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Amjad M Husaini
Genome Engineering and Societal Biotechnology Lab, Division of Plant Biotechnology, SKUAST-K, Shalimar, Srinagar, J&K, India

Amir Bashir Wani
Genome Engineering and Societal Biotechnology Lab, Division of Plant Biotechnology, SKUAST-K, Shalimar, Srinagar, J&K, India

Corresponding Author:
Amjad M Husaini
amjadhusaini@skuastkashmir.ac.in;
amjadhusaini@yahoo.com

Prospects of organic saffron kitchen gardens as a source of phytochemicals for boosting immunity in common households of semi-arid regions: A case study of trans-Himalayan Kashmir valley

Amjad M Husaini and Amir Bashir Wani

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Abstract
Saffron grows well in arid regions with well drained sandy soil, under warm and dry summers. It requires minimal irrigation, mostly during critical stages prior to flowering. Currently, saffron is faced with a number of challenges, especially outside Iranian region. The few prominent ones are lack of good-quality corms as seed material, poor soil fertility, lack of assured irrigation, increased urbanization on saffron land, and rampant adulteration. Initiatives are needed to reverse the declining trend by its cultivation in non-traditional sites like in arid as well as semi-arid regions. Instead of spending huge amount on large irrigation projects for big areas especially when financial resources are a constraint, a good alternative strategy is introduction and popularization of organic saffron in kitchen gardens. This would ensure small-scale cultivation as it would be easier to assure irrigation during critical growth stages, and hence supply of good quality genuine saffron for in-house consumption, and also increase awareness about organic agriculture. Herein we present a first report on the establishment of organic saffron kitchen gardens by women in their households, and successful cultivation of saffron in non-traditional semi-arid trans-Himalayan regions of Kashmir valley.

Keywords: *Crocus sativus* L., vegetable, semi-arid, non-traditional, ethnobotany, health, geographical indication, climate change

Introduction
Saffron (*Crocus sativus* L.) is the dried orange-red trifid stigma of a perennial bulbous plant *Crocus sativus* L., a triploid male-sterile plant flowering in autumn, one of the costliest culinary spice of the world [1]. It is included in the family Iridaceae. Some recent research reports indicate two possible sites of saffron origin: one in Greece in the Mediterranean area, and the other at East in Turkey-Iran-India [2]. Highly coveted for its beauty, aroma, healing powers, and overall appeal, "Red Gold" is the most expensive spice in the world [3]. Its production is typically favoured in countries where labour is cheap, such as Iran, India and Azerbaijan, but is also produced in countries like Greece, Switzerland, Spain, Argentina or the USA and newer areas being brought under its cultivation, viz. China and Japan [4].

Jammu and Kashmir, which encompasses the western Himalayas and the Karakorum mountains is well known for best quality saffron (*Crocus sativus* L. Kashmirianus) (reviewed in Husaini *et al*. [5,6]). It is the only high-altitude saffron in the world that is cultivated at 1600-1800 m above mean sea level, and this could be one of the major contributors towards its unique characteristics and good quality. The major characteristics that constitute its uniqueness are its longer and thicker stigmas, deep-red colour, great aroma, bitter taste and chemical free processing. It is a traditional niche plantation crop of Kashmir, where it has been under cultivation since past twenty five centuries. There had been a long pending demand for granting it the status of Geographical Indication for Kashmir Saffron on a pattern similar to that for Spanish "Azafrán de la Mancha", Greek 'Krokos Kozanis', and Italian "Zafferano dell'Aquila" [6]. Its connection with the Indian soil can be illustrated by the fact that in the ancient Saffron language it is known by the name '*Bahukuma*', and as '*Kesar*' in Hindi, '*Zafran*' in Urdu and '*Koung*' in Kashmiri. Its distinction as being reflected in its scientific name '*Crocus sativus* L. Kashmirianus' [5, 6] is supported by its genetic distinction. This was validated by the study of karyograms, and reporting significant distinctions as well as difference in total length of chromosomes between *Crocus sativus* L. and *Crocus sativus* L. Kashmirianus [7]. In 2011, Food and Agricultural Organization of United Nations included it in

the list of globally important agricultural heritage systems (GIAHS) [8]. The time at which saffron was introduced to Kashmir is not precisely known, although evidence from 'Rajatarangini', written by a 12th century poet-historian 'Kalhana', indicates its presence in Kashmir even before the reign of King Lalitaditya in 750 AD [5]. Recently saffron was granted Geographical indication as "Kashmir Saffron" by the Government of India under the Geographical Indication of Goods (Registration and Protection) Act, 1999 under section 16(2) and geographical indication number 635 dated 3rd December, 2018 (Figure 1a). The documents in support of geographical indication status claim that 'saffron' finds its name in the oldest text of Kashmir (Nilamatapurane, Vol. 1) and in the 5th century BC Kashmiri records.

Phytochemical composition and medicinal properties

The chemical composition of dried saffron stigmas has been extensively studied since the end of the 19th century. Proximate composition of dried stigmas of saffron indicate that they contain water (10–12%), mineral matter (5–7%), fat (5–8%), protein (12–13%), reducing sugars (20%), free sugars (trace), starch (6–7%), pentosans (6–7%), gums and dextrins (9-10%), crude fibre (4–5%), crocin pigment (8–9%) and essential oil (0.3%) [9, 10]. It also contains riboflavin, thiamine and small quantities of β-carotene. Riboflavin content range from 56 to 138 µg/g and is the highest to be found in any food. Thiamine concentration levels range from 0.7 to 4 µg/g, which are average values found in vegetables [11]. These red stigmas of *C. sativus* accumulate three different apocarotenoids: crocin, picrocrocin, and safranal which are responsible for the color, taste and aroma of saffron, respectively (reviewed in Maggi *et al*. [12] and Gomez-Gomez *et al*. [13]). The ability to synthesize these compounds is not common across species: picrocrocin and crocin, in fact, have only been identified in stigma tissues of some *Crocus* species and few others species such as *Buddleja* [14] and Gardenia [15]. Understanding carotenoid metabolism in stigma of saffron is a principle area of focus where a lot of work is underway [13]. Many studies are underway on genomics, transcriptomics, and phytochemical profiling of the active compounds using modern technologies [16, 17]. Recently we introduced activity-based protein profiling (ABPP) of a-glycosidases in saffron and used it to identify and quantify 67 active glycosidases in four different developmental stages of stigma [18]. Our data suggest candidate glycosidases responsible for the conversion of picrocrocin into safranal in harvested stigmas. All these omics- based studies will be of immense significance in understanding the physiological behaviour of this peculiar spice crop.

Some major medicinal properties of saffron include: a) antidepression effect [19]; b) effect on blood pressure [20]; c) antinociceptive and anti-inflammatory effects [21]; d) anticonvulsant, antigenotoxic effects [22]; e) mutagenic or anti-mutagenic effects [23, 24]; f) anti-parkinsonian effect [25]; g) antigastric effects [26]; h) tumoricidal effect [27]; i) anti-cancer effect [28]; j) effects on ocular blood flow and retinal function [29]; k) effect on coronary artery disease [30]. Saffron constituents are patented in various drug preparations of poly herbal formulations for the treatment of cardiovascular and central nervous system diseases as well as promotion of immune function and treatment of depression. One such product (in Canada) is 'Saffron 2020' which combines saffron with important eye health nutrients activates mechanisms of self-defence and self-repair in the retina of the eye protecting it against oxidative damage as well as age-related macular degeneration (AMD) and cataracts (https://www.persavita.com/ca/). Microarray experiments have established that saffron is able to modulate gene expression modified by retinal induced damage, and that saffron treatment modulates metalloproteinase expression, enzymatic activity and reduces external matrix dis-organization through the activation of multiple pathways [31].

Health benefits for common households

The perusal of literature (reviewed by Licón *et al*. [32]; Premkumar and Ramesh [33]; Christodoulou *et al*. [34]) reveals the following benefits of saffron for a common household. It is equally effective as chemically synthesized drugs, in mild or moderate depression (antidepressant action) and epilepsy (anticonvulsant action) without causing side effects. It helps in ameliorating neurodegenerative disorders (Alzheimer's and Parkinson's disease) and related memory impairments. It is suggested that its antioxidant properties may help β-pancreatic cells to increase insulin secretion and reduce elevated blood glucose levels, and hence is good for diabetic patients. Safranal is useful in treating chronic bronchitis. It (safranal) sedates coughing by its anaesthetic action on vagal nerves of the alveoli. Picrocrocin has sedative effect on spasms and lumbar pains (back pain), which are generally routine problems nowadays. Crocin is useful for women in painful menstruation, typically involving abdominal cramps (dysmenorrhoea), relief as it decreases uterine contractions. Crocetin, because of its ability to increase the speed of oxygen transport and diffusivity, is useful in situations like atherosclerosis, alveolar hypoxia, haemorrhages, and arthritis.

Saffron has been traditionally associated with famous Kashmiri cuisines, medicinal values and rich cultural heritage of Kashmir. It has been traditionally used to colour and flavour number of dishes like 'phirini', 'kheer', 'tahaer' as well as 'wazwaan' and is used as a key spice for preparation of Kashmiri 'kehwa', a traditional beverage served in social gatherings in Kashmir. Saffron has had a significant role in all religious rituals having roots in Kashmir, and branching out in Hinduism, Buddhism, and Islam. 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.

Decline in saffron production

In Kashmir, saffron is traditionally grown on uplands (termed in the local dialect as 'Karewas'), which are lacustrine deposits located at an altitude of 1585 to 1677 m above mean sea level (amsl), under temperate climatic conditions. Kashmir is home to several valleys viz. the Kashmir Valley, Tawi Valley, Chenab Valley, Poonch Valley, Sind Valley and Lidder Valley. Kashmir valley are the only major saffron growing areas in India. Within Kashmir valley district Pulwama, commonly known as Saffron bowl of Kashmir, is the main contributor to saffron production, which is followed by Budgam, and Srinagar, while in Jammu the only district that grows saffron is Kishtwar. Khunmoh, Zewan, Balhama, Sampora, Ladhoo, Chandhara, Woyan, Khrew, Shar Konibal, Dussu, Namblabal, Kadlabal, Hatiwara, Samboora and Lethpora are prominent saffron villages of Tehsil Pampore where this cultivation is being practiced. Saffron cultivation, in Kashmir, is in a serious crisis [4]. This is evident from its dwindling share in global production. The area under saffron crop in 1997 was 5707 hectares and the production at that time was approximately 16 million tonnes. The newer challenges of climate change and access to assured irrigation

sources have necessitated a shift in production technology by including modern microbial biotechnological interventions for alleviating stress levels [35]. In fact in the last two years (2018, 2019) there was untimely and early snowfall during first week of November, and this caused loss of flowers which got covered under snow. During passage of time the area as well as production of this crop showed a declining trend. In 2015, the area under saffron crop was 3674 hectares and production were 9.6 million tonnes with the productivity of 2.61 kg/ha [36].

The major factors responsible for lower production and productivity in traditional areas of Kashmir are: a) inadequate moisture management in large farm tracts of Heritage area (Figure 1 a, b), as it is traditionally grown on these uplands under rainfed conditions; b) non-application of well decomposed organic manures and poor soil fertility; c) inhibition in the adoption of improved production practices among small and marginal farmers; d) lack of financial support for modern drip-based irrigation system (reviewed in Husaini *et al*. [5]).

Even though India ranks only second to Iran in saffron production, yet it ranks twelfth among global saffron exporters. Unlike Spain, France and Italy which import Iranian saffron, add value to it, and resell at a higher price, India imports saffron to meet domestic demand, which is around 20 t annum^{-1}. US$ 18.3 million in saffron was imported to India in 2018 to satisfy its demand, making it the world's fourth-largest importer ([37]; https://www.trademap.org/). This domestic demand for saffron can be met by extending its cultivation to new sites, mostly neglected or marginal and in the non-traditional areas of trans-Himalayan region of Jehlum and Chenab valleys of Kashmir, and is being demonstrated through a Ministry of Environment, Forests and Climate Change, Government of India sponsored project under National Mission on Himalayan Studies at SKUAST-K by the corresponding author.

There is a need to popularize the crop outside the traditional belt by sharing the production technology with common people of the semi-arid region as well as areas not suitable for irrigated crops. Further, there is an untapped potential to introduce organic saffron in each household of this region. This would not only help in fulfilling the domestic demand but also provide opportunity to the commercial units for diverting a part of their produce for export, and could serve as means of earning foreign exchange and in turn lead to overall growth in the saffron-based green-economy besides enhancing the individual income of saffron farmers.

Organic Saffron Kitchen Garden

In Kashmir, vegetable cultivation is being undertaken over a net area of 22517.96 hectares with a gross production of about 1539.59 (000' M. tonnes) with an annual value of 3079.174 crore [38]. The average size of a kitchen garden in Kashmir valley generally ranges from 25 to 100 m^2 depending on the size of holding and average strength of the family.

Introduction and popularization of saffron cultivation in kitchen gardens can prove as a successful approach to satisfy the average demand of saffron for a family of average strength. Widespread adoption of such system would definitely bring down domestic demand of this product to some extent and would in turn help in the economic revival of this crop to a large extent. Diversifying kitchen gardens with cultivation of organic saffron can change the scenario. There are evidences of growing garlic and saffron as mixed/intercrops and it has been claimed that the allelopathic effect of garlic in the control of mites, predisposing agents for saffron corm rot [39]. Corm rot of saffron caused by *Fusarium oxysporum* and *F. solani* is considered to be most destructive in Kashmir [35] and has a quite complicated molecular biology behind its virulent nature [18, 40].

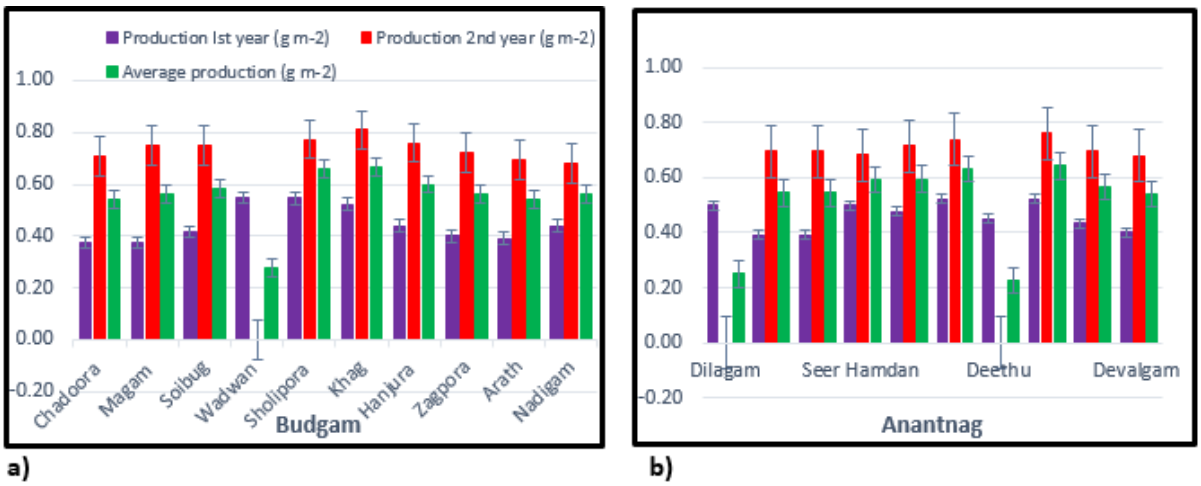
In the present case study carried out in Kashmir, organic saffron kitchen gardens were set up in five districts of Kashmir, and all these sites were never used for saffron cultivation and the sources of water were from local household supply. This study was carried out in 2018-19 with the active participation of 50 women from Srinagar, Budgam, Pulwama, Anantnag, and Ganderbal districts of Kashmir region. Most of these volunteers were registered with the women empowerment cell of the Directorate of Extension Education, SKUAST-Kashmir. These women were mainly growing vegetables like common beans (*Phaseolus vulgaris*), spinach (*Spinacia oleracea*), potatoes (*Solanum tuberosum*), onion (*Allium cepa*), Knol khol (German turnip), tomato (*Solanum lycopersicum*) etc., in their kitchen gardens. On an average 25 m^2 of kitchen garden was devoted for saffron. Free kits comprising of big corms (18-20 g) of saffron (10 kg for each site), vermicompost, biofertilizers (PSB, KSB, VAM) etc., were distributed among women participants. Proper training about package and practices of organic saffron cultivation was also provided to them. Soil was well ploughed 3-4 times and made loose, and added with ample amount of organic compost available locally (Figure 1h). The saffron beds were prepared on sloppy sites or as raised beds with good drainage facility (Figure 1 e, f, g, h, i). The texture of soil varied from site to site, being clayey, sandy, sandy-loom, gravelly, silty etc. The corms were planted at a depth of 10 cm in a planting geometry of 20 × 10 cm in beds of variable size (depending on local dimensions of kitchen garden) with deep drainage channels on both the sides. The corms sprouted and flowers were picked by the women from 10th October to 5th November (Figure 1). In Kashmir, generative phase is recorded in mid-October to the first week of November and covers about 20–25 days [5]. One problem which was noticed was that, despite repeated instructions, some women irrigated their site to field capacity whenever water was available in plenty, as is a common practice in most vegetable crops. This caused rotting of corms in the sites having poor drainage, and hence failure of crop in the second year. Another issue was regarding the harvesting of flowers, which is by necessity a speedy affair: after blossoming at dawn, flowers quickly wilt as the day passes. At some (five) sites the women reported some rodent damage to corms, which was controlled by application of rodenticide (Aluminium phosphide) (Figure 1 l). The recommended packages of practices for saffron production were shared with the stakeholders [41, 42]. The women did not face any problems despite its cultivation in the arid regions with very less rainfall, because they could manage its water requirement during critical stages through mild sprinkle irrigation [41]. All the information about the phenological stage needing critical irrigation along with instructions about stigma separation from the harvested flowers were communicated in real-time through social media platforms like Whatsapp. The harvested stigma was shade dried in the household and was stored in glass or moisture proof airtight containers for household consumption (Figure 1r). It was also suggested to them that the saffron tepals, instead of thrown away can be added with feed additive for improving egg quality in backyard poultry [43].

The statistical analysis for the randomized block design (RBD) was done by ANOVA using Opstat software [44]

(http://14.139.232.166/opstat/). The perusal of the data (Table 1) shows that effect of location with respect to districts was non-significant and that the yield was not affected by it (Figure 2). It showed that the management of kitchen gardens must have been uniform perhaps because of the smaller size of the plots as well as closer monitoring by the project team and the concerned women beneficiaries. The added advantage with saffron is that this plant can be cultivated in arid or semi-arid areas where the water deficit is extreme in summer [45]. There are many traditional regions worldwide which grow saffron despite low precipitation. Castile-La Mancha is a low altitude region (600 amsl) in Spain with low precipitation (300-400 mm), while Krokos Kozani in Greece and Aquila, Cerdena, Emilia-Romagna and San Gimigiano (a sub-mountainous 650- 1100 amsl region) in Italy get an average annual precipitation of 690 mm [46, 47]. Apsheron is a saffron cultivating region in Azerbaijan with a low precipitation of 223 mm only [48]. In Morocco, saffron is cultivated in several areas around Taliouine located at an altitude between 1200 to 1400 m near the Atlas mountain with extremely low precipitation between 100 to 200 mm [49].

Due to the delicacy of cultural operations in saffron as well as its marginal nature, mechanization has not been successful, and therefore the cost of labour for large farms has become an additional constraint, especially in European countries. Further, the situation for large farms has worsened due to the adverse effect of climate change, especially if there are dry spells at the critical saffron flower-initiation stage. Both the problem of labour shortage as well as dry-spells during flower-initiation stage can be tackled by introducing saffron cultivation through organic means in small farms of manageable size in marginal areas like hill slopes etc. Every Kashmiri family, on an average, annually requires 3-15 g of saffron for domestic consumption like Kehwa preparation on special occasions like Eid, marriages, and other festivals. It is generally given to special guests and to those family members who suffer from cough, common cold, general weakness etc. Saffron, if cultivated over 5 m^2 in kitchen garden, can yield 4 g laccha saffron. Based on these estimates, it can be perceived that saffron cultivation on an area of about 20 m^2 would yield about 16 g of laccha saffron and this quantity would be sufficient to meet average requirements of saffron for a family of average strength i.e., a family consisting of 5-6 persons. Overall the results of organic kitchen garden were very promising and therefore need to be popularized on a larger scale.

Fig 1: Status of saffron and establishment of Organic Saffron Kitchen Gardens in semi-arid non-traditional areas: a) Region specifying "Geographical Indication of Saffron"; b) A local newspaper report on traditional saffron growing region facing serious challenges; c) Harvesting of a local arid-zone millet '*Digitaria compacta*' and d) planting of saffron in its place; e-f) Small kitchen gardens in high altitude semi-arid area of Pir Panchal ranges; g) Forest soil under ulm trees on top of Benhama hill; h-i) Virgin soil on a mountain hill slope at Zabarwan hills and vegetative growth of saffron beds at the same site; j) Vermicompost application; k) hand weeding; l) Rodenticide application into burrows; m,n,o) poor socio-economic condition of the people living in these semi-arid regions; p) Participation of women in 'Seeing is Believing' on Saffron Day at High Altitude Saffron Research Station, Pampore; q) Flowering in full bloom; r) Fresh Stigma.



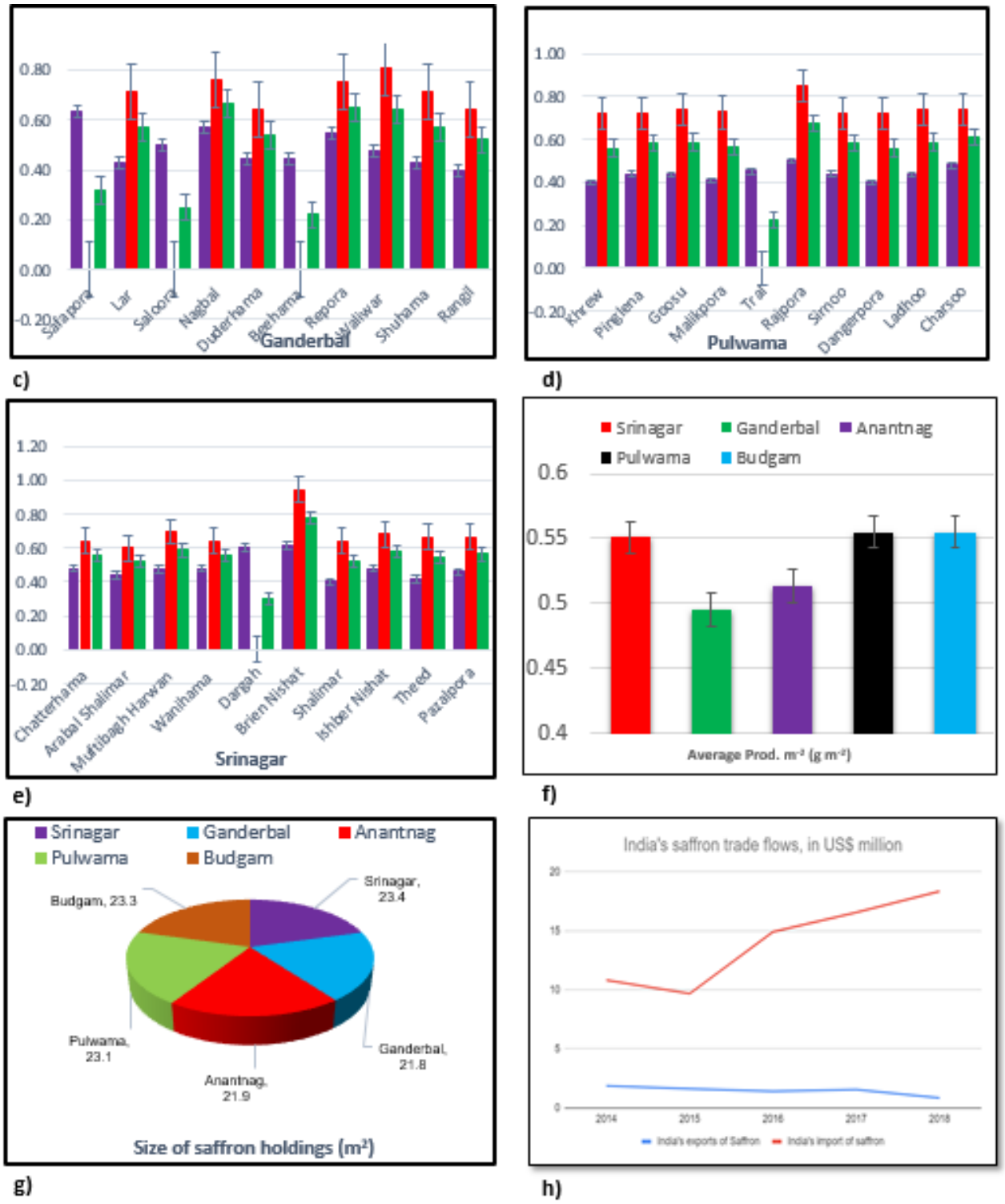


Fig 2: Productivity of organic saffron kitchen gardens at a) Badgam, b) Anantnag, c) Ganderbal, d) Pulwama, e) Srinagar; f) Average productivity in districts; g) Average size of the saffron kitchen garden in each district; h) India's saffron trade flow showing a sharp increase in import since 2015.

Table 1: Average yield of saffron (g m^{-2}) in each of the ten organic kitchen gardens laid down in a total of five districts of Kashmir valley

District	Year-wise detail	Site-wise Production (g m^{-2})										Mean#*	Mean	S.E.
Srinagar	Ist year	0.48	0.44	0.48	0.48	0.60*	0.61	0.40	0.48	0.42	0.46	0.47		
	2nd year	0.64	0.60	0.70	0.64	0.00*	0.94	0.64	0.68	0.67	0.67	0.68		
	Average of 2 years	0.56	0.52	0.59	0.56	0.30*	0.78	0.52	0.58	0.54	0.56	0.58	0.549	0.026
Ganderbal	Ist year	0.63*	0.43	0.50*	0.57	0.44	0.44*	0.55	0.48	0.43	0.40	0.47		
	2nd year	0.00*	0.71	0.00*	0.76	0.64	0.00*	0.75	0.81	0.71	0.64	0.72		
	Average of 2 years	0.32*	0.57	0.25*	0.67	0.54	0.22*	0.65	0.64	0.57	0.52	0.59	0.547	0.083
Anantnag	Ist year	0.50*	0.39	0.39	0.50	0.48	0.52	0.45*	0.52	0.43	0.40	0.52		
	2nd year	0.00*	0.70	0.70	0.68	0.71	0.74	0.00*	0.76	0.70	0.68	0.71		
	Average of 2 years	0.25*	0.54	0.54	0.59	0.60	0.63	0.23*	0.64	0.57	0.54	0.58	0.558	0.029
Pulwama	Ist year	0.40	0.44	0.43	0.41	0.45*	0.50	0.44	0.40	0.43	0.48	0.44		
	2nd year	0.72	0.72	0.74	0.73	0.00*	0.85	0.72	0.72	0.74	0.74	0.74		

	Average of 2 years	0.56	0.58	0.59	0.57	0.23*	0.68	0.58	0.56	0.59	0.61	0.59	0.398	0.079
Budgam	Ist year	0.38	0.38	0.42	0.55*	0.55	0.52	0.44	0.40	0.39	0.44	0.43		
	2nd year	0.71	0.75	0.75	0.00*	0.77	0.81	0.76	0.72	0.70	0.68	0.74		
	Average of 2 years	0.54	0.56	0.58	0.28*	0.66	0.67	0.60	0.56	0.54	0.56	0.58	0.501	0.076
CD: N/S; SE(m): 0.068; SE(d): 0.096; CV: 41.985														
#The values that are marked asterisk (*) where excluded while calculating over-all combines mean values, as the sites had got completely spoilt because of excessive irrigation, and did not represent the overall status														

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