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Saffron Blooms Beyond Soil: A Thorough Review on Soilless Corm Production Strategies

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Author's contribution

The sole author designed, analyzed, interpreted and prepared the manuscript.

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Review Article

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ABSTRACT

Saffron (*Crocus sativus L.*) is a highly valuable spice and medicinal plant known for its potent aromatic compounds. Due to its scarcity and susceptibility to various challenges, including adverse weather, soil conditions, and adulteration. There is a growing interest in soilless cultivation methods such as hydroponics to enhance saffron production. This article discusses the potential benefits of soilless cultivation, the structure for cultivating corms in hydroponic systems, the choice of growing media, nutrient solutions, electrical conductivity (EC), pH, and environmental conditions, including light spectrum modulation, to optimize saffron corm production.

Keywords: Corm production; hydroponics; Saffron; soil less cultivation.

1. INTRODUCTION

Saffron, scientifically called as *Crocus sativus L.*, an annual herbaceous spice and medicine plant, belongs to the Iridaceae family. The Arabic term za-faran, which means "yellow," is where the name "saffron" originated [63]. The red stigmatic lobes of the *Crocus sativus* plant's flower are of

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tremendous commercial significance because they contain concentrated amounts of the ingredients that give the spice its scent (safranal), flavor (picrocrocin), and pigment (crocin) [25].

Saffron's high cost can be attributed to its scarcity, the labour-intensive harvesting method, and its nutritional and medicinal benefits. Saffron possesses a range of medicinal properties, including being an aphrodisiac, antispasmodic, antimicrobial, antibacterial, antifungal, antiseptic, and anti-inflammatory agent. Additionally, its documented anticancer properties have contributed to its increased market value [54].

There are three stigmas on each saffron flower, and the dry weight is close to 5 mg. In order to produce 1 kg of saffron stigmas, between 150,000 and 200,000 saffron flowers need to be harvested and this process takes more than 400 hours [44]. On 121,338 hectares, 418 t of saffron are expected to be produced per year [6]. Iran [24] produces 404 tons of the total, or more than 95% of global production on an area of 112,000 hectares [18].

Saffron productivity, production, and marketing have decreased over the past ten years due to a number of factors, including unreliable weather patterns, inadequate irrigation systems, a shortage of high-quality corms and seed, deficient soil fertility, and rodent infestation, inadequate postharvest management, insufficient marketing facilities and growing urbanization lands. In addition, saffron is a frequent target of adulteration and fraud due to its high price [60]. Saffron production is hampered by the poor rate of cormlet proliferation and related fungal diseases [11]. Furthermore, the use of traditional agronomic techniques contributes to the low saffron production [32].

2. CORM PRODUCTION

Saffron is a sterile auto triploid and stemless monocotyledonous plant [2,47]. The corm duration is for one season and during that season, it reproduces by producing new cormlets on top of the old one, which results in the growth of new plants. As a result, the only way to propagate saffron is by the propagation of daughter corms from mother corms [16]. Through field culture, a mother saffron corm typically yields one to four cormlets per season [2,7]. One to four apical shoots with developing flowers and leaves is produced by each corm [2].

According to earlier studies, large corms (>10 g) have a higher capacity to absorb water and nutrients than small corms, which results in a higher yield of stigma and more cormlets [2,16, 23,30,31,42]. Corm size and weight significantly influence flowering and the number of daughter corms produced. Small mother corms (less than 1 cm in diameter and 6 g in fresh weight) do not flower and produce cormlets that do not have flowers [2,16]. Since a corm provides storage for photosynthetic products, which are most needed during dormancy and at early phases of crop growth, corm size is crucial in the life cycle of saffron [3]. Corm size has an impact on the growth of saffron flowers, any increase in crop production or enhancement of crop quality must be the result of simultaneous improvements in the bulbs [10].

Therefore, it is crucial to understand the effect that growing conditions may have on the efficiency of saffron bulbs [37] Production of saffron in open fields can be replaced by hydroponics [58]. It can lower saffron production expenses while increasing yield [40]. Furthermore, by producing pathogen-free stock corms, it has enormous promise for sustained saffron production [12].

3. SOILLESS CULTIVATION

Soilless agriculture is an unusual method of growing crops that does not rely on traditional soil-based cultivation [21,36]. Without soil, plants are grown in controlled environments using nutrient-rich solutions (hydroponics) or other inert substrates (soilless culture), which support the plant and supply nutrients to the roots directly [37]. Soilless cultivation has become a promising crop production technique in recent years due to factors like limited arable land availability, resource efficiency, increased yields and crop quality, capacity for climate adaptation, technological advancements, sustainability benefits, and increased knowledge sharing [37]. Due to its potential to overcome land limits, maximize resource usage, and alleviate the effects of climate change, soilless agriculture is an optimistic method for ensuring future food security.[5] Overall, soilless agriculture offers adaptability, precision, and sustainability in the face of numerous agricultural obstacles, making it a promising technique of crop production. It keeps developing as a result of improvements in technology, research, and innovation, supporting agriculture's future [39].

Saffron can be produced using the soilless method of crop growing, which has a lot of potential because it offers a lot of benefits that can increase yield and production [27]. Saffron production under controlled environments (CE) is one of the recent advances in its production. Saffron production under CE has many benefits, including reducing the negative effects of climate change on flowering, eliminating the harmful impacts of improper soil structure on flower emergence, eliminating the effects of cold, rain, and wind on the flowers, providing an appropriate microclimate for flowering, lowering flower contamination, making flower harvesting easier, and eventually producing stigmas of higher quality and quantity [49,41,4,17,29].

By utilizing the advantages of soilless culture, which would aid to promote healthy bulb development, robust daughter bulb creation, flower production, and eventually better saffron harvests, the production of saffron might be improved [37].

4. STRUCTURE FOR CULTIVATION OF CORMS

The continuous immersion technique based on volcanic rock had the maximum number of cormlets (5.8), average cormlet diameter (24.1 mm), and weight (6.62 g) observed. With the exception of the stigma length, which was considerably influenced by the type of hydroponic system, they did not detect any correlation between the saffron blooming parameters and the type of hydroponic system, growth substrate, or their interaction [12].

Aeroponic techniques can be used in saffron. Spray filming techniques are used to provide the roots that are floating in the air with the necessary nutrients. In order to encourage quicker root growth, a sealed box is used to prevent light penetration and algae growth. Additionally, the length of the fertilizer spray is determined for crops like tomatoes, cucumbers, saffron, lettuce, peas, onions, etc [38].

In a soilless media, aeroponics was used to grow saffron. In a controlled environment, tiny, non-flowering mother corms were employed to produce the corms for the plantations. Researchers looked at the impact of using corms from a controlled environment on the yield. Through the use of superabsorbent, the roots' ability to hold water and absorb nutrients was improved. After growing, the corms produced new corms with more mass and weight. The ability to produce contractile roots and dry aerial components were two of this method's drawbacks [19].

In order to cultivate saffron, ebb and flow method can be employed. Based on the effectiveness and expenses of various current hydroponic system, a comparison was developed. The suggested system includes ebb table, a water management, a fertilizer system and a ventilation system can be used [28].

In order to cultivate saffron, growth chamber with four different environments: an organic layer, a pin tray, a control group, and a hydroponic system were used. Temperature controllers and LED lighting were included in the vertical hydroponic system that was created [53]. The saffron plants were originally grown in the field until they bloomed, at which point they were moved into the growing chamber. Despite an increase in agricultural productivity, the method had high expenditures. Additionally, the IoT was not utilized in order to improve performance. In addition, the authors noted that not all of the plants flowered.

5. GROWING MEDIA

The efficiency of the growing environment in a hydroponics culture system is determined by the interaction of the plant, growing medium, and nutrient solution [48]. Porosity, water holding capacity, water availability, buffering capacity, and cation exchange capacity (CEC) are the main variables affecting how a growth medium interacts with the nutrient solution [42]. Diverse hydroponic medium is used by growers to nurture their roots and keep a proper water-to-oxygen ratio such as cocopeat, perlite, rockwool, rice hull etc.,[22] Plant growth can be strongly impacted by the choice of suitable substrates and the establishment of the best environmental controls [14,13,15,51].

In this work, two distinct greenhouse experiments were conducted to determine the best growth medium for corm production of saffron under soilless circumstances, using varied perlite particle sizes and its mixing ratio with peat moss. The first experimental treatments used 100% volumetric perlite in the following particle sizes: very fine (less than 0.5 mm), fine (0.5–1 mm), medium perlite (1–1.5 mm), coarse (1.5-2 mm), and very coarse (more than 2 mm). The second experimental treatments used 50% peat moss in addition to the measured perlite particle sizes. Three replications and a fully randomized design were used to create the trials. The findings revealed dry corms weight, diameter of daughter corms, and content of daughter corms, were significantly impacted by the administered treatments. In a mixed growing medium that contained 50% perlite (1-1.5 mm) and 50% peat moss, the greatest weight of corms (17.89 g) was attained. In general, it can be said that the use of a mixture of medium-sized perlite (1-1.5 mm) and peat moss (at a 50:50 v/v peat moss to perlite ratio) is introduced as an ideal growth media when the goal is to increase the yield of saffron through the production of coarse corms in the hydroponic system [20].

They discovered that the kind of growing substrates (perlite and volcanic rock) strongly influenced plant growth, photosynthetic rate and cormlet development but had no discernible impact on flowering features. Large-sized corms transplanted to volcanic rock-based, aerated continuous immersion hydroponics can produce optimal yields of saffron stigma and daughter corms in a regulated environment. [12].

In a study about the vertical production of saffron using a mixture of perlite, soil and manure as the substrate, corm production was unfavourable even though flowering was much higher than its outdoor production in soil media [1].

There was a notable increase in the quantity of new replacement corms in perlite as opposed to the peat/perlite mixture. This result might be linked to the varying physical characteristics of these two substrates, which could impact the growth of corms [35].

6. NUTRIENT SOLUTION

An aqueous solution containing primarily inorganic ions from soluble salts of key elements for plants serves as the fertilizer solution for hydroponic systems [59]. Essential nutrients are dissolved in hydroponic systems at the right quantities and relative ratios to promote normal plant growth [65]. Establishing a nutrient solution that delivers a desirable ratio of ions for plant growth and development is regarded as a crucial step in cultivating crops in hydroponic systems since all the necessary ingredients for plant growth are supplied using various chemical combinations [62].

The study was conducted to compare the yield of saffron corms in the protected soil cultivation in polytunnels and protected soilless cultivation in polytunnel using “Radon grow” as hydroponic fertilizer and soilless substrate of 1:1 mixture of peat and crushed silica. The study found out that the protected soilless culture (PS2) is superior to protected soil-based cultivation (PS1) in terms of the pace of growth of different organs and the accumulation of biomass [37].

The pH (5.5–6.5) slightly acidic standard nutrient solution of Sonneveld and Voogt (2009) [56] was used in a study to identify the appropriate strength of the fertilizer solution for soilless saffron growth in the Mediterranean region, pH for fertigation [50].

In an experiment they employed a nutritional solution that comprised (mgL1) 105.11 calcium, 33.83 magnesium, 62.70 sulphur, and 163.20 nitrogen as macronutrients. It also contained 34.53 phosphorus, 172.56 potassium, 105.20 calcium, and 33.83 magnesium 1.83 iron (Fe), 0.23 boron (B), 0.27 manganese (Mn), 0.19 zinc (Zn), 0.12 copper (Cu), and 0.07 molybdenum (Mo) [12].

The electrical conductivity (EC) of a solution serves as a gauge for its electrolyte and salt concentrations. The number of ions available to plants in the root zone is correlated with the EC of the nutrient solution [58]. The ideal EC varies depending on the crop and the surrounding environment [56,33]. Higher EC generally reduces nutrient uptake by raising the osmotic pressure of the nutrient solution, wastes nutrients, and increases nutrient discharge into the environment, leading to environmental pollution. Lower EC may negatively impact the health and yield of plants [55,52] The nutrient solution EC was kept at 1.1-1.3 dS m1 in a number of earlier investigations on the hydroponic growth of saffron [8,58]. On the other hand, an EC level of 3 dS m1 was suggested for hydroponically growing saffron and corms [50].

A study was conducted to find optimum concentration of nutrient solution for saffron. The nutrient solution which was used to estimate had variable EC (EC2.0, EC2.5, and EC3.0), the highest concentration of provided mineral nutrients produced the finest quality corms, indicating that managing a nutrient solution is a significant tool for optimizing corm production. The highest number of corm m^{-2} was linked to an EC of 2.5 ds/m2, which also led to a 20% increase in corm yield [50].

In an open field in Iran, Effects of brackish irrigation water at four different salinity levels was estimated. Corms and saffron were negatively impacted when the irrigation water's EC was between 2.0 and 3.0 dS m1[9].

The pH of a nutrient solution, which is measured on a scale of 1 to 14 to indicate a solution's acidity or alkalinity, is a crucial chemical characteristic. Water has a pH of 7, indicating that it is neither basic nor acidic at normal temperature. If the pH is more than 7, the solution is basic; otherwise, it is acidic. The majority of publications believe that the pH of the nutritional solution must be between 5 and 7[34].

The ideal water pH range for saffron cultivation is between 6.0 and 6.25, or slightly acidic. The individual saffron corms are planted in two-inch plastic mesh pots that are filled with an inert substrate in the soilless hydroponic environment [58].

7. ENVIRONMENTAL CONDITION

Light seems fundamental, not only for plant growth and development modulation, but also to improve the nutritional quality and yields of plant products[45].The advent of LED light technology, it is now possible to modulate light spectrum, intensity, duration and direction of the light beam, to which the plant reacts with changes in leaf morphology, adjustments in the chloroplast architecture and/or in the electron transport chain influencing photosynthesis [61] Within the spectrum of light, each wavelength triggers distinct reactions in plants.

sprouted corms were cultivated at 8 1°C till collecting daughter corms at the stage of leaf senescence after subjecting them to a 2-week period of gradual air temperature decline, commencing at 10 °C and ending at 8 °C (2 °C per week). For a 16/8 h light/dark cycle, cool white fluorescent lights were used to produce light intensity that was set to 100 mol m 2 s 1 [50].

In saffron a low red/far-red ratio during the development of offspring corms activates a phytochrome-mediated response, preparing the corms to produce flowers with a higher concentration of crocin in the stigmas [26].

Certainly, blue light radiation has the potential to impact the secondary metabolism of plants. It has been observed to promote the synthesis of phenylpropanoid compounds, which are frequently linked to antioxidant properties. In saffron plants, exposure to blue light has been documented to enhance the size of corms by decreasing their quantity and changing how biomass is distributed, favouring corms and flowers. This influence on plant growth and the production of secondary metabolites is a topic of keen interest in agricultural studies and can be harnessed to enhance crop yields and the quality of saffron cultivation [43].

8. CONCULSION

Using soilless cultivation techniques, such as hydroponics, can significantly enhance saffron production by providing a controlled environment that improves corm development, flowering, and ultimately, saffron harvest. Factors like the choice of growing medium, nutrient solution, electrical conductivity, and light conditions play pivotal roles in optimizing saffron production in hydroponics. These soilless methods offer adaptability, precision, and sustainability in saffron corm production. Further studies have to be conducted to increase the corm production as it plays a key role in flowering.

COMPETING INTERESTS

Author has declared that no competing interests exist.

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