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Monika Menia
Faculty of Agriculture, Sher-e-Kashmir University of Agricultural Sciences and Technology of Kashmir, Wadura, Sopore, Jammu and Kashmir, India

Sadaf Iqbal
Faculty of Agriculture, Sher-e-Kashmir University of Agricultural Sciences and Technology of Kashmir, Wadura, Sopore, Jammu and Kashmir, India

Zahida R
Faculty of Agriculture, Sher-e-Kashmir University of Agricultural Sciences and Technology of Kashmir, Wadura, Sopore, Jammu and Kashmir, India

Tahir S
Faculty of Agriculture, Sher-e-Kashmir University of Agricultural Sciences and Technology of Kashmir, Wadura, Sopore, Jammu and Kashmir, India

Kanth RH
Faculty of Agriculture, Sher-e-Kashmir University of Agricultural Sciences and Technology of Kashmir, Wadura, Sopore, Jammu and Kashmir, India

Saad AA
Faculty of Agriculture, Sher-e-Kashmir University of Agricultural Sciences and Technology of Kashmir, Wadura, Sopore, Jammu and Kashmir, India

Aashq Hussian
Faculty of Agriculture, Sher-e-Kashmir University of Agricultural Sciences and Technology of Kashmir, Wadura, Sopore, Jammu and Kashmir, India

Correspondence
Zahida R
Faculty of Agriculture, Sher-e-Kashmir University of Agricultural Sciences and Technology of Kashmir, Wadura, Sopore, Jammu and Kashmir, India

Production technology of saffron for enhancing productivity

Monika Menia, Sadaf Iqbal, Zahida R, Tahir S, Kanth RH, Saad AA and Aashq Hussian

Abstract
Saffron is the most expensive spice in the world. Saffron is a perennial herbaceous plant attaining a height of 25 to 40 cm. The saffron known the world over as the 'Golden Condiment' because of its extreme high cash value and low volume. Saffron is widely used in food preparations especially Kashmiri 'Kehwa', fabric dying, medicinal drug, perfume and cosmetic industries. Saffron have medium feed value for ruminants and its value is less than alfalfa and more than cereal straw (Valizadeh, 1988). Saffron essentially contains three active ingredients such as crocin, picrocrocin and safranal which determines the intensity of colour, power of the flavour and strength of the aroma respectively. J&K is only state in the country which has the capability of producing this golden spice of the world. The total area recorded under saffron production was 5.707 thousand hectares with an annual production of 15.95 tonne and productivity of 2.8 kg/ha in 1997 which has reduced to 3.674 thousand hectares with an annual production of 9.6 tonne and having 2.61 kg/ha of productivity. The major constraints that limit its production and productivity is poor management of saffron cultivation, as it involves inadequate plant population, incidence of corm rot disease, nutrient depletion, lack of irrigation facilities, inadequate post-harvest handling, processing and marketing as well as adulteration in quality saffron. Turhan et. al. (2007) stated that the effect of different growing medias namely field soil+ sand, field soil+ sand+ cow manure, field soil+ sand+ manure applied as double layer above and bottom of corm bed and field soil+ sand+ manure+ nitfojips-K on most of the characters were significant but cow manure mixtures especially with double layers had a positive effect on the flower and stigma weight. Cavusoglu et. al. (2009) reported that the big size corm dimension (10-24 mm) has a great impact than small size corm dimension (25-40 mm) on fresh or dry saffron yield and to extend harvest period under greenhouse condition. Yau and Nimah (2004) found that the spacing had a large effect on flower production on the basis of per unit area and the ratio of actual flower production for low to medium to high density was 1:2:4. Unal and Cavusoglu (2005) found that the highest values of fresh and dry saffron weight were obtained from the application of urea fertilizer while the lowest values of fresh and dry saffron weight were obtained from ammonium sulphate fertilizer. Nehvi *et al.* (2010) revealed that the application of FYM at 350 kg/ha in combination with N: P: K at 30:20:15 kg/ ha recorded maximum saffron yield averaged over 3 years (4.350 kg ha-1) showing an increase of above 91% over the control plots. Wani (2004) suggested that the inoculation with nematodes and pathogenic fungus either separately or simultaneously significantly affected the disease development and the saffron yield. It is shown that the growing medium was one of the important factors for saffron flower production. In conclusion, the good management practices are recommended to enhance the productivity of saffron.

Keywords: Saffron, growing media, corm size, urea fertilizer, yield

Introduction
Saffron is the most expensive spice in the world. The scientific name for saffron is *Crocus sativus* L. belonging to the family of Iridaceae. Saffron is a perennial herbaceous plant attaining a height of 25 to 40 cm. The word 'saffron' is derived from Arabic word "Zafaran" which means yellow, 'Kum Kum' in Sanskrit, 'Kesar' in Hindi and in Kashmiri language, it is known as 'Koung'. The saffron known the world over as the 'Golden Condiment' because of its extreme high cash value and low volume and this great commercial activity is known as 'Golden Zest' in Indian agriculture.

Saffron has been traditionally used to colour and flavour number of dishes and is used as a key spice for preparation of Kashmiri 'Kehwa'. Saffron has had a significant role in all religions branched out from Hinduism. It is essential in performing some rituals; the Buddhist monks have adopted the saffron colour as the most important one and Hindus use saffron for marking their foreheads. It is used in traditional and modern medicines as antiseptic, antidepressant, antispasmodic, anticancer and carminative and also used as a herbal medicine for curing respiratory infections such as coughs, common colds, scarlet fever and asthma. It has many other uses in industries such as cosmetic, perfumery as well as in the textile dyes.

Saffron have medium feed value for ruminants and its value is less than alfalfa and more than cereal straw (Aga, 2008; Valizadeh, 1988) [1].

Chemical composition of saffron

Saffron essentially contains three active ingredients such as crocin, picrocrocin and safranal which determines the intensity of colour, power of the flavour and strength of the aroma respectively. Kamili and Wani, 2006 [5] reported that the commercial saffron also contains total nitrogen free extract, water, protein, starch and sugars, essential oil, crude fiber, ash (salty inorganic material) and traces of potassium, phosphorous and boron as depicted in table- 1. Crocetin glycosyl esters responsible for its characteristic colour and compound are found in extremely important proportion in stigmas (Sampathu *et al*., 1984) [18].

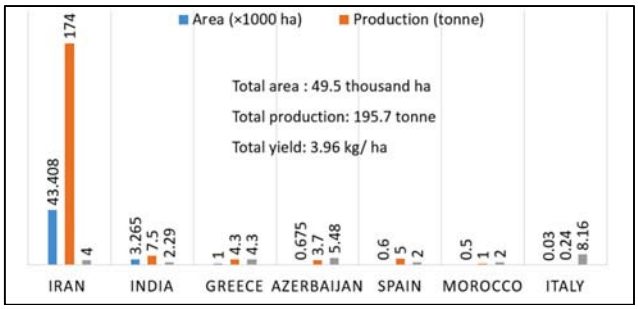
Table 1: Saffron chemical composition.

Constituents	Percentage (%)
Total nitrogen free extract	54.5 – 57.5
Water	14.5 – 15.5
Crocin	13.5 – 15.0
Protein	12.5 – 13.5
Starch and sugar	12.0 – 13.5
Essential oil	4.7 – 8.5
Valuable crude fiber	4.0 – 5.0
Ash	4.0 – 4.5
Picrocrocin, safranal, potassium, phosphorus, boron	In traces

(Source: Kamili and Wani 2006, Research priority setting in saffron) [5]

Global Scenario

Saffron is currently being cultivated in some of the major countries of the world such as Iran, India, Greece, Spain, Italy, Turkey, France, Azerbaijan, Egypt, United Arab Emirates, Afghanistan, Iraq and Pakistan. The country wise area, production and productivity were depicted in figure 1, it is observed that Iran occupying a maximum area of 43.408 thousand hectares under saffron cultivation with the production of 174 tonnes and the productivity of 4 kg/ha contributing about 88% of the world's saffron production. India ranks second largest area of 3.265 thousand hectares of land but the production is only 7.5 tonnes and the productivity of 2.3 kg/ha, followed by Greece (1 thousand hectares of area) and so on. However, Italy has the lowest area and production, but ranks first in productivity. The few key factors for higher saffron production in Iran are as shorter age of saffron fields, higher planting density, proper nutrient management with adequate irrigation facilities and the most important is non-incidence of corm rot and proper weed management practices.



Source: Annual Report of Directorate of Agricultural Jammu and Kashmir, 2014

Fig 1: Saffron status across the world.

District wise area, production and productivity under saffron cultivation in Jammu & Kashmir state

Saffron is an important cash crop of Jammu and Kashmir state. In J&K state, saffron is mainly cultivated in four districts namely, Pulwama district (Pampore, Chandhara, Befin, Barsoo, Lethpora, Konibal, Dussu, Kadlabal, Namlabal, Sampora, Konibal, Woyan, Khrew and Balhama), Budgam district (Chadura, Kralpura, Nagam, Ompora and Lasjan), Srinagar district (Ganderbal, Zewan and Zawreh) and Doda district (Kishtwar). Pampore has the rich saffron heritage site which is also known as "SAFFRON TOWN" of Kashmir. Table 2 provides an insight across the district wise area, production and productivity under saffron cultivation. The table indicates that in Jammu and Kashmir Pulwama appears to be at the highest scale in terms of area i.e.1851.75 hectares and production having 1.85 tonne, followed by Budgam 398.28 hectares and production having 0.40 tonne, while on the other hand Doda was having lowest area of 61.73 ha and 0.06 tonne production.

Table 2: District wise saffron cultivation in Jammu & Kashmir state.

District	Area (hectares)	Production (tonne)	Productivity (kg/ha)
Pulwama	1851.75	1.85	0.99
Budgam	398.24	0.40	1.00
Srinagar	157.28	0.16	1.01
Doda	61.73	0.06	0.97
Total	2469	2.47	3.97

Source: Annual Report of Directorate of Agricultural Jammu and Kashmir, 2014

Trends in area, production and productivity of saffron in Jammu and Kashmir state

J&k is only state in the country which has the capability of producing this golden spice of the world. A steady decline trend has been observed in area as well as in production. The total area recorded under saffron production was 5.707 thousand hectares with an annual production of 15.95 tonne and productivity of 2.8 kg/ha in 1997 which has reduced to 3.674 thousand hectares with an annual production of 9.6 tonne and having 2.61 kg/ha of productivity. There was negative growth rate of -35.62 % over the years with negative growth rate of -6.78 % observed in the productivity of saffron. The matter of concern is that why the area under the high value spice is declining? The major constraints that limit its production and productivity is poor management of saffron cultivation, as it involves inadequate plant population, incidence of corm rot disease, nutrient depletion, lack of irrigation facilities, inadequate post-harvest handling, processing and marketing as well as adulteration in quality saffron. It is worth to study the imporved technology of saffron cultivation in Kashmir, so that those who are concerned with saffron such as researchers, policy makers, development workers, planners, etc. can work appropriately for the development of saffron growers, by minimizing the gap between poor management of saffron cultivation that prevails at present.

Source: Jammu and Kashmir Agriculture Department and Jammu & Kashmir ENVIS, 2016

Fig 2: Year wise status of saffron in Jammu & Kashmir.

Production technology of saffron

Edaphic conditions

Malcom Doughlas (2003) observed that saffron likes light friable soils that have high nutrient contents. It grows on wide range of soils but thrives best in deep well drained clay calcareous soils with loose texture that permits easy root penetration. Best soils for saffron production are sandy or loamy textured soils.

Climatologic conditions

Saffron grows well in temperate climate with sunny days and flourishes best at an altitude of 2140 m amsl. It requires a mean temperature of 6 to 8℃ at night and 15 to 20℃ during day times in the months of October and November provide a pleasant climate for better blooming (Molina *et. al*., 2005) [10]. Saffron prefers cold winters, autumn and spring rainfall and warm dry summers with annual rainfall ranging from 800-900 mm (Srivastava, 1968 and Malcom Doughlas, 2003) [22]. Spring rains are favourable for corm multiplication and early autumn rains boost flower production.

Land preparation

Plough the land 3 to 5 times to a depth of about 30 cm in the months of May to July. About 10 tonne of well decomposed farm yard manure (FYM) and is sufficient for one hectare of land, to keep the soil in loose form and it helps in rapid corm multilication (Shah and Tripathi, 2008) [20].

Sorting of corms

Corms with diameter ranging from 2.5 to 3 cm weighing about 8 g and above are ideal for higher saffron production and productivity. The corms must be free from injuries and disease lesions are sorted out as well as the outer loose scales are removed before planting.

Corm treatment

Nehvi (2003) [11] reported the incidence of corm rot as 46% in traditional saffron growing areas. Corm rot of saffron caused by *Fusarium oxysporum* and *Fusarium solani* is considered to be most destructive in Kashmir (Wani 2004; Ahmad and Sagar 2006) [25]. Selected corms must be treated with 150 g of Mancozeb 75 W.P. @ 0.3% and 50 g of Carbendazim 50 W.P. @ 0.1% in 50 litres of water before planting to control corm rot disease. The graded corms are dipped in the

fungicidal suspension (Mancozeb and Carbendazim) for a period of 5-10 minutes. The corms of saffron are taken out and spread on a clean cloth and then allowed to dry in shade for another 10 to 15 minutes to drain off excess moisture.

Planting of corms

The corms should be planted from second fortnight of August to first fortnight of September in 2m×3 m stripes with a width of 30 cm and a depth of 15 cm drainage channesl on both sides. Sowing is done by hand dropping of saffron corms behind plough after bed formation. Saffron corms are planted in furrows at inter-row distance of 20 and inter-corm distance of 10 cm with a depth of 15 cm with 1 corm/ hill with a planting density of 5 lakh corm/ hectare with a seed rate of 50 quintals/ hectare resulted in the production of quality planting material with a maximum proportion of flower producing corms.

Organic and mineralized fertilizers

Application of nitrogen, phosphorus (P_2O_5) and potassium (K_2O) in the form of urea, DAP and MOP in the ratio of 90:60:40 kg respectively is recommended for one hectare of area. Full dose of well rotten FYM (10 tonnes/ hectare), vermicompost (5 quintals/ hectare), phosphorus, potassium and half dose of nitrogen shoul be applied at the time of second hoeing and remaining half quantity of nitrogen must be applied at the time of third hoeing.

Intercultural operations

Weeding and hoeing are done to destroy weeds as well as to aerate the saffron beds. One light hoeing is done in the month of June and second hoeing in September month befor the flower appears with the aid of short handled hoe called Zoon. Weeding is also practiced from December to April to promote daughter corm production after the flowering is over. According to Pir *et. al.* (2008) [16], the long period from April to September provides an open space for weeds in saffron fields, which gain a monopoly to spread over the entire fields without any resistance that would otherwise be encourted in the presence of the crop. The major weeds found in saffron fields of Kashmir include *Euphorbia helioscopia, Papaver rhoae, Lepidium virginicum, Salvia moorcroftiana, Chonspora tanella, Galium tricorne, Tulipa stellata, Lithospermum arvense, Ranunculus arvensis, Medicago lupilina, Filago arvense, Poa bulbosa, Crepis saneta, Descurainea sophia, Polygonum aviculare, Chenopodium album*, among others (Pir *et. al*., 2008) [16]. Norouzzadeh and Delghadi (2006) [15] in Iran reported that Ioxynil (750 g a.i./ ha) and Tribenoronmethyl (18.75 g a.i./ ha), when sprayed at the 6-8 leafy stage of weeds after saffron harvest, were highly efficient in controlling weeds. The appliciation of Metribuzin (560 g a.i./ ha) in spring or autumn controlled weeds to a large extent without any injury to saffron.

Irrigation facilities

Saffron crop is grown under rained conditions in Kashmir valley. Srivastava (1963) [21] reported that areas receiving 100-150 cm of well distributed rainfall with snow in winter are suitable for saffron cultivation, and rains in September are essential for meeting the water requirement of corms for good flower yields. Kamili *et.al.* (2007) [6] suggested that rainfall of 100-150 mm is considered essential during the pre- flowering stage. According to Nehvi (2004) [12] and Nehvi and Makhdoomi (2007b) [13], the saffron crop requires 10 irrigations, and should be sprinkler irrigated at 700 m^3/ ha at an interval of 7 days at the sprouting stage (25th August to 15th September) followed by 3 irrigations at the post-flowering stage (8th November to 30th November) at weekly intervals.

Pests management

Saffron fields infested by many species of plant parasitic nematodes cause damage to corms by sucking the sap. Zaki and Mantoo (2008) [27] reported the percentage infestation at the Konibal area of Pampore as *Helicotylenchus vulgaris* (16%), *Pratylenchus throrne*i (8%), *Tylenchus* sp. (13%), *Tylenchorynchus* sp. (10.7%), *Xiphinema* sp. (14.6%), *Aphelenchus avenae* (5.8%) and *Hemicriconemoides* sp. (3.2%). They also recommended the application of Chlorpyriphos 10G (at 1000 g a.i./ ha) or Fenvalerate 0.4% (at 120 g a.i./ ha) as soil treatment effectively reduces the pest population. Manzar *et. al.* (2008) that the extent of damage to saffron corms by rodents ranges from 10 to 50%. Saffron rodents can be managed either using zinc phosphide baits or aluminium phosphide pellets. A burrow fumigator has been found to be effective in the control of rodents using cow dung cakes.

Harvesting of saffron flowers

The harvesting of saffron flowers starts from the first week of October and continue till the mid of November. Each flower lives only for 48 hours. That's the reason why saffron has such a high value crop. The picking of saffron flowers should be done early in the morning before their opening. The flowers should be cut from the plant near to the ground by the aid of finger nails. The flowers must be collected in clean wicker baskets to avoid contamination. The number of flowers required per kg of standard saffron of Kashmir varies between 2680 and 3840 (Kafi and Showket, 2007) [4]. The saffron can be collected in three different grades namely mongra is the costliest and finest one, lacha which is the purest form and less costly than mongra and the third one is zarda, tail part of flower that is cheapest.

On farm evaluation of performance of Saffron

Growing media

Turhan *et al.* (2007) [23] were conducted an experiment to determine the effects of different growing media on the various characters of saffron plant in greenhouse conditions in Turkey. The results of variance analysis revealed that effects of the growing media on most of the characters were significant as shown in table- 3. The four types of growth media were used namely (1) field soil, (2) field soil+ sand+ cow manure, (3) field soil+ sand+ manure applied as double layer above and bottom of corm bed and (4) field soil+ sand+ manure+ nitfojips-K. Treatment 4, containing nitfojips-K (commercial organic fertilizer) produced significantly shorter plants than the other treatments. Although number of shoots per plant was the highest in treatment 4, the lowest stigma weight, and consequently the lowest flower weight was produced in treatment 4. The highest flower and stigma weights were obtained by treatment 3. This indicates that cow manure mixtures especially with double layers had a significant effect on the stigma and flower weight.

Table 3: Effect of different growing Medias on the various characters of the saffron plant.

Growing media	Plant height (cm)	Number of shoots	Flower weight (g)	Stigma weight (g)
1) Fs	28.0	6.08	0.200	0.019
2) M+S+Fs	32.3	4.72	0.215	0.022
3) M+S+Fs (DL)	29.9	7.17	0.240	0.024
4) M+S+Fs+N	8.6	7.42	0.157	0.010

*Fs: Field soil, M: Cow manure, S: Sand, N: Nitfojips-K.

Saffron corm dimension size

Fernandez (2004) [3] studied saffron plant has a slow growth and a sterile triploid crop that propagetes through vegetative method, forming only 3- 4 cormlets each season as it is a geophytic in nature. An experiment based on the effect of mother corm dimension on yield and on harvest period under glass- greenhouse condition in autumn-winter in Kocaeli province of Turkey investigated by Cavusoglu *et. al.* in the year 2005 [24]. The big dimension corms (25- 40 mm) blossomed earlier and lasted for 22 days than small dimension corms (10- 24 mm), reveals that flowering begins earlier as well as extend the time of harvest period by using big dimension corms. The research also showed that the big dimension corms produce more number of flowers per plant and great impact on saffron yield of fresh and dry stigma.

Planting densities

Yau and Nimah were conducted field experiment to determine the spacing effect on saffron flower in Lebanon over the three seasons (2000- 02). The spacing has a large effect on the flower production on the basis of unit area in the year. The higher density treatment (10×10 $cm^{2)}$ gave higher number of flowers than low density treatment (20×20 cm^2), swhile no significant difference found in the next year.

Various nitrogen fertilizers on saffron yield properties

The study was carried out in Turkey to determine the effect of various nitrogen fertilizers on number of flower, length of leaf, fresh and dried saffron yield in 2004- 05 growing seasons by Unal and Cavusoglu. The highest value of fresh saffron weight was obtained from urea fertilizer than ammonium sulphate fertilizer. The flowers number obtained from the application of urea were determined to be highest as 14330 per da and the lowest value was found to be 8330 per da in the control treatment. The application of urea fertilizer has significantly positive impact on the dry stigmas of saffron in comparison to ammonium sulphate fertilizer as the latter causes loss of productivity owing to the acidic physiological character of the fertilizer.

Integrated Plant Nutrient Supply

Nehvi *et. al.* (2010) [14] investigated the impact of different organic and inorganic manures/fertilizers on saffron yield were performed simultaneously over 4 years (2005-2008) at the Saffron Research Station Konibal Pampore. Urea at 46% and Compound Liquid Fertilizer (12% N, 7% P2O5, K2O, Fe, Zn Chelates) at 7 g/1000 m were studied on saffron yield. Application of FYM had more pronounced effect on saffron yield as compared to in-organic fertilizers. FYM alone at different levels recorded the highest saffron yield (4.011 kg/ha), whereas impact with inorganic fertilizers was exhibited to the tune of 3.417 kg/ha (CLF). Application of FYM at 350 kg ha-1 in combination with N:P:K at 30:20:15 kg/ha recorded maximum saffron yield averaged over 3 years (4.350 kg/ha) showing an increase of above 91% over the control plots. Effect of animal manure is attributed to enhancement of physical criteria of the soil including better aeration, better water holding capacity and good balance between nutrients in the soil solution and improvement of nutrient exchange between of the soil (Coleman and Crossley, 1995; Lampkin, 1990) [7]. Slow release of nutrients from animal manure during the growth period and hence low leaching of the nutrients could also be other criteria for animal manure.

Time of pre-flowering irrigation

Timing of irrigation is very crucial for flower initiation. The saffron yield as influenced by the time of irrigation scheduled reported by Sepaskhah (2009) [19]. An irrigation should be scheduled at a right time before the beginning of vegetative growth that promotes flowering as presented in table- 4. The leaf growth may interfere with harvesting practice when flowering and leaf growth occurs simultaneously. It has been suggested that pre- flowering irrigation is required at the time of mid October obtain the highest yield of saffron.

Table 4: Saffron yield as influenced by time of pre-flowering irrigation.

Time of first irrigation	Flower dry weight (g/m^2)	Saffron yield (g/m^2)
Early October	8.25	0.156
Mid October	11.02	0.226
Late October	8.47	0.170
Mid November	6.74	0.114

Development of corm rot and yield of saffron

The interaction effects of Fusarium solani and namatodes on the development of corm rot and saffron yield studied by Wani in the year 2004 [25]. Simultaneous inoculations with both the pathogens (nematode and *Fusarium* fungus) produced more diseased corms (50%) with highest disease intensity (14.66%) as compared to separate infestation of nematode and fungus. It was reported pale yellow colour of corm due to nematode infestation, dark brown colour with fungus colonization and the combined inoculation of both fungus turn the corms into black. The lowest saffron yield was recorded in case of simultaneous inocultation of fungus along with nematode compared to the saparate infestaion of the pathogens.

Post-harvest handling practices

The three steps are important for post- harvest practices followed by farmers are as follows:

i. Saffron stigma separationl
ii. Saffron drying
iii. Packaging and storage of saffon

i. Separation of Stigmas from Flowers

The sorting of stigmas is the crucial step for the quality of the final product. Stigma should be separated within 10-12 hours of flower picking to achieve maximum pistil recovery. Delay in separation by 36-72 hours results in loss of recovery from 37 g/kg of fresh saffron flowers.

ii. Drying of stigmas

Drying is the most important part of the whole procedure of the processing. Drying of saffron in Kashmir is done by two different methods. The farmers of Kashmir usually practice traditional method in which stigmas are spread out on large surfaces and left to dry that takes about 27 to 53 hours under shade leaving a moisture of about 8 to 10%. Sampathu *et. al.* (1984) [18] reported that a longer drying period of 27 to 53 hours adversely affects the quality, possibly due to both biodegradation and oxidative destruction of the principle components. The other method is artificial drying in which the high temperature of about 40±5 ˚C has to be applied on the stigmas through hot air streams.

iii. Packaging and storage

Storage and packaging are two very significant procedures for preserving the initial quality of the saffron spice. The growers of saffron in Kashmir generally store saffron in earthen pots or polythene bags without taking care of moisture (Mir *et. al.*, 2008). Saffron with initial moisture content of 8 to 10% can be stored at an ambient temperature of 10℃ in air tight containers safely for 6 months.

Conclusion

Saffron nutrient demands could be supplied by application of both animal manures as well as mineral fertilizers. The application of nitrogenous fertilizers especially urea results greater impact on dry and fresh stigma weights of saffron. Various types of disease control fungicides, pesticides and other materials should be used in adequate proportion by the growers so that they have easy to control these devastating diseases at the earliest. The establishment of weather stations in the main saffron growing areas of the state so that it can provide daily information bulletins regarding weather to the growers. There is necessity to take steps to educate farmers of the latest developments by state government and help them to enhance their yield and productivity by adopting the good management practices.

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