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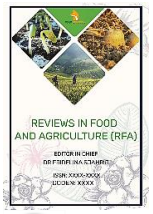

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REVIEW ARTICLE

SAFFRON (*CROCUS SATIVUS* L.): A POTENTIAL HIGH VALUE CROP FOR HILLY AREAS

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ABSTRACT

Saffron (*Crocus sativus* L.) is a perennial, herbaceous geophyte successfully grown in the temperate region. Its stigmas are the most economical part and the most expensive spice on earth. Secondary metabolites: crocin, picrocrocin and safranal are responsible for its colour, flavour and aroma respectively. It is used as spice, fragrance, dye, cosmetics and for medicinal purposes. It can also be grown under rainfed conditions and low nutrient input in the hilly areas of Nepal at an altitude of 1500-2800 meters above sea level. Annually, Nepal produces around 7-10 kilograms of saffron which is far beyond the national demand. It is a low volume high value commodity and the availability of its suitable agroclimatic conditions in Nepal has created an immense possibility towards its production leading to import substitution and export promotion. Along with the proper nutrient management, proper plant density with adequate irrigation facilities and weed management, availability of disease free and quality corms, technical knowledge on modern room cultivation and proper postharvest processing are the key factors that should be looked after for the higher production of saffron.

KEYWORDS

Corms, quality, room cultivation, saffron, stigma

1. INTRODUCTION

Crocus sativus L., commonly known as the saffron plant, is a triploid (2n=3x=24) monocotyledonous, herbaceous, perennial geophyte about 20-30 cm tall belonging to the family Iridaceae (Iqbal et al., 2012; Kahriz, 2020). Saffron is cultivated for its dried stigma and styles of flower which is the economical part of it (Andabjadid et al., 2015; Brian, 2006). Among the 85 species under the Crocus genus, *Crocus sativus* L. (saffron) is economically the most important species (Behdani, 2011). It is also known by the name "Red gold" and is appreciated for its color, flavor, and aroma which are due to the presence of crocin, picrocrocin and safranal respectively (El Hajj et al., 2019; Rashed-Mohassel, 2020). It is the most expensive spice crop in the world (Chaudhary and Pandey, 2003). The price of saffron depends upon the type of saffron, its origin and its quality. Super Negin type of Persian saffron, grade 1 costs around 10 USD per gram in Europe and in India its price ranges from 3 to 4 USD per gram (Saffranir, 2021).

Saffron is native to Asia minor and is geographically distributed in Mediterranean climates, East Asia (latitudes 30-50° N and longitudes 10° E to 80° W), as well as in Irano-Touranian regions with low annual rainfall, cold winters, and hot summers (Kafi et al., 2006; Kumar et al., 2009). It is being cultivated in some of the major countries of the world such as Iran, India, Afghanistan, Morocco, Greece, Spain and Italy, and more or less in many other countries with a world production of 418 t/yr (Cardone et al., 2021). Iran is the leading country, occupying a maximum area of 43.408 thousand hectares under saffron cultivation with the production of 174 tonnes and the productivity of 4 kg/ha contributing about 88% of the world's saffron production. India ranks second and Greece ranks third (Mashayekhi and Latifi, 1998; Menia et al., 2018).

Table 1: List of Supplying Markets for Saffron Imported by Nepal

Exporters	Imported value in 2020 (NPR)	Imported value in 2019 (NPR)	Imported value in 2018 (NPR)	Imported value in 2017 (NPR)	Imported value in 2016 (NPR)
India	9,175,762	4,794,387	3,305,104.33	7,320,684	4,607,067
Spain	2,394,499	1,993,272	3,583,118.30	3,259,183	2,572,973
U.S.A.	1,867	0	0	0	0
Thailand	0	0	12,872	0	0
Iran	0	0	0	16,998	0
China P. R.	0	469,387	54,465	0	600
Total import of Nepal	11,572,128	7,257,046	6,955,559	10,596,865	7,180,640

Note. Adapted from NTIP (2020).

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In Nepal, Saffron cultivation was initiated in Jumla during 2045 B.S. and has been cultivated in Makawanpur (Daman), Lalitpur and Ilam (Chaudhary, 2004; Investopaper, 2021). Production of saffron is about 7-10 kg per year in Nepal which is not be able to meet the national demand. Saffron is worth NRs. 11,572,128 was imported in Nepal in 2020 mainly from India, Spain, USA and others whereas export is very little. Nepal is exporting saffron to China, India, Switzerland, Korea, etc. (NTIP, 2020).

Table 2: List of Importing Markets for Saffron Exported by Nepal

Importers	Exported value in 2020 (NPR)	Exported value in 2019 (NPR)	Exported value in 2018 (NPR)	Exported value in 2017 (NPR)	Exported value in 2016 (NPR)
Korea R	15,373	0	0	0	0
Switzerland	0	0	0	126,852	0
India	0	0	0	0	344,950
China P. R.	0	93,000	38,000	1,840	42,000
Total export of Nepal	15,373	93,000	38,000	128,692	386,950

Note. Adapted from NTIP (2020).

1.1 Uses

The three-branch style of *Crocus sativus* flowers, called saffron, is the most important economic part of the plant. Saffron has a long history of use as a spice, as well as for its beautiful color, aroma, and flavor. Saffron is a well-known spice, but it also has a variety of applications in the food, pharmaceutical, cosmetics, and perfume industries, as well as in the manufacture of textile dyes (Kafir et al., 2010). It is used in confectionery, alcoholic and non-alcoholic beverages and also used as a coloring agent. Saffron is used in dairy products such as butter, cheese and ice cream for its color and flavor improvement.

It is commonly used as herbal medicine against coughs, common cold, scarlet fever asthma, etc. and also as an antiseptic, antidepressant, antispasmodic, anticancer and carminative (Mashayekhi and Latifi, 1998; Menia et al., 2018). Relaxant, expectorant, invigorating agent, digestive stimulant, spasm calmative, menstruation and fetus abortion are the other qualities of saffron. Saffron is also used against bloody diarrhea, dysentery, fever, measles, hepatitis, jaundice, liver and spleen syros, urine infections, hysteria, cholera, diabetes, and dermal diseases (Kafir et al., 2010; Sampathu et al., 1984). People use saffron leaves as a forage although it has an intermediate quality and digestibility due to higher fiber content compared to other feeds such as alfalfa. They are either directly grazed or are used in the form of hay. About 1.5 t/ha dry matter leaf is produced per year (Mohammad-Abadi et al., 2007).

1.2 Saffron toxicity

Saffron possesses narcotic and ecstatic effects, as well as excessive delight, which can lead to temporary paralysis when consumed at large doses. Doses of more than 10 g of saffron may induce abortion with reported side effects including decreased appetite, drowsiness, nausea, vomiting, dizziness, uterine bleeding, haematuria and bleeding of the gastrointestinal mucosa (Schmidt et al., 2007).

2. Biological Description

Spherical and compact saffron corms with flat bases can have a diameter up to 5cm and can weigh up to 50 grams. They bear thin reticulated fibrous tunics that extend upward approximately 5 cm above the neck of the plant. The corms are dormant during summer and sprout in autumn. Flowering occurs from late autumn to December, depending on the climatic conditions. Flowers of saffron appear before any vegetative development, its growth starts in autumn and ends in spring. Flowers should be harvested early morning before sunrise (Behdani, 2011; Rashed-Mohassel, 2020).

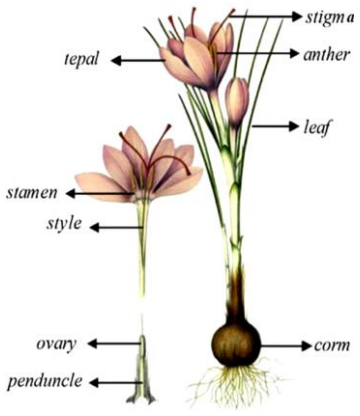

Figure 1: Structure of Different Parts of Saffron Plant

Note. Adapted from "Main chemical compounds and pharmacological activities of stigmas and tepals of 'red gold'; saffron," by T. Shahi et al., 2016, *Trends in Food Science & Technology* 58, 69-78.

Each corm produces six to nine narrow, grass-like leaves which are dorsiventral and navicular, and a long narrow tubular purple-colored flower (borne singly or in two or three) made up of six petals, expanding out at the top. The pistil, which is made up of a bulbous ovary and a thin stalk called the style, is located in the center of the flower. The style is pale yellow and divides into a brilliant orange-red three-lobed stigma, 2.5 to 3 cm long. The three stigmas along with its long style (about 5 cm), when dried, constitute the pure saffron of commerce (Sampathu et al., 1984).

Absorbing roots, contractile roots and contractile absorbing roots form the adventitious root system in the saffron plant. Absorbing roots, originating from the base of the corm, are thin, rather long, and fibrous. Contractile roots are thick, short and develop singly at the base of sprouting buds acting in deepening the newly formed corm. It may also absorb water and nutrients. Contractile absorbing roots develop on the parent corm near sprouting buds and bear the contractile roots (Rashed-Mohassel, 2020).

2. Cultivation Practices

3.1 Climatic requirement

Saffron can be cultivated in temperate, semi-arid, and arid areas at an altitude of 1500–2800 m above sea level with an average temperature of 15°C and an average rainfall of 600-1000 mm (Chaudhary and Pandey, 2003; Rahimi et al., 2017). Northern aspects of the same altitude and higher altitude affect the yield through delayed flowering (Sampathu et al., 1984). Saffron prefers cool to cold winters with autumn-winter spring precipitation and warm summers with very little rainfall (Brian, 2006). Early flowering can be obtained at 17°C and higher temperature causes flowers to wilt (Molina et al., 2010). Spring rains are considered favorable for new corm production but frosts or rains during the flowering are harmful and damage the crop. Dry or moderately humid weather is the ideal condition at the flowering time to grow quality saffron (Sampathu et al., 1984).

3.2 Soil requirement

Saffron can be grown on a broad range of soil types but it should be loose, friable, well-watered as well as well-drained with high organic content and a pH of 6.8-7.8 (Zarghani et al., 2016). The corms tend to rot in humid or water-logged soils (Sampathu et al., 1984). It can be well grown from well drained clay soil and loose clay calcareous soils to sandy or loamy textured soils with slightly saline conditions (Dar et al., 2017; Mashayekhi and Latifi, 1998; Menia et al., 2018; Shahandeh, 2020). A group researchers reported that the yield was highest in the sandy soil while soil water supply, nutrient uptake, and safranal content were higher in clay soil (Husaini et al., 2010).

3.3 Propagating material

Since the saffron plant is triploid, it is necessarily sterile and no seeds are formed. They multiply vegetatively through the corms (Brian, 2006). Therefore, the selection of proper corms is crucial for production. The size of the corm plays important role in flower and corm production (Kaushal and Upadhyay, 2002). The larger the corms, the higher will be the production because they have more reserved food materials which result in more emergence percentage, early flowering and long flowering span, more number of plants, more flowers per unit area and also larger flowers

(Investopaper, 2021). A corm size of more than 10 grams is recommended for the commercial plantation otherwise flowering will be delayed (Chaudhary and Pandey, 2003). A group researchers suggested 7-10 cm (circumference) corms for flower production, 2-4 cm and 4-7 cm sized corms for the corm production and there is no difference in the quality of saffron in using different sized corms (Ozel et al., 2017). A study reported that two corms per hill weighing >15g planted at a distance of 25cm*15cm gave the highest saffron yield and corm yield (Iqbal et al., 2012).

3.4 Field preparation and planting time

Saffron can also be grown in marginal land with low nutrient input. Flower yield mainly depends on the reserve food materials of the corms. The size and weight of the corms determine the yield and the quality of the saffron. That's why nutrient management should be done considering the performance of 3-4 years of cultivation practice. It also depends upon the preceding crops grown on the field. The use of organic manure not only provides nutrients to the plant but also improves overall soil health (Kumar and Sharma, 2017). The incorporation of chemical fertilizer in less fertile soil increases the yield. Before planting in September, incorporating 30 tons of farmyard manure per hectare, 2.5 quintals of vermicompost, and 30:20:15 kg/ha or FYM at 10 tons/ha, vermicompost at 5 q/ha, and 90:60:50 kg/ha NPK assures a saffron yield of 7.00 kg/ha, compared to 1.55 kg/ha in traditional approaches (Yasmin and Nehvi, 2013). Planting of the corm is done from August to early October, but in some cases early planting in June and July may be carried out. In Spain, planting is done from the middle of May to the beginning of June, and in Kashmir from mid-July to the end of August. In Nepal, planting is done in September, and flowers are harvested in November whereas corms are harvested in April which are then stored till September for plantation.

3.5 Planting methods

There are two methods of planting: traditional field cultivation and modern room cultivation. In traditional methods, corms are directly planted in the field so both flowers and corms are harvested from the field but in the modern room cultivation method, flowers are harvested from the room cultivation and corms are planted in the field for the multiplication of corms (Chaudhary and Pandey, 2003; Chaudhary, 2004). They can also be used as an intercrop with vegetables and in the fruit orchard.

Figure 2: Different Planting Methods of Saffron

Note. Field cultivation of saffron (top) and room cultivation of saffron (buttom). Adapted from "How to grow saffron," Gruloda team, 2019/20, Gruloda. https://gruloda.com/tag/grow-saffron/. Copyright 2021 by gruloda.com

Corms are planted at the row spacing of 20 cm with corm to corm spacing of 10 cm. Higher flower production as well as higher dry leaf yield was reported in the narrower spacing of 5cm*20cm (Mohammad-Abadi et al., 2007). Saffron corms when planted at a distance of 20cm*10cm with 1 corm/ hill or 2 corms per hill at a distance of 25cm*15cm, needs 50 quintals of corms/ hectare resulting in a planting density of 5 lakh corms/ hectare (Menia et al., 2018).

Generally, corms are planted at the depth of 15 cm. Deep planting provides more or less uniform soil temperature which is necessary for good production. The yield is also higher than the surface planting (Molina et al., 2005). More number of corms can be obtained when planted at the shallow depth (10cm) while flower yield is maximum when planted at a depth of 15 cm (Galavi et al., 2008).

3.6 Corm treatment

Corm rot is a major disease for the saffron decline in most parts of the world so quality planting materials should be used (Gupta et al., 2021). Corm rot of saffron is a destructive fungal disease caused by *Fusarium oxysporum* and *Fusarium solani* over which *Trichoderma viride* and *Trichoderma herzianum* have shown effective control in in-vitro condition (Shah et al., 2018). Captan 50WP (50 µL mL^{-1}) effectively inhibited mycelial growth on *F. oxysporium* and *F. solani* followed by mancozeb 75 WP (100 µL mL^{-1}) as non-systemic fungitoxicants (Shah et al., 2018). Selected corms must be treated with 150 g of Mancozeb 75 W.P. @ 0.3% and 50 g of Carbendazim 50 W.P. @ 0.1% in 50 liters of water before planting to control corm rot disease. The graded corms are dipped in the fungicidal suspension (Mancozeb and Carbendazim) for a period of 5-10 minutes and then allowed to dry in shade for another 10 to 15 minutes to drain off excess moisture (Menia et al., 2018).

3.7 Irrigation

Water is sprinkled on the corms to keep them moist in case of room cultivation. In the field method, no more water is given after planting in rainfed conditions, but water scarcity during the active growth stage adversely affects saffron yield and corm multiplication (Kumar and Sharma, 2017). For proper growth and development, corms can be primed with water before planting. Sufficient water is required from October until May to obtain a higher yield (Behdani, 2011). The water requirement of saffron is around 3600 m^3 ha^{-1} during the first growing season (Fallahi and Mahmoodi, 2018). It is a shallow rooted crop that utilizes moisture within 40 cm soil depth so frequent irrigation is necessary (Aghhavani Shajari et al., 2020). It has been reported that irrigation in the early flowering caused higher yield. Irrigation during flowering will damage the product. During dry climatic conditions, watering can be done during spring or summer, before or after flowering (Sampathu et al., 1984).

3.8 Weed management

Weeds are manually removed in time as required. Delay in weeding interferes with the flower and corm harvesting. They also compete for moisture, light, nutrients and other inputs. Weed control is necessary for a crop's healthy growth. Weeds can also be managed with the herbicides Simazine or Atrazine at 1.0 kg ha^{-1} (Dar et al., 2017; Pandy and Srivastava, 1979).

3.9 Harvesting

Harvesting is done in late autumn and flowering lasts for about 4 to 6 weeks. After the dew has disappeared in the early morning, flowers should be picked before the flowers wither, because of the sun getting hot. It is better to harvest when the flowers are closed or when they just start to open as it offers easiness for harvest and stigma also does not get deteriorated. The gathering has to be done manually as they are very delicate. Flowers are caught in between thumb and forefinger and are detached without damaging the leaves. Abundant laborers, care, and patience are required for this operation (Antonelli et al., 2011; Sampathu et al., 1984).

3.10 Separation of stigmas

The blossoms are placed on tables indoors and the stigmas are removed on the same day.

3.11 Yield

The number of flowers per unit area depends on many considerations including soil, locality, climatic factors like temperature regime and rainfall, and quality of planting material. The bigger the corms, the higher will be the production (Pandy and Srivastava, 1979). In India, the yield is 2.29 kg/ha whereas Iran has the highest productivity of 8.16 kg/ha (Menia et al., 2018). In the first year of flowering, the yield of saffron is negligible. A good amount of saffron can be harvested after the second year only which gradually declines after 3 to 4 years. One kilogram of saffron is gathered from 5 kg stigmas derived from 80 kg (or 150,000) fresh flowers.

4. Processing of Stigmas

Fresh saffron must be dried to preserve it. Proper drying ensures the quality of saffron. The characteristic odour of saffron is produced at the

time of drying when the bitter constituent picrocrocin is hydrolyzed, releasing the volatile aldehyde, safranal. In sun drying, the stigmas are dried for 3 to 5 days in the sun till the moisture content is reduced to 8 to 10%. Sometimes, whole flowers are sundried and the stigmas are picked from the dried flowers. It is considered less efficient and the product is liable to become moldy, if not thoroughly dried. They can also be dried by placing a 2-3 cm thick layer of saffron on the sieve of 30 cm diameter over a small fire of wood charcoal. The sieves are stacked and their order and position is changed for uniform drying. It takes about 5-6 hours at an optimal temperature of 35-45 °C using an oven or solar driers to obtain high quality saffron (Raina et al., 1996). The amount of secondary components, crocin, picrocrocin and safranal, remain higher when oven dried at 40 °C than the shade drying. After one year of storage, a significant decrease in the level of crocin and picrocrocin was observed in the shade dried saffron (Chaouqi et al., 2018).

5. Storage

Saffron quality is heavily dependent upon its storage methods. Impermeability towards gases, moisture and light are vital factors in the selection of packaging materials. Dried saffron should be stored in a cool and dry place in small, clean, dry and airtight containers so that it does not absorb moisture from the air. It can be well preserved for 2-3 years if stored in the right place and with the right methods. Crocin content, responsible for the coloration, was decreased under the storage condition whereas safranal was increased during the storage as compared to fresh saffron (Sereshti et al., 2018).

Packaging materials such as glassware, polyethylene bags, polyethylene jars and aluminium-layered bags can be used. Aluminium has also a great potential for saffron packaging as it is opaque, impermeable to water and gases, resistant to oxidation and corrosion, does not react with food materials or any other chemicals to produce any toxic residues and can be easily recycled. Glasswares allows for photo-oxidation which discolours saffron though it offers a quality look for the consumers. Low density polyethylene (LDPE) is a commonly used packaging material for saffron. When stored at 0 °C, the physical and quality properties of saffron was well preserved (Shoormij et al., 2013). Modified atmospheric packaging (MAP) can significantly increase the shelf-life of the products. Nanosilver when added to the packaging materials aids further protection against microorganisms. Biofilms can be an environment friendly alternative as packaging material but they should be developed with a good barrier property (Koocheki, 2020).

6. Production and Technical Constraints

Saffron is one of the most historic and traditional crops. The traditional method of cultivation has been adopted in most parts of the country for saffron production which yields lesser than the room cultivation (Chaudhary and Pandey, 2003; Chaudhary, 2004). It needs some skillful manpower for the room cultivation which is lacking due to poor technical manpower and poor extension services. Focus is given in commercial cultivation as well as in research on high value low volume crop but its implementation seems poor. Being a triploid plant, no seeds are produced from the sterile saffron flowers and corms are the propagating materials. The big hurdle in saffron cultivation is the production and supply of saffron corms as seed. Only four to five daughter corms are produced each season. Expensive corms make first planting costlier and deterrent for the farmers. Harvesting is done manually in a short time which extends about a month and is a laborious job. Mechanization is inappropriate due to its delicate flowers. This creates a challenge in the timely availability of a large number of laborers at the time of harvest.

7. Conclusion

Saffron is a low volume high value spice and there is an immense possibility of saffron production in Nepal. There's a huge global market for saffron. Nepal produces only about 7-10 kilograms of saffron per year which is very negligible as compared to its national demand. It is low water demanding crop and can be grown under harsh conditions as well giving satisfactory income for farmers. So, most of the rainfed hilly areas from east to west are suitable and have great potential for saffron production. Use of disease free and quality corms, proper nutrient management with adequate irrigation facilities, proper weed management practices, proper processing and storage are the key factors for successful saffron cultivation. Technical and financial support should be provided to the farmers for the modern room cultivation and well managed field cultivation of saffron. Quality corms should be made easily available and affordable. Automation or semi-automation of saffron harvesting should be developed which solves the problem of harvesting due to shortage of laborers. Effective and efficient plans, policies and programs should be formulated and implemented by the government in the research and development of saffron in Nepal.

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