Scientia Agraria Paranaensis

Scientia Agraria Paranaensis – Sci. Agrar. Parana.
ISSN: 1983-1471 – Online

SAFFLOWER: IMPORTANCE, USE AND ECONOMICAL EXPLOITATION

Janine Farias Menegaes[1*], Ubirajara Russi Nunes[1]

SAP 21250 Received: 06/12/2018 Accepted: 09/03/2019
Sci. Agrar. Parana., Marechal Cândido Rondon, v. 19, n. 1, jan./mar., p. 1-11, 2020

ABSTRACT - The safflower is an ornamental, medicinal, oleaginous, annual and herbaceous plant, and it is cultivated in more than 60 countries. In Brazil, it presents great edaphoclimatic adaptations for the different regions of the country. With wide economic exploitation, it encompasses: the floricultural sector with the floral stems in a fresh and dry form; the animal feeding with grazing, silage and seed cake; the food, pharmaceutical and oil industries with the use of oil according to its refine for the emulsification in bakery, elaboration of medicine and biodiesel; besides the use of coloring that comes from the dried petals in culinary, cosmetics and in fabrics, among other aptitudes of use. Thus, the present work had as objective to perform a national and international review of literature about the importance, use and economic exploitation of safflower.
Keywords: *Carthamus tinctorius* L., biodiesel, medicinal, ornamental, multiple purpose plants.

CÁRTAMO: IMPORTÂNCIA, USO E EXPLORAÇÃO ECONÔMICA

RESUMO - O cártamo é uma planta ornamental, medicinal, oleaginosa, anual e herbácea, sendo cultivado em mais de 60 países. No Brasil apresenta ótimas adaptações edafoclimáticas para as diferentes regiões do país. Com ampla exploração econômica, abrangendo: o setor florícola com as hastes florais de forma fresca e seca; a alimentação animal com pastejo, silagem e torta de sementes; as indústrias alimentar, farmacêutica e petroleira com a utilização do óleo conforme seu refino para emulsificação na panificação, elaboração de medicamentos e biodiesel; além do emprego do corante oriundo das pétalas secas na culinária, na cosmética e em tecidos, entre outras aptidões de uso. Assim, o presente trabalho teve como objetivo realizar uma revisão de literatura nacional e internacional sobre a importância, uso e exploração econômica de cártamo.
Palavras-chaves: *Carthamus tinctorius* L., biodiesel, medicinal, ornamental, plantas de múltipla aptidão.

INTRODUCTION

The safflower (*Carthamus tinctorius* L.), which belongs to Asteraceae family, coming from Asia, is considered one of the oldest agricultural productions, in virtue of its broad fitness for use – culinary and textile coloring, ornamental, oleiferous, animal feeding, among others, being cultivated in more than 60 countries (EKIN, 2005; KINUPP and LORENZI, 2014; NIMBKAR, 2017).

Species of great economic importance, especially, in the Asian countries, actually its production is intended for the extraction of oil (medicinal and biodiesel), being India the main research center with institutes and national germplasm bank (DAJUE and MUNDEL, 1996; SINGH and NIMBKAR; 2006). In Brazil, the safflower was introduced as ornamental plant in the South region of the country, for the cultivation of floral stems. Recently, this species is being used as alternative of income for animal feeding and production of grains, in off-seasons periods of great cultures, mainly, in Northeast region of the country, due to its great edaphoclimatic adaptations (BELLÉ et al., 2012; SANTOS and SILVA, 2015).

Phytoremediative attributes of safflower were observed by researchers, Madaan et al. (2011), who verified, when studying the biochemistry of the accumulation of heavy metals in the plant, potentialities of species as phytoremediative plant of areas contaminated with Hg (mercury) and Se (selenium), in which the absorption of these metals via roots is translocated by plant, concentrating in the seeds. However, when the safflower plants are used for this purpose, the use of seeds should be intended only to the production and biodiesel and, never, for the human and animal consumption.

In this context, the present work aimed to carry out a national and international review of literatures about the importance, use and economic exploitation of safflower. For the review of literatures, we used as scientific basis data of books, papers of journals and scientific events, theses and dissertations, technical bulletins, and government electronic sources.

DEVELOPMENT

Environmental demands of cultivation

The safflower plants thrive well in environments with precipitation above 400 mm, however, the great yield precipitation is between 600 to 1000 mm per year. In regions of low precipitation, the use of bees for pollination is a traditional and profitable practice, having the production of honey as by-product of the crop (OELKE et al., 1992; CORONADO, 2010; EMONGOR and OAGILE; 2017).

The safflower cultivation is recommended at altitudes that vary from the sea level to 1000 m; however,

[1]Doctor, Federal University of Santa Maria (UFSM), Avenida Roraima, 1000, Building 70, Seed Laboratory (LDPS), Crop Science Department,CEP 97105-900, Santa Maria, Rio Grande do Sul, Brazil. E-mail: janine_rs@hotmail.com, urussinunes@yahoo.com.br.
*Corresponding Author.

above 800 m of the sea level the yield is negatively affected. Figure 1 demonstrates the regions where the safflower is cultivated, between the latitudes between 60º N (Russia) and 45º S (Argentina and Australia), with restriction to the cultivation in regions near the equatorial line, due to the high humidity, which provides to the plants high incidence of diseases, harming the quality of seeds and, above all, the floral stems (RIVAS and MATARAZZO, 2009; CORONADO, 2010; EMONGOR, 2010; HUSSAIN et al., 2015).

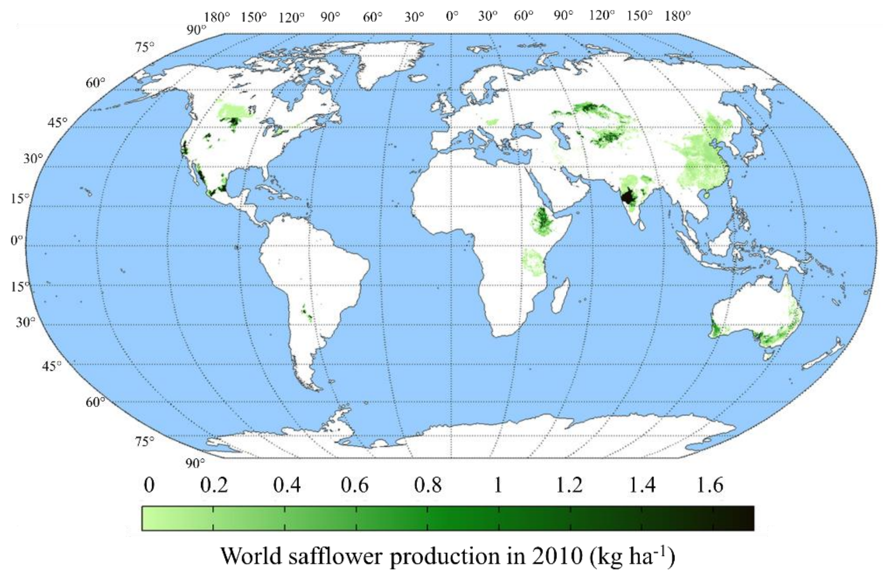

FIGURE 1 - Location of world production of safflower seeds in 2010. Source: FAOSTAT (2017).

The plants endure the thermal amplitude of -7 to 40ºC, depending on their development stage. In the initial stages, they tolerate low temperatures, however, in the ramification phase they need minimal temperatures of 15ºC, having their great development with temperatures between 20 to 35ºC, non-responsive to photoperiod (OELKE et al., 1992; MÜNDEL et al., 2004; HUSSAIN et al., 2015).

In general, the culture adapts itself to all types of soil, mainly, the deep ones, little compacted and well drained, the roots do not tolerate waterlogging, being susceptible to root rot. The pH of soil must be in the range of 5-8, because the plant is tolerant to salinity, nevertheless, high salinity reduces considerably the yield (MÜNDEL et al., 2004; RIVAS and MATARAZZO, 2009; CORONADO, 2010; EMONGOR and OAGILE; 2017).

The fertilization favors the productive potential of species, being the nitrogen (N) and potassium (K) the most demanded nutrients by the plant. N in the establishment of vegetative canopy and K for the full flowering. However, in spite of several research in relation to the productiveness of seeds, we do not have a definite recommendation for the culture, the advisable is to fertilize the soil according to soil analysis report (KHALIL et al., 2013; HUSSAIN et al., 2015; EMONGOR and OAGILE; 2017).

The cultivation cycle for floral stems vary from 80 to 140 days for the periods of summer and winter, with good adaptation to the climate conditions of the South of Brazil, and can be cultivated the whole year (STRECK et al., 2005; BELLÉ et al., 2012). Yet, the average cultivation cycle for the seed is around 150 days for the states of São Paulo and Mato Grosso, and can be cultivated the whole year, mainly, in off-season periods of great cultures of major economic importance (AMBORASANO, 2012; SANTOS; SILVA, 2015).

The FAOSTAT (2017) reports the average cycle of safflower cultivation, in global level, for production of seeds, varies from 200 to 230 days in autumn and winter seasons and, from 120 to 160 days in spring and summer seasons, counting the emergence periods the harvest of seeds/grains. Nevertheless, the seed sowing period is the key point to optimize the productivity and the quality of floral stems, in which studies performed in different parts of the world demonstrated that its cultivation is more responsive to seed sowing in regions of mild temperatures, such as spring and with average precipitations above 400 mm per year (GOLZARFAR et al., 2012; OMIDI et al., 2012).

Safflower petals: food coloring, cosmetic, textile and others

The safflower name comes from the word “Carthamus”, derives from Hebraic “Kartami”, which means dye. Reference to the red, orange and yellow coloring extracted from its dried petals, which is basically constituted by carthamin and its derivatives, used as food coloring and in textile dyeing (OELKE et al., 1992; CORONADO, 2010).

There are registrations of safflower cultivation that date back to 4,500 b.C., and its floral stems were used in Egypt in religious ceremonies and, the coloring extracted from its petals in the process of mummification due to its preservative property (EKIN, 2005; EMONGOR, 2010).

Until the current days, the coloring extracted from the dried petals is used as seasoning with food purpose, specially, in the Asian countries – India, China, Turkey, among others; in Brazil and in Portugal the safflower powder is known as bastard-saffron and is commercialized in the colors dark yellow, orange and red. On average, one kilogram costs US$ 1,000.00 according to the origin and coloring of the powder extract (EKIN, 2005; EMONGOR, 2010).

The seasoning use in food is a generalized and antique tradition in Asia, which was disseminated in the world by the Arabian culture. The coloring is used in beverages (juices, sodas, yogurt, among others), bread, cakes, biscuits, butter, ice cream, rice, soup, sauces, meat, among others; highlighting the color and taste of food, at the same time that acts as preservative (PINTÃO an SILVA, 2008; KINUPP and LORENZI, 2014).

The true saffron (*Crocus sativus* L.) of reddish coloring is, probably, the most expensive seasoning of the world, one kilogram costs on average US$ 18,000.00, because to make one kilogram of this seasoning it is used around 150 thousand of plants in an area of 2 thousand m^2. From the tuberculous of true saffron, it is made the coloring of reddish color, of lower aggregated value, one kilogram costs on average US$ 7,000.00 (SERRANO et al., 2008; EMONGOR, 2010).

Thus, the safflower powder, due to its appearance and taste similar to the true saffron was its cheapest and most appreciated substitute, especially in Europe, since that for one kilo of dried petals of safflower it is used on average 48 thousand plants cultivated in 400 m^2. The safflower as seasoning was widely used, in the 18^{th} Century, in the food industries in Italy, France and Great Britain to give color to cheese, savor to sausages and others and, canned preservative (SERRANO et al., 2008; DYE, 2017; NIMBKAR, 2017).

For obtaining powder coloring initially, we collect the chapters and the drying occurs in a natural form in the shadow, for maintenance of orange color. Following the processing of natural extraction indicated by FAO (2006), in the first process, we retire the yellow pigmentation that is soluble in water, in the sequence; we use acids for the extraction of the reddish pigments with several washes during several days. The coloring of the extracts varies according to the structuring of carthamin naturally reddish and insoluble in water; the yellow coloring has neocartamidine and less carthamin; and the orange coloration has similar quantities of cartamone and carthamin (SCHWEPPE, 1986; FAO, 2006; SERRANO et al., 2008; PINTÃO; SILVA, 2008; NIMBKAR, 2017).

In Brazil, the carthamin and its derivations are registered as natural organic coloring, with use is indicated for the food, pharmaceutical, cosmetics and textile industries (VELOSO, 2012). We understand as natural coloring the ones obtained from plants (leaves, flowers, fruit, roots, tubercles), animals (insects, leather) and microorganisms (fungus and bacteria) (MENDONÇA, 2011).

In the 20th Century, with the advent of synthetic coloring and, consequent cheaper as the aniline, the use of safflowers petals gradually decreases passing not to be used. Nevertheless, in the last years the European Union together with the World Health Organization initiated a process of regulation and prohibition of synthetic coloring in processed food. In this context, the safflower petals become an alternative of natural coloring and food seasoning, besides presenting diverse medicinal properties indicated for hypertension, cardiovascular diseases, arthritis, spondylosis, menstrual pain, diabetes, among others (LI and MUNDEL, 1996; EKIN, 2005; SINGH and NIMBKAR; 2006).

In 2010, China produced approximately 2.2 tons of dried petals of the plant for the extraction of coloring and medicinal prepares (ZHAOMU and LIJIE, 2001; SINGH and NIMBKAR; 2006). The inflorescences presented caloric value on average of 375.93 Kcal $100g^{-1}$, this value can be in virtue of the seeds presenting high oil value (35 to 40%), also, are rich in minerals and presented all the essential amino acids, with the exception of tryptophan (SINGH, 2005).

In relation to the cosmetic area, the reddish coloring was widely used for the manufacturing of powder “blush” known as “rouge” in France and Brazil, and “beni” in Japan, besides of lipsticks of reddish coloring. The soot of carbonized plants is used to make the Egyptian cosmetic “Kohl kajal” used around the eyes protecting the high luminosity of the desert, with the medicinal and mystical attributions (protector of the negative spirits) (WEISS, 1983; DAJUE and MUNDEL, 1996; SMITH, 1996).

In India, the make-up of the third eye between the eyebrows is performed in married people for protection, known as “bindi” of orange coloring is made with safflower coloring. The safflower coloring and oil are also used in the manufacturing of shampoo, toilet soaps, perfumes, lotions and body oils, healing ointments, among others (WEISS, 1983; DAJUE and MUNDEL, 1996; SMITH, 1996).

In Asia, the extracts in powder are used in solutions for the coloring of fabrics, such as linen, cotton, silk and wool in different shades. The colorings of safflower were particularly important for the industries of tapestry in East Europe, Middle East and India in the 17^{th} and 20^{th} Centuries (PINTÃO and SILVA, 2008; EMONGOR, 2010).

The textile coloring of the region of Dacca in Bangladesh are considered of high quality with average yield of 30 kg ha^{-1}, the form of extraction of pigments and the treatment with the solution of sodium carbonate for extracting the carmine is what values the coloring of region. The safflower petals have on average 0.7% of carthamin, in which to dye 1 kg of wire of cotton needs 1 kg of this coloring (WEISS, 1983; DAJUE and MUNDEL, 1996).

Araújo (2007) reports the textile coloring of vegetal origin most used in the world, in the 17th Century were the redwood (*Cesalpinia echinata* Lann.) of great exploitation in Brazil in the colonial period by the reddish pigmentation of wood and the true saffron (*Crocus sativus* L.), in this case the yellow coloring extracted of its tubercles. The use of coloring of safflower was used by the Portuguese, in virtue of the value and of different colorations that the species originates according to its extraction. Currently, the use of the coloring extracted from the petals of this plant restricts to the Asian countries.

Diniz et al. (2011) report that the use of natural coloring, besides the low environmental impact by its productive and dyeing processes, generates income to the familiar agriculture with the cultivation of vegetal species for this purpose, as well as aggregating commercial value in the final product. The most usual in Brazil are: coffee powder, erva-mate, beetroot, carrot, onion peel, turmeric, roots and peels of medicinal and forestry plants, among others.

Safflower plant: medicinal

In Japan, the inflorescences of safflowers are known as Suetsumuhana (Safflower Princess), due to the name of the princess of the epic novel "The Tale of Genji" of 11th Century, written by Murasaki Shikubu. In this book, in the chapter six the prince Genji falls in love with the princess Suetsumuhana that offers him a safflower tea for the relief of his chronicle pains (LYONS, 2011).

In Bhutan, the Tsheringma tea is very common in the traditional medicine and it is offered to the visitors as synonym of welcome, because it is attributed to the Goddess of longevity, wealth and prosperity. This tea is composed by two ingredients, the petals of safflower known as Gurgum, which treats the heart and the nerves, and the peel of the Shing-Tsha root (*Cinnamomum tamala* (Buch.-Ham.) Nees & Eberm) which treats the digestion (DAJUE and MUNDEL, 1996).

In the popular and traditional medicine in the Asian countries all the safflower plant is used as medicinal – root, leaves, inflorescences, seeds, in the most diverse forms of use, decoction, tea, coloring, ointments, encapsulated oil, among others; for different ends (EMONGOR, 2010; ASGARPANAH and KAZEMIVASH, 2013; ZHOU et al., 2014).

The safflower seeds are rich in carotene, riboflavin and vitamin B, C, D and E, being edible in seedling stage, because as the plant develops, the seeds are acquiring leathery aspect, and it is not indicated for consumption *in natura*, not even for animals (EMONGOR, 2010; KINUPP and LORENZI, 2014).

In China, good part of the safflower cultivation is intended for obtaining its inflorescences, which are used in treatment of diseases, in the form of tonic tea; however, this tea presents a bitter taste and due to its popularity, the Institutes of Botany of China (LI and YUANZHOU, 1993) and India (SINGH, 2005) developed a sweetened composition, rich in amino acids, minerals and vitamins of complex B, C, D and E (EMONGOR, 2010; NIMBKAR, 2017).

The inflorescences are collected, selected and stored in the absence of light, for maintenance of their medicinal properties (WEISS, 1971; DAJUE and MUNDEL, 1996). The main active ingredient in medicine based on safflower is the yellow coloring, soluble in water, but the extracts of alcohol are used in some preparations. Several clinical and laboratorial studies indicate the use of this medicine for the menstrual problems, cardiovascular diseases, pain and swelling associated to trauma, purgative, anti-thermal, anti-oxidant, anti-inflammatory, analgesic and anticonvulsant, among others (ASGARPANAH and KAZEMIVASH, 2013; ZHOU et al., 2014).

From 2000, the commercialization of safflower as medicinal plant intensified itself and has provided to the local farmers, in China and India, an alternative of income with high monetary return, mainly, for the production of organic physiology (SAWANT, 2000).

The safflower is also recognized as high medicinal potential for the modern medicine in virtue of the recent pharmacological and clinical discoveries (ASGARPANAH and KAZEMIVASH, 2013; ZHOU et al., 2014). For example, in Canada the plants are used as substrate for the production of insulin for the human reposition, this insulin presents great quality and low cost (ANON, 2006).

Floral stems of safflower: ornamental

The inflorescences of safflower present ornamental character (Figure 2) due to its beauty, rusticity and versatility, and it can be used as fresh or dried cut flower, with durability of post-harvest of 15 days and more than two months (OELKE et al., 1992; MÜNDEL et al., 2004; KHALIL et al., 2013).

The plant presents height between 0.3 to 1.5 m, with ramified stem and each ramification produces from 1 to 5 chapters solitaire in the apex of the branches (Figure 2a) (MÜNDEL et al., 2004; EKIN, 2005; EMONGOR, 2010). However, for cut flower the safflower stems must present length of 60 to 90 cm, being divided in classes and, with minimum of three floral buds, and the central inflorescence must be in the beginning of the opening (Figure 2b, 2c) (IBRAFLOR, 2000; COOPERATIVA VEILING HOLAMBRA, 2016).

The commercialization standards and criteria of classification for the safflower in cut flower in Brazil follow the Dutch standards, which are authenticated by IBRAFLOR (2000) and by the Veiling Holambra Cooperative (2016) in which the lot must be homogeneous, with 95% of uniformity while the length, thickness of stem and flower opening point, with the minimum of three floral buds. The bunches are classifies in two, being the summer-bunch with the thin stems having from 9 to 10 stems and, the winter-bunch with thick stems having from 5 to 8 stems (Figure 2d).

The floral stems are collected when the central inflorescences are "appearing", that is, with a minimum of

¼ of the floral opening point and, the other inflorescences in form of a close bud, the average of durability is of 10 days without treatment of post-harvest (DOLE and WILKINS, 2005). Currently, more than twenty varieties of inflorescences and seeds of safflower are commercialized in Holland in the value of € 0.28 the stem and, € 1.99 the packet with 45 seeds. The orange inflorescences are the favorite ones of the consumers, with annual offer, both for fresh and dried flowers (UHER, 2008; EMONGOR and OAGILE, 2017; NIMBKAR, 2017).

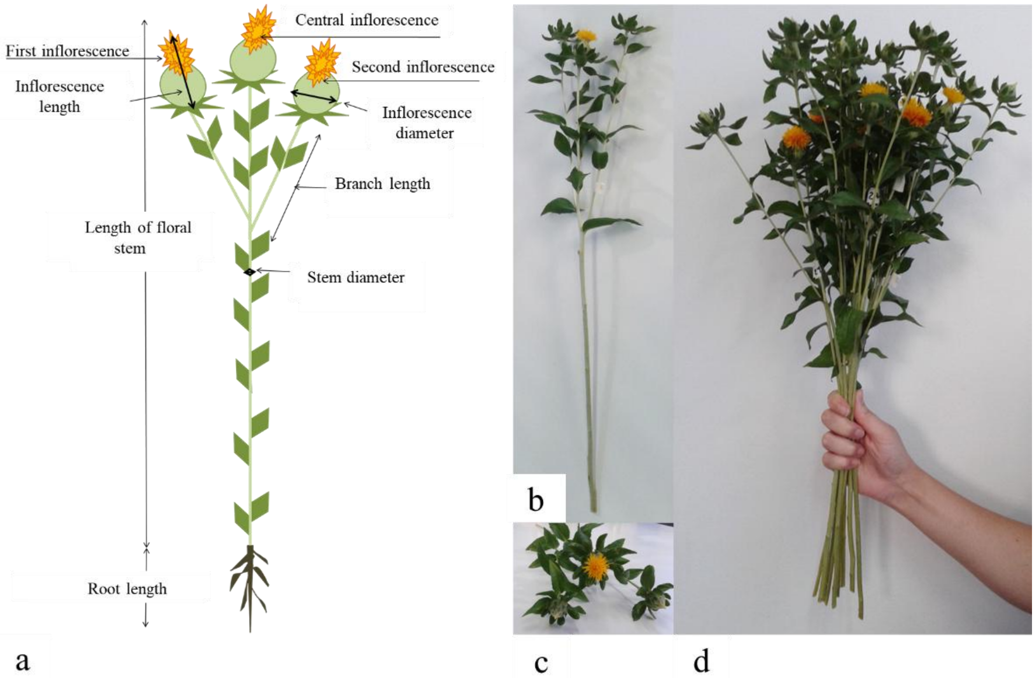

FIGURE 2 - Illustration for evaluating the biometric parameters of the floral stem of *C. tinctorius* (a), standardized floral stem with 60 cm (b) and with three inflorescences (c) and a bundle with 10 stems (d). Photograph: MENEGAES, J. F. (2016).

The floral stems, generally, initiate their flowering in the yellow coloring, going through the orange coloring with the total opening of the inflorescences and going to senescence with the reddish coloring. This transition of colors during the beginning of the flowering to the senescence is due to the natural degradation of the oxidative enzyme (β-glucose oxidase) present in the petals (EMONGOR and OAGILE, 2017).

Besides that, the floral stems of safflower are appreciated in Europe in the form of dry flowers, having their commercialization peak in the last decades of the 20th century, imported from Pakistan and Israel. In Japan and in America, the inflorescences are appreciated in the fresh form for composition of floral arrangements, in the other Asian countries they are appreciated of two ways, being mainly, used in religious cults and in garlands/funeral wreath (EKIN, 2005; EMONGOR, 2010; EMONGOR and OAGILE, 2017; MÜNDEL et al., 2004).

Uher (2008) researching about the safflower floral stems market, verified that only in the Auction of Holland Flower Cooperative (Royal FloraHolland – Aalsmmer) the consumption in 1990 was of € 3.2 million (126 million of stems) occupying the 46th position among the cut flowers of the Auction. In 2000, the sales got to € 5.3 million (353 million of stems) occupying the 39th position. Nevertheless, in 2005, it began the reduction of the floral stems of safflower, going to the 55th position among the cut flowers of the auction, with the value of sales of € 3.4 million (193 million of stems), however this year the import was greater than 50% of the total sale, occupying the 19th position among the 20 the cut flowers imported by Holland.

In the floriculture, the flowers and ornamental plants present a seasonality in relation to the consumption preference, similar to what happens to the fashion sector of clothes. Nevertheless, the safflowers stems were widely commercialized from the years of 1980 to 2000, in Europe with registration in the scientific literature. In Asia, the consumption is constant in virtue of the religious cults, where the safflowers stems are offered to the Goddess of prosperity, because the plant is medicinal and edible (UHER, 2008; EMONGOR; OAGILE, 2017).

In Brazil, the safflower was introduced, in the 90s, as an ornamental plant by the Dutch in the South region of the country, with the purpose of producing floral stems for import. Being cultivated for a short time, in the states of Rio Grande do Sul and Santa Catarina, in which the sensitivity to the leaf and floral wetting affected negatively the aesthetic and ornamental quality of the plant, being determinant for the reduction of the cultivation in the country; another factor was the choice of the region, with high levels of precipitation and well defined seasons. The species requires environment with low relative humidity of air and little leaf wetting. The cultivation in protected environment is an alternative for the production of floral stems in Rio Grande do Sul (ARANTES, 2011; AMBORASANO, 2012; BELLÉ et al., 2012).

Safflower seeds: medicinal oil, edible and biodiesel

The safflower seeds have high oil content, 35 to 40%, broadly, used in the food and pharmaceutical industry, mainly for elaboration of cosmetics and medicine such as insulin, oil is consumed as aesthetic product with powerful antioxidant action and, also, as biodiesel (OELKE et al.,1992; GIAYETTO et al, 1999; MÜNDEL et al., 2004; EKIN, 2005; ARSLAN, 2007; MORAIS, 2012).

According to FAO (2005) 97.5% of the seeds produced worldwide are used for extraction of oils, being 50% used for biodiesel extraction, 41% for medicinal oil and 6.5% for edible oil; the other 2.5% are used for consumption *in natura*, especially in feeding of birds. The oil extraction occurs in more than 60 countries, where Asia contributes with 51.5% of total production, followed by America with 33.4%, Europe with 11.7%, Africa with 2.7% and Oceania with 0.7% (FAOSTAT, 2017).

The safflower production was stagnated until the 70s, it was with the increase of the demand of floral stems by Europe, as well as the increase in the medicinal and edible oil consumption and, above all, for the production of biodiesel, enabled that the area and productivity of safflower doubled in less than 40 years (MAILER et al., 2008). In relation to the production costs, in 2014, data of Turkey showed that US$ 148.1 ha^{-1}, and the paid value was of US$ 575.6 ton^{-1}. In 2016, in the United States the average price of safflower was US$ 10.65 by kilogram (US$ 4.84 the pound) totaling the harvest value in US$ 45 million (NASS, 2017; YILMAZ et al., 2016).

In 2014, the seed production was around 868 thousand tons, with cultivated area of approximately one million hectares (Table 1). Kazakhstan has the largest safflower producing area with about 310 thousand hectares, almost 30.7% of the total cultivated area, with average productivity of 632 kg ha^{-1}, followed by India with 13.9% of total cultivated area with average production of 807 kg ha^{-1}. China stands out by the greatest productivity by hectare, with 1,541 kg. In America, the greatest producers are: Peru, United States, Mexico and Argentina with 1,399; 1,374; 1,260 and 700 kg ha^{-1}, respectively (FAOSTAT, 2017).

TABELA 1 - Worldwide safflower cultivation (*Carthamus tinctorius* L.) in 2014.

Producing countries	Cultivated area (ha)	Contribution in cultivated area (%)	Productivity (kg ha^{-1})
Kazakhstan	310.000	30,7	632
India	140.000	13,9	807
Russia	115.018	11,4	757
Mexico	114.574	11,3	1.260
Argentina	94.770	9,4	700
United States	68.880	6,8	1.374
Peru	44.305	4,4	1.399
Uzbekistan	40.000	4,0	650
Tanzania	24.230	2,4	551
China	23.290	2,3	1.541
Kyrgyzstan	12.909	1,3	824
Australia	8.670	0,9	580
Ethiopia	6.890	0,7	898
Tajikistan	2.797	0,3	912
Canada	2.750	0,3	1.375
Will	800	0,1	713
Ukraine	200	0,02	500
Hungary	50	0,005	1.400
Pakistan	20	0,002	1.000
Spain	20	0,002	500
Palestine	7	0,001	143
Total cultivated area (ha)		1.010.180	
Average productivity (kg ha^{-1})		882	

Source: adapted FAOSTAT (2017).

Among the nine oleaginous cultures (seeds) intended to biodiesel production in global level (Table 2), average data of the harvests from 2007 to 2012, the safflower is the eighth culture preceded by *Glycine max* (L.) Merr., *Brassica napus* L., *Arachis hypogaea* L., *Helianthus annus* L., *Sesamum indicum* L., *Linum usitatissimum* L.. *Ricinus communis* L. and, finally, *Guizotia abyssinica* (L. f.) Cass. (RAI et al., 2016; FAOSTAT, 2017).

In Brazil, the cultivation is still incipient and in experimental phase in the region of Cerrado and in Northeast. In the list of FAOSTAT (2017), there are no registration of Brazil as safflower producer. All the safflower oil used in the country is imported. In 2012, the import final value of the category “sunflower oil or safflower oil, gross or respective fractions, even refined, but not chemically modified” was of US$ 6.1 million according to MAPA (Ministry of Agriculture, Livestock and Supply) in material Commercial exchange of agribusiness Brazil (BRASIL, 2013); nevertheless, there were no distinction in percentage for sunflower and for safflower.

In the last years, the Mato-Grossense Institute of Cotton (Instituto Mato-Grossense do Algodão - IMA-MT) acquired 926 accesses of safflower that came from the United States, together with the College of Agricultural Sciences of Botucatu (Faculdade de Ciências Agronômicas de Botucatu - FCA/UNESP), in 2010 (ZOZ, 2015), with the objective of culture development in the country as option for the energetic matrix.

TABLE 2 - Oilseeds from crops destined for the production of biodiesel worldwide and productive potential.

Species	Cultivated area (ha)	Yield (t)	Productivity (kg ha^{-1})	Average oil content (%)	Oil yield (kg ha^{-1})
Glycine max (L.) Merr.	967.666	2.400.345	2.441	18	439.4
Brassica napus L.	322.295	593.162	1.840	44	809.6
Arachis hypogaea L.	234.897	383.196	1.631	45	734.0
Helianthus annus L.	283.778	332.089	1.391	44	612.0
Sesamum indicum L.	74.058	39.592	535	47	251.4
Linum usitatissimum L.	21.275	18.667	877	39	342.0
Ricinus communis L.	15.738	17.937	1.140	48	547.2
Carthamus tinctorius L.	7.298	6.272	859	35	300.7
Guizotia abyssinica (L. f.) Cass.	3.824	1.064	278	35	97.3

Source: Rai et al. (2016).

From 2010, with the acquisition of safflower genotypes, several researchers have been working focusing in the productivity for oil production in the country. For example, Silva (2013) researching the agronomic characteristics of different safflower genotypes, in the municipality of Botucatu and São Manuel, SP, in 2010, obtained average productivity of 1057 kg ha^{-1}. Zoz (2015) researching 12 safflower genotypes in the municipality of São Manuel, SP, in 2012, obtained average productivity of 516 kg ha^{-1}. Guidorizzi (2016) researching two genotypes in different management of fertilization obtained, in the municipality of Botucatu, SP, in 2014, average productivity of 1,927 kg ha^{-1}. Sampaio et al. (2017) cultivating safflower in different sowing periods in the municipality of Cascavel, PR, in 2014, obtained productivity of 922 kg ha^{-1} in autumn and 858 kg ha^{-1} in winter.

According to what was exposed, we observe that Brazil presents potential for safflower cultivation with oil exploitation; however, work is still necessary, specially, regarding the treatment of seeds, hydric management and fertilization, among others.

The chemical composition of safflower registers more than 200 isolated compounds, among phenols, glycosides phenylethanoics, coumarin, flavonoids, omega 6, polyunsaturated and monounsaturated fatty acids, antioxidants, carthamin, beta-carotene, lignins, polysaccharides, vitamins B, C, D and E, essential oils – 0.1% myristic acid, 6% palmitic acid, 0.2% palmitoleic acid; 2% stearic acid, 72% oleic acid, 16% linoleic acid, 1.4% linolenic acid, 0.3% arachidic acid and 2% gadoleic acid (CORONADO, 2010; ASGARPANAH and KAZEMIVASH, 2013).

The oil, because it presents greater quantity of linoleic acid containing tocopherols, known by their antioxidant effects and high content of vitamin E, is indicated for diets of patients with cardiovascular diseases and diabetes, since that it helps in the reduction of the cholesterol level in blood, being nutritionally similar to the olive oil (ARSLAN, 2007; SINGH and NIMBKAR, 2006).

As industrial oil, safflower offers potentialities for many uses, and they are applied in the fabrication of paints, enamels, soaps, among others (OELKE et al., 1992; EKIN, 2005). Stone (2017) reports that the great quantity of oleic acid in safflower oil, on average of 72%, has attracted the industries of plastics, resins, inks, printing pigments, solvents, cosmetics, lubricants, among others; replacing the petroleum derivatives, because of its high stability and biodegradability. In Australia and in the United States, since 2012, genetic improvement programs have been developed for raising the percentage of oleic acid in safflower oil to 92% with high purity, at the same time reducing undesirable polyunsaturated inputs

Safflower: animal feeding

The safflower in the form of grazing forage, silage (voluminous) and of seed cake (industrial by-product, with protein content of 35%), is indicated as supplementary feed for cattle, goats, sheep, pigs and poultry (MÜNDEL et al., 2004; ARANTES, 2011), in the form of seeds is intended to the consumption *in natura* for feeding of pet birds, such as, parrots, parakeets, canaries, cockatiel, among others, mainly, in Canada, besides that, Dajue and Mündel (1996) report the use of seed for feeding small animals, such as guinea pigs, hamsters, chinchillas and rabbits.

Landau et al. (2005) in research in the North of Sardinia, Italy, with safflower as forage plant for sheep grazing, observed an average yield of MS (dry matter) of 5.1 ton ha^{-1}, using 43 kg ha^{-1} of seeds for forage establishing. Danieli et al. (2011) verified great adaptation of safflower forage for agriculture and livestock production in the region of Viterbo, Italy, as supplementary option for grazing of sheep production of wool.

The silage of safflower occurs in vegetative phase, before flowering, with good quality, presents good yield of seeds, similar to oat (*Avena sativa L.*) and canola (*Brassica napus* L.), recommended the use in lactating animals. According to the technology used and the development stage, the production of dry matter can reach the average of 6.0 ton ha^{-1}. The use of seed cake by-product of the industry presents a protein value of 35% ideal for feeding of ruminants and monogastrics, because it does not have antinutritive factors (LANDAU et al., 2004; MÜNDEL et al., 2004).

The Agronomic Institute of Paraná (Instituto Agronômico do Paraná - IAPAR) has been researching the destiny of residual from oil extraction for biodiesel in Brazil, and, interesting results were produced, mainly, for animal feeding (Table 3). However, we must take care in diet formulation not to exceed 8% of total fat for ruminants, thus the residues of seed cake contribute for the supplementation of animal diet in different percentages (IAPAR, 2017).

Possenti et al. (2016) report that the shortage of silage in Brazil is a recurrent problem in the agricultural and livestock sector, due to the alternation of cultivation and seasonality. Besides, they quote that the increasing demand for renewable fuels makes Brazil a country with potential for biodiesel production and derived from vegetable oils, and from those extractions a great volume of residues is generated, which can be destined to animal feeding.

TABLE 3 - Seed cake - oil extraction residue for biodiesel (100% of dry biomass) (IAPAR, 2017).

Species	Crude protein (%)	Ethereal extract (%)
Gossypium hirsutum L.	27.79	8.26
Carthamus tinctorius L.	17.36	24.02
Helianthus annuus L.	19.40	29.80
Raphanus sativus L.	39.75	15.93
Jatropha curcas L.	25.04	11,57
Glycine max (L.) Merr.	45.49	15.27
Vernicia fordii (Hemsl.) Airy Shaw	15.55	38.11

Arantes (2011) researching the safflower culture for animal nutrition, in the municipality of Nova Odessa, SP, verified that the production of dry matter was of 14.5 ton ha^{-1}; grains was of 3.5 ton ha^{-1} and raw oil was of 0.7 ton ha^{-1}, with great indexes of palatability and digestibility indicating the safflower conserved in silage in the diet of ruminants, as alternative to voluminous. Possenti et al. (2016) observed ensilage of safflower biomass in different ways, such as safflower in silage *in natura*, faded safflower (two hours of sun exposure) safflower + 5% citric pulp; they do not presented differences in the physicochemical evaluations, in consumption and in digestibility of nutrients for ruminants.

FINAL CONSIDERATIONS

The safflower (*Carthamus tinctorius* L.) as a plant of wide fitness of uses offers raw materials for several sectors of economy and becomes an alternative of cultivation in the country, because it presents great edaphoclimatic adaptations. With an ornamental character due its beauty and rusticity, its floral stems can be used as fresh or dry cut flower, with post-harvest durability. The coloring of dried petals are used as preservatives for food and beverages and, also, for dyeing fabrics. Its oil is widely used by the pharmaceutical industry in the elaboration of cosmetics and medicines, in virtue of presenting more than 200 isolated compounds beneficial to health. In addition, by the oil industry due to its good yield of biodiesel, on average of 300 kg ha^{-1}, with waste recovery of the extraction for animal feeding. The plant *in natura* presents medicinal character, and it can be consumed in form of tea or preparations, moreover, in initial stages it can also be used for grazing and silage production.

ACKNOWLEDGEMENTS

To CAPES (Coordenação de Aperfeiçoamento de Pessoal de Nível Superior) by the incentive and funding of this work, and to the Postgraduate Program in Agronomy of Universidade Federal de Santa Maria.

REFERENCES

AMBROSANO, L. **Avaliação de plantas oleaginosas potenciais para cultivo de safrinha.** 2012. 82p. Dissertação (Mestrado em Agronomia) - Universidade Federal de Lavras, Lavras, 2012.

ANON. SemBiosys. **Canadian company develops safflower as a new source of insulin.** 2006. Disponível em: <http://www.isb.vt.edu/articles/oct0605.htm>. Acessado em: 15 nov. 2019.

ARANTES, A.M. **Cártamo (*Carthamus tinctorium* L.) produção de biomassa, grãos, óleo e avaliação nutritiva da silagem.** 2011. 46p. Dissertação (Mestrado em Produção Animal Sustentável) - Instituto de Zootecnia, Nova Odessa, 2011.

ARAÚJO, M.E.M. Corantes naturais para têxteis - da Antiguidade aos tempos modernos. **Conservar Património**, v.3, n.4, p.37-49, 2007.

ARSLAN, B. The determination of oil content and fatty acid compositions of domestic and exotic safflower (*Carthamus tinctorius* L.) genotypes and their interactions. **Journal of Agronomy**, v.6, n.3, p.415-420, 2007.

ASGARPANAH, J.; KAZEMIVASH, N. Phytochemistry, pharmacology and medicinal properties of *Carthamus tinctorius* L. **Chinese Journal of Integrative Medicine**, v.19, n.2, p.153-159, 2013.

BELLÉ, R.A.; ROCHA, E.; BACKES, F.A.A.L.; NEHAUS, M.L.; SCHAWB, N.T. Cártamo cultivado em diferentes épocas de semeadura e densidades de plantas. **Ciência Rural**, v.42, n.12, p.2145-2152, 2012.

BRASIL. **Intercâmbio comercial do agronegócio - principais mercados de destino.** Brasília: Ministério da Agricultura, Pecuária e Abastecimento. 2013. 449p.

COOPERATIVA VEILING HOLAMBRA. **Padrão de qualidade - Cartamus de corte**. Holambra: Cooperativa Veiling Holambra, 2016. 4p.

CORONADO, L.M. **El cultivo del cártamo (*Carthamus tinctorius* L.) en México.** Obregon: Ed. SGI. 2010. 96p.

DAJUE, L.; MÜNDEL, H.H. **Safflower - *Carthamus tinctorius* L.** Promoting the conservation and use of underutilized and neglected crops. 7. Rome: Institute of Plant Genetics and Crop Plant Research, Gatersleben/International Plant Genetic Resources Institute, 1996. 83p.

DANIELI, P.P.; PRIMI, R.; RONCHI, B.; RUGGERI, R. PUGLIA, S.; CERTI, C.F. The potential role of spineless safflower (*Carthamus tinctorius* L. var. inermis) as fodder crop in central Italy. **Italian Journal of Agronomy**, v.6, n.4, p.19-22, 2011.

DINIZ, J.F.; FRANCISCATTI, P.; SILVA, T.S. Tingimento de tecidos de algodão com corantes naturais açafrão (curcúma) e urucum. **CESUMAR**, v.13, n.1, p.53-62, 2001.

DOLE, M.J.; WILKINS, H.F. **Floriculture, principles and species.** London: Prentice Hall, 2005. 1023p.

DYE, Y.K.K. **Safflower dyeing with Kazuki Yamakazi. Flextiles.** 2017. 11p. Disponível em: <https://flextiles.wordpress.com/>. Acesso em: 20 nov. 2019.

EKIN, Z. Resurgence of Safflower (*Carthamus tinctorius* L.). Utilization: a global view. **Journal of Agronomy**, v.4, n.2, p.83-87, 2005.

EMONGOR, V. Safflower (*Cartamus tinctorius* L.) the underutilized and neglected crop: a review. **Asian Journal of Plant Sciences**, v.9, n.6, p.299-306, 2010.

EMONGOR, V.; OAGILE, O. **Safflower production.** Botswana: RUFORUM, 2017. 67p.

FAO. FOOD AND AGRICULTURE ORGANIZATION OF THE UNITED NATIONS. **Carthamus red - Compendium of food additive specifications**. Geneva: FAO, 2006. 3p.

FAO. FOOD AND AGRICULTURE ORGANIZATION OF THE UNITED NATIONS. **Production and processing of small seeds for birds.** Rome: FAO, 2005. 51p.

FAOSTAT. FOOD AND AGRICULTURE ORGANIZATION OF THE UNITED NATIONS STATISTICS DIVISION. **Crops:** Safflower. 2017. Disponível em: <http://faostat3.fao.org/browse/Q/QC/E>. Acesso em: 20 nov. 2019.

GIAYETTO, O.; FERNANDEZ, E.M.; ASNASL, W.E.; CERIONI, G.A.; CHOLAKY, L. Comportamiento de cultivares de cártamo (*Carthamus tinctorius* L.) en la region de Río Cuarto, Córdoba (Argentina). **Investigación Agraria: producción y protección vegetales**, v.14, n.1, p.203-216, 1999.

GUIDORIZZI, F.V.C. **Acúmulo de macronutrientes e produtividade de genótipos de cártamo (*Carthamus tinctorius* L.) em função da adubação nitrogenada no sistema plantio direto.** 2016. 80p. Dissertação (Mestrado em Agronomia) - Universidade Estadual Paulista “Júlio de Mesquita Filho”, Botucatu, 2016.

IAPAR. INSTITUTO AGRONÔMICO DO PARANÁ. **Uso de tortas residuais do Biodiesel na alimentação animal.** 2017. 22p. Disponível em: <http://www.iapar.br/arquivos/File/biodiesel/seminario270508/tortasalimentacao.pdf>. Acesso em: 10 nov. 2019.

IBRAFLOR. INSTITUTO BRASILEIRO DE FLORICULTURA. **Padrão de qualidade - Cartamus de corte.** Holambra: IBRAFLOR, 2000. 4p.

KHALIL, N.A.A.; DAGASH, Y.M.; YAGOUB, S.O. Effect of sowing date, irrigation intervals and fertilizers on safflower (*Carthamus tinctorius* L.) yield. **Discourse Journal of Agriculture and Food Sciences**, v.1, n.5, p.97-102, 2013.

KINUPP, V.F.; LORENZI, H. **Plantas alimentícias não convencionais (PANCs) no Brasil - guia de identificação, aspectos nutricionais e receitais ilustradas.** Nova Odessa: Instituto Plantarum, 2014. 768p.

LANDAU, S.; FRIEDMAN, S.; BRENNER, S.; BRUCKENTAL, I.; WEINBERG, Z.G.;ASHBELL, G.; HEN, L.; DVASH, L.; LEN, Y. The value of safflower (*Carthamus tinctorius*) hay and silage grow under Mediterranean conditions as forage for dairy cattle. **Livestock Production Science**, v.88, n.1, p.263-271, 2004.

LI, D.; MÜNDEL, H.H. **Safflower (*Carthamus tinctorius* L.) promoting the conservation and use of underutilized and neglected crops.** 7. Institute of Plant Genetics and Crop Plant Research, Gatersleben/International Plant Genetic Resources Institute, Rome, Italy. 1996. 150p.

LI, D.; YUANZHOU. H. The development and exploitation of safflower tea. In: LI, D.; YUANZHOU, H. (Eds.). **Proceedings of the 3rd International Safflower Conference**, v.14, n.8, p.837-843, 1993.

LYONS, M. **Books:** a living story. Los Angeles: Paul Getty Museum. 2011. 30p.

MADAAN, N.; MUDGAL, V.; MIHRA, S.; SRIVASTAVA, A.K.; SINGH, R.B. Studies on biochemical role of accumulation of heavy metals in safflower. **The Open Nutraceuticals Journal**, v.4, n.1, p.199-2014, 2011.

MAILER, R.J., POTTER, T.D.; REDDEN, R.; AYTON, J. Quality evaluation of safflower (*Carthamus tinctorius* L.) cultivars. In: INTERNATION SAFFLOWER CONFERENCE, 7., 2008. Wagga Wagga, Australia. **Anais...**Wagga Wagga, Australia. p.4-12, 2008.

MENDONÇA, J.N. **Identificação e isolamento de corantes naturais produzidos por actinobactérias.** 2011. 89p. Dissertação (Mestrado em Ciências) - Faculdade de Filosofia, Ciências e Letras, Universidade de São Paulo, Ribeirão Preto, 2011.

MORAIS, E.K.L. **Estudo do óleo de sementes de *Carthamus tinctorius* L. para produção de biodiesel.** 2012. 96p. Dissertação (Mestrado em Química) - Universidade Federal do Rio Grande do Norte, Natal, 2012.

MÜNDEL, H.H.; BLACKSHAW, R.E.; BYERS, J.R.; HUANG, H.C.; JOHNSON, L.; KEON, R; KUBIK, J.; MCKENZIE, R.; OTTO, B.; ROTH, B.; STANFORS, K. **Safflower production on the canadian prairies:** revisited in 2004. Alberta: Agriculture and Agri-Food Canada, Lethbridge Research Center, 2004, 43p.

NASS. NATIONAL AG STATISTICAL SERVICE. **Crop Production.** Annual Summary. Florida: Agricultural Statistics Board, 2017. 51p.

NIMBKAR, N. **Safflower rediscovered - though safflower flowers find mention in of ayurveda and in european and japanese pharmacopoeias, the interest in this crop has been rekindled in the last few years, says.** Times Agriculture Journal. 2017. Disponível em: <http://www.nariphaltan.org/Times%20Agricultural%20Journal.htm>. Acesso em: 05 nov. 2019.

OELKE, E.A.; OPLINGER, E.; TEYNOR, T.M.; PUTNAM, D.H.; DOLL, J.D.; KELLING, K.A.; DURGAN, B.R.; NOETZEL, D.M. **Safflower:** alternative field crop manual. Madison: Purdue University. 1992. 8p.

PINTÃO, A.M.; SILVA, I.F. A verdade sobre o açafrão. In**:** WORKSHOP PLANTAS MEDICINAIS E FITOTERAPÊUTICAS NOS TRÓPICOS. 2008. Lisboa, Portugal. **Anais ...**Lisboa, Portugal. p.1-5, 2008.

POSSENTI, R.A.; ARANTES, A.; BRÁS, P.; PANDRADE, J.; BFERRARI JÚNIOR, E. Avaliação nutritiva da silagem de cártamo, produção de biomassa, grãos e óleo. **Boletim de Indústria Animal**, v.73, n.3, p.236-243, 2016.

RAI, S.K.; CHARAK, D.; BHARAT, R. Scenario of oilseed crops across the globe. **Plant Archives**, v.16, n.1, p.125-132, 2016.

SAMPAIO, M.C.; SANTOS, R.F.; BASSEGIO, D.; VASCONSELOS, E.S.; SILEIRA, L. LENZ, N.B.G.; LEWANDOSKI, C.F; TOKURO, L.K. Effect of plant density on oil yield of safflower. **African Journal of Agricultural Research**, v.12, n.25, p.2147-2152, 2017.

SANTOS, R.F.; SILVA, M.A. *Carthamus tinctorius* L.: Uma alternativa de cultivo para o Brasil. **Acta Iguazu**, v.4, n.1, p.26-35, 2015.

SAWANT, A.R. **Cultivation of spineless safflower is profitable.** In: Oilseeds and Oils Research and Development Needs in the Millennium. Nova Delhi: Hyderabad, 2000. p.29-40.

SCHWEPPE, H. **Safflower - pratical hints on dyeing with natural dyes, prodution of comparative dyeings for the identification of dyes on historic textile materials.** Washington: Conservation Analytical Laboratory of the Smithsonian Institution, 1986. 61p.

SERRANO, M.C.; LOPES, A.C.; SERUYA, A.I. Plantas Tintureiras. **Revista de Ciências Agrárias**, v.3, n.2, p.3-21, 2008.

SILVA, C.J. **Caracterização agronômica e divergência genética de acessos de cártamo.** 2013. 59p. Tese (Doutorado em Agronomia/Agricultura), Faculdades de Ciências Agronômicas de Botucatu - Universidade Estadual Paulista "Júlio de Mesquita Filho", Botucatu. 2013.

SINGH, V. **To study the usefulness of petal from Indian cultivars of safflower for developing value added products of edible nature.** Paper presented at Group Monitoring Workshop on DST, New Delhi, p.7-11, 2005.

SINGH, V.; NIMBKAR, N. **Safflower (*Carthamus tinctorius* L.).** In: SINGH, R.J. (Ed.). Genetic Resources, Chromosome Engineering and Crop Improvement. CRC, New York, v.4, p.167-194, 2006.

SMITH, J.R. **Safflower.** London: AOCS Press, 1996. 624p.

STONE, A. **Safflower plants enabling a bio based industrial economy.** 2017. Disponível em: <https://fuelsandlubes.com/fli-article/safflower-plants-enabling-a-bio-based-industrial-economy/>. Acesso em: 15 nov. 2019.

THOMÉ, O.W. **Flora von Deutschland, Österreich und der Schweiz.** Gera: Berlin, Germany. 1885. Disponível em: <http://biolib.mpipz.mpg.de/thome/index.html>. Acesso em: 10 mar. 2020.

UHER, J. Safflower in European floriculture: a review. In: INTERNATION SAFFLOWER CONFERENCE, 7., 2008. Wagga Wagga, Australia. Anais...Wagga Wagga, Australia. p.1-8, 2008.

VELOSO, L.A. **Dossiê técnico - corantes e pigmentos.** Curitiba: Instituto de Tecnologia do Paraná. Curiba: TECPAR. 2012. 40p.

WEISS, E.A. **Castor, sesame and safflower.** Barnes and Noble, Inc., New York, 1971. p.529-74.

WEISS, E.A. **Oilseed crops:** safflower. Longman Group Limited, Longman House, London, UK, 1983. p.216-281.

YILMAZ, H.; COMAK, M.B.; TURGUT, F. Analysis of factors related to farmers' benefiting from safflower *(Carthamus Tinctorius L.,*) production support: the case of central anatolia in Turkey. **The Journal of Animal & Plant Sciences**, v.26, n.5, p.1411-1417, 2016.

ZHAOU, W.; LIJIE, D. Current situation and prospects of safflower products development in China. In: INTERNATIONAL SAFFLOWER CONFERENCE, 5., 2001. Montana, USA. **Anais…**Montana, USA. p.315-39, 2001.

ZHOU, X.; TANG, L.; XU, Y.; ZHOU, G.; WANG, Z. Towards a better understanding of medicinal uses of *Carthamus tinctorius* L. in traditional Chinese medicine: a phytochemical and pharmacological review. **Journal of Ethnopharmacology**, v.151, n.1, p.27-43, 2014.

ZOZ, T. **Avaliação de genótipos de cártamo quanto ao desempenho agronômico, divergência genética e produtividade da água.** 2015. 77p. Tese (Doutorado em Agronomia) - Universidade Estadual Paulista "Júlio de Mesquita Filho", Botucatu, 2015.