local and JLSF - 88 which are obtained from Oil seed specialist, Agricultural Research Station, Jalgaon (Maharashtra), were selected for the present investigation.