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Review

Saffron as a valuable spice: A comprehensive review

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Saffron (*Crocus sativus* L.) is an autumn flowering high value, low volume spice crop that grows throughout Mediterranean Europe and Western Asia between 10° west and 80° east longitudes and 30 to 50° north latitudes. At present, saffron production is limited to Iran and countries of older civilizations such as India, Spain, Italy, Greece, and Turkey. Its cultivation is under threat of extinction and thus warrants attention of researchers and policy makers. Like Kashmir, its revival is to be taken on mission mode approach, particularly in the areas where its cultivation has been abandoned by the farmers. Sher-e-Kashmir University of Agricultural Sciences and Technology of Kasmir, India, and other International Organizations, have instituted research programme for systematic improvement of saffron from production to consumption system. This review deliberates on the latest work being done for promotion of saffron farming as an economically viable venture for livelihood security.

Key words: Plant, research and development (R & D), saffron.

INTRODUCTION

History and distribution

Saffron as a cultivated plant grows from altitude of sea level to almost 2000 m, although it is more acclimatized to hill sides, plateaus and mountain valleys ranging in altitudes between 600 and 1700 m (Delgado et al., 2006). The advantage with this crop is that this plant can be cultivated in arid or semi arid areas where the water deficit is extreme in summer (Agavev, 2003). There are different accounts on the origin of saffron from the mountainous regions of Asia Minor to Greece, Western Asia, Egypt or Kashmir (Delgado et al., 2006). Saffron was known by the Sumerian civilization (6th millennium BC) and Greece was the physical bridge for its entry in Europe. Polien, the Greek historian at 2 BC, has recorded all the spices from the metal column erected in front of the King's palace (Kafi et al., 2006).

Around 2400 BC, there were evidences of its use in coloring tunics in Castile-la-Mancha region of Spain (Perez-Bueno, 1995). Saffron became more renowned in Mesopotamia with the development of Babylonian culture. Several texts speak of its use as a condiment during the reign of Hammurabi (1800 to 1700 BC) and also of the fact that dyes and paints constituted other uses to which it was put (Perez, 1995). It was also reported to be important in Acadia culture around 2350 BC (Polunin and Smythies, 1981). Iranian historians have different theories about the origin of saffron. According to the Iranian history, saffron originated from Zagross and Alvand Mountains. Its oldest evidence dates back to "Achaemenian", an ancient Persian dynasty (Kafi et al., 2006)

Saffron finds its name in the oldest text of Kashmir (Nilamatapurane, Vol. 1). Also, in the much celebrated ancient cluster of Kashmir, "Rajtarangini", Kalhana includes Kashmiri saffron among those special attributes of Kashmir, which according to the people of Kashmir cannot be available even in the paradise (Nehvi, 2010; Nehvi and Salwee, 2010). Saffron is mentioned in the 5th century BC in Kashmiri records (Nauriyal et al., 1977).

Iran, Kashmir and Spain are the major saffron producing countries of the world. In Iran, saffron is cultivated in Sourthern Khorasan province located at an altitude of around 1000 m.a.m.s.l (Koocheki, 2004; Agavev

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et al., 2009). Birjand, Ghaen, Gon-Abad, Torbathadariah, Firdous, Istahban, Kerman, Isfahan, Kashan and Shahr-kord are major saffron producing areas of Iran (Ehsanzadeh et al., 2004). Kashmir, the second largest contributor of saffron to the global market accounts pampore Tehsil of Kashmir (India) the main hub of saffron activity located at 34° 1' N, 74° 56' E, with an average alleviation of 1574 m.a.m.s.l. Khunmoh, Zewan, Balhama, Sampora, Ladhoo, Chandhara, Woyan, Khrew, Shar Konibal, Dussu, Namblabal, Kadlabal, Hatiwara, Samboora and Lethpora are prominent saffron villages of Tehsil Pampore (Nehvi and Yasmin, 2011). Castile-La-Mancha region located at an altitude of 600 m with pluviosity of 300 to 400 mm is famous for Mancha saffron produced in the regions which are, Albacete, Cidadreal, Cuenca, Toledo and Teruel.

Greece, Azerbaijan, Turkey, Morrocco, Italy and France are other saffron producing countries, contributing about 2% to the total global saffron production. In Greece, Krokos Kozani region is dedicated to saffron cultivation (Theodora et al., 2004). Sub mountainous areas between 650 and 1100 m of Aquila, Cerdena and Emilia-Romagna and San Gimigiano are famous in Italy for saffron cultivation (Galigani and Garbati, 1999). In Azerbaijan, it is cultivated on the peninsula of Apsheron near Baku in a region of reduced precipitation 223 mm (Azizbekova and Milyaeva, 1999). In Turkey, Hivan Hapier village, Viran village of Urfa and saffron bolu, are famous for saffron cultivation since ages. In Morocco, saffron is cultivated in several areas around Taliouine located at an altitude between 1200 to 1400 m near the Atlas mountain with extremely low precipitation between 100 to 200 mm (Ait-Oubahou and El-Otmani, 1999)

The plant

Saffron is classified into Magnoliophyta division, Class *Liliopsida* and Order *Asparagales*. It is a member of the Iridaceae family and the *Crocus* L. genus. Crocus consists of 9 species, *Crocus cartwrightianus* and its derivatives, *C. sativus*, *moabiticus, oreocreticus, pallasii, thomasii, badriaticus, asumaniae* and *mathewii* (Nehvi and Shafiq, 2008).

The karyotype of *C. sativus* was the subject of research by many authors for genetic differentiation in relation to chromosome number, arm ratio, arm size and centromere position while the other species of *C. sativus* aggregate in this respect remain poorly studied (Chichiricco, 1984; Dhar et al., 1988; Himmelbauer, 1926; Rzakuliyev, 1945; Ghaffari, 1986; Grilli, 2004; Agayev, 2002; Agayev et al., 2010).

It has been established that saffron cultivation in many countries has 2n = 24 chromosomes, is triploid and for this reason sterile. Agavev et al. (2010) reported that saffron from Kashmir is identical in structure of karyotype with usual saffron (*C. sativus* L.). However, some significant distinctions are present: (1) All three satellites at three chromosomes of the second triploid are identical in size; (2) the total length of all chromosomes of triploid set 2n = 3x = 24 in saffron of Kashmir is authentically more than in usual *C. sativus*. In a triplet four, the homologues 1 and 2 have arm ratio equal to 1.50 whereas the homologue 3 has arm ratio of 1.2. The difference is significant and absent in usual *C. sativus*.

Saffron with subhysteranthous behavior is a perennial herbaceous plant attaining a height of 25 to 40 cm. Corm, foliar structure and floral organs constitute main parts of saffron plants (Nehvi and Salwee, 2010). Corms consist of nodes and are internally made up of starch-containing parenchyma cells. These corms are 3 to 5 cm in diameter and are covered by tunics. Apical, subapical and auxillary buds are found in internodes. Apical, subapical and axillary buds are also seen protected by dark reddish scales. As their diameter increases, they tend to group together so that majority can be found in one, two or three internodes (Perez, 1997). Roots emerge radically at the height of the third basal internodes. They are thin white in color, numerous and variable in length. At the base of the daughter corm, a much thicker root than the absorbent roots may arise, which is known as the contractile roots (Maryam et al., 2004).

Each corm produces five to eleven green leaves or monophylls, 1.5 and 2.5 mm wide found per sprout and are called bristles and can measure up to 50 cm (Dhar and Mir, 1997; Lucceno, 1999). The photosynthetic activity of the leaves during the early winter and the early spring months contributes to the formation of replacement corms at the base of the shoots.

Corms that are covered by tunic are dormant during summer and sprout in autumn, producing 1 to 4 flowers in cataphyll with linear leaves. Cataphylls protect and strengthen the stem in the course of its appearance on the surface (Botella et al., 2002) and protect the corms once formed from degradation and possible lesions (Lopez, 1989).

The flower has an underground ovary, a style 5 to 9 cm long dividing at the top into three red trumpet like stigmas (2 to 3 cm long) which when dried, form the commercial spice saffron. Flowers with six stigmas are also observed in the saffron fields, however this kind of variation does not persist in the next flowering season and are generally termed as freaks (Nehvi et al., 2004).

Biological cycle

Saffron blooms in autumn when other plants are preparing to protect themselves against the rigors of winters and contrarily to others, its activity slows down during spring. Biological cycle is completed in 5 to 6 stages (Jirage et al., 1994). It has two years plant cycle starting in the month of July of the first year, the apical bud takes a year to acquire its maximum size and fully

becomes a corm, while it takes another year before it is depleted and ends up like a wrinkled black disc (recapitulation stage). In midway, the plant enters a dormant stage (Medina, 2003). During dormancy, floral and vegetative buds and roots begin to differentiate (Le Nard and Hertogh, 1993). In mid June, a progressive decrease of starch concentration is observed in the total dry matter of corms at one level (67%). Activation stage in saffron begins from September when the day temperature reaches about 25°C, with night temperature of about 15°C. Corms begin to sprout with floral and vegetative structures increasing in length inside the cataphylls.

Flowering starts in the second fortnight of October and lasts up to first week of November (Nehvi and Salwee, 2010). Flowers emerge in three to four flushes with massive emission known as covering in second flush. At the beginning of November, commencement of degradation of mother corm is visible, which looks quite wrinkled and flat (Medina, 2003). Vegetative phase starts immediately in November after flowering is over, with young leaves emerging from the corms.

The young sprouts are transformed into daughter corms and start to develop by photosynthesis besides contribution from the mother corms, which become wrinkled and leaves space for new corms. Corms enter a dormant stage from May.

Although important ontogenic process that leads to differentiation of vegetative buds takes place, nothing is observed externally (Koul and Farooq, 1984). During dormancy, there is decrease in starch concentration in the corms. Starch is converted into sucrose and other suitable soluble sugars which go to tissues where buds are being differentiated and developed (Nehvi and Yasmeen, 2010)

Propagation

Triploid nature of the species allows for vegetative multiplication, but not for regular sexual reproduction. This is because triploids meiosis and gamete development are irregular, resulting into many anomalies in sporogenesis and gametophyte development (Chichiricco, 1984). Saffron infertility is mainly related to the male gametophyte (Chichiricco, 1989). It does not produce viable seeds; therefore corms are indispensable for its propagation. The corm is vegetative organ of saffron. After flowering, the base of the stem enlarges, producing a daughter corm that propagates the plant.

According to morphological and physiological characters observed in the corm, corm development can be divided into six stages; C1 to C6. Corm at C1 stage appears as latent bud attached to the surface of older corms, and protected by scale like leaf. Stage C2 begins with floral stem sprouting and lasts until the end of flowering. It is a stage of active tissue formation, when the roots, flowers and green leaf appear. An enlargement characterizes C3 corms. During this period, the plant has green leaves and the corms act as sink organ for carbohydrates originated during photosynthesis. Once the leaf dry up, the corm advance to stage 4. During the dormancy period, the daughter corms grow independently because the mother corm is senescent. Corms at stage C5 maintain sprouting and growth of daughter corm from stage C1 to C3. Finally, corms at stage C6 are senescent, when the daughter corms advance to C4 and become independent (Manuel et al., 2004). The number of scar like buds covered by scaly leaf present on the surface of mother corm varies from 2 to 20 depending on the corm size (1.0 to 6.0 cm). Micropropagation protocols are presently underway as an alternative route for propagation. Explants from corm tissues, lateral or apical buds, leaf or nodal tissues and different floral parts have been used for *in vitro* regeneration of saffron (Dhar and Sapru, 1993; Ahuja et al., 1994; Karamian and Ebrahimzadeh, 2001; Karaoglu et al., 2006; Salwee et al., 2010, 2011a, b).

Composition

Saffron is valued for its color, taste and aroma. The compounds that give it these properties are what define its quality. Saffron predominantly contains chemical constituents such as crocin, picrocrocin and saffranal which are responsible for its color, flavor and aroma, respectively (Figure 1). Crocetin glycosyl esters are responsible for its characteristic color. These compounds are found in extremely important proportion in stigmas (Sampathu et al., 1984). These are the majority carotenoids present and other minority ones include alpha and beta carotene, lycopene and zeaxanthin as well as a conjugated xanthocarotenoid. Saffron contains flavonoids, and one of the general properties defining this extensive group of compounds is bitterness. The first researchers to identify a flavonoid in saffron extracts through mass spectrometry were Tarantilis et al. (1995). The characteristic bitter taste of saffron has been postulated due to the presence of a glycoside named picrocrocin whose structure was established by Khun and Winterstein (1934).

Picrocrocin is a precursor of safranal, the major compound in saffron aroma. The study of saffron aroma began around the first quarter of the 20th century with the isolation and identification of safranal, the major aromatic compound. It is generated from crocetin esters. It was obtained for the first time by Winterstein and Teleczky (1922), by means of alkaline or acid hydrolysis of picrocrocin. Carotenoid degradation either by thermal treatment or enzyme activity gives rise to small compounds that contribute to aroma and flavor. Saffron is also a rich source of proteins, vitamins (riboflavin and thiamine), potassium, iron, copper, zinc, sodium and

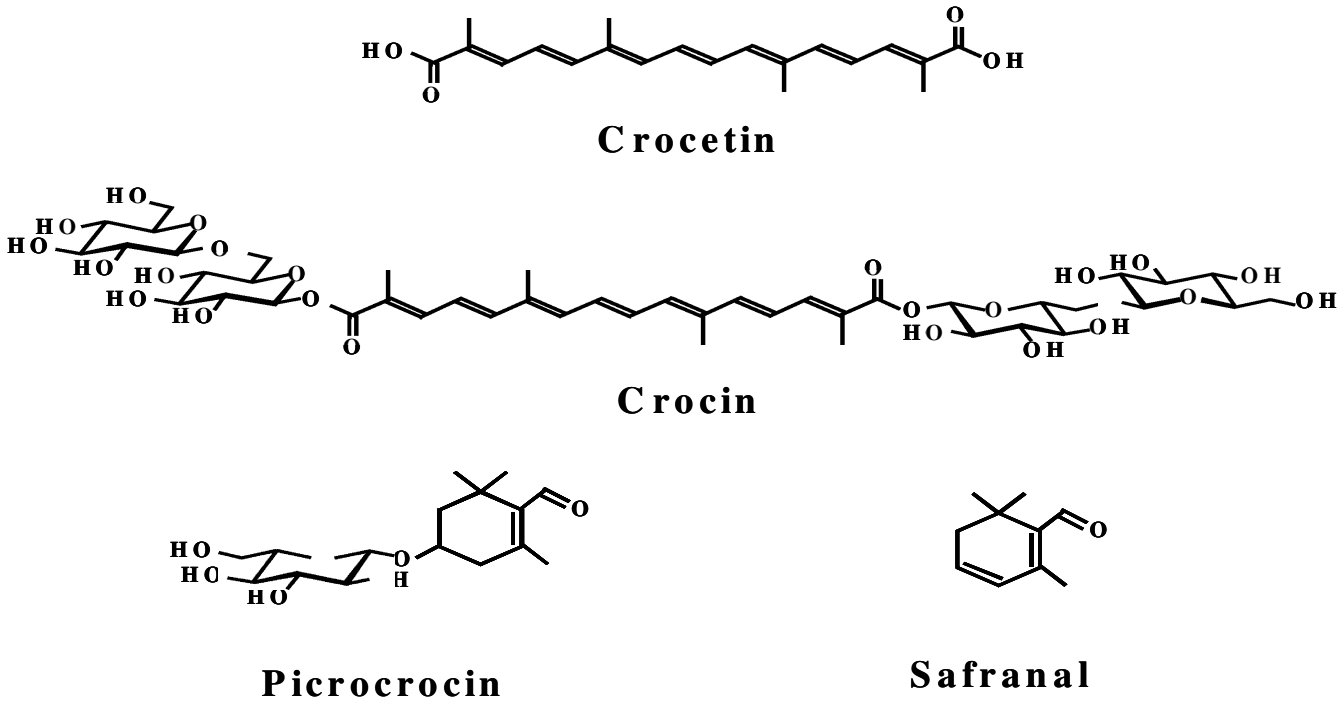

Figure 1. Contains chemical constituents predominant in saffron.

manganese thus imparting antioxidant property to it. This property confirms the status of saffron as functional food (Nehvi et al., 2011a).

Uses

The most ancient cultures on record that used saffron, established in Mesopotamia, utilized it principally as a condiment, in religious rites and celebrations, and also as a dye for their clothes (Perez, 1995). Egyptians and Hebrews used it to carry out ablutions in temples and sacred places (Capel and Girbes, 1988). Saffron, its extracts and tinctures have been used in traditional medicine as an antispasmodic, eupeptic, sedative, carminative, diaphoretic, expectorant, stomachic, stimulant, aphrodisiac, emenagogue and abortive agents (Rios et al., 1996). It has also been used for the treatment of ocular and cutaneous conditions (Xuan et al., 1999), lowering blood pressure (Soeda et al., 2001), for wounds, fractures and joint pain; to prevent the plague and other epidemics; to cure anaemia, migranes and insomnia, promoting and regulating menstrual periods (Akhondzadeh et al., 2004, 2007) sores and as a cardiotonic (Schmidt et al., 2007; Bathaie and Mousavi, 2010) and treatment of respiratory disorders (Xi et al., 2007; Xiang et al., 2006).

It is known for its antigastric effects (Al-Mofleh et al., 2006), antidiabetic activity (Shen and Quin, 2006), anticonvulsion and antidepressant remedy (Zhang et al., 1994), anti-inflammatory effect (Hosseinzadeh and Yiounesi, 2007), antigenotoxic effect (Prem-kumar et al., 2003), antioxidant activity (Chatterjee et al., 2005), antitumoural and anticarcinogenic activity and its cytotoxic and antimutagenic effects have also been reported (Abdullaev, 2002). It is also used as a tonic and promoter of defenses in Ayurvedic medicine, for some disorders in the central nervous system in Chinese medicine and for homeopathic preparations.

Saffron finds its use in the perfumery and cosmetic industry, besides the most important current use of saffron is in food. This spice forms a part of some of the best known traditional dishes. It is used to dye high textiles manufactured with silk, cotton or wool (Liakopoulou-Kyriakides et al., 1998; Tsatsaroni et al., 1998). As a dye, it is also utilized in combination with hematoxylin, erythrosine and others to achieve human and animal histological staining (Alyahya et al., 2002; Edston et al., 2002). In Kashmir, saffron has a long history of being used in culinary (Kashmiri cusine, wazwaan), Kashmiri tea (Kehwa). It is also widely used in confectionary, alcoholic and non alcoholic beverages, colouring agent for sausages, oleomargarines, dairy products such as butter, cheese and ice cream for color and flavour improvement (Hosseini et al., 2010)

RESEARCH AND DEVELOPMENT

Sher-e-Kashmir University of Agricultural Sciences and

Technology of Kashmir India and other International Organizations have instituted research programme for systematic improvement of saffron from production to consumption system. Review deliberates on the latest work being done for promotion of saffron farming as an economically viable venture for livelihood security.

Conservation, characterization and utilization of *Crocus* germplasm

Till date, no variety is available in saffron that would confirm productivity gains. Saffron in the world is cultivated as a temporal sub-population since ages. Due to triploid nature of saffron, conventional breeding methods offer a limited scope for saffron improvement therefore clonal selection offers maximum opportunity for capitalizing genes for high yield, inbuilt tolerance to disease and pests and better quality.

The loss of land surface dedicated to saffron cultivation in some areas, particularly in the Mediterranean Basin countries has resulted in a corresponding genetic erosion of this crop. Since saffron multiplies exclusively in a vegetative way, preservation of the presumably scarce genetic diversity is highly available to carry out in any breeding programme.

In 2005, European Commission launched a programme for the conservation, characterization, collection and utilization of genetic resources in agriculture, AGRI GEN RES. A consortium of 14 group of 9 countries, led by the University of Castille La-Mancha (Spain). The mother plant collection is located in the Bank of Plant Germplasm of Cuenca, where 384 accessions of saffron and wild *Crocus* are preserved, multiplied and particularly characterized at the moment (Pascual et al., 2010). Similarly in Kashmir, SKUAST-Kashmir started conservation programme in 2000 and till date, about 700 accessions collected from temporal sub populations of Jammu and Kashmir have been conserved and are being characterized. About 30 clones with high productivity and quality potential with distinct variability at genetic and molecular level are under breeding trails for release as high yielding clone (Nehvi et al., 2007, Makhdoomi et al., 2010; Imran et al., 2010). For genetic conservation and utilization, work is also being carried out in Azerbaijan (Agavey 2002, 2003; Agavev et al., 2010), Iran (Koocheki, 2007) and Greece (Tsoktouridis et al., 2009).

Technologies for high income productivity

In order to address issues relating to decline in saffron production, productivity and quality, research organi-zations at international level have developed relevant production, protection and post harvest technologies to achieve high productivity. The strategies recommended for realizing higher yields includes the following.

Production technologies

Good agricultural practices involving plantation of graded c work being done for promotion of saffron farming as an orms (> 8 g) with inter and intra row spacing of 10 × 20 cm, improving soil health through supplementation of well rotten FYM, Vermicompost, biofertilizers and inorganic fertilizers, water scheduling during critical stages of crop growth from August to October (sprouting to flowering), management of diseases, pests and weeds using mancozeb, carbendizime Zinc Phophide and Alumunium Phosphide and saffron mechanization, ensures high factor productivity and high income per unit area. Studies carried out at Kashmir revealed that under monocropping/intercropping farming system, plantation of graded saffron corms (> 8 g) at 2 corms/hill with a planting geometry of 25 × 15 cm or 1 corm/hill with a planting geometry of 20 × 10 cm on raised beds supplemented with FYM at 30 tons/ha in combination with N:P:K at 30:20:15 kg/ha, vermi compost at 2.5 q/ha together with Azatobactor or FYM at 10 tons/ha, in combination with N:P:K at 90:60:50 kg/ha and vermi compost at 5 q/ha before plantation in September, ensures average saffron yield of 7.00 kg ha^{-1} under 2 years of planting cycle in comparison to traditional practices of 1.55 kg/ha. Achieved productivity level is 2.00 kg/ha above bench value of 5.00 kg/ha (Ganai et al., 2000; Nehvi, 2003; Nehvi et al., 2006, 2010, 2011a; Nehvi and Yasmeen, 2010; Khan et al., 2010; Kirmani et al., 2010).

Irrigating saffron at 700 m^3/ha through sprinklers enhances saffron productivity by 40% (Nehvi and Maqhdoomi, 2007). Similarly, initial corm treatment with 0.3% mancozeb and 0.1% Carbendizime or initial corm dressing with *Trichoderma viridae* at 4 g/kg of seed and initial spore load adjusted to 2×10^7 spores m^{-1} with the help of haemocytometer helps in the management of corm rot over shorter planting cycle (Nehvi, 2003; Ghani, 2002; Kalha et al., 2008; Nehvi et al., 2011b). Similarly, fumigation of live reopened burrows with Aluminum Phosphide pellets at 2 pellets/burrow or 3 g Aluminum Phosphide Pouch (56% poison)/burrow and covered with wet mud helps in management of rodents (Manzar et al., 2008, 2010).

To make saffron more economically viable, mech-anization of some operations, particularly bed preparation plantation, furrow opening and hoeing in June and September is a must. Diesel/petrol operated weeders with a tilling depth of 3 to 5 inches (adjustable), working width 18 to 27 inches and tilling width of 17 to 21 inches operated through 12 to 16 tynes, is a suitable substitute for manual hoeing. Technology with an input cost of Rs 1300 to 2400 /ha ensures saving of Rs 33,900 to Rs 34,700/ha. Furrows opening with tractor mounted ridger adjusted to a furrow width of 70 cm accom-modating 3 rows at a distance of 23 cm, is an economical substitute for manual operation. Technology with an input cost of Rs

1120 /ha ensures saving of Rs 9600/ha. Burrow fumigator is efficient protoypes for control of rodents using local herbs (Alam, 2008; Nehvi, 2011b; Mudasir, 2011). Similarly, in other saffron growing countries, specific technologies for enhancing saffron productivity are available (Koocheki, 2004; Molina et al., 2004; Rezian and Forouhar, 2004; Delgado et al., 2006; Kafi et al., 2006; Mollafilabi, 2009; Bazoobandi et al., 2009; Abedin, 2009a, b; Amini Dehaghi, 2009a, b; Behnia and Mokhtari, 2009; Daneshvar and Hemmatzadeh, 2009; Koocheki et al., 2009).

Post harvest management and value addition

Post harvest technologies for higher saffron recovery and better product quality are available for better economic returns. Traditional post harvest practices are responsible for quality degradation and low saffron recovery. To make industry more profit earning and consumer friendly, adoption of new technologies, ensuring flower picking at appropriate time in a proper collection material at an appropriate age, quick stigma separation within 10 h of flower picking, followed by quick drying using hot air/solar or vacuum dryers is imperative as picking of aged flowers, delayed stigma separation and delayed dying under sun or shade leads to biodegradation of crocin to crocitin and thus lowers saffron recover by about 30% and quality by 50%. Studies conducted by SKUAST-Kashmir have identified 2 days aged flowers collected early morning in craft paper bags or willow baskets ideal for good recovery and quality. Stigma separated from such flowers within 10 h from picking time followed by drying in vacuum dryers leads to a saffron recovery of 37 g/kg of fresh saffron flowers as compared to 22 g achieved under old aged traditional practice (Raina et al., 1996; Nehvi et al., 2005, 2011b; Nehvi and Salwee, 2011). Similar recommendations have been put forth by scientists from Iran and Spain (Alonso et al., 2001; Hemati, 2006; Manuel et al., 2006)

In vitro micropropagation

Triploid nature of saffron restricts use of conventional breeding procedures for its genetic improvement. Vegetative propagation is the only route for mass multiplication of corms. One of the possible recourse to produce quality corms and to overcome the problems of corm rot (due to infection by several fungal pathogens) together with low rate of multiplication is application of micro propagation technique like tissue culture. The technique, however, calls for development of convenient protocols and their standardization that will not only help in mass multiplication of elite-disease free clones but also open new vistas for application of recombinant DNA technologies for development of transgenics in this crop.

SKUAST-Kashmir has developed *in vitro* protocol for mass multiplication of corms using corm slice as an explant. The explant develops sprouts, shoots and mini corms when inoculated on Murashige and Skoog (MS) medium supplemented with different concentration of BA, NAA, sucrose and paclobutazol or CCC (Raja et al., 2007; Salwee et al., 2011a).

Similarly, Ahuja et al. (1994) reported corm differentiation and development at base of excised shoots proliferated from callus cultures. Induction from cultured bulblets was achieved on half-strength Murashige and Skoog (MS) basal medium containing BA (5×10^{-6} M) and (5×10^{-6} M) NAA+ 2% activated charcoal incubated at 15 ± 1°C and reported that the microsurgery of the apical meristematic bud in corms prior to culture increased the induction of cormogenic nodules. High concentrations of BA (2 mg cnt.dotl^{-1}) and low levels of 2,4-D (0.1 mg cnt.dotl^{-1}) were found to be essential for the development and proliferation of cormogenic nodules. The application of paclobutrazol and imazalil increased the induction rate of adventitious shoots in the nodular cormogenic calli and the growth of microcorms. The corms with adventitious shoots were rooted in medium without growth regulators and were able to generate dormant microcorms *in vitro* (Parray et al., 2010).

Maximum number (70.0 ± 0.3) of cormlets was recorded indirectly from corm slices on Murashige and Skoog (MS) half strength medium supplemented with Thidiazuron (TDZ) 20 µM + Indole acetic acid (IAA) 10 µM + sucrose 40 g/l. The prominent increase in corm size with a weight range of 1.9 to 2.1 gm was recorded on Thidiazuron (TDZ) 15 µM + Indole acetic acid (IAA) 12.5 µM + sucrose 30 g/l in 40% of *in vitro* raised minicormlets through callus. Mir et al. (2010) reported that maximum corm size (1.3 g) were obtained from eye bud explant on the LS media supplemented with 21.6 µM NAA and 22.2 µM benzylaminopurine (BAP). Micro-corm formation was influenced by external BAP concentration; also growth of corm was improved with increasing period of inoculation. Cultural conditions under light or in dark did not affect the corm formation and growth. Regenerated corms were kept at 5°C for 5 weeks and then transplanted to a potting mixture where the germination percentage was very low (4%) which may be due to small corm size

Devi et al. (2010) used Murashige and Skoog (1962) medium containing BAP and 2,4-D. Irrespective of the corm size, bud sprouting was season dependent. Maximum bud sprouting was in the months from November to December and minimum from May to August. Buds sprouted from the months of March to May regained further growth only in the next growing phase that is, from September to December, indicating thereby that the *in vitro* propagules followed the same natural rhythm for bud sprouting. Young leaves from these bud sprouts were used as explants for initiation of somatic embryos using TDZ and picloram. Lumps of somatic embryos proliferated further to form secondary somatic

embryos. Different treatments of PGRs (plant growth regulators) (ABA, GA_3, BAP, 2,4-D, IAA, NAA), of varying medium strengths (¼, ½, ¾) and sucrose concentrations (3, 6, 9, 12%) were used for the conversion of these embryos into plantlets. Cormlets developed at the base of these plantlets on medium supplemented with growth retardants (paclobutrazol and CCC). These *in vitro* produced cormlets were transferred to green house conditions for further growth evaluation.

CONCLUSION

Saffron, the legendry crop is under threat of extinction and thus warrants attention of researchers, farmers and policy makers. Strong market demand is the biggest opportunity for revival of this industry as is being presently done in Kashmir India. There is need to work more on genetic enhancement, GAP, post harvest technologies. Need has arisen to establish a consortium group of traders and producers at the International level for market assurance and price stability

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