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Safflower (*Carthamus tinctorius* L.) the Underutilized and Neglected Crop: A Review

V. Emongor
Department of Crop Science and Production, Botswana College of Agriculture,
Private Bag 0027, Gaborone, Botswana

Abstract: Safflower (*Carthamus tintorius* L.) belongs to the family Compositae or Asteracea. It's a multipurpose oilseed crop grown mainly for its high quality edible oil and bird seed. Initially safflower oil was used as a source of oil for the paint industry, now its edible oil is used for cooking, making margarine and salad oil. Safflower is also grown for its flowers which are used as cut flowers, colouring and flavouring foods, making dyes for the textile industry, livestock forage, vegetable, making herbal teas and medicinal purposes. In China safflower is grown as a medicinal plant for the treatment of cardiovascular diseases, male and female sterility, lowering blood cholesterol, release of retained placenta and still birth, induction of labour in expectant women, delayed, heavy and painful menstrual periods, various types of rheumatism (sciatica, thorax, arthritis), respiratory diseases (whooping cough, chronic bronchitis), gastritis, etc. Despite the many uses of safflower, it has remained a minor crop. Therefore, it is essential for the scientific community to carry out research on this crop and popularize it as a commercial crop for development of pharmaceuticals, edible oil, paint and varnishes industry, dye extraction (carthamin), source of α-tocopherol, livestock feed, vegetable and cut flower.

Key words: Safflower, oilseed crop, cut flower, medicinal plant, food colouring, dye plant

INTRODUCTION

Safflower (*Carthamus tinctorius* L.) is commonly known as kusum in India and Pakistan and honghua (red flower) in China (Chavan, 1961). Its use as a less costly saffron is indicated by the names false saffron, bastard saffron, thistle saffron and dyer's saffron (Weiss, 1983). The common names of safflower vary with country, region, language and use (Chavan, 1961; Smith, 1996).

Safflower is one of humanity's oldest crops, with its use in China reported over 2,200 years ago. Safflower seeds are reported in Egyptian tombs over 4,000 years ago. However, safflower cultivation remained a backyard crop for personal use and as a result it remained a minor and neglected crop with world seed production in 1989 estimated at 908,000 tons (Rowland, 1993). Safflower oil has been produced commercially and for export more than 50 years ago (Dajue and Mundel, 1996). Crop is also now grown commercially as a cut flower, vegetable and medicinal plant. India is the main safflower producer (Ekin, 2005). The other producing countries of safflower are USA, Mexico, Ethiopia, Argentina, Australia, China, Kenya, Canada, Spain, Italy, Turkey, Iraq, Iran, Morocco and Russia (Dajue and Mundel, 1996). Safflower has great potential to be developed as an important oilseed crop, cut flower, medicinal plant, vegetable and animal feed. Therefore, the objective of this manuscript is to create awareness of the potential of safflower so that the international scientific community should research on the agronomy, physiology, ecophysiology, high yielding varieties and hydrids with high oil seed content and clinical and pharmacological trials to elucidate the effectiveness of safflower in the treatment or prevention of cardiovascular diseases such as hypertension, inhibition of thrombus formation and dissolving thrombi, lowering blood cholesterol, male sterility and dead sperm excess disease, infertility in women, etc.

Botany of safflower: Safflower belongs to the family Compositae or Asteraceae, genus *Carthamus*. The cultivated *Carthamus tinctorius* L has a chromosome number of 2n = 24 (Knowles, 1989; Lopez, 1989; Ekin, 2005). Safflower is a branching, thistle-like herbaceous annual or winter annual plant, with numerous spines on leaves and bracts (Fig. 1), mainly grown in dry hot climates as an oil seed, birdseed or for its flowers, used as dyes and for medicinal purposes. Safflower plant can grow to a height of 30-200 cm tall with globular flower heads, bright yellow, orange or red flowers. It has a strong tap root that can grow to a depth of 2-3 m, enabling it to thrive under dry climates. Safflower is also grown in regions where rainfall is high and under greenhouse production as a cut flower or vegetable. It can be grown in altitudes ranging from sea level to 2000 m above sea level provided frost does not occur during the elongation and flowering stages plant growth and development in the high altitudes.

Fig. 1: *Carthamus tinctorius* L. showing the branching, flower heads and open flowers

Fig. 2: *Carthamus tinctorius* L. at the start of the elongation phase

Fig. 3: *Carthamus tintorius* L. 1 week after start of elongation phase

Figure 2 to 7 show the different stages of growth and development of *Carthamus tintorius* L. (safflower). The white achenes (seeds) weigh on average between 0.031 to 0.0589 g, are smooth and four sided, with a thick pericarp (Fig. 8). Arslan (2007) reported a seed weight of between 0.3767 to 0.444 g. Dajue and Mundel (1996) reported safllower seed weight of between 0.030 to 0.045 g. Germination takes 3-8 days depending on temperature and germination occurs at temperature as low as 2-5°C. Germination is followed by a slow growing rosette stage, during which numerous leaves are produced near the ground level and strong taproots develop. Safflower tolerates a wide range of temperatures from -7 to 40°C, provided during the elongation and flowering stages of growth and development there is no frost. During the rosette stage, safflower plant can withstand a temperature of -7°C (Mundel *et al*., 1992). The rosette stage takes 20-39 days after emergence depending on the cultural practices, temperature and photoperiod. Increasing day length from 10 to 14 h shortened the rosette stage from 39 to 23 days for various safflower genotypes (Weiss, 1971). After the rosette stage, the stems elongate rapidly and branch extensively (Fig. 3-5). The branch to angle range from 30 to 70° and the degree of branching is genetically and environmentally controlled (Dajue and Mundel, 1996). Each stem ends with a globular flower capitulum, enclosed by clasping bracts, which are typically spiny (Fig. 1, 6, 7). Safflower can grow to a

Fig. 4: *Carthamus tinctorius* L. 4 weeks after the start of elongation phase

Fig. 5: *Carthamus tinctorius* L. start of branching phase

Fig. 6: *Carthamus tinctorius* L. at the start of flowering (Botswana)

height of 44 to 210 cm, depending on planting date, spacing, soil moisture availability, soil fertility,

Fig. 7: *Carthamus tinctorius* L. with scarabid bird beetle pollinator

Fig. 8: *Carthamus tinctorius* L. seeds (white)

photoperiod and temperature. Flowering begins from the primary capitulum, then secondary capitula and so forth. Within a capitulum, flowering begins in the outer circle of florets and progresses centripetally towards the centre of the capitulum. The flowering period lasts 4-6 weeks depending on the cultural practices and climatic conditions especially temperature. Shades of orange, yellow and red flowers are produced. The florets are tubular and largely self-pollinating with generally less than 10% cross-pollination (Knowles, 1969). Bees, bumblebees, beetles and other insects increase the level of cross-pollination (Fig. 7). Developed capitula (flower head) contain 13-71 achenes (seeds), which mature in 4-5 weeks after flowering.

Safflower seed is composed of 33-60% hull and 40-67% kernel (Dajue and Mundel, 1996; Pahlavani, 2005). The seed oil content ranges between 20 to 45% depending on the variety and growing environment. Leaf size varies significantly among varieties and even within

the individual plant, but ranges between 2.5 to 5 cm wide and 10 to 15 cm long. Leaves are usually deeply serrated on the lower stem, but short and stiff, ovate to obovate around the inflorescence, where they form the involcral bracts (Dajue and Mundel, 1996). Lower leaves are generally spineless, but further up the stem spines develop in the bud stage and become strong, hard spines by full flowering. Varieties that are spineless have been developed for cut flower and seed production and petal harvest for medicinal purposes in China and India (Dajue and Mundel, 1996).

Uses of safflower: Safflower is a multipurpose oilseed crop grown mainly as cut flowers, vegetables and for its high quality oil. The uses of safflower have been recorded in China approximately 2,200 years ago (Dajue and Mundel, 1996). Traditionally, safflower was grown for its seeds, for colouring and flavouring foods, as medicines and for making red and yellow dyes, especially before cheaper aniline dyes became available (Weiss, 1971). In Egypt, dye from safflower was used to color cotton and silk as well as ceremonial ointment used in religious ceremonies and to anoint mummies prior to binding. Safflower seeds and packets and garlands of florets have been found with 4000-year-old mummies (Weiss, 1971).

Medicinal uses: In traditional Chinese medicine, safflower petals are regarded as a stimulant for blood circulation and phlegm reduction, healing of fractures, contusions and strains and for various female maladies. Production of safflower has yielded many medicinal solutions. Thus safflower in China is a medicinal plant. In Europe and the Middle East, petals are sometimes used as an adulterant for saffron. In Pakistan, the seed decoctions are used to produce heat and dryness in the body. When sugar is added it acts as a laxative (Knowles, 1965). The seeds can also be boiled and taken as a remedy for problem in menses to increase blood flow. Ground safflower seeds mixed with mustard oil reduce rheumatic pain (Knowles, 1965). In Kashmir, a decoction of whole or ground seeds is used to flush out the urinary tract, improve the liver and reduce hives (Knowles, 1965). Knowles (1965), Wang and Li (1985) reported that safflower seed is used for the treatment of urinary calculi. It has been realized that a nasal drop of safflower and other herbs speed blood flow in the medial cranial artery (Duo *et al*., 1992). It is also used to treat cerebral thrombosis and has lowered blood pressure in over 90% of the patients (Dajue and Mundel, 1996).

According to Liu (1985) it can be used to induce labour and is more effective than western medicine. When boiled in wine along with other flower decoctions is recommended to encounter retained afterbirth and retained stillbirth Wang and Yili (1985). Women in Afghanistan and India use a tea made from safflower foliage to prevent abortion and infertility (Weiss, 1983). Herbalists in these countries sell all parts of safflower to cure various ailments and as an aphrodisiac (Knowles, 1965).

In April 2007 it was reported that genetically modified safflower has been bred to create insulin (SemBiosys, 2006). A pharmaceutical company called SemBioSys Genetics is currently using transgenic safflower plants to produce human insulin because the global demand for the hormone has grown (SemBiosys, 2006). Safflower-derived human insulin is currently in the PI/II trials on human test subjects. Insulin (SBS-1000) that was extracted from safflower plants and was created by Sembiosys, has been injected into people for the first time. The hope is that plants will provide a cheaper source of insulin for people with diabetes (SemBiosys, 2006).

High oleic safflower oil is lower in saturates and higher in monounsaturated than olive oil. High oleic oil is a beneficial agent in the prevention of coronary artery disease (Dajue and Mundel, 1996).

Clinical use of safflower: Safflower dilates arteries, reduces hypertension and increases blood flow and, hence, oxygenation of tissues (Deng, 1988; Wang and Yili, 1985). It also inhibits thrombus formation and, over time, dissolve thrombi. Many prescriptions for invigorating blood circulation, especially those for treatment of heart disease, include safflower along with other herbs and have been used in the treatment of many diseases (Wang and Yili, 1985). Cardiovascular disease treatment is the main use of safflower because it invigorates blood circulation. In 83% of patients with coronary disease, blood cholesterol levels was reduced after 6 weeks of treatment (Wang and Yili, 1985). Experiments with dogs showed that injections of safflower reduced damage done to the heart muscle by an infarction. Heart arrhythmia and hypertension were reduced by safflower treatment 3 times a day for 4 weeks (Wang *et al*., 1978; Wang and Yili, 1985). Treatment of cerebral thrombosis with safflower improved and lowered blood pressure in over 90% of patients (Wang and Yili, 1985; Damao, 1987). Herbal decoctions including safflower were effective in the treatment of cerebral embolism (Zhou, 1992).

Safflower decoctions have been used successfully for the treatment of male sterility (Qin, 1990) and dead sperm excess disease (Qu, 1990). Treatment with safflower resulted in pregnancy in 56 of 77 infertile women who had been infertile for 1.5-10 years (Zhou, 1986).

Livestock feed: Safflower can be grazed or stored as hay or silage (Bar-Tal *et al*., 2008). The forage is palatable and its feed value and yields are similar to or better than oats or alfalfa (Smith, 1996; Wichman, 1996). The *in vivo* digestibility and the intake of green safflower fodder are similar to those of a vetch-oat mixture (Vonghia *et al*., 1992). Grazed safflower has been shown to support satisfactory growth rates in Australian steers (French *et al*., 1988) and to improve fertility in Canadian ewes (Stanford *et al*., 2001). Safflower also makes an acceptable livestock forage if cut at or just after bloom stage (Bergland *et al*., 2007). Safflower hay, given *ad libtum*, has been successfully used as a sole feed for late-pregnancy dairy cows (Landau *et al*., 2004). Safflower cropped at the budding stage can be ensiled (Weinberg *et al*., 2002, 2005, 2007) and safflower silage was substituted for cereal silage in the diet of high-yielding dairy cows (Landau *et al*., 2004) and dairy sheep (Landau *et al*., 2005) without affecting their dairy performance. Safflower meal contains about 24% protein and is considerably high in fiber. It can also be taken as a nutritional supplement. Therefore, it is used as a protein supplement in livestock and poultry feeds. Safflower silage has the potential for widespread adoption as a feed in many countries especially in the semi-arid arid countries since safflower is drought tolerant. Special characteristics such as protein degradability are taken into account to optimize its inclusion in Total Mixed Ration (TMR) (Landau et al., 2004).

Another use of Safflower seeds is as birdseed especially for members of the parrot family and pigeons (Dajue and Mundel, 1996). Safflower seed is also used quite commonly as an alternative to sunflower in bird feeds, as squirrels do not like the taste of it (Blackshaw, 1993). The bird feed industry prefers to use the white hull or normal hull type of safflower even though striped and partial hull types usually are higher in oil and protein content. The birdseed market does not have a preference for a fatty acid type.

Food uses: Food producers and industries use safflower oil. Safflower oil is often considered a healthier option than using sunflower oil (Dajue and Mundel, 1996). The oil consists of two types: that which is high in monounsaturated fatty acid (oleic acid) and that which is high in polyunsaturated fatty acid (linoleic acid). At the moment the predominant oil market is for the varieties that produce seeds higher in oleic acid and very low in saturated fatty acids.

For the last 50 years or so, the plant has been cultivated mainly for the vegetable oil that is extracted from its seeds. The tests in India have shown that seed production from ratoon crop is also possible. Safflower oil is heat-stable, therefore it is used as cooking oil to fry such foods as French fries, chips and other snack foods. Safflower oil is also used in food coatings and infant food formulations. Safflower oil is also used in salad dressing and for the production of margarine. The flowers are occasionally used in cooking as a cheaper substitute for saffron (Bergland *et al*., 2007). Safflower leaves are eaten as vegetables (Weiss, 1983). Safflower petals are used for colouring foods. Rice, soup, sauces, bread and pickles take on a yellow to bright-orange colour from the florets. Health concerns regarding synthetic food colourants may increase the demand of safflower-derived food colourant. China produces carthamin dye for use in food. Safflower yellow (carthamidine) and red (carthamin) pigments are safe and natural pigments which can be used for colouring food and cosmetics (Kulkarni *et al*., 1997; Zhaomu and Lijie, 2001). Safflower petals is also used a pleasant-tasting herbal tea. In Iran, a paste of safflower seeds is used to hasten cheese curd formation (Knowles, 1965). Roasted seeds, generally mixed with chickpeas, barley or wheat, are eaten as a snack food in Ethiopia and Sudan (Belayneh and Wolde-Mariam, 1991). The Egyptians grind the kernels and mix in sesame (Knowles, 1965).

Other uses of safflower: High linoleic acid safflower oil has an important use in the paint industry. Before 1960's in the USA, the oil was used mainly as a base for superior quality paints. It is used as a drying agent in paints and varnishes because of its non-yellowing characteristic (Bergland *et al*., 2007). Safflower oil is also used in making paint in place of linseed oil. In textiles, dried flowers are used as natural dyes. Natural dyes from plants are getting more important nowadays because of their naturality and fashion trends. The colorful matter in safflower is carthamin which is benzoquinone-based (SemBiosys, 2006). It has a dye of flavonoid type. Hydrophilic fibres like cotton, wool and others can be dyed with safflower dye because it is a direct dye. Safflower yellow or red pigments are safe for cosmetics colourings such as hair cream, shampoo, face cream, perfume or body lotions (Shouchun *et al*., 1993).

In Western Europe, Japan, Latin America and Kenya spineless varieties are grown and used as cut flowers both for the domestic and export market. Safflower straws have similar use as straws of cereals. Two or three rows of safflower around a cereal field can help keeping free ranging cattle out of the grain field (Chavan, 1961).

Safflower agronomy: Safflower is a day neutral plant. However, the origin of varieties is very important because

summer crop varieties from temperate regions, planted during short days as a winter crop in subtropical and tropical regions, have a very long rosette phase, with delayed maturity. Plant density varies greatly among countries. The plant density adopted is influenced by the variety, climatic factors and cultural practices. When soil moisture is not limiting, safflower compensates for low plant density by increased branching and other yield components adjustments (Mundel, 1969). The seeding rate ranges between 10 to 45 kg ha^{-1}.

During the rosette stage of growth, safflower is a poor competitor with weeds. Therefore, weed control at this stage is very important for yield optimization. Herbicides such as triflurains and ethalfluralins (pre-emergence) and sethoxydim (post-emergence) can be used for weed control (Blackshaw *et al*., 1990). Safflower grows well in well-drained, deep, fertile, sandy loam soils. In heavy clay soils, crusting may reduce seedling emergence. In general, if soil moisture is limiting, good irrigation just prior to bloom increases seed yield significantly. Safflower seed yield is affected cultural practices (Siddiqui and Oad, 2006; Nikabadi *et al*., 2008), cultivar (Arslan, 2007; Pahlavani, 2005; Pahlavani Saeidi *et al*., 2006; Alizadeh and Jirair, 2006; Mahasi *et al*., 2006; Oad *et al*., 2002) and climatic factors (Kolte, 1985; Abdulahi *et al*., 2007). Excessive rainfall during flowering causes several leaf and flower head diseases resulting in yield reduction (Kolte, 1985). Prolonged rainfall during flowering interferes with pollination and seed set, so do high temperatures greater than 32°C (Mundel *et al*., 1992). Siddiqui and Oad (2006) reported that application of 120 kg N ha^{-1} significantly increased safflower branches, seed index, plant height and seed yield, but delayed maturity.

Safflower was developed from wild species of desert or arid environment and is very susceptible to foliar diseases favoured by a moist growing environment. Safflower is susceptible to leaf blight caused by *Alternaria carthami* in growing areas with high rainfall and where rainfall occurs between the late bud stage and near maturity. Other foliar diseases of concern are those caused by *Botrytis cinerea*, *Cercospora carthami*, *Pseudomonas syringae*, *Puccinia carthami* and *Ramularia carthami* (Mundel *et al*., 1992). Safflower is also susceptible to root-rot caused by several species of *Phytophthora*, *Fusarium oxysporum* f. sp. *carthami* and *Verticillium dahliae*. The most serious insect pest that has limited safflower distribution is the safflower fly (*Acanthiophilus helianthi*) which is confined to Africa, Asia and Europe (Mundel *et al*., 1992). Aphids are also a major problem in India, Spain and Botswana (Mundel *et al*., 1992).

CONCLUSION

Despite the many uses of safflower, this crop it has remained minor. Therefore, awareness of the usefulness of this neglected and underutilized economically important crop be created to the international community. It is hoped that scientists will develop interest on safflower and develop multidisciplinary research projects to address issues related with the agronomy, ecophysiology, diseases and pests, developmental patterns, morphological ideotypes, increase seed yield through genetic manipulation, product-related research, utilization research, development of pharmaceuticals and clinical trials to elucidate the effectiveness of safflower products, decoctions and concotions in the treatment of various human diseases.

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