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Policy and research initiatives for promotion of saffron farming system and trade for doubling farmers' income

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ABSTRACT

Purpose: Purpose of this paper is to highlight policy initiatives of Ministry of Agriculture & Farmers Welfare Govt of India and research support of SKUAST-Kashmir India, that has not only given stability to the saffron area, production and productivity but has also opened new options for promoting saffron cultivation in new areas that is expected to increase saffron production to 104000 kg. **Findings:** Standardized descriptors of Kashmir saffron has facilitated seeking of Geographical Indication Tag to Kashmir Saffron and is a step forward towards promotion of authenticated quality brand "Kashmir Saffron". Good Agricultural Practices for enhancing productivity and quality through integrated value chain involving plantation of graded corms weighing above 8 g with integration of micro and macro nutrients, composts, farm yard manures, initial corm dressing with fungicides followed by hygienic post-harvest handling have been standardized ensuring yield and quality gains. Ethymethyl Sulphonate and Colchicine have been identified as potent mutagens for creation of genetic variability. *In vitro* micropropagation involving different growth regulators, growth retardants and sucrose as energy source have been standardized. **Limitations:** Decline in saffron area over the years due to urbanization of saffron heritage site and diversification to other commercial activities is a major concern for growth of saffron Industry. **Directions for future research:** Climate change over the years have become a serious threat for the saffron industry therefore future research needs to be focused on to mitigate the ill effects and to ensure the adaptabilities studies of all the developed modules under changed environment so as to ensure sustainability and profitable of saffron farming system. Research priorities needs to be focused on quality promotion and marketing under one roof processing, quality testing and e-trading.

POLICY INITIATIVES

Jammu & Kashmir Union Territory of India situated between 32° 17' and 36° 58' north latitude and 32° 26' and 80° 30' east longitude falling in the great north Western range of the Himalayas is the place where saffron is predominately cultivated in India. Saffron farming system was under distress as area and production declined by 42.5% and 51.72%, respectively in the year 2008-09. Prolonged drought over the years leading to low production and low market demand and price made farmers despondent about saffron farming system and started giving place to other commercial ventures. In this pursuit about 1992 hectares of traditional saffron area was permanently lost to Industrialization. To restore glory of saffron, Ministry of Agriculture and Farmers Welfare Department Govt of India reshaped the Industry by addressing the issues of production, quality and marketing under the banner of National Saffron Mission from 2010. Saffron growers were provided financial assistance under different following policy initiatives under the umbrella of research support that stabilized not only saffron area (3715 ha) but also enhanced saffron production (19000 kg) and productivity (5.1 kg ha^{-1}) by 146.7% & 118.4%, respectively in the year 2020-21. This increase occurred compared to the year 2008-09 (Anonymous, 2020). Husaini et al. (2010 a, b) also reported problems and policy interventions for sustainable development of saffron in J & K.

Rejuvenation

Traditional saffron farms had become less productive due to poor soil health, buildup of disease inoculums leading to low plant density and distress of water vagaries. Policy strategies of Govt of India targeted over 3715 hectares of traditional saffron area to get rejuvenated using modern scientific technologies developed by Sher-e-Kashmir University of Agricultural Sciences & Technology Kashmir has helped to combat issues of low productivity, corm rot menace and poor soil health. Scientific farming system involving plantation of graded corms weighing above 8 g with a planting geometry (20×10 cm) and corm density of 500 thousand corms /ha supplemented with 90 kg ha^{-1} N, 60 kg ha^{-1} P, 50 kg ha^{-1} K, involving initial corm dressing with Carbendizime (0.1%) and Mancozeb (0.3%) has not only improved production from 7700 kg to 19000 (2020), but also enhanced productivity from 2.7 to 5.87 kg ha^{-1}. Over 4 years of planting cycle success stories from farmers have reported an average yield of 1.5 kg ha^{-1} in Ist year of cultivation followed by 5,7 and 10 kg ha^{-1} in 2nd, 3rd and 4th year, respectively (Nehvi & Salwee, 2014b; Salwee et al., 2018a; Nehvi, 2011)

Strengthening of irrigation facilities

Traditional saffron area was rainfed and non-availability of sufficient precipitation during critical stages of crop growth (September to November) was a big impediment for enhancing saffron productivity. A network of 125 bore wells with well-established pressurized sprinkler system ensuring gradual wetting to the depth of 6 inches (Cormosphere) has been established to meet out water requirement of saffron. Sprinklers with emitter discharge of 9.3 ltr/min (558 ltr/hr) associated with a radius of throw of 9.6 m and spacing of 10×10 m between two adjacent sprinklers were installed using HDP underground main and sub main pipes and above lateral pipes. Lateral pipes are detachable and can be put to use only during irrigation period. A strong network of irrigation assures availability of 980 m^3 ha^{-1} of water (Nehvi et al., 2017b; Nehvi et al., 2018b).

Saffron mechanization

Different prototypes used in agriculture were validated for different field operations particularly weeding/hoeing in June and September and furrow opening in August for corm plantation aiming at to reduce the cost of cultivation thus making saffron farming more remunerative. Validation of Diesel/petrol operated weeders with a tilling depth of 3-5 inches (adjustable), working width 18-27 inches and tilling width of 17-21 inches operated through 12-16 tynes mechanized the saffron farming. This has in turn led to reduction in women drudgery as 90% of saffron field operations are carried by farm women ensuring a saving of Rs 34,800 to Rs 35,600/ha. Based on the research feedback about 500 weeders have been distributed to the saffron growers with a financial assistance maximum up to $688/unit (Nehvi, 2014).

Establishment of India International Saffron Trade Centre

In world Kashmir saffron is known for its intrinsic quality. But farmers are not able to maintain the quality as post-harvest practices are traditional on account of delayed stigma separation, sun/shade drying leading to 13% product loss. To redress post-harvest losses Govt of India established India International Saffron Trade Centre in the saffron hub of Kashmir with hitech facilities for stigma separation, refrigeration, drying, packing, and quality testing and e-trading. Saffron trade centre is provided with 4 processing halls with seating capacity for 432 registered farmers to process about 2.6 tons of saffron flowers per day. Refrigeration facility is provided to store surplus flowers on daily basis. Saffron drying is carried in vacuum dryers based on the principle of creating a vacuum to decrease the pressure below the vapour pressure of the water. With a drying capacity of 95 kg/ hour saffron is dried at a product temperature of 60ºC. Centre is provided with NABL accredited quality testing laboratory where saffron samples are being evaluated as per ISO 3632 Quality Standards and certificates are issued strictly as per the ISO grade. Product is packed and labeled under a registered GI tagged brand as “Kashmir Saffron”. Marketing of Branded saffron is facilitated through e-trading centre where an open auction through bidding process is facilitated for registered farmers every week (Annonymous, 2018)

Saffron crop insurance to mitigate ill effects of climate change

After implementation of National Saffron Mission in 2010 by Agriculture Production & Farmers Welfare Department J and K Saffron farming system a legendary crop of Jammu and Kashmir state was on rise up till 2013, as overall Saffron production of state increased from 9460 to 15000 kg with an increase in average productivity from 2.5 to 4.03 kg ha^{-1} (Nehvi & Salwee, 2019). However, excess precipitation observed in 2014 by 53% (280 mm as against requirement of 183 mm) during sprouting stage (August-October) lead to decline in saffron production of J & K state by 70% (4500 kg as against 15000 recorded during 2013). Similarly, precipitation deficit during sprouting stage recorded by 56.9 % in 2016 and 100% in 2017 lead to decline in saffron production by 90% during 2017 (from 15000 recorded in 2015 to 1500 kg recorded in 2017). Excess summer precipitation associated with high humidity has become concern of saffron growers as during 2015 saffron growers lost about 30% of corms due to corm rot caused by fungal infestation as saffron area recorded 400% more precipitation from May to July (550 mm as against normal precipitation of 110 mm) (Nehvi & Salwee, 2019). All these factors have resulted in annual exchequer loss to the tune of $30832875 during 2017 affecting about 17000 saffron families involved with saffron farming system directly or indirectly. Alarming situation made farmers despondent about future of saffron and thus introduction of crop insurance policy for saffron is the only way to make saffron growers confident about future of saffron under changed climatic conditions of Kashmir. To give stability and surety to the saffron farming system Agriculture Production & Farmers welfare Department is contemplated to introduce saffron insurance policy based on Weather Based National Crop Insurance Programme (NCIP) for Saffron based on trigger weather including Deficit Rainfall Volume, Excess Rainfall Volume, Decrease in Day Temperature, Increase in Day Temperature or under Pradhan Mantri Fasal Bima Yojna (PMFBY) introduced in 2017 using the sampling design adopted in the crop cutting surveys of saffron is Multi-stage. For assessment of yield losses crop cut experiments is mandatory to be carried by Insurance companies in collaboration with a team of technical experts to be designated by the Nodal officer at district level. As CCEs is not available for saffron therefore SKUAST-Kashmir developed guidelines for Crop Cut Experiment (CCEs) for saffron (Nehvi & Salwee, 2019).

RESEARCH INITIATIVES

Research initiates over the years were focused to double farmer's income and for seeking Geographical Indication Status to Kashmir Saffron.

Research initiatives for doubling farmer's income

Research was carried on new technological backup support involving farmer's participatory research approach:

Standardization of good practices for high density production system module and to investigate role of micronutrients for yield gains in J & K

Correction of saffron value chain through incorporation of production, postharvest and mechanization modules by researchers of SKUAST-K and its adoption by 12000 saffron farm families under National Saffron Mission has ensured availability of large quantity of quality corms from the rejuvenated areas. Each hectare of rejuvenated area is expected to yield 10000-15000 kg of mixed grade corms. Surplus corms available with the saffron growers can thus be utilized for adopting high density production system module. Success of Good Agricultural Practices for raising saffron under normal density (500000 corms per ha) depends on using graded corms of more than 8 g weight for better corm proliferation and flower production. However, availability of such grades (>8 g) under field conditions is only up to 60%.

Under high density production system module (1200000 corms per ha), plantation of mixed grade corms with proportion of corms weighing above 8 g to the tune of 57.6 quintals (700000 corms) and corms weighing 6-8 g to the extent of 33.6 quintals (500000 corms) per hectare using ditch plantation method with 5 corm/ditch with a ditch geometry of 25x15 cm on raised beds supplemented with FYM @ 15 tons ha^{-1} in combination with N:P:K @ 120:90:80 kg ha^{-1} and vermicompost @10 q ha^{-1} before plantation in July ensures average productivity of 11.88 kg ha^{-1} (5-6 kg ha^{-1} in the first year to 15-16 kg ha^{-1} in the 4th year of planting cycle) as compared to 6.37 kg ha^{-1} achieved under normal planting practices (1-2 kg ha^{-1} in the first year to 11 kg ha^{-1} in the 4th year). High density production system module confirms significant increase in saffron productivity by 46.38% over scientific normal density plantation (Nehvi et al., 2017a). Average productivity of 11.88 kg ha^{-1} achieved under high density plantation compared to 6.37 kg ha^{-1} achieved under normal density over four years plant cycle will boost overall production of state from present 16500 kg to about 43840 kg fetching an additional exchequer of $59199120. At the farmers' field impact study confirmed an average saffron yield 6 kg ha^{-1} in First year of Planting cycle which is more than realized potential yield (5.5 kg ha^{-1}) by 8.3% (Nehvi et al., 2017a). Similar impact of land configuration and planting density in saffron has also been reported by several workers (Koocheki et al., 2011; Kumari & Sharma, 2018; Sabina Nasseer et al., 2018).

Standardization of good practice for enhancing saffron quality under high density plantation in Jammu & Kashmir

High density plantation ensures more flowers per unit area. Existing good practice of flower picking suggests picking of 2 day old flowers in early morning hours but presence of dew on the flowers hinders picking process hence growers usually pick opened flowers after sunrise. Sun rays in presence of dew deteriorate saffron color. Secondly opened flowers have low shelf life and for high pistil recovery separation has to be done within 10-12 hours which is a troublesome process when flower yields are high (Salwee & Nehvi, 2013; Nehvi et al., 2018a).

Under high density production system module picking of unopened flowers is recommended for better quality and recovery. One kg of unopened fresh flowers on average yield 33 g dry saffron when pistil separation is completed within 10 hours. Delay of pistil separation in unopened flowers up to 24-26 hours results in recovery of 30g showing a recovery loss of 9.1% compared to a recovery loss of 41.6% in 2 day old flowers. Substantial delay in pistil separation up to 96 hours reduces pistil recovery up to 10.5 g in unopened flowers and 6.8 g in case of 2 day old flowers. Study confirms that unopened flowers exhibit more shelf life compared to aged flowers. Drying saffron from unopened flowers using SKUAST-K recommended technologies to a safe moisture level of 10-12% maintains saffron quality for which Kashmir saffron is famous in the world. Product confirms to ISO grade-I. Unopened flowers improve color strength imparted by crocin by 9.2%, bitterness imparted by picrocrocin by 4.6% and aroma imparted by safranal by 6.6% (Nehvi et al., 2017a).

Development of value added product

A value added product has been developed in the form of 500 mg dispensable saffron tablets using 5-15 mg saffron, blended with Almond, Cashew, Cardamom and Carboxy Methyl Cellulose (CMC) was used as binding material (Imtiaz, 2020).

Studies on irrigation scheduling of saffron

Application of water from 20th August to 26th October (pre flowering Stage) accelerate growth of adventitious roots which promotes development and growth of floral primordia. Similarly post flowering period (7th November to 4th December) requires water to promote growth of radical leaves ensuring efficient source sink relationship for better corm development with high big corm index. Irrigation scheduling using sprinkler mode confirmed that saffron requires 980 m^3 ha^{-1} (980000 lit ha^{-1}) under normal density and 1479 m^3 ha^{-1} (1479000 lit ha^{-1}) under high density to be supplemented at fortnight intervals during critical stages of crop growth w.e.f 20th August to 4th December. During sprouting stage (20th August to 2nd September) one irrigation is recommended with a total water requirement of 140 m^3/ha under normal density and 210 m^3 ha^{-1} under high density followed by four irrigations with a total requirement of 560 m^3 ha^{-1} under normal density and 840 m^3 ha^{-1} under high density to be applied during pre-flowering stage (3rd September to 26th October). During flowering period no irrigation is recommended. Post flowering period (7th November to 4th December) requires 280 m^3 ha^{-1} and 429 m^3 ha^{-1} water to be applied in two split irrigations under normal and high density, respectively. While scheduling the irrigation the precipitation realized during the period has to be accounted for total water requirement and only the balance requirement is to be supplemented through sprinkler system. In case of zero per cent precipitation during the period of irrigation estimated total quantity of water has to be supplemented through irrigation. Working hours of each section has to be adjusted to the quantity of water to be applied in that particular period keeping in view the initial soil moisture content. Impact study of application of water @ 1044 m^3 ha^{-1} through designed irrigation system during critical stages of crop growth (August to October with 0 percent precipitation) recorded saffron yield of 7.5 kg ha^{-1} confirming relevance of irrigation at critical stages of saffron cropping cycle (Nehvi et al., 2017b; Nehvi et al., 2018b). Several workers also reported that Saffron yield as well as WUE and IWUE are found to respond to the various irrigation methods & irrigation levels in saffron (Behdani et al., 2008; Sepaskhah & Kamgar-Haghighi., 2009)

Devising package of practices based on GAP for saffron

To study phenological growth stages of saffron under temperate conditions of Jammu & Kashmir-India

Phenological studies at different stages of crop growth are important to mitigate the ill effects of climate change to which saffron is very much sensitive and to predict the production system modules involving cultural practices and crop protection systems. Study on phenological growth stages of natural temporal sub-populations of Kashmir saffron carried over 2 years revealed that the ontogenesis of Kashmir saffron is spread over 6 developmental stages from Ist May to 25th June (corm dormancy), 26th June to 25th August (flower ontogenesis), 26th August to 20th October (bud sprouting), Ist October to 10th November (Reproductive), 11th November to 30th March (Vegetative) and Ist April to 30th April (Plant senescence) and is presented in Figure 1-7 & Table 1. The ontogenesis period of saffron with above ground organs (183 days) is almost similar to period showing non above ground organs (182 days). Study revealed that among various ontogenic periods vegetative phase is the longest period (142 days), followed by flower ontogenesis (60 days), dormancy phase (55 days), reproductive (41 days), bud sprouting phase (36 days) and plant senescence (30 days). Timing of the phenological stage is observed to be closely related to weather parameters particularly air temperatures (Minimum & Maximum). Relative humidity on an average was observed to be uniform over different timings of phenological stages. The earlier rise in temperature from 26.1^{o}C (dormancy) to 29.3^{o}C (flower ontogenesis) during summer (26th June to 26th August) accelerates flower initiation. Average air temperature of 27.5^{o}C with a total precipitation of 418.90 mm ha^{-1} (33.70% of total precipitation) favored shoot and root development. When the average maximum air temperature reaches below 20^{o}C anthesis is favored under temperate conditions of Kashmir. Similar findings of importance of mean air temperature of 15 to 17^{o}C for anthesis in saffron has also been reported by Molina et al. (2015). A low average temperature of 11.4^{o}C accompanied with sub-zero temperatures (-0.33^{o}C) ensures development of replacement corms through better photosynthetic accumulation resulting in efficient source sink relationship. Among ontogenic periods vegetative phase is the longest period (142 days), followed by flower ontogenesis (60 days), dormancy (55 days), reproductive (41 days), bud sprouting phase (36 days) and plant senescence (30 days). Timing of the phenological stage is observed to be closely related to weather parameters particularly air temperatures.

Dormant corms show reduced impression of mother corm. No change in the size of the bud (the length of the outermost cataphylls) was observed from the time of corm lifting in early May to late June, some 55 days after leaf senescence. Incubation period of 97 days lead to increase in size of the apex followed by the formation of sprouts with complete flower embedded in whorl of tepals (gynoecium, stamen, tepals). Initial corm weight has been found responsible for increased number of flowers/spathe, more activation of meristematic regions and greater biomass lading to efficient replacement corm production. The flowering stage starts when the sprout (usually composed of three sheaths) emerges from the soil surface and is influenced by weather parameters.

Vegetative stage is most critical as chilling requirement for vernalization is received during 66 days (11th November to 15th February). The period is critical for development of replacement corms which largely depends on efficient translocation of photosynthates from source to sink. Phenological growth stage is completed with plant senescence with production of full mature corms showing impression of mother corms (Salwee & Nehvi, 2018a). A staging system for development saffron that relies on simple, visual, non-destructive criteria was proposed to allow for quick determination of development stage. This system can be used by both farmers and for experimental trials. Phenological growth stages of saffron have also been reported by Horacio Lopez-Corcoles et al. (2015).

Fig. 1. Corm Dormancy Phase (S0). a) corms with tunic. b) Dormant corms with mother corm residue. c) Naked corm showing dormant meristimatic regions. e) The apex of dormant corm looks like a resting bud with protective cataphylls.

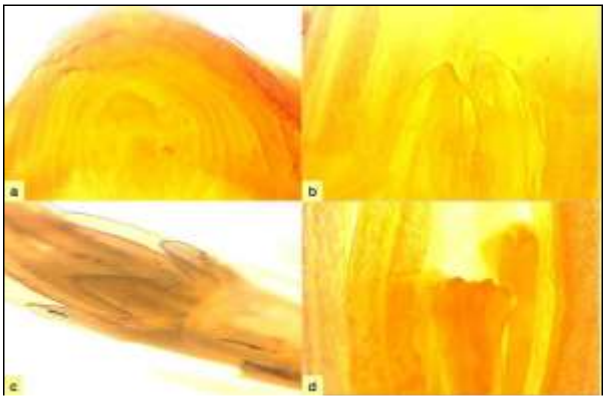

Fig. 2. Flower ontogenesis phase (F0). a) Shoot apex has increased in size and leaves differentiated at the flank (F0.1). b) Stamen initiate (F.0.2). c) Base of meristem covered by the developing primordial. The stamens are much longer than the leaves, a consequence of hysteranthy of this species. e) Gynoecium formation (F0.4)

Fig. 3. Bud sprouting (BS). a) Sprout initiation and fibrous root development (BS). b) Sprout length reaches to 4 cm length (BS.1). c)Sprout length reaches to 12 cm (BS.2). d, g) Longitudinal section showing floral initials in vascular bundles (BS). e, h) Longitudinal section showing floral parts in sprout. (BS.1). f, i) Sprout length reaches to 13 cm and longitudinal section showing complete floral parts embedded in whorl of tepals (BS.3).

Fig. 4. Effect of corm weight on number of flowers/sprout and sprout width (cm). a)>10g corm weight showing profuse activation from apical and axiullary buds. b)8-10g corm showing activation from apicular region.c) <8g corm showing slow sprout growth. d)>10g corm showing 3 flowers/spathe with 2.7 cm sprout width. e)8-10g corm showing 1 flower/spathe with 2.1 cm sprout width. f) <8g corm showing no flowers/spathe with 1.2 cm sprout width.

Fig. 5. Flowering phase (R). a) Emergence shoots (cataphylls) breaking through soil surface. Flower cataphylls are visible aboveground, enveloped by its bracts. Flower cataphylls still closed (R1). b) Blooming (unopened flowers with floral organs enclosed by tepals (R2). c)Anthesis (Opened tepals with visible stigma and anthers. (R3). d) Flower senescence (when the tepals dehydrate and fall on the ground) (R4).

Fig. 6. Vegetative phase (VE). Leaves from the lateral bud region are first visible above ground (VE.1). b) Leaves grow at 80% of final length (VE.1.1.). c) Development of corm lateral bud and terminal bud contractile roots (VE.2). d) Formation of replacement corms (VE.3). e) Leaves grow at 100% of final length (VE3.1). f) Leaf & corm development completed (VE.4)

Fig. 7. Plant senescence (R). a) Leaves show signs of prominent senescence (VE.5). b) Development of fully mature daughter corms (VE.5-1).

Standardization of com lifting time and planting time in saffron viz-a-viz phenological stages of com development

Saffron phenological studies confirm that resting corms undergo 60 days flower ontogenesis process starting from 26th August followed by sprout activation phase of 35 days starting from 27th August leading to flowering by Ist fortnight of October. To standardize ideal time for corm lifting and subsequent sowing under prevailing climatic conditions of Kashmir studies were carried out over 4 timings' of corm lifting and planting. Studies revealed maximum number of flowers (1180/10 m^2) from corms lifted between 15-25th June with subsequent planting between 15-30th July. Increased number of flowers leads to maximum dry saffron yield (7.40 kg ha^{-1}). Early corm lifting and sowing recorded an increase of 23.51% in saffron yield over recommended practice. Early sowing ensures activation of maximum meristimatic regions leading to more flower number (Nehvi, 2018). Best time for corm plantation in saffron has also been reported by Mahdi Bayat et al. (2016).

To standardize shade effects on enhancing saffron flowering

Weather fluctuation in the recent past with respect to temperature and precipitation has delayed flowering pattern of Kashmir saffron by 15 days. Study over weather parameters have revealed above normal maximum temperatures by 5.3°C during ontogenesis, 3.2°C during sprouting and 4.4°C during flowering. Similarly, minimum temperatures were recorded above normal by 1.5°C during ontogenesis and below normal by 1.8°C and 3.9°C during sprouting and flowering periods, respectively. This deviation in maximum and minimum temperatures is responsible for delayed flowering as observed in Kashmir after 26th of October when night temperatures are not suitable for proper flower development leading to yield losses. Evapo-transpiration losses due to high temperatures accompanied with precipitation deficit by 44.7 mm during sprouting and by 24.8 mm during flowering are also responsible for yield losses. To mitigate the challenges of high temperature and high evapotranspiration losses experiment was conducted to study shade effect of 50% & 75% UV stabilized shade nets on reducing the aerial temperature to induce early flowering. Studies revealed that growing saffron under 50% UV stabilized shade nets led to early saffron flowering by 13 days associated with more number of flowering buds. Increase in fresh flower weight by 26% was observed under shade nets accompanied with 8% increase in fresh pistil weight. Early flowering led to better plant development as observed from increased leaf length by 21.6% (Nehvi, 2018).

To standardize effects of different herbicides on weed management in saffron

Weed management module using different types of weedicidies viz; T1: Mertibuzin in Dec. fb Metribuzin In Feb @ 560 g ha^{-1}; T2: Atrazine + Metribuzin fb Atrazine + Metribuzin @ 500 +560 g ha^{-1}; T3: Metribuzin fb Sulfosulfuron @ 560 + 35 g ha^{-1}; T4: Sulfosulfurin fb Sulfosulfuron @ 35 g ha^{-1}; and T5: Weedy check was validated and refined for control of winter and spring weeds prevalent in saffron villages of Kashmir. No weeding was used as control. Herbicide application recorded significant impact on control of winter and spring weeds of saffron. Weedy Check recorded maximum fresh (410.0 g m^{-2}) & dry weed biomass (81.5 g m^{-2}). Herbicide application of Mertibuzin in December followed by Metribuzin in February @ 560 g ha^{-1} recorded minimum fresh (95 g m^{-2}) and dry (19.5 g m^{-2}) weed biomass followed by Atrazine + Metribuzinin in December followed by Atrazine + Metribuzinin in February @ 500 +560 g ha^{-1}. Weed management exhibited significant impact on maximum number of leaves per m^2 (1250), leaf length (45.5 cm), corm yield (1500 g m^{-2}) and big corm index (54.6%) (Parviz et al., 2012; Iqbal et al., 2018; Nehvi, 2018).

To standardize impact of micro and macro nutrients in enhancing saffron yields

To manipulate factor productivity per unity area experiment involving recommended Integrated Nutrient Management Module in combination with Sulphur @ 20 kg ha^{-1}, Copper @ 0.20%, Boron@ 0.20% either as sole or in combination revealed that integration of micro nutrients (Boron @ 0.2% + Copper @ 0.2%+ Sulphur @ 20 kg ha^{-1}) with recommended nutrients (N: P205: K20 @ 120:90:80 kg ha^{-1}) and manures (15 ton FYM+10q vermicompost) improves saffron yield under high density plantation from 5.45 kg ha^{-1} recorded in Ist year to 6.32 kg ha^{-1} (16.05%), associated with a big corm index of 51.2% and flower raising index of 11.60 g per plot (Nehvi, 2018). Similar impact of nutrient application on saffron yield has also been reported by Rezaian and Paseban (2007), and Mokhtabdaran et al. (2018).

Table 1. The developmental staging system of saffron

Stage	Period	Phase	Code	Description
0	Ist May to 25th June	Dormancy	S0	saffron corms apparently show neither morphological change nor external growth and the apex looks like a resting bud with protective cataphylls
1	26th June to 25th August	Flower ontogenesis	FO	
	26th June to 14th July		F0.1	Shoot apex has increased in size and leaves differentiated at the flank
	15th July to 25th July		F0.2	Stamen initiate
	26th July to 15th August		F0.3	Base of meristem covered by the developing leaf primordia
	16th August to 25th August		F0.4	Gynoecium formation
2	26th August to 30th September	Bud Sprouting	BS	Sprout Initiation and fibrous root development & Longitudinal section showing floral initials in vascular bundle
	26th August to 9th September		BS.1	Sprout length reaches to 4 cm length & Longitudinal section showing floral parts in the sprout
	10th September to 19th September		BS.2	Sprout length reaches to 12 cm& Longitudinal section showing floral parts in the sprout
	20th September to 30th September		BS.3	Sprout length reaches to 13 cm & Sprout showing complete floral parts embedded in whorl of tepals
3	Ist October to 10th November	Reproductive	R	sprout are visible above ground and saffron flower are within the sheath
	Ist October to 10th November	Flowering	R1	Unopened flowers with floral organs enclosed by the tepals
	Ist October to 10th November	Blooming	R2	opened teplas with visible stigma and anthers
	Ist October to 10th November	Anthesis	R3	opened teplas with visible stigma and anthers
	Ist October to 10th November	Flower Senescence	R4	When the tepals dehydrate and falls on the ground
4	11th November to 30th April	Vegetative	VE	
	11th November to 31st December		VE.1	Leaves from the apicular bud region are first visible above ground and leaves growth at 20% of final length
			VE.1	Leaves from the lateral bud region are first visible above ground and leaves growth at 10% of final length
			VE.1.1	Leaves growth at 80% of final length, continues with the spee
	Ist January to 15th February		VE.2	Development of corm ,lateral bud and terminal bud contractile root s
	16th February to 30th March		VE.3	Formation of replacement corms
			VE.3.1	Leaves grow at 100% of final length
			VE.4	Leaf and corm Development completed
5	Ist April to 30th April		VE.5	Leaves show signs of prominent senescence
			VE 5.1	Development of fully mature daughter corms

Fig. 8. a) Filed view of *R. solani* affected plants. b) Diseased leaves. c) *R. solani* lesions on leaf. d) *R. solani isolates* on agar sucrose medium. e) Microscopic view of mycelium of *R. solani.* f) Monilioid cells of *R. solani.* g) Mycelium at early stage. h) Mycelium at maturity with branches at right angles bearing spores. i) Bsidiospores. j) Pathogenecity test.

To standardize impact of organic sources of nutrition on improving saffron productivity

Experiment involving recommended dose of FYM in combination with Vermicompost @ 2,4,6 q ha^{-1}; Avainlitter @ 1.5, 3, 4.5 q ha^{-1}; Poultry Manure @ 2, 4, 6 q ha^{-1}; Sheep dropping @ 2, 4, 6 q ha^{-1}; Azospirilium @ 3, 5, 7 kg per 100 kg corm; Azotobactor @ 2, 4, 6 kg per 100 kg corm and recommended dose of FYM + N:P:K revealed that application of Azatobator @4kg per 100 kg corm in combination with sheep manure@ 6q ha^{-1}+ FYM @ 10 t ha^{-1} + Vermicompost @10q ha^{-1} improves saffron yield by 10.71%. Best combination records an average saffron yield of 6.2 kg ha^{-1} in first year of planting compared to 5.6 kg ha^{-1} achieved under recommended INM. Best combination is associated with very high big corm index of 57.60% and lower flower raising index of 11.20 g per plot (Nehvi, 2018). Similar impact of organic sources on enhancing saffron yield has been reported by Mohammad, (2008), Nehvi et al. (2010a), Mohammad Mohammad et al. (2012), Mohammad Zadeh (2012) and Kumar and Sharma (2017).

To investigate biotic stress management

Saffron corm rot is a major challenge, but climatic vagaries observed in J & K from August 2014 in terms of erratic precipitation pattern particularly during critical stages of crop growth has resulted in appearance of new foliar disease affecting the plant at vegetative phase. New foliar disease of saffron caused by *Rhizoctonia solani* has been identified and management scheduled has been standardized. The leaves showed purple to dark brown lesions and partially or completely yellowing appearance particularly starting from tips (Fig. 8). Application of carbendazim 12% + Mancozeb 63% 75 WP @ 0.25% (2.5 g per litre of water) or carbendazim 50 WP or thiophanate methyl each @ 0.05% (5 g per10 litre of water) as foliar spray manages the disease (Salwee & Nehvi., 2016; Nehvi et al., 2018). Corm rot management in saffron has been reported by several workers (Hassan & Devi, 2003; Ahmad et al., 2018; Tong Zhang et al., 2019; Gupta et al., 2021).

Standardization of cost effective *in vitro* protocols for corm production

Triploid nature of saffron forces vegetative propagation that occurs every year via formation of daughter corms. Low multiplication rate and fungal infestation of corms due to weather fluctuations in Kashmir are the bottlenecks for availability of sufficient quality planting material. Horizontal expansion of saffron to other districts of J & K will require about 60,000,000 kg of quality corms and thus warrants investigation to explore possibility of efficient alternative method of corm production. Study confirmed highest mean percentage of aseptic cultures to the tune of 81.5% with highest explants survival (81.5%) after following three step sterilization procedure (carbendizime 0.1% + mancozeb 0.2% in combination with 50% sodium hypochlorite and 1.6% mercuric chloride).

Influence of different growth regulator regime on percent corm sprouting revealed maximum mean percentage of sprouting to the tune of 85.94 % associated with maximum number of sprouts per explant (9.10) when explants were cultured on MS-medium supplemented with 2,4-D (4.0 mg l^{-1}) in combination with zeatin (3 mg l^{-1}). Similar effects were also observed with NAA (0.5 mg l^{-1}) in combination with BAP (1.5 mg l^{-1}) and 2, 4-D (2 mg l^{-1}) in combination with BAP (1.5 mg l^{-1}) revealing 7.65 sprouts per explant, respectively.

MS medium supplemented with different level of cytokinins revealed progressive increase in average number of shoots with increase in concentration of cytokinins up to 6.0 mg l^{-1} for zeatin (5.38), 6.5 mg l^{-1} for BAP (5.18) and 7.0 mg l^{-1} for kinetin (4.30) associated with maximum shoot length to the extent of 8.2 cm and 7.6 cm respectively. Data pooled over combinations revealed similar effects of 6.0 mg l^{-1} zeatin in combination with 2.0 mg l^{-1} 2,4-D, 6.5 mg l^{-1} BAP in combination with 0.5 mg l^{-1} NAA and 6.5 mg l^{-1} BAP in combination with 1.5 mg l^{-1} 2,4-D for maximum number of multiple shoots (32.5, 29.92, 29.25) associated with maximum number of viable shoots (21.8, 20.5, 20.1).

MS medium supplemented with 0.2 ml l^{-1} CCC and 3% sucrose for first 6 weeks followed by 90% sucrose recorded maximum number of *invitro* corms per viable shoot (7.5) of 8 g final corm weight. Evaluation of *in vitro* corms (1.5 mg l^{-1} 2,4-D + 6.0 mg l^{-1} zeatin) under actual field conditions revealed maximum survival percentage of 85.9% associated with 58 flowers per plot, 78.0% flowering, 306.5 mg fresh flower weight, 5.90 cm pistil length, 326.50 $E^{1\%}$ crocin, 129.0 $E^{1\%}$ picrocrocin and 67.5 $E^{1\%}$ safranal (Salwee et al., 2013; Salwee & Nehvi., 2013; Salwee & Nehvi, 2014a, d; Salwee & Nehvi, 2017). Cormlet production through in vitro micropropagation has also been reported by lazquez et al. (2001), Raja et al. (2007), Quadri et al. (2008), Quadri et al. (2010), Javid et al. (2012) and Karaoğlu et al. (2010).

Saffron improvement through utilizing indigenous germplasm resources of SKUAST-K

Till date no variety is available in saffron growing countries of world showing high yield potential and thus is a major reason for low saffron productivity. Farmers cultivate saffron as a natural temporal sub-population which primarily lacks enough genetic variability due to triploid nature of saffron. Therefore efforts need to be initiated for creation of genetic variability among elite gene pool available with SKUAST-K.Diversity in saffron has been reported by Anil et al. (2015) and Soukrat (2019).

220 naturally occurring homogygous lines collected from 75 locations of traditional saffron areas were exposed to 4 doses each of gamma radiation (0.05 Kilorad, 0.10 Kilorad, 0.15 Kilorad, 0.2 Kilorad), 12 doses of chemical mutagens viz; Ethyl Methane Sulphonate

(EMS) (0.05%, 0.1%, 0.15%, 0.2%), Ethidium Bromide (Etbr) (0.05%, 0.1%, 0.15%, 0.2%), Colchicine (0.0125%, 0.025%, 0.0375%, 0.05%) and 3 combined doses of 0.20 Kilorad gamma radiation & 0.1% EMS, 0.20 Kilorad gamma radiation & 0.2% Ethidium Bromide and 0.2 kilorad gamma radiation & 0.05% Colchicine. Mutation breeding approach followed by selection has facilitated development of a composite variety Shalimar Saffron-1, a composite population of 13 mutagenic lines SSR-463 (SS/EMS 0.15% / 23), SSR-563 (SS/EMS 0.15% /113), SSR-573 (SS/EMS 0.15% /132), SSR-603 (SS/EMS 0.15% /163) , SSR-605 (SS/EMS 0.15% /165),SSR-611 (SS/EMS 0.15% /171), SSR-706 (SS/EMS 0.20% /46), SSR-744 (SS/EMS 0.20% /84), SSR-758 (SS/EMS 0.20% /98), SSR-1850 (SS/Colchicine 0.0125% /90), SSR-2214 (SS/Colchicine 0.0375% /14), SSR-2252 (SS/Colchicine 0.0375% /52) and SSR-2387 (SS/ Colchicine 0.0375% /184). Elite mutagenic lines are suitable for high density plantation and are superior for yield and quality attributes confirming high values for big corm index (52.6%), low flower raising index (11.4g/plot), high saffron yield (14.5kg/ha) and high values of picrocrocin (124.5E1%), safranal (54.1 E1%) and crocin (379.2E1%). A composite population of 13 sister lines was evaluated over 4 years (2013-2016) under high density production system module.

Minikit testing of Shalimar Saffron-1 (SD 1-13) was undertaken during 2018 in saffron districts of Srinagar & Budgam by Agriculture Production Department Kashmir. Results recorded an average productivity of 3.10 Kg/ha compared to 2.00 Kg/ha under rainfed conditions during Ist year of planting which is much higher showing a yield advantage of 55%.

Adoption of Shalimar saffron-1 under high density plantation method with an average productivity of 14.5 kg ha^{-1} is expected to increase overall saffron production of J & K state from present 19000 kg to 53800 kg. High yielding variety fetches returns to the tune of $ 170505 on account of sale of saffron and quality corms produced per hectare over 4 years planting cycle. Benefit Cost ratio reveals a B:C ratio of 5.26:1 as compared to 4.28:1 obtained from natural population (Salwee & Nehvi 2014c, 2017). Mutagenesis as a tool for genetic improvement in saffron has also been used by several workers (Nehvi et al., 2010b; Khan et al., 2011; Mir et al., 2015; Mahpara et al., 2018).

Comparative study through DNA isolation, amplification and sequencing

44 exotic saffron germplasm lines from Netherland, 42 Exotic Germplasm lines from Spain and germplasm lines from Kashmir were subjected to genetic characterization. Total genomic DNA was isolated from leaf (170 mg each) of saffron germplasm lines. The leaf was immersed in liquid nitrogen and crushed into a fine powder. DNA was extracted using CTAB method. Quality of extracted DNA was determined using gel electrophoresis. Amplification of ITS region was obtained. PCR amplifications of the samples carried out in thermocycler were performed in 25 ul reaction, mixture containing 2.5ul of 10X PCR buffer, 1ul of l MgCl2, 0.5 mmol /l dNTPs, 0.5ul each of primer, 0.5 U of Taq polymerase, 1 ul of genomic DNA and water. PCR products were examined using 1% agarose gel elctrophoresis in TAE buffer at 100V FOR 30 min. purifying and sequencing were completed by SciGenom. Total DNA was extracted from samples and used, as template, for PCR amplifications. Barcode genes were analyzed in all samples. Resulting sequences were aligned and compared to create a partial phylogram on *Crocus* genus. Sequences were successfully submitted and published in Gene Bank. Phylogenetic tree clearly showed the early separation of germplasm lines from Kashmir from the other lines from Netherland and Spain. *C. sativus* Kashmiranus turned away from the rest of *Crocus* group that could be divided in two sub-clades: the first one

including Kashmir saffron and the second one containing Netherland and Spanish saffron (Nehvi, 2018).Such studies for Deciphering genetic diversity in saffron have also been reported by Angela Rubio-Moraga et al. (2009), Han-jie Zheng et al. (2013), Mingming Zhao et al. (2016), Mudasir et al. (2021) and Busconi et al. (2021).

Validation and refinement of technologies for extension of saffron in non-traditional areas of Jammu and Kashmir

Expansion of saffron to District Budgam during 1980's broke the myth that saffron can be cultivated only in heritage site of Pampore. Expansion thus exhibited chance of saffron diversification in non-traditional areas with similar topography and other physical conditions. Target districts of Kashmir and Jammu are mostly involved with cereal or horticulture cropping system. Introduction of saffron either as a sole crop or as an intercrop in apple orchard system warrants investigation for productivity gains/unit area in the target areas.

Saffron cultivation has been introduced in 104 villages of Kashmir and 57 villages of Jammu through conduct of 274 OFT's and demonstrations. Evaluation of 274 on farm trials/demonstrations conducted over six years (2011-2016) over an area of 4.58 ha in collaboration with Dept of Agri Kashmir & Jammu, KVK'S of SKUAST-K and farmers in non-traditional areas revealed that under monocropping/intercropping farming system, plantation of graded saffron corms (>8 g) at 1 corm per hill with a planting geometry of 20×10 cm on raised beds supplemented with FYM @ 10 t ha^{-1} in combination with N:P:K @ 90:60:50 kg ha^{-1} and Vermi compost @5 q ha^{-1} before plantation in September ensures average productivity of 7.19 kg ha^{-1} (Jammu) to 8.45 kg ha^{-1} (Kashmir) as compared to 9.73 kg ha^{-1} obtained from traditional saffron areas of Kashmir associated with a benefit of R$44123 per ha under sole farming system and Rs. $ 63581 per ha under orchard intercrop farming system (Salwee et al., 2018b).

Comparative study on yield and yield attributing traits revealed that average leaf number (14.8) and leaf length (42.50cm) observed in traditional areas of Kashmir was comparable with plant development pattern for leaf number ranging from 12.1 (Jammu) to 14.87 (Kashmir) and leaf length ranging from 36.10cm (Jammu) to 39.59cm (Kashmir) observed in nontraditional areas. Similarly, corm multiplication index an important selection criteria was observed to be 3.50 in traditional areas compared to 3.29 and 3.25 observed in Kashmir and Jammu regions respectively. Fresh flower weight an important yield attributing trait ranged from 288 mg (Jammu) to 298 mg (Kashmir) in nontraditional areas compared to 300mg recorded in traditional areas. Study confirmed that introduction of saffron in nontraditional areas did not affect saffron quality as crocin content an important color attributing carotenoids was observed to be above 350 in all areas of study. The upper range value suggests possibility of saffron diversification in identified nontraditional villages of Kashmir and Jammu except for Malhar, machhedi, sarthal, lowing, bachanfathpur (Kathuwa) and Nurala, Temisgam, Khalsi, Drass, Skurbachan, Chuschot, Phyang, Matho, Stakna,Gompa, Sankar, Skara (Leh region) where saffron cultivation was not comparable. Introduction of saffron in 161 nontraditional villages of Jammu and Kashmir with an anticipated potential area of 2200 hectares in Jammu and 4500 hectares in Kashmir together with 1992 hectares of fallow traditional area is expected to enhance overall production to 89 metric tons. Validation of Good Agricultural Practices revealed that saffron behavior in non-traditional areas (except for district Kathuwa and Leh) is comparable with traditional areas of J&K for saffron yield and quality. Study has envisaged a future potential of 12407 ha with 10207 ha in Kashmir and 2200 ha in Jammu including 3715 ha presently under saffron cultivation in traditional areas of J & K. With an estimated average productivity level of 8.45 kg/ha saffron production in J&K

is expected to enhance from present 19000 kg to about 104000 with increase in overall exchequer from $ 30832875 to $ 213774600 (Nehvi et al., 2017c; Nehvi, 2018; Salwee et al., 2018b).

Research initiatives for seeking geographical indication status to Kashmir Saffron

Saffron in J & K is cultivated as a natural population with long history of its cultivation since 500 B.C. Kashmir saffron has its name at the global market due to its intrinsic quality as saffron is cultivated under temperate condition the unique of its kind in the world. FAO Rome has recognized saffron heritage site of Pampore as Globally Important Agriculture Heritage System in 2011 and thus give a claim for Kashmir saffron to get Geographical Identification. On this pursuit and the research findings confirming uniqueness of Kashmir saffron Geographical Indication Registry Govt of India vide Indication No 635 & certificate No 366 dated 01-05-2020 has accorded GI to Kashmir Saffron in the name of The Director, Directorate of Agriculture, Kashmir Division. Facilitated by Sher-e-Kashmir University of Agricultural Sciences & Technology and Saffron Research Station Dussu Pampore, Jammu and Kashmir India.

Historically Iran, Kashmir, Spain and Greece are the major saffron producing countries of the world. Distinct geographical difference exists between Kashmir and other saffron producing countries of the world particularly for altitude, latitude and longitude leading to different type of climates. Kashmir observes temperate type of climate compared to arid type in Iran, continental Mediterranean in Spain and Humid Sub-Tropical climate in Greece. The geographical difference contributes to uniqueness of Kashmir Saffron for quality and physical parameters for Pistil. The specific quality of Kashmir Saffron is linked to GX E interaction and is attributed to geographical identification. As a result of a favorable geo-agro-climatic situation, specific soil characteristics, plantation conditions, traditional human practices and a skilled local workforce saffron pistil of Kashmir Saffron confirms wide variability for parameters related to flower development particularly stigma weight. On an average 1 kg of fresh saffron flowers yield 22-25g obtained under Kashmir conditions indicating heavier pistil leading to more saffron recovery, which is a unique characteristic of Kashmir saffron (Salwee & Nehvi., 2018b).

Morphological descriptors of Kashmir saffron

Morphological descriptors of Kashmir saffron were developed on corm, floral and foliar attributes. Study confirmed that Saffron cultivated in heritage site of pampore is a natural sub population without any new recombinants due to its triploid nature and structural variants observed for flower and leaf exhibit a non-heritable nature suggesting that chances of somatic recombination at the time of division of corm can give rise to variants found in the natural population. Wide range of variation for economic and corm attributing traits offers tremendous scope for its improvement in the base population through clonal selection (Salwee & Nehvi, 2014a). Morphological descriptors of saffron from different saffron growing regions have also been reported by Mitsopoulou et al. (2004), Maria et al. (2010), Saxena (2010), Ibtissam et al. (2019) and Cardone et al. (2021).

Biochemical markers of Kashmir saffron

Kashmir saffron flower is a rich source of minerals. Stamens are rich source of ash, proteins, lipids, phosphorous, magnesium, potassium and Inositol, whereas, tepals are important source ofreducing sugars, glucose, sucrose, maltose and mannitol. Besides pigments pistil an economic product is rich source of carbohydrates, calcium, sodium, iron, fructose and sorbital. Study confirmed high intrinsic quality of Kashmir saffron for all the three carotenoids (Iffat Hassan et al., 2015). Chemical profile of saffron has also been reported by Heriberto et al. (2004), Srivastava et al. (2010), Tayebeh et al. (2016) and Maria et al. (2020).

Molecular markers of Kashmir saffron

Molecular characterization was carried out using 21 Random Amplified Polymorphic DNA markers. Primer pair SA-D+SA-S found to be the best primer pair. Considerable amount of diversity was observed. In all, 20 out of 25 primers were selected on the basis of amplification robustness, clarity and scorability of banding patterns, which provided 1562 repeatable fragments. DNA different fingerprinting using RAPD markers during showed considerable genetic variability among saffron genotypes (Hina et al., 2012). Molecular studies have also been carried by several workers (Angela Rubio-Moraga et al., 2009; Mingming Zhao et al., 2016; Mudasir et al., 2021).

Pollen Morphology of Kashmir saffron

Study on pollen of Kashmir saffron was carried in 2015. The study revealed that on an average, *C. sativus* pollen has pollen grain dimensions ranging from 80.5 to 161.9 µm with pollen grain germination of 16.18% (10.5 to 21.2%). Maximum pollen grain viability (49.4%) with abnormal grains designated as smaller, empty, collapsed and broken walls were observed in the range of 46.3% to 58.0% with a mean of 50.5%. Percentage of abnormal grains increased with decline in temperatures indicating adverse effect of low temperatures on pollen viability. Exine breakage is considered to be the most plausible reason for large proportion of abnormal grains leading to pollen sterility. Low day temperatures (9.50-14^{o}C) recorded detrimental impact on pollen germination. Only 0.53% pollen grains exhibited regular pollen tube and thus is a major obstacle in fertilization leading to sterility. Study confirmed pollen sterility of saffron under temperate conditions of Kashmir on account of abnormalities in grain shape and pollen tube germination (Salwee et al., 2016). Pollen studies in saffron have also been reported by Chichiricco and Grilli Caiola (1986), Sani et al. (2013), and Chichiricco and Grilli Caiola (2014).

Cytological markers

Study revealed that Kashmir saffron has 24 chromosomes in the somatic cells. The total length of chromosomes on an average from 30 metaphase plates (10plates/subpopulation) of triploid set 2n=3x=24 in Kashmir saffron was observed to be 160.56 µm with an average chromosome length of 6.69 µm for. The arm ratio of total karyotype was observed to be 2.10. The length is authentically more than in usual *Crocus sativus* as reported by Chichiricco (1984) for Italian saffron (85.36 µm) and is at par with reports of Agayev (2002) for Iranian saffron (164.21 µm) revealing an average chromosome length of 6.84 µm and average arm ratio of 2.18 (Salwee et al., 2019). Karyotype studies in saffron have also been reported by Chichiricco (1984), Ghaffari (1986), Aghayev (2002) and Aghayev et al. (2004).

CONCLUSION

Future of Indian saffron is bright as efforts are being made for area expansion, quality promotion and market stability**.**

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Conflict of interest
The authors have no conflict of interest.

REFERENCES

Aghayev, Y. (2002). New Features in Karyotype Structure and Origin of Saffron, *Crocus sativus* L. *Cytologia*, *67*(3), 245-252.

Aghayev, Y., Shakib, A.M., & Fathi, M. (2004). Study of the karyotypes of saffron (*C. sativus* L.) and its close wild relatives with application of routine and banding technique. *Agricultural Biotechnology Research Institute of Iran* – ABRII

Ahmad, M.,Vinay S., Shah, M. D. (2018). Corm rot of saffron (*Crocus sativus* L.) and its management. *Acta Horticulturae*, 1200, ISHS, 111-114.

Angela, R., Raquel, C., Lourdes, G., & Oussama, A. (2009). Saffron is a monomorphic species as revealed by RAPD, ISSR and microsatellite analyses. *BMC Res Notes*, 2, 2009.PMC2758891

Anil, K, S., Manibhushan, N. C., & Narayan B. (2015). Extent and pattern of diversity in saffron germplasm of Indian kashmir. *Bangladesh Journal of Botany*, *44*(4), 635-642.

Anonymous. (2018). Report on National Saffron Mission. Agriculture Production and Farmers Wellfare Department, J&K India.

Anonymous. (2020). Report on National Saffron Mission. Agriculture Production and Farmers Wellfare Department, J&K India.

Behdani, M.A., Mahalatti, M.N., & Koochiki, A. (2008). Evaluation of irrigation management of saffron at agroecosystem scale in dry region of Iran. *Asian Journal of Plant Science*, *7*(1), 22-25.

Blazquez, S., Piqueras, A., Rubio, C., & Fernández, J. A. (2001). Comparative effect of BAP and TDZ on multiplication of micropropagated saffron (*Crocus sativus* L). II corms. *Vitro Cell and Developmental Biology–Plant*, *37*, 20-36.

Busconi, M., Wischnitzki, E., Del Corvo, M., Colli, L., Soffritti, G., Stagnati, L., ... & Fernández, J. A. (2021). Epigenetic variability among saffron crocus (*Crocus sativus* L.) accessions characterized by different phenotypes. *Frontiers in Plant Science*, *12*, 349. https://doi.org/10.3389/fpls.2021.642631

Cardone, L., Castronuovo, D., Perniola, M., Cicco, N., Molina, R. V., Renau-Morata, B., ... & Candido, V. (2021). *Crocus sativus* L. ecotypes from mediterranean countries: phenological, morpho-productive, qualitative and genetic traits. *Agronomy*, *11*(3), 551.

Chichiricco, G., & Grilli Caiola, M. (2014). *Crocus sativus* pollen tube growth in intra- and interspecific pollinations. *Caryologia*, *37*(1-2), 115-125.

Chichiricco, G., & Grilli Caiola, M. (1986). *Crocus sativus* pollen germination and pollen tube growth *in vitro* and after intraspecific and interspecific pollination. *Canadian Journal of Botany*, *64*(II). https://doi.org/10.1139/b86-369.

Ghaffari, S. M. (1986). Cytogenetic studies of cultivated *Crocus sativus* (*Iridaceae*). *Plant Systematics and Evolution* , 153, 199–204.

Gupta, V., Sharma, A., Rai, P. K., Gupta, S. K., Singh, B., Sharma, S. K., Singh, S. K., Hussain, R., Razdan, V. K., & Kumar, D. (2021). Corm Rot of Saffron: Epidemiology and Management. *Agronomy*, *11*(339), 1-19. https://doi.org/10.3390/agronomy11020339

Han-jie, Z., Meng-hua, L., Cui-ping, Y., Chang, S., & Weiwei, S. (2013). Construction of DNA finger printing for dry saffron. *Academic Journal*, *7*(42), 2807-2812.

Hassan, M. G., & Devi, L.S. (2003). Corm rot diseases of saffron in Kashmir valley. *Indian Phytopathology*, *56*(1), 122.

Heriberto, C., Rogelio, P., Leticia, R., & Juan, M. H. (2004). Chemical Composition of Saffron *(Crocus sativus* L.) from Four Countries. *Acta Horticulturae*, 650

Hina, Q., Sharma, P. C., Nehvi, F. A., Asif. M. I., & Singh, S. P. (2012). DNA Fingerprinting of Saffron (*Crocus sativus* L.) by RAPD. *Vegetos, 25*(1), 194-197.

Horacio, L., Antonio, B. R., Francisco, J. M. G., Miguel, R., & Francisco, M. (2015). Phenological Growth stages of saffron plant (*Crocus sativus* L.) according to the BBCH scale. *Spanish Journal of Agriculture Research*, 13(3), 1-7.

Husaini, A. M., Kamili, A.N., Wani, M.H., Teixeira, J. A., & Bhat, G.N. (2010b). Sustainable Saffron (*Crocus sativus* L. Kashmirianus) Production: Technological and Policy Interventions for Kashmir. *Functional Plant Science and Biotechnology*, 4, 116-127.

Husaini, A.M., Hassan, B., Ghani, M.Y., Teixeira, J.A., & Kirmani, N.A. (2010a). Saffron (*Crocus sativus* L. Kashmirianus) cultivation in Kashmir: Practices and problems. *Functional Plant Science and Biotechnology*, *4*, 108-115.

Ibtissam, M., Mohamed, A., & Abdelbasset, B. (2019). Traditional and Modern Uses of Saffron (*Crocus Sativus*). *Cosmetics*, *6*, 63.

Iffat Hassan., Afifa, K., Farhan, R., Firdous, N., Parvaiz, R., Salwee, Y., Rafiq, A. P., Yasmeen, J., Atiya, Y., Safia, B., & Saima, N. (2015). Contact Dermatitis in Saffron Workers: Clinical Profile and Identification of Contact Sensitizers In Saffron-Cultivating Area of Kashmir Valley of North India. *Dermatitis*, *26*(3), 136-141.

Imtiaz, Z. (2020). Impact of drying methods and packaging materials on the storage of quality saffron. *Ph.D Thesis Submitted to SKUAST-Kashmir.*

Iqbal, A.M., Ellahi, B.A., Nehvi, F.A., Sameer, S. S., Naseer, S., Ali, G., Nagoo. S. A., Arshid, A., & Dar, N.A. (2018). Effect of herbicides for weed control in saffron (*Crocus sativus* L.). *Acta Horticulturae*, 1200, 107-110.

Javid, A. P., Azra, N. K., Rehana, H., & Amjad, M. H. (2012). *In vitro* cormlet production of saffron (*Crocus sativus* L. Kashmirianus) and their flowering response under greenhouse. *GM Crops & Food*, *3*(4), 289-295. https://doi.org/10.4161/gmcr.21365

Karaoğlu, C., Çöcü, S., İpek, A., & Parmaksız, I. (2010). *In Vitro* Micropropagation of Saffron. *Acta Horticulturae*, 739(1), 723-72.

Khan, M. A., Shaheena, N., Sabina, N., Nehvi, F.A., & Sajad, M. Z. (2011). Induced mutation as a tool for improving corm multiplication in saffron (*Crocus sativus* L.). *Journal of Phytology*, *3*(7), 08-10.

Koocheki, A., Siah, M., Azizi, G., Jahani, M. (2011).The effect of high density and depth of planting on agronomic characteristic of saffron (*Crocus sativus* L.) and corms behavior, *Agroecology*, *3*(1), 36-49.

Kumar, R., & Sharma, O.C. (2017). Saffron (*Crocus sativus* L.) growth and yield as influenced by organic farming practices**.** *Journal of Agriculture and Ecology*, *4*, 25-32.

Kumari, R., & Sharma, O.C. (2018). Enhancing saffron (*Crocus sativus*) productivity by land configuration and corm intensity manipulation under Kashmir condition. *Indian Journal of Agricultural Sciences*, 88 (5), 798–804.

Lazquez, S., Piqueras, A., Rubio, C., & Fernández, J. A. (2001). Comparative effect of BAP and TDZ on multiplication of micropropagated saffron (*Crocus sativus* L). II corms. *Vitro Cell and Developmental Biology–Plant*, *37*, 20-36.

Mahdi, B., Mehdi, R., & Mehdi R.(2016). Determining the most effective traits to improve saffron (*Crocus sativus* L.) yield. *Physiology and Molecular Biology of Plants*, *22*(1), 153-161.

Mahpara, K., Aijaz, A. W., Manoj, K. D., Sabbi, J., & Azra, N. K. (2018). Development of an efficient in vitro mutagenesis protocol for genetic improvement of saffron (*Crocus sativus* L.). *Physiology and Molecular Biology of Plants*, *24*(5), 951-962.

Maktabdaran, M., Sayyari Zohan, M.H., Jami Alahmadi, M., & G. R. Zamani. (2018). Relationship between nutrient concentration in saffron corms and saffron yield in perennial fields of South Khorasan province. *Asian Journal of Agricultural & Biological, 6*(4), 481-494.

Maria, A.M., Silvia, B., & Cristiana, P. (2020). Saffron: Chemical Composition and Neuroprotective Activity. *Molecules*, 25, 5618. https://doi.org/10.3390/molecules25235618.

Maria, G. C., & Anoneela, C. (2010). Looking for saffron (*Crocus sativus* L.) parents. *Functional Plant Sciences and Biotechnology*, 4(Sp 2),1-14.

Mingming, Z., Yuhua, S., Lan, W., Licheng, G., Wei, L., Chao, X., Song, Y., Wei, S., & Shilin, C .(2016). Rapid authentication of the precious herb saffron by loop-mediated isothermal amplification (LAMP) based on internal transcribed spacer 2 (ITS2) sequence. *Scientific Reports*, *6*(25370).

Mir, J. I., Ahmad, N., Singh, D. B., Khan, M.H., Zaffer, S., & Shafi, W. (2015). Breeding and biotechnology opportunities in saffron crop improvement. *Academic Journal*, 10(9), 970-974

Mir, J. I., Ahmed, N., Wani, S. H., Rashid, R., Mir, H., & Sheikh, M. A. (2010). In vitro development of microcorms and stigma like structures in saffron (*Crocus sativus* L.). *Physiology and Molecular Biology of Plants*, *16*(4), 369-373.

Mitsopoulou, T., & Tsimidou, M.Z. (2004). Morphological characteristics of Greek saffron stigmas from Kozani region. *Acta Horticulture*, 650, 189-193.

Mohammad, E. A. (2008). Impact of animal manures and chemical fertilizers on yield components of saffron (*Crocus sativus* L.). *American-Eurasian Journal of Agriculture. & Environmental Science*, *4*(3), 274-279.

Mohammad, M., Mohammad, E. A., & Younes, S. (2012). Respond of saffron (*Crocus sativus* L.) to animal manure application. *Journal of Medicinal Plants Research*, *6*(7), 1323-1326.

Mohammad, Z. A. (2012). Effect of organic matter from different sources on yield of saffron. *Agricultural Research and Education Organization*.

Mudasir, A.M., Sheikh, M., Sugapriya, M., Mohammed, N., Leonard, W., & Parvaiz, A. (2021). Deciphering genetic diversity analysis of saffron (*Crocus sativus* L.) using RAPD and ISSR markers. *Saudi Journal of Biological Sciences*, *28*, 1308-1317

Nehvi, F. A., & Yasmin, S. (2017c). Advance in saffron research for integrated development of saffron in Kashmir, India. *Acta Horticuture*, 1184, 63-68.

Nehvi, F.A. (2011). Good Practices for Saffron Cultivation in Kashmir. A Practical Manual. *SKUAST-K Publication.*

Nehvi, F.A. (2014). Final Report: A Value Chain on Kashmir Saffron. Submitted to National Agriculture Innovation Project ICAR, New Delhi Under Component-2.

Nehvi, F.A. (2018). Final Report "Economic Revival of J&K Saffron Sector" Under National Saffron Mission. Submitted to Agriculture Production and Farmers Welfare Department, J & K.

Nehvi, F.A., & Salwee, Y. (2014 a). Quality Saffron. *Indian Farming*, *64*(2),71-73.

Nehvi, F.A., & Salwee, Y. (2014 b). Enhancing Saffron Production. *Indian Farming*, *64*(2), 69-70.

Nehvi, F.A., & Salwee, Y. (2019). Saffron (*Crocus sativus* L.) Crop Insurance to Mitigate ill Effects of Climate change - a Priority of Jammu and Kashmir State. *International Journal of Current Microbiology and Applied Science*, *8*(1), 2972-2984.

Nehvi, F.A., Dhar, J.K., Sheikh, S.S., Iqbal,A.M., & John,A.A. (2018). Conventional postharvest practices and their impact on saffron quality - a study. *Acta Horticulturae*, *1200*, ISHS,139-143.

Nehvi, F.A., Khan, M.A., Lone, A. A., Maqhdoomi, M.I., Wani, S.A., Yousuf, V., & Yasmin, S. (2010b). Effect of radiation and chemical mutagen on variability in saffron (*Crocus Sativus* L.). *Acta Horticulture*, 850, 67-74.

Nehvi, F.A., Lone, A.A., Khan, M.A., & Maqhdoomi, M.I.(2010a). Comparative study on effect of nutrient management on growth and yield of saffron under temperate conditions of Kashmir. *Acta Horticulture*, 850, ISHS, 165-170.

Nehvi, F.A., Salwee, Y., Ishfaq, A., Dar, S.A., Mudasir, A., & Ghulam, H. (2018a). Problems and Prospects of Saffron Cultivation in Jammu & Kashmir. *Spice India*, *31*(12), 25-28.

Nehvi, F.A., Salwee, Y., Sabeena, N., Shaheena, N., Niyaz, A., & Bashir, A. E. (2017a). Good practices for saffron production under high density plantation in Jammu & Kashmir. *Sher-e-Kashmir University of Agricultural Sciences and Technology of Kashmir*.

Nehvi, F.A., Salwee, Y., Sabina, N., Shahina, A.N., Bashir, A. E., Aijaz, A. L., & Aflaq, H.(2017b). Irrigation: A Critical Input for Enhancing Production and Productivity of Saffron In J & K. *SKUAST-K Publication.*

Nehvi,F.A., Salwee, Y., Shahina, A. N., Sabina, N., Bashir, A. E., Tariq, A. S., Niyaz, A. D., Mushtaq, A. J., Altaf, A. A., & Irfan, A. (2018b). Water management in saffron. *Spice India*, *31*(12), 29-33.

Parviz, G., Bahram, M., & Parvin, B. (2012). Application of Herbicides with Limited Dose Can Play a Major Role in Suitable Weeds Control in Saffron Fields. *World Applied Sciences Journal*, *20*(9), 1266-1269.

Quadri, R.R., Kamili, A.N., Husaini, A.M., Shah, A.M., & Teixeira da Silva, J.A. (2010). *In vitro* studies on cormogenesis and maximization of corm size in saffron. *Journal of Functional Plant Science and Biotechnology*, 4, 132-135.

Quadri, R.R., Shah, F.A., Kamili, A.N., & Shah, A.M. (2008). *In vitro* response of Corm and needle segments of saffron. *Journal of Himalayan Ecology and Sustainable Development*, *3*(94), 104.

Raja, W., Zaffer, G., & Wani, S.A. (2007). *In vitro* micro corm formation in saffron (*Crocus sativus* L.). *Acta Horticulture*, 739, II 291-296.

Rezaian, S., & Paseban, M. (2007). The effect of micronutrients and manure fertilizers on the quantity and quality of khorasan saffron. *Acta Horticulture*, 739, 155-158.

Sabina, N., Shahina, A. N., Niyaz, A. D., Shabir, A., Ishfaq, A. A., Gowhar, A., Sabia., & Nehvi, F.A. (2018). High density plantation in saffron (*Crocus sativus* L.) for achieving higher yields. *International Journal of Current Microbiolgy and Appied Science*, *7*(5), 748-750.

Salwee, Y., & Nehvi, F. A. (2013). Saffron as a valuable spice: A comprehensive review. *African Journal of Agricultural Research*, *8*(3), 234-242.

Salwee, Y., & Nehvi, F. A. (2013). Seasonal Bud Sprouting: A Challenge For *in vitro* Micropropagation in Saffron. *Vegetos*, *26*(2), 154-158.

Salwee, Y., & Nehvi, F. A. (2014a). Structural Variations and Biology of Kashmir Saffron-A Study. *Vegetos*, *27*(02), 376-381.

Salwee, Y., & Nehvi, F. A. (2016). Economic loss of Saffron (*Crocus Sativus* L.) caused by *Rhizoctoni asolani* under temperate conditions of Kashmir-an emerging threat. *Journal of Cell and Tissue Research*, *16*(1), 5529-5533.

Salwee, Y., & Nehvi, F. A. (2017). Ethyl Methane Sulphonate- a potent mutagen for inducing genetic variability in saffron (*Crocus sativus* L.). *Applied Biological Research*, *19*(2), 164-171.

Salwee, Y., & Nehvi, F. A. (2017). Tissue culture for improving scope of saffron in Jammu and Kashmir. *SKUAST-K Publication.*

Salwee, Y., & Nehvi, F. A. (2018a). Phenological Growth Stages of Saffron (*Crocus sativus* L.) under temperate conditions of Jammu & Kashmir-India. *International Journal of Current Microbiology and Applied Science*, *7*(4), 3797-3814.

Salwee, Y., & Nehvi, F. A. (2018b). Uniqueness-The strength of Kashmir saffron. Agriculture Today-*The National Agriculture Magazine*, March, *21*(3), 42-44.

Salwee, Y., & Nehvi, F. A.(2014b). *In vitro* Microcorm Formation in Saffron (*Crocus sativus* L). *Journal of Cell and Tissue Research*, *14*(2), 4463-4470.

Salwee, Y., & Nehvi, F. A.(2014c). Creation of Genetic variability in Saffron (*Crocus sativus* L.) using induced mutation. *Journal of Cell and Tissue Research*, *14*(02), *4455-4461*.

Salwee, Y., & Nehvi, F. A.(2014d). *In Vitro* Studies on Effect of Corm Weight and Availability of Moisture on Plant Development in Saffron (*Crocus Sativus* L.). *Journal of Cell and Tissue Research*, *14*(3), 4665-4669.

Salwee, Y., Nehvi, F. A., & Azra, K. (2016). Pollen Abnormalities of Kashmir Saffron (*Crocus sativus* L.). *Vegetos*, *29*, 20-25.

Salwee, Y., Nehvi, F. A., & Rafiya, R. (2019). Karyotyping of Kashmir saffron (*Crocus sativus* L.). *International Journal of Agricultural Sciences*, *11*(6), 8051-8053.

Salwee, Y., Nehvi, F. A., & Shafiq, A. W. (2013). Tissue culture as an alternative for commercial corm production in saffron: A heritage crop of Kashmir. *African Journal of Biotechnology*, *12*(25), 3940-3946.

Salwee, Y., Nehvi, F. A., Ishfaq, A., & Dar, S.A. (2018a). India's Share in World Saffron Market. *Spice India*, *31*(12), 13-25.

Salwee, Y., Nehvi, F. A., Joyti, S., & Ameek, A. W.(2018b). Horizontal Expansion of Saffron in New Areas of Jammu and Kashmir—A Case Study. *Acta Horticulturae*, *1200,* ISHS, 139-143.

Sani, A.M., Abbas, H. K., & Elahe, M. (2013). Chemical composition and nutritional value of saffron's pollen (*Crocus sativus* L.). *Nutrition & Food Science*, *43*(5), 490-495.

Saxena, R.B. (2010). Botany, Taxonomy and Cytology of *Crocus sativus* series. *31*(3), 374-381.

Sepaskhah, A.R., & Kamgar-Haghighi, A.A. (2009). Saffron Irrigation Regime. *International Journal of Plant Production*, *3*(1), 1-16.

Soukrat, S., Metougui, M. L., Gabone, F., Nehvi, F.A., Abousalim, S., & Benlahabib, O.(2019). Study of diversity in some Moroccan population of saffron (*Crocus sativus* L.). *African Journal of Agricultural Research*, *14*(16),759-769.

Srivastava, R., Ahmed, H., Dixi, R. K., Dharamveer., & Saraf, S. A. (2010). *Crocus sativus* L.: A comprehensive review. *Pharmacogn Review*, *4*(8), 200-208.

Tayebeh, S., Elham,A., & Seid, M. (2016). Main chemical compounds and pharmacological activities of stigmas and tepals of 'red gold'; saffron. *Trends in Food Science & Technology*, *58*, 69-78.

Tong, Z., Chao, H., Changping, D.,Yi, Z.,Yue, F., Jiangning, H.W., Limei, Z.,Yao, W , & Guoyin, K.(2019). First report of corm rot on saffron caused by *Penicillium solitum* in China. *APS Publication*. https://doi.org/10.1094/PDIS-09-19-1927-PDN