WEBINARS ON

Sustainability of *Crocus sativus* L. Cultivation in the World in the Era of Climatic Change

BOOK OF ABSTRACTS

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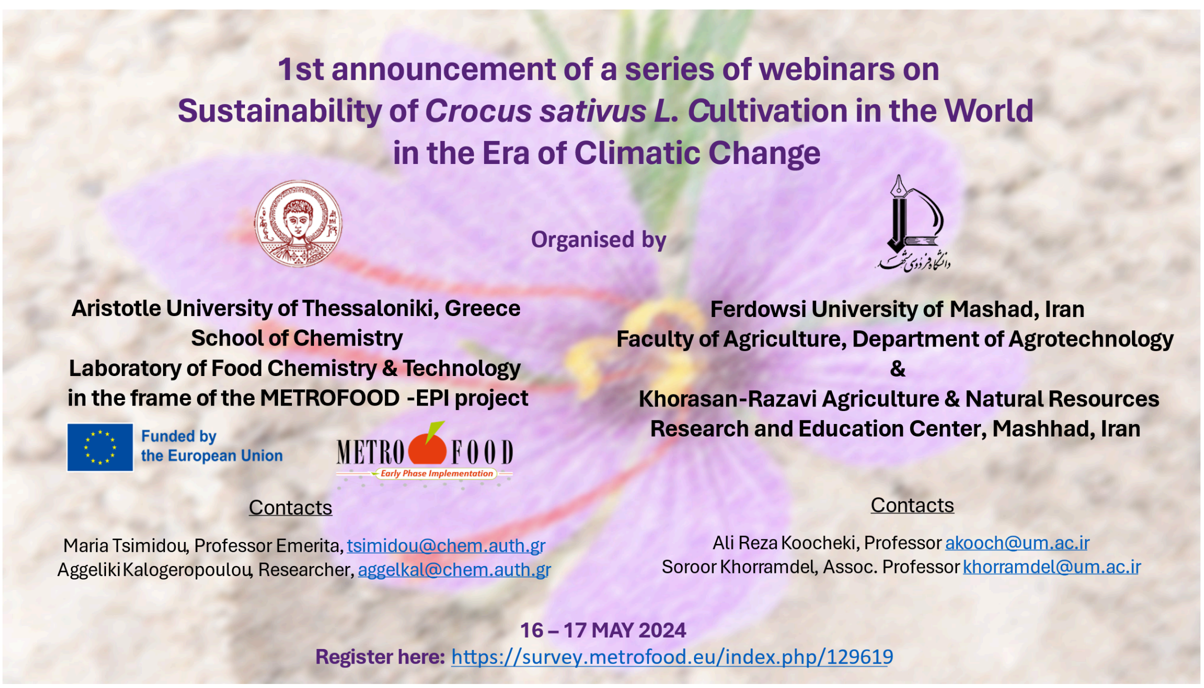

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Webinar series on Sustainability of *Crocus sativus L.* Cultivation in the World in the Era of Climatic Change

AGENDA

Day 1: 16 May 2024
15:30-19:30 (time zone Athens, Greece - GMT+3)

15:15	**Opening of the platform**
15:30 - 15:45	**Introduction: Why we undertook the initiative to organize this series of webinars.** Professor M.Z.Tsimidou (Aristotle Univ. Thessaloniki, Greece) & Professor A.R. Koocheki (Ferdouwisi Univ. of Mashad, Iran)
15:45 – 16:00	**Current status of Greek saffron cultivation – Krokos Kozanis PDO.** Vassilis Mitsopoulos, (Saffron grower and president at Cooperative de Safran, Krokos, Greece)
16:00 – 16:15	**The dichotomy of a local culture in a global market: challenges of saffron cultivation in La Mancha.** Lecturer Héctor Martínez S-Mateos (University of Castilla-La Mancha, Spain)
16:15 – 16:30	**The peculiarities of saffron production in L'Aquila area (Italy).** Massimiliano D'Innocenzo (Saffron producer, President of the Consortium of Saffron of L'Aquila PDO, Italy)
16:30 – 16:45	**Impact of climate change on saffron cultivation in Morocco.** Soukrat Sakina (agronomist, PhD, manager, SoukratSeeds sarl company, Rabat, Morocco)
16:45 – 17:45	**Coffee break**
17:45 - 18:00	**An overview of saffron produced in Italy (recorded talk).** Lecturer Luca Giupponi (University of Milan)
18:00 - 18:15	**The DNA and genomes of saffron crocus & opportunities for improvement of sustainability.** Professor Pat Heslop –Harisson (Genetics and Genome Biology, University of Leicester, UK)
18:15 - 18:30	**Current status and prospect of the Cuenca Crocusbank.** Marcelino de los Mozos Pascual (Researcher and genebank curator at the Bank of Plant Germplasm - Regional Inst. of Agri-Food & Forestry Res. & Development Castilla-La Mancha Spain)
18:30 - 18:45	**The Saffron Flower Production in Spain. Problems and perspectives.** Professor Rosa Victoria Molina Romero (Polytechnical University of Valencia), Agronomist & saffron expert Horacio López Córcoles & Llanos Simón (ITAP, (Instituto Técnico Agronómico Provincial. Diputación de Albacete, Spain)
18:45 - 19:30	**Discussion among speakers and attendees & Concluding Remarks.** Conveners: Professors Maria Tsimidou & Alireza Koocheki

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AGENDA

Day 2: 17 May 2024
10:30-17:30 (time zone Athens, Greece - GMT+3)

10:30	Opening of the platform
10:30 - 10:45	**Weather Impact and Constraint Analysis of Kashmir Saffron.** Firdous Ahmad Nehvi (Spice Board Ministry of Commerce, India)
10:45 – 11:00	**Assessment of climate change and climate extremes on temporal and spatial changes of saffron yield.** Saeedeh Kouzegaran (Responsible expert in applied meteorological research in Research Institute of Meteorology and Atmospheric Science, Climate Research Institute, Iran)
11:00 – 11:15	**Mitigation of climate change effects on saffron using agricultural biotechnology.** Professor Amjad M. Husaini (Professor/Senior Scientist in Plant Biotechnology at SKUAST-Kashmir, J&K/India)
11:15 – 11:30	**Effect of climate changes on saffron production in Herat, Afghanistan.** Associate Professor Ramin Nazarin (Agronomy Department, Faculty of Agriculture, Herat University, Afghanistan)
11:30 – 11:45	**Biotic Stress of Saffron.** Associate Professor G.H.Mir (Advanced Research Station for Saffron & Seed Spices, University of Agricultural Sciences & Technology, India)
11:45 - 12:00	**Promotion of saffron in India under changing climatic scenario.** Bashir Ahmad Alie (Advance Research Centre for Saffron & Seed Spices SKUAST-Kashmir, India)
12:00 - 12:15	**The effect of climate change and the agro-ecological zoning on quality of saffron in Iran.** Associate Professor Soroor Khorramdel (Ferdowsi University of Mashhad, Iran)
12:15 - 12:30	**Climatic variability and its impact on crops with special reference to Kashmir region.** Sameera Qayoom (Division of Agro-meteorology, SKUAST-Kashmir, India)
12:30 - 12:45	**Can changes in corm weight justify changes in saffron yield under different climatic conditions.** Associate Professor Hamid Reza Sharifi (Khorasan Razavi Agricultural and Natural Resources Research Center, Mashhad, Iran)
12:45 - 13:00	**Trends of the past and future impacts of climate change on saffron production in Iran.** Associate Professor Roohola Moradi (Department of Plant Productions, University of Torbat Heydarieh, Iran)
13:00 - 13:15	**Studying physiological reactions of saffron under changes in climatic parameters.** Saffron expert Hashim Aslami, Lecturer and Researcher Alireza Nejadmohammad Namaghi (Director of the Department of Medicinal Plants of the Applied Scientific University, Afghanistan)

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Webinar series on Sustainability of *Crocus sativus L.* Cultivation in the World in the Era of Climatic Change

AGENDA

Day 2: 17 May 2024

10:30-17:30 (time zone Athens, Greece - GMT+3)

13:15 - 13:30	**Can heat stress be mitigated in summer by using mulch and shading in saffron fields?** Hamidreza Tavakkoli-Kakhki (Speaker), Hamidreza Sharifi and Zohre Nabipour (Khorasan Razavi Agricultural and Natural Resources Research and Education Center, Iran)
13:30 – 14:15	Coffee break
14:15 – 14:30	**The Saffron holobiome.** Sheetal Ambardar (School of Biotechnology, University of Jammu, India)
14:30 – 14:45	**Synoptic analysis of sudden drop in air temperature and its effect on saffron yield in 2023.** Professor Seyed Hossein Sanaei Nejad, Researcher Khosro Salari (Speaker), Associate Professor Soroor Khorramdel (Ferdowsi University of Mashhad, Iran)
14:45 – 15:00	**Saffron (*Crocus sativus L.*) production beyond Kashmir: Efforts and Challenges.** Rakesh Kumar (Institute CSIR-IHBT, Palampur, HP, India)
15:00 - 15:15	**Evaluation of saffron yield using machine learning and remote sensing techniques in the face of climate change.** Assoc. Professor Soroor Khorramdel, Researcher Mehdi Mohammadnezhad (Speaker), Research Director of Water and Environment Research institute Pooya Shirazi (Ferdowsi University of Mashhad, Iran)
15:15 - 15:30	**The possibility of the effect of climate change on the growth and development of bacterial rot of saffron corms (*Burkholderia gladioli*).** Assistant Professor Plant Pathology Mahmoud Reza Karimi Shahri (Khorasan Razavi Agricultural and Natural Resources Research Center (KANRRC) Plant Protection Research Dept. Mashhad, Iran)
15:30 - 15:45	**Saffron- microbe interaction; identifying and managing friends and foes.** Jyoti Vakhlu (Researcher, School of Biotechnology, University of Jammu/India)
15:45 - 16:00	**Planting in closed environment: A strategy for producing saffron under climate change and global warming.** Associate Professor S. Khorramdel, Researcher Mohammad Hassan Hatefi Farajian (Speaker) (Ferdowsi University of Mashhad, Iran)
16:00 - 17:30	Discussion among speakers and attendees & Concluding Remarks. Conveners: Professors Alireza Koocheki & Maria Tsimidou

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DAY 1 CVs and Abstracts of Presentations

Introduction: Why we undertook the initiative to organize this series of webinars

Maria Z Tsimidou

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Professor Emerita of Food Chemistry, Laboratory Food Chemistry and Technology, School of Chemistry, Aristotle University of Thessaloniki Greece

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Professor Maria Z. Tsimidou (Laboratory of Food Chemistry and Technology, School of Chemistry, Aristotle University of Thessaloniki) is a food chemist (School of Chemistry AUTH, Food Science Dept. Reading Univ.) She has a long career in the field of valuable natural products; cooperates with many scientists in Greece and abroad; participates as expert in different committees; her published work is well recognized and can be found in Scopus and Google Scholar bases. Expert in saffron quality and authenticity working on this cultivation since 1989, chair of the COST ACTION saffronomics, partner of various research projects related to saffron.

Abstract

Sustainability of saffron plant cultivation is important for all the producing countries. The effect of climate change is now more than evident in all of the producing countries. Collaboration of interested parties among all producing countries is required so that to have a cartography of the problems in each of them, examine the effects on the sustainability and the future of saffron growers and finally get prepared for the unexpected as far as it concerns this cultivation on a scientific basis

Alireza Koocheki

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Abstract

Climate change and global warming is a serious threat to human beings in the present time and all aspects of his/her activities, including agricultural production and hence food security will be affected. In the agricultural activities saffron production seems to be very sensitive to these changes, because this plant is fundamentally dependent on a specific set of temperature mainly during generative and vegetative phases of cell initiation and flower emergence. Since this demand is not fulfilled therefore this together with other negative impacts of climate change (e.g heat stress, pest and disease spread, water deficit, etc) caused yield of saffron to reduce sharply during the last few years in the growing areas worldwide. The purpose of the present series of webinars is to discuss and find possible solutions in an international scientific platform.

Current status of Greek saffron cultivation – Krokos Kozanis PDO

Vassilis Mitsopoulos

Saffron grower and president at Cooperative de Safran, Krokos, Greece

mitsopoulos@safran.gr

Abstract

Saffron cultivation in Greece is facing very low productivity the last couple of years which can threaten sustainability of Cooperative de Safran. Although demand for “Krokos Kozanis”,PDO saffron from Greece, is very strong and the prices are high, recent social and economic conditions lead young people and workers away from the area. We have succeeded to improve and secure farmers income and currently we are looking new ways to fight soil borne pathogens that threaten saffron cultivation with traditional practices.

Production data from previous years up to now show us that the average production has dropped to a point that is no more profitable.

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The dichotomy of a local culture in a global market: challenges of saffron cultivation in La Mancha.

Héctor Martínez S-Mateos

ORCID: 0000-0002-3613-9958

Lecturer, Department of Geography and Land Planning, University of Castilla-La Mancha, Spain

Geographer with specialization in Human Geography, specifically in transport, spatial policy and landscape management. During his post PhD period he was at the University of Oxford in 2009 (UK) and University of Twente in 2014 (Netherlands) as a visiting researcher and, in 2018, he was an invited professor at the University of Sassari (Italy). He has been working with several research groups since 2005, collaborating in different projects at different scales and fields, always related with spatial analysis and land use. In the recent years he has been part of a research group that has been exploring the concept of cultural landscapes, and empirically developing case studies in the region of Castilla-La Mancha (Spain).

Abstract

Beyond its productive purpose, saffron cultivation can also identify a cultural function that is expressed in the existence of a rich heritage associated with the interactions between nature and humans over time. This heritage includes tangible and intangible assets, the latter including traditional knowledge, history, knowledge of natural cycles, and the identification of the local population with its landscapes; in short, resources are understood as a legacy that needs to be reappraised and passed on to future generations. Saffron cultivation is an example of an agricultural landscape with significant intangible heritage values associated with the know-how and the family-run nature of the farms. The resources linked to saffron cultivation in the region of Castilla-La Mancha (Spain) are singular in the national and regional scopes, with an emphasis on how local communities perceive them as an integral part of their geographical identity. The results, following in-depth interviews with different local actors, demonstrate the potential for the intangible values associated with saffron to drive local development in many rural areas once they have been reappraised and classified as assets for attracting tourism. On the other hand, the production is declining in the last years and shows difficulties in the global market for different reasons, being a threat for the years to come.

The peculiarities of saffron production in L'Aquila area (Italy}

Massimiliano D'Innocenzo

Saffron producer, President of the Consortium of Saffron of L'Aquila PDO, Italy)

Saffron producer since 2001 (and before as family), president of the Consortium since 2015, I work for University as project manager in International projects with third countries.

Abstract

In L 'Aquila area, mainly in Navelli plateau, there is an old tradition of saffron cultivation since the XIII Century. Thanks to climate, type of soil and a specific method of production, saffron from this area has always been appreciated for the quality. In fact, the method of cultivation and of production of saffron presents many little differences in accuracy, with the consequences of very low quantity, but higher quality.

Impact of climate change on saffron cultivation in Morocco.

Souкrat Sakina

agronomist, PhD, manager, SoukratSeeds sarl company, Rabat, Morocco, Managing agricultural production projects ; Extensive experience in micropropagation (*in vitro*) techniques (30 years) (severa lspecies: potato, sweet potato, citrus, grapevine, stone fuit rootstock, strawberry,saffron ...) and Management of commercial tissue culture laboratories ; great experience in developing economic model of certified seed production ; Study and implementation of seed production projects: potato, sweet potato, yam, saffron, cereals, legumes, etc; Modeling soil-less cropping systems ; Managing plant breeding program ; Coaching and leading work teams.

Abstract

In Morocco Saffron is considered a "local product", with very specific physico-chemical and organoleptic properties that distinguish it from those of other producing countries. It is the main source of income for most of the 4,000 families who produce it, mainly in the Taliouine-Taznakht region. The socio-economic importance of this product has led the Moroccan government to include this sector in its agricultural development strategies since the launch of the Green Morocco Plan in 2008, by extending the area under cultivation, and implementing strategies for organizing the production chain to enhance the value of the product.

Morocco is the fourth saffron producer in the world. In 2021, the total area under this crop was 2,140 ha, with total production of 7.49 tonnes. High temperatures are the main factor limiting the development of safran in the new region of Morocco.

The recorded climate change is worrying farmers, who have already noted a reduction in the annual saffron production. The increase in temperature in recent years has induced a shortened saffron vegetative cycle with leaf senescence in early February in some plots, and caused the corms drying and small size, affecting their reproduction. Moreover, the high temperatures in September to November affect saffron flowering, it's reported in some plots affected by heat less than 1/3 of the corms flowering in November 2022. The high temperatures recorded in September 2023 (35/19°C), October (30/16°C) and November (28/11°C) delayed flowering by 20 to 30 days. In addition to heat the delay in the autumn rains, which allows the corms to break dormancy, but this delay can be overcome by irrigating early in the season in the future.

An overview of saffron produced in Italy (recorded talk).

Luca Giupponi

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Luca Giupponi is a botanist at the University of Milan. He carries out floristic and ecological studies of plant communities in the Alps, and is involved in research projects aimed at characterizing and valorizing the plant agrobiodiversity of Italian mountain territories. Over the past decade, he has characterized (from morphological, ecological, phytochemical and agronomic perspectives) various traditional cultivars (landraces) cultivated in mountain areas of Italy. He has also been involved in analyzing the quality of saffron produced in Italy. At the laboratories of the Ge.S.Di.Mont. research center, he analyzes over 150 samples of saffron produced in Italy each year and organizes training activities and webinars to promote the cultivation of *C. sativus* in marginal and mountainous areas of the country.

Abstract

Currently, there are over 700 Italian farms producing saffron. The majority of these are small to medium-sized family-run businesses located in marginal areas of the country, producing small quantities of the spice (around 300 grams per year) using low-impact environmental methods (only 1% of farmers use agrochemicals, and more than 90% do not require irrigation). Recent studies conducted by the University of Milan have demonstrated that the quality of Italian saffron is excellent. In fact, over 85% of the spice produced in Italy falls into the top quality category according to ISO 3632 standards. Currently, much of the Italian territory boasts suitable climatic conditions for saffron cultivation. However, predictive distribution maps generated by various species distribution models (SDMs) indicate a gradual contraction of the *C. sativus* habitat in the future due to climate change. This suggests that saffron will only be able to be cultivated, using traditional methods, in some mountain areas of the Apennines and the Alps.

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The DNA and genomes of saffron crocus & opportunities for improvement of sustainability

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Abstract

Fundamental studies of the DNA of saffron crocus, its organization in the genome, and the chromosomes, underpins key aspects of research into the origins and future of saffron. As a hybrid species, saffron or *Crocus sativus* originates from three ancestral species or genotypes, and is sterile. We can use the DNA to examine variation in the species, and, in fact, find remarkably little in accessions from around the saffron-growing areas of the world, suggesting a strong genetic bottleneck during formation of the hybrid species. However, the identification of the ancestors might allow re-creation of saffron by making new hybrids, and introduction of more genetic variation allowed the crop to grow well under new climatic conditions, using rain and soil fertility efficiently. The genome information gives access to all the genes present in the species, and the modification of their behaviour gives major opportunities to improve the quality and sustainability of saffron, making it ever more widely available.

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Current status and prospect of the Cuenca Crocusbank	
Marcelino de los Mozos Pascual	**Researcher and genebank curator at the Bank of Plant Germplasm of Cuenca** Researcher and genebank curator at the Bank of Plant Germplasm - Regional Inst. of Agri-Food & Forestry Res. & Development Castilla-La Mancha Spain, expert in saffron plant and wild allies germplasm mde@jccm.es Activities related to the conservation and study of plant genetic resources in the Bank of Plant Germplasm of Cuenca (FAO code ESP124) began about 35 years ago. Approximately 4.000 accessions of different plant groups are currently conserved, involving mainly grain-legumes, garlic, saffron and different species of aromatic and medicinal plants. Most part of these collections are integrated into the Spanish Network of Plant Germplasm Collections and requests from different users are regularly attended. Many collaborations are also established with other research centers to develop different studies related to the conserved materials.

Abstract

The collections of saffron and other species of the *Crocus* genus were established through several successive national projects that were developed between 2005 and 2015, and whose fundamental objective was to prospect, conserve and study the Spanish germplasm of this crop that was at imminent risk of disappearance (only 83 hectares cultivated in all of Spain in 2005). In addition, between 2007 and 2011, the European project 018-AgriGenRes (Crocusbank) was developed. This project was leaded by Prof. José Antonio Fernández Pérez (University of Castilla – La Mancha, Spain), and allowed the creation of a wide working collection of saffron and allies with accessions collected in many different saffron producing countries and also with materials of different *Crocus* species collected directly in the wild or purchased in nurseries. Different collection designs and preserving strategies were initially established in the bank to manage such highly diverse genetic material, involving vegetative and seed collections, and always trying to make compatible the preservation of the materials with the supply and utilisation for potential users. Current activities have been greatly reduced due to financial and staff restrictions. However, an important collection of saffron (247 accessions from 13 countries) and other *Crocus* species (282 accessions from more than 50 taxa) is still preserved in vegetative state, maintaining a main collection and another security collection in flowerpots. Numerous *Crocus* accessions currently extinct from vegetative collections, are also preserved as seed in small quantities. These seeds were obtained years ago through pollination (some by hand and others by free pollination) and in many cases they can be used if necessary to obtain new corms from the original material.

Current preservation of these collections is officially guaranteed in the long term with permanent financial from IRIAF (Castilla – La Mancha Government), and partially also by Spanish programs on Plant Genetic Resources.

The Saffron Flower Production in Spain. Problems and perspectives

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Abstract

In recent years, saffron production in some places of Spain has undergone a decrease in yield, which together with the need for a large amount of trained hand labor to process the flower, reduces incentives for its cultivation. This situation demands an in-depth study of the problems and prospects for saffron flower production in Spain. The saffron's life cycle has been well adapted to the Mediterranean climate, allowing floral induction and floral primordium development in summer, as well as sprouting in autumn. However, the current trend of rising temperatures may be affecting this development, requiring the identification of the concerned process and a change in cultivation methods. Additionally, flower production is directly related to corm size, also being affected by climate change in this region. Traditional rainfed cultivation may become unviable. An additional problem is the lack of certified varieties ensuring healthy and guaranteed production. Saffron corms, a byproduct of saffron cultivation, are sold at high prices without quality assurance. An approach that considers corm and saffron production as different activities and under different conditions may be required. In addition to seeking the most suitable environmental conditions, treatments that affect the physiology of the corm by increasing its sink strength should be considered. The unhealthiness of the corms resulting from the lifting method is also a relevant problem that needs to be addressed considering the goal to implement organic farming. Finally, improving ISO standards to adequately characterize different bioactive products would be necessary. Possible approaches to these issues and alternative cultivation methods will be presented in this seminar.

DAY 2 CVs and Abstracts of Presentations

Weather Impact and Constraint Analysis of Kashmir Saffron

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Abstract

A highly complex process, *Saffron flowering* is regulated by the endogenous signals and synchronized action of environmental cues. The complex process of the flowering transition is co-regulated by both the external environment and the internal factors in plants to ensure flowering at an appropriate time. The temperate climate makes Jammu and Kashmir proud of being the only place in India with a historical story of cultivating saffron since aegis. India (Jammu & Kashmir) accounts for 3.1% of the rainfed saffron area (3715h) and 4% of the production share (18.05 tonnes), with an average productivity of 4.92 kg/ha. Saffron plant phenology spread over six developmental stages is under the influence of fluctuating weather parameters, revealing an annual total precipitation of 941.2 mm recorded in 73.4 wet days, maximum temperature of 21.1^{0}c, minimum temperature of 6.6^{0}c, mean aerial temperature of 13.8^{0}c, maximum relative humidity of 85%, minimum relative humidity of 58.6%, mean relative humidity of 72.2%, mean sunshine of 5.6 hours/day, mean evaporation rate of 2.5 mm/h and mean wind speed of 1.6 km/h. Abiotic stresses in terms of abnormal levels of precipitation, aerial temperatures and relative humidity in recent years have led to low saffron production, as observed in 2014(5.572 tons) and 2017 (5.200 tons), compared to 2013(14.005 tons), 2022(18.050 tons) and 2023 (20 tons), which showed high production due to favourable Weather. Present study was thus aimed to develop an ideal twelve-month weather module ensuring stable production based on congenial average weather data observed at different development stages.

Abnormal weather received during 60 days of sprouting and flower initiation period (26th August to 24th October) disfavours the interplay of hormones beneficial for saffron flowering via regulating floral integrator and homeotic gene expression. For best yields, the crop should receive 93-100 mm water with 60% availability in the corm preparatory phase for flowering (I^{st} to 20^{th} October) and 40% in September (1^{st} to 30^{th} September). Deficit water, as observed in 2017, restricted better sprout activation on account of restricted adventitious root development and quick and timely activation of meristematic regions, leading to 71% production loss. Similar production loss was also observed in 2014 due to excess water, resulting in forced sub-hysteranthus characteristics of saffron (appearance of leaves instead of flowers).

In saffron, the flowering transition process is divided into three stages: flower bud undifferentiated period (DS), early flower bud differentiation (BS), and late flower bud differentiation (FS). Sugar, gibberellin (GA3), and auxin (IAA) levels are steadily up-regulated on account of increased expression of genes such as LFY, TSF, SOC1, FT, and SPL, ten unigenes

encoding sucrose synthase (SUS) and auxin influx transport proteins (AUX1). In contrast, starch and abscisic acid (ABA) levels are gradually down-regulated due to differential expression of ABA biosynthesis and signal transduction genes, including NCED, PP2C and ABF. Deviations of maximum temperatures of 18.0^{0}c, minimum temperatures of 1.2^{0}c, mean air temperature of 9.6^{0}c and relative humidity of 72% drastically affect the saffron bloom period, affecting average yields.2017 recorded sparse flowering due to increase in maximum temperature by 1.7^{0}c and decline in relative humidity by 7%. The peak in the saffron bloom is achieved with average maximum temperature of 15^{0}c-18^{0}c, average minimum temperature of 0.5^{0}c-1.5^{0}c and average sunshine hours of 2-3h/day associated with constant values for maximum (88-93%) and minimum (75-78%) relative humidity and average evaporation rate (1-2mm/h) and average wind speed (0.1-0.3Km/h). Saffron flowering ends immediately with an increase in night temperature above 4^{0}c, associated with precipitation in terms of rain/snow.

Sixty-one days of incubation of corms in the average air temperature of 23.6^{0}C (22.85^{0}c - 24.45^{0}c) associated with an average relative humidity of 68.6% triggered flower formation. Maximum flower formation (2.5-3.0 flowers/corm) is reported when incubation is under a mean air temperature of 23-25^{0}c, and a decline in air temperature to 17^{0}c produces a maximum of one flower per corm. Weather parameters recorded during the flower ontogenesis period did not reveal any relationship with saffron production, as during the deficit years of 2014 and 2017, the weather parameters were recorded within the normal range, indicating that the flower ontogenesis process must have been completed generally in these years. However, excellent yielders recorded a 104% increase in precipitation (270.9 mm) over poor yielders (132.7 mm) and thus can be a cause of poor yields observed during 2014 and 2017.

For the development of quality replacement corms with the capacity to flower during a period of 110 days (11th November to 28th February), the replacement corms should receive 200-300 mm precipitation, involving 20-30 wet days, with an average maximum temperature ranging from 8-10.5^{0}c, average minimum temperature > -1.40c for a period ranging from 70-72 nights, average maximum relative humidity of 88-93%, average minimum relative humidity of 67- 75% accompanied with 2-3 hours average sunshine/day, 0.4-0.5 mm/h average evaporation rate and 1.2-1.5 Km/h average wind speed. Incubation at minus temperature satisfies the requirement of chilling required for vernalization process, which involves setting the FLC expression level before exposure to cold, cold-induced FLC silencing and, lastly, epigenetic silencing of FLC after re-exposure to warm temperatures. In other words, the floral repressor gene, FLC, which is highly expressed before exposure to cold, is repressed when plants are exposed to the cold and remain stably repressed on returning to warm temperatures. The intensity of chilling hours received by the replacement corms is the precursor for flowering in the coming year. Study revealed that, on average, replacement corms of both sets of years received 1108.2 hours of chilling. Therefore, it is concluded that saffron, under temperate conditions, on average, required 1044 hours to 1170 hours of chilling to induce vernalization. The study confirmed that the amount of chilling hours received by the crop is not the decisive factor for the quantum of saffron flowering but is a precursor for vernalization. The excess precipitation accompanied by high relative humidity during maturation and senescence can cause corm rot initiation, leading to

corm death and, thus, affecting the corm population/unit area. It could thus cause poor flowering in poor yielders of 2014 and 2017.

Assessment of climate change and climate extremes on temporal and spatial changes of saffron yield

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Abstract

During recent years, monitoring of saffron has revealed that in spite of increasing cultivated areas of saffron in Iran, its yield per unit area has decreased. Regarding the importance of saffron in this region and its strong dependency to meteorological indices, recognition and evaluation of extreme events and their influences on saffron yield can lead to better production and management. To evaluate the extreme climate indices trend (1991-2015), 27 core indices of rainfall and temperature, recommended by the CCl/CLIVAR Expert Team for Climate Change Detection Monitoring and Indices (ETCCDMI), are used. The long-term daily precipitation data and the minimum and maximum temperature of some synoptic stations of the northeast of Iran in the period of 1991-2015 were used. And using the stepwise regression analysis, the effects of weather extreme events were evaluated. Then, by selecting the best indices, saffron yield model was proposed. The model accuracy was monitored and evaluated by indices of R Square (R2 ,0.68), Root Mean Square Error (RMSE,0.), and Normalized Root Mean Square Error (NRMSE,14) which show that the model has high efficiency and the accuracy of model is estimated good, tends to excellent. The best indices were selected and the model of yield–climate extreme indices was presented. Model verification was performed by using Relative Deviation) RD, 9.5%). In order to predict temperature extreme indices, the daily minimum and maximum temperature data of MPI-ESM-LR model, and to evaluate extreme precipitation indices the ACCESS global climate model were used for trend evaluation in three coming periods of (2025-2010), (2051-2075) and (2076-2010) according to RCP8.5 and RCP4.5 scenarios for all stations. Indices analysis demonstrates the trends of region warming and precipitation decrement. From the results of this study, it can be concluded that the incremental trend of warming extreme indices coupled with the negative trend of precipitation are the most significant factors in decrease of saffron yield. According to constructed model and simulation of saffron yield in coming climate change situations and extreme events, the productivity of saffron in this region will decrease in future. The most yield decrease (31%) happened in the period of (2075-2100) for RCP8.5. The decrement in RCP8.5 in all three period was more than RCP4.5.

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Mitigation of climate change effects on saffron using agricultural biotechnology

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Abstract

Kashmir valley is a major saffron (Crocus sativus Kashmirianus) growing area of the world, second only to Iran in terms of production. In Kashmir, saffron is grown on uplands (termed in the local language as "Karewas"), which are lacustrine deposits located at an altitude of 1585 to 1677 m above mean sea level (amsl), under temperate climatic conditions. Despite being one of the oldest historical saffron-producing areas, Kashmir faces a rapid decline in the saffron industry. Among many other factors responsible for the decline of the saffron industry, the preponderance of erratic rainfalls and drought-like situations have become major challenges imposed by climate change. Saffron has a limited coverage area as it is grown as a 'niche crop' and is a recognized "geographical indication," growing under a narrow microclimatic condition. As such, it has become a victim of climate change effects, which could potentially jeopardize the livelihood of thousands of farmers and traders associated with it. The talk will discuss the potential and actual impact of the climate change process on saffron cultivation in Kashmir and the biotechnological measures to address these issues.

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Effect of climate changes on saffron production in Herat Afghanistan

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Abstract

Afghanistan is one of the 10 major saffron producing and exporting countries. In the last 20 years, the Afghan government encouraged farmers to grow saffron instead of poppy (*Papaver samniferum* L.) to improve their livelihood. Herat province of Afghanistan is geographically located in the neighborhood of Khorasan province in Iran. In addition Herat province is the main center of saffron production in the country. The National Environmental Protection Agency (NEPA) in 2016 reported that: Climatic changes caused by the increase in temperature +1.8 degrees Celsius and the decrease in spring rainfall by 27.2% over 60 years have had a significant impact on the amount of production and the cultivated area of crops in Afghanistan. Climate change will cause the amount of rainfall to decrease or fall more intensely in a short period and cause floods. We may also face severe temperature fluctuations in the future. Last year, we experienced a sharp drop in temperature in winter. The decrease in saffron production due to the severe cold of the previous year (up to -20 °C) was more noticeable in farms three years old and above. Although the area under saffron cultivation in Herat increased from 7610 to 8110 ha last year and the total production of saffron was 21 tons, but a decrease in production was observed. Meanwhile, according to the report of the Ministry of Agriculture, Irrigation and Livestock (MAIL) of Afghanistan, the export of saffron reached 31 tons last year. The decrease in yield was not the same in all regions of Herat (more decrease in the west of Herat). Because the leaves were damaged and unable to photosynthesize and produce daughter corms. Due to climate change and warming weather, saffron is not growing well this year. As a result of irrigation and hot weather, fungal diseases and mites have spread. According to the visits made, the following we will have a reduction in the yield the coming year. As farms get older, the severity of the reduction will be greater. Therefore, farmers may be able to prevent this damage by changing the cultivation pattern and planting different crops instead of saffron. Perhaps it is possible to deal with the reduction of the yield by moving towards the annual cultivation of saffron which of course needs much bigger corms.

Promotion of Saffron in India under Changing Climatic Scenario

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Abstract

Kashmir valley provides the uniquely optimal environment for growing saffron in India. A change in climate can lead to adverse effects on saffron production. Many factors are responsible for decline of saffron industry in Kashmir viz., the lack of availability of good quality corms, poor soil fertility, lack of assured irrigation, infestation of rodents and diseases, poor post-harvest management, improper marketing facilities, urbanization on saffron land, rampant adulteration. Climate change is the latest and the most formidable challenge that threatens the existence of saffron industry. Temperature and moisture are the most important parameters affecting corm sprouting, flower initiation and time of flowering and ultimately the yield. Saffron is still grown as rainfed crop, however water stress affects yield, growth and development. Assured irrigation at pre-sprouting and pre-flowering stages is important for quick corm sprouting and good harvests. Due to climate change weather has become quite erratic and rains are either scanty or distribution is irregular, thus adversely affecting the critical stage of flowering in saffron, although excess of water is as detrimental as the scarcity. Heavy rains over a short period on poorly drained saffron soils pre disposed saffron corms to rotting fungi. Corm rot is quite widespread and causes loss of a considerable proportion of the produce every year. Climate change may promote the growth of some weeds due to favorable growth conditions for the vigorous growth causing heavy losses to saffron production. All these biotic and abiotic stresses not only affect the productivity adversely but may also have negative impact on saffron quality. The present value chain of saffron signals that the saffron industry of Kashmir is running at production loss to meet the domestic demand. Keeping in view the present scenario, SKUAST-Kashmir has developed and up scaled effective production management strategies under changing climatic scenario for realizing higher yield for both indoor and outdoor saffron cultivation.

The effect of climate change and agro-ecological zoning on quality of saffron in Iran

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Abstract

The average yearly temperature has risen by 0.0067°C over the past 172 years since 1850. This trend has accelerated with annual temperature increases of 0.0155 (since 1951) and 0.0198 (since 1971). As global temperatures continue to rise, the resulting climatic variability, including changes in extreme events' frequency, intensity, timing, and duration, is becoming more severe. These changes significantly impact crop yields and food production systems in developing nations.

Saffron (*Crocus sativus* L.) is a plant that thrives in unique ecological niches and plays a vital role in subsistence and family farming systems in Eastern Iran. Six key growth stages of saffron have been identified, from sprouting to corm dormancy. Saffron cultivation can yield good results under various environmental conditions, with warm summers, autumn rains, and mild winters being favorable for high yields. Climate variables like precipitation and temperature greatly influence saffron cultivation, with reports indicating decreasing yields in Iran due to climate change and reduced groundwater levels, primarily driven by high temperatures.

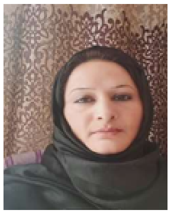
The induction of flowering and flower appearance in saffron are complex processes regulated by internal and external cues, such as temperature and precipitation. In Iran, the optimal temperature ranges for flower induction and emergence are 10-30°C and 15.5-22°C, respectively, with temperatures around 23°C and 18°C being ideal. Higher temperatures lead to reduced saffron growth rates and prolonged flowering periods. The best temperature range for flower formation is between 23 and 27°C, with 23°C being slightly more favorable.

Saffron quality is intricately linked to climatic conditions and the composition of secondary metabolites like crocins, picrocrocin, and safranal, which contribute to color, bitterness, and aroma, respectively. Climatic factors have a significant impact on saffron quality, with altitude affecting crocin content. Interestingly, safranal content shows a positive correlation with altitude but a negative correlation with precipitation levels.

In collaboration with

Climatic variability and its impact on niche crops in Kashmir

Sameera Qayoom



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Abstract

Saffron (*Crocus sativus* L.) cultivation in Kashmir, India, has long been renowned for producing high-quality saffron, known as "Kashmiri Saffron," prized globally for its aroma, flavor, and medicinal properties. However, the sustainability and productivity of saffron cultivation in Kashmir are increasingly threatened by the impacts of climate change. This abstract delves into the multifaceted challenges faced by saffron cultivation under Kashmir conditions in the age of climate change.

One of the most pressing issues affecting saffron production is the changing temperature regime. Kashmir has experienced a noticeable increase in average temperatures over the past few decades, leading to altered phenological stages in saffron plants. Higher temperatures during corm development and flowering stages have been linked to decreased corm size, delayed flowering, and reduced stigma yield. These temperature shifts not only affect saffron quality but also contribute to lower overall yields per hectare.

Moreover, changing precipitation patterns pose significant challenges to saffron cultivation. Kashmir relies heavily on snowmelt and seasonal rainfall for irrigation, and any disruptions to these patterns can lead to water scarcity during critical growth stages. Irregular rainfall, coupled with increased evapotranspiration due to higher temperatures, exacerbates water stress in saffron fields, impacting corm growth, nutrient uptake, and overall plant health.

Climate change also brings about shifts in pest and disease dynamics, further threatening saffron cultivation. Pests like aphids, thrips, and nematodes have become more prevalent, causing damage to saffron plants and reducing yields. Additionally, diseases such as corm rot, Fusarium wilt, and leaf spot are becoming more widespread, necessitating vigilant monitoring and management practices to mitigate losses.

To address these challenges, various adaptive strategies and technological interventions are being explored. Sustainable agricultural practices, such as mulching, drip irrigation, and organic fertilization, are being promoted to improve soil moisture retention, nutrient availability, and overall crop resilience. Precision agriculture techniques, including remote sensing and GIS-based monitoring, can be utilized to optimize resource use and mitigate environmental stress.

Furthermore, the development of climate-resilient saffron varieties through breeding programs and genetic engineering is underway to enhance tolerance to temperature extremes, water scarcity, and pest/disease pressure. These efforts aim to safeguard saffron cultivation in Kashmir against the adverse effects of climate change while ensuring sustainable production and economic viability for local farmers.

In conclusion, the challenges posed by climate change to saffron cultivation in Kashmir are complex and multifaceted, requiring a comprehensive and integrated approach that combines

traditional knowledge with modern technologies. By implementing adaptive strategies, promoting sustainable practices, and investing in research and development, the resilience of saffron cultivation can be strengthened, securing its cultural heritage and economic importance in the region for generations to come.

Can changes in corm weight justify changes in saffron yield under different climatic conditions?

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Abstract

In order to investigate the effects of corm weight variations on stigma saffron yield in different climatic conditions, results of several research experiments under different managements conditions including density, corm weight, planting depth, irrigation methods, water amount and use of mulch studied in Khorasan-Razavi agricultural and natural resources research and education center (Gonabad research station, latitude 34º, 21 north and longitude 58º, 41 east) from 2018-2023 was conducted. Saffron yield decreased significantly especially in 2021 and 2023 due to different climatic situations (cold and heat stress). Correlation coefficients showed that corm characters including corm number, mean of corm weight and corm weight per m^2 can justify saffron yield variations in different years and under managements conditions, however allometric coefficients change under various conditions. This means that out-of-season stresses such as summer heat stress as a consequence of climate change are responsible for that and therefore this problem can be overcome with better saffron management practices such as production of larger corm during the season.

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Trends of the past and future impacts of climate change on saffron production in Iran

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Abstract

According to the IPCC report, the climate change is no longer a possible phenomenon, but the world is now exposed to it. In the latest report of IPCC, the term "global boiling" is used instead of the "global warming". The negative effects of climate change are evident in the most important saffron-growing region of Iran and the world with more than 90% of the world's saffron cultivation area. The most important consequences of climate change in this area have been manifested by an increase in temperature and a decrease in precipitation. Only in the last five years, the saffron production in Torbat-Heydarieh region, where the most saffron is produced in this area, has decreased from about 320 tons to about 140 tons. This issue was due to a remarkable decrease in precipitation in autumn and winter, on the other hand, a significant increase in temperature in spring and summer. Thus, the amount of precipitation in Torbat Heydarieh region has declined from 325 mm in 2018 to 158 mm in 2022 and 109 mm in 2023. All the studies have predicted that the temperature will increase and the effective precipitation will decrease in the region for the future. Researchers illustrated that if the climatic change continues at the same trend, due to an increase of at least 1.5˚C in temperature and a considerable decrease in winter precipitation compared to 30 years average of them, it will no longer be possible to cultivate saffron in this region from 2030. This issue greatly affects the well being of the people of Torbat-Heydarieh region where many of their production and related industries are dependent on saffron. Therefore, it is necessary to examine the appropriate mitigation and adaptation strategies for reducing the negative impacts of climate change on saffron production.

Studying physiological reactions of saffron under changes in climatic parameters

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Abstract

The action and reaction of organisms in the ecosystem provides food and support for human survival. Without a view based on the science of ecology, its continuation is not possible. The danger of the destruction of ecosystems and their sequence towards the reduction of production capacity, under the influence of climate change, has faced the future of humanity with a vague and uncertain situation. With the correct management of production based on the correct understanding of ecological concepts, it is possible to have a sustainable production level based on the preservation of natural resources while increasing the production per unit.

One of the reasons for the decrease in flowering and yield of saffron in Afghanistan can be changes related to climatic conditions such as decrease in rainfall, increase in summer temperature and severe irregularities in climatic parameters (temperature, precipitation, wind). From the end of May to the beginning of September, the saffron bulb is in its sleep period, which during this period has two stages: real sleep and apparent sleep. According to the research of Mr. Kol and Farooq (1983) in the state of Kashmir, the true dormancy period of saffron, which lasts until July 16, does not show significant mitotic activity in the embryonic tissue of the meristem of the apical bud of saffron, but after this period has passed Although the saffron bulb is still apparently "sleeping", but with the increase of mitosis, the activity of cell proliferation starts in the embryonic tissue of the apex bud, so that from July 16 to August 10, the stage of development and differentiation of vegetative organs takes place, and from August 10 to August 25 The development and differentiation of reproductive organs of saffron is done.

The conducted studies show that humidity as a physical factor can affect the differentiation stages of saffron plant, so that any irrigation or rainfall in the time intervals of July to August 10 (this period is comparable to the differentiation stage of saffron reproductive organs) It is very harmful, it causes the vegetative phase to prevail over the reproductive phase of saffron

and causes no reproductive organs to form. saffron fields are harvested. Musafari Zia Al-Dini, by conducting experiments for 2 years in Mashhad, showed that irrigation in July causes a 17% decrease in the flowering and yield of saffron (Masafri Zia Al-Dini). If the same irrigation is done in the saffron fields from the 10th of August onwards, it will increase the flowering and yield of saffron by 20%. Behzad Sadeghi et al. conducted an experiment for 2 years in Khorasan saffron fields and concluded that irrigation in August in newly planted saffron fields increases the flowering and yield of saffron by 17% and in multi-year fields by 40%, but irrigation in July in both The item was found to be harmful.

The results of scientific investigations showed that the reduction of flowering and yield of saffron due to the effects of untimely rainfall during the dormant period of saffron bulb (corm) has caused the dominance of vegetative growth of saffron over reproductive growth and the absence of saffron flower formation. So that the rainfall that took place between July and August 10 (this period corresponds to the differentiation stage of saffron's vegetative organs), which is very harmful, caused the dominance of the vegetative phase over the reproductive phase of saffron, and as a result, the absence or reduction of the formation of reproductive organs and It has resulted in a decrease in flowering and yield of saffron.

Can heat stress be mitigated in summer by using mulch and shading in saffron fields?

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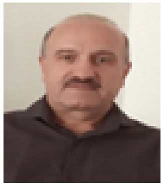

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Abstract

In order to investigate the effect of vegetation cover and shading on the growth and yield of saffron *(Crocus sativus* L.*)* in the summer, an experimental was conducted with three replications in the form of split plots with Randomized Complete Block Design (RCBD) over four cropping years (2014–2018) at the Saffron and Medicinal Plants Research Station of Gonabad which is located in the south of Khorasan Razavi province. This experiment was included corm density as the main factor at four levels (60, 90, 120, and 150 corms m^{-2}) and plant residue management and shading as the sub-factors at four levels (removal of saffron residues at the end of the growing season as a control and conventional method in the region, presence of saffron and weed residues, use of cereal straw, and finally use of shading) at the end of the growing season. The results of the combined variance analysis showed that the effect of density and use of vegetation covering, mulch and shade on the measured characteristics related to the growth and yield of saffron was significant. Means comparison results showed that the use of covering (plant residues, cereal straw, and shading) caused an increased in saffron yield, individual flower weight, number of flowers per unit area, number of leaves per plant, and weight of daughter corms by 70, 7, 63, 16, and 44 percent, respectively. Considering the positive effect of using a type of covering on the mitigation of the soil temperature compared to the maximum air temperature in summer and the simultaneous positive effects of this method of field management with the flowering initiation in saffron. It seems that the use of different types of covering, especially cereal stubble, due to its lower cost compared to shade and easier access for covering fields, could be emphasized as a practical recommendation for the sustainability of saffron production in arid and semi-arid regions.

The Saffron Holobiome

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Abstract

Saffron, the dried stigmas of *Crocus sativus* flowers, is referred to as the "golden condiment" being the world's most expensive spice costing about 11000 USD per pound. Even though saffron is cultivated in various countries worldwide, India ranks second after Iran in its global production. *Crocus sativus* is a sterile triploid plant (3n=24), bearing no seeds and reproducing via vegetative propagation. The holobiome of saffron (i.e. saffron genome and microbiome) has been studied by our group. Lack of genetic variations has been reported in various accession of saffron grown worldwide due to its vegetative propagation. However, the microbes associated with different parts of saffron are reported to vary. The microbes associated with the different underground parts of saffron (rhizosphere and cormosphere) were studied using culturomics and metagenomics approaches. It was observed that saffron rhizomicrobiome was distinct from cormomicrobiome with few overlapping bacterial species, thereby indicating that microbes are niche specific. Variations in saffron microbiome were also observed temporally i.e. across the different growth stages i.e. the cormomicrobiome during flowering stage were distinct from dormant stage. Additionally, spatial variations were also observed in saffron microbiome wherein rhizomicrobiome and cormomicrobiome across were significantly varying different geographical regions respectively even though there is no genetic variation in saffron plant across different geographical locations. In-spite of the variation in the microbiome, a core microbiome i.e. the microbes that remain same irrespective of geography was identified in saffron. Additionally, the first draft genome of *C. sativus* was reported by our group. Genome size of *C.sativus* was estimated to be 3.5 Gb using flow cytometry. The assembled genome of *C.sativus* was 3.0 Gb with 84% of the genome covered and with N50 value of 1860 using Illumina sequencing technologies. A total of 862,275 repeats were identified in the assembled genome wherein simple repeat (48.41%) and LTR (30.34%) were the most abundant. 964,231 SSR markers were identified in the assembled genome that can be further evaluated for their application in *C. sativus*. The genome was functionally annotated and 53,546 genes were identified including the 5726 transcription factors. *C. sativus* genes were compared with the closely related plants namely *Asparagus officinalis, Phalaenopsis equestris, Apostatia shenzhenica* along with a model monocot plant *Oryza sativa* (Rice) and was found phylogenetically closer to *A. officinalis.* This was due to the presence of more orthologous protein clusters in *A. officinalis* as compared to other selected plants. 85.2% of total identified genes (45632 genes) were found orthologous with one or more plants, however only 7914 were specific to *C. sativus* that need further investigation. In addition, all the genes encoding the enzymes involved in apocarotene biosynthesis pathway were identified in the *C. sativus* genome.

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Synoptic analysis of sudden drop in temperature and its effect on saffron yield in 2023

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Abstract

Saffron, a perennial herb belonging to the Iris family, reproduces through its corms. This plant thrives in Mediterranean climatic conditions and regions situated between 30 and 50 degrees north latitude and 10 to 80 degrees east longitude, typically in areas with low rainfall, cold winters, and hot summers. The plant's high economic value, coupled with its management advantages, renders it an attractive option for many farmers. However, in recent years, saffron cultivation has encountered various challenges, including climate-related issues and management obstacles. Notably, the winter of 2023 witnessed an extreme cold wave affecting a significant portion of Razavi Khorasan province, resulting in substantial agricultural losses. While data regarding the specific impact of this cold wave on saffron yield remains limited, available information suggests a stark decline in yield in the affected regions compared to the average. Given that saffron plants retain green leaves during the winter, making them susceptible to severe cold, investigating the origins of such extreme weather events is crucial for better preparedness in the future. A synoptic analysis conducted on the 2023 cold wave revealed its source in higher latitudes, where the movement of a high-pressure system from Siberia towards Khorasan Razavi province brought about the influx of cold air, leading to a significant temperature drop. As these high-pressure systems' formation and movement are primarily influenced by the polar jet stream, future research should explore the impact of climate change on this atmospheric phenomenon. The warming of the North Pole due to global warming is altering the temperature gradient between polar and midlatitude regions, potentially influencing the behavior of the polar jet stream and exacerbating extreme weather events like the one experienced in 2023.

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Khorasan-Razavi Agriculture & Natural Resources Research and Education Center, Mashhad, Iran

Saffron (*Crocus sativus* L.) Production beyond Kashmir: Efforts and Challenges

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Abstract

Saffron (*Crocus sativus* L) is one of the most expensive crop (family Iridaceae) among medicinal plants in the world and is one of the 85 members of the genus Crocus. Saffron comprises antioxidant, anticancer, anti-depressive, antitussive, anti-ischemic and anti-inflammatory properties. Due to its pungent color and aroma, it has been used in culinary dishes since time immemorial. The spice is actually the stigma, manually pulled out from a beautiful purple flower. It is widely grown in Iran, India, Morocco, Afghanistan, Greece, Italy, and Spain. In India, it is cultivated in the Pulwama, Budgam, and Kishtwar districts of the union territory of Jammu and Kashmir. The predicted global annual production of saffron is 418 tons to which India contributes 5% of the world's total production of which 90% is supplied only from its Jammu and Kashmir (J&K) region. In India, the yield of saffron has suffered severely from rapid urbanization, climate change, frequent incidence of natural calamities and corm rot diseases. The annual demand for this spice is 100 tons per year but its average production in India is about 9-13 tons and hence a large amount of the spice is imported. Saffron cultivation in Kashmir is under threat of extinction. Therefore, there is a need to increase the production of saffron to meet the increasing gap between demand and supply. There is need to identify areas like J&K with the same ecological and environmental conditions and the potential to introduce this crop if we are to meet the demand for saffron in our country. To extend saffron cultivation beyond Kashmir, CSIR-IHBT started working on saffron to develop production technology and identifying suitable locations in India. CSIR-IHBT standardized agro-technology for the introduction of this crop in non-traditional areas of Himachal Pradesh, Uttarakhand, North East and Leh. With the help of niche modelling, we have identified the potential sites for saffron cultivation and validated those sites physically by conducting experimental trials for analyzing the growth, yield and quality of the spice. Initial experiments conducted in the non-traditional areas of H.P. and Uttarakhand yielded promising results from some locations in Himachal Pradesh and Bageshwar of Uttarakhand. The quality of the produce was tested in the laboratory of CSIR-IHBT and it was found to be at par with the quality of Kashmiri saffron. There are some potential niches for growing saffron in India and concentrated efforts should be made to grow saffron in these locations.

Estimation of saffron yield using machine learning and remote sensing techniques in the face of climate change

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Abstract

Accurately estimating saffron yield is crucial for agricultural planning and managing this valuable product. The objectives of this study encompass developing a robust model utilizing meteorological and satellite data to predict saffron yield, assessing the integration of Sentinel-2 and Landsat-8 imagery, establishing a predictive framework, selecting suitable machine learning algorithms, and computing various vegetation indices. The methodology employed involves calculating vegetation indices (such as NDVI, and EVI) from satellite images (Sentinel-2, Landsat 7 and 8), merging them with meteorological data, and employing machine learning algorithms for predictive analysis. Through correlation analysis, the most influential factors affecting saffron performance were identified. Evaluation of the models generated during the testing phase revealed that the coefficient of determination (R^2) values indicate the model's accuracy. By analyzing the top-performing models, it was determined that the most effective saffron yield estimation model incorporates three datasets: vegetation indices, geographical information, and meteorological data, leading to a more precise and reliable estimate. This model serves as a comprehensive biomass and yield predictor for saffron, identifying key variables influencing yield and offering a dependable forecast for arid regions with limited meteorological data.

The possibility of the effect of climate change on the growth and development of bacterial rot of saffron corms (*Burkholderia gladioli*)

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Abstract

In 2018-2020, comprehensive surveys were primarily conducted in saffron fields within the Razavi Khorasan province, located in the northeast of Iran. Field symptoms were characterized by early leaf yellowing and drying in the autumn and winter seasons. During sampling, certain saffron corms, excavated from the soil, displayed signs of decay on the apical buds, while newly formed sprouts exhibited tissue burnings and browning. On specific saffron corms, precisely within the root germination zone, we observed a distinctive ring-shaped red-brown discoloration that progressively decayed and extended into the deeper layers of the corm. Regarding multiple bacterial detection methods used, including morphological characters, differential biochemical and physiological tests, proving pathogenicity and bacterial molecular detection as well as sequencing and 16s r DNA gen blast of the saffron isolates, revealed *Burkholderia gladioli*. In laboratory conditions, the relationship between temperature and pH with the population of *B. gladioli* bacteria was investigated. The results indicated that an increase in temperature leads to an increase in bacterial population. The optimum temperature for bacterial growth was 28°C. It cannot grow below 13 or above 38°C. *B. gladioli* were also able to grow within a pH range of 5 to 9. Given the significant temperature fluctuations during saffron germination and flowering, it can play a crucial role in the development of disease in saffron fields. Climate change can affect microbial communities and their interactions in various ways, but any specific connection between climate change and *B. gladioli* would depend on factors like temperature, precipitation patterns, and ecosystem dynamics, which may indirectly influence its abundance or activity.

Saffron- microbe interaction; identifying and managing friends and foes

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Abstract

Though plants are immobile but that does not mean that, they do not encounter friends and foes. Literature is replete with the stories of the social life of plants with other plants, animals and microbes. One such microbial friend of saffron *Bacillus* sp. strain D5 (Bar D5) was found be best for saffron growth promotion in fields. The trials were conducted in both traditional area i.e. Pulwama and non-traditional area i.e. Poonch in NW Himalayas in Jammu & Kashmir, India. Bar D5 corm priming increased the morphological parameters of saffron such as, root length, root number, shoot length, leaf length and number, weight of daughter corms, number of flowers and yield of spice. The most interesting observation is that it decreased the shoot number and number of daughter corms but increased the size of the daughter corm compared to unprimed corms. We hypothesized that it could be due to resource allocation alteration directed by the Bar D5 or its effect on microflora and /on soil fertility. Bar D5 based bio-formulation is available for third party evaluation by any researcher, since saffron is grown as a revenue crop across continents.

Not that saffron is surrounded by friend microbes only, it encounters foes as well, particularly corm that is underground and rich source of carbohydrates. One such example is of *Fusarium oxysporum* R1 (Fox R1), a fungal pathogen. In addition, an endophyte identified as *Fusarium oxysporum* CSE15 isolated from the healthy saffron corm but becomes a pathogen when the corm is injured . So, this shows how a friend becomes an enemy in the changing circumstances. Our group is trying to understand the molecular basis of the difference in the lifestyle of these two different strains of the same fungal species that is *Fusarium oxysporum* by comparative genomics.

Planting in closed environment: A strategy for producing saffron under climate change and global warming

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Abstract

Today, due to the limitations and threats posed by climatic conditions on the quantity and quality of saffron, there is a suggestion to replace traditional production methods in various areas with production methods in closed environments. One key strategy to enhance the productivity of saffron production systems in response to climate change is the utilization of closed systems and controlled environments. Cultivating saffron in controlled conditions can serve as a viable alternative to conventional methods. Among the modern techniques that have garnered interest from saffron producers are hydroponic and aeroponic cultivation. Hydroponics is a soilless method of plant production, while aeroponics involves plant growth in a misty environment without soil or other substrates, representing a new technology that enhances plant yield and growth rate. These systems significantly reduce water consumption compared to field cultivation, which is crucial given the global water scarcity issue. In recent years, saffron production in major producing countries, including Iran, has declined due to the lack of advancements in cultivation technologies and rising labor costs. The adoption of these innovative methods allows for an extended flowering period, simplified crop management, and improved plant growth without the presence of pests or pathogens. Moreover, controlled environments can mitigate the adverse effects of soil degradation and climate change (e.g., increased salinity and temperatures) while enhancing land use efficiency.