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IN VIVO CULTIVATION OF SAFFRON (*CROCUS SATIVUS* L.) UNDER CONTROLLED ENVIRONMENT SYSTEM IN THE THAR DESERT OF RAJASTHAN

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ABSTRACT
The Saffron grows extremely well in an indoor controlled environment system and thus has a potential of its propagation in nontraditional areas. In recent past through Aeroponics some attempts have been made to grow saffron in controlled conditions outside jammu and Kashmir. In the present study besides (a) aeroponics five culture Variable i.e. (b) Vermicompost 100%, (c) Vermicompost, Sand, Cocopeat (2:1:1) (d) Vermicompost, Sand, Clay (2:1:1) (e) Vermicompost, Sand, Clay (2:2:1) (f) Vermicompost, Sand, Clay (1:1:2) were prepared to study the flowering performance and vegetative growth of corms of *Crocus sativus* in the culture room where temperature, light and humidity etc. were regulated. The corm weight class 7-10 gm. was selected for the detailed study and three replicates of 200 corms each were placed in wooden trays in the culture room, other weight class i.e. 2-6.9 gm., 10.1-15 gm., 15.1-20 gm. and 20.1-25 gm. were also placed @ 200 corms per tray for general observations. It was observed during the study that flowering of saffron depends upon the weight of the corms and type of the culture, in Culture variable "a" and "b" no flowering occurred when the corm weight was less than 7 gm. while in other variable flowering occurred between 5% to 12%. The flowering percentage and number of flowering shoot increases with increase in the weight of the corm; in weight class >15 gm. generally three flowering shoots were reported while in weight class 7 to 10 & 10 to 15 mostly two and in weight class < 7 gm. only one flowering shoot was reported. The flowering percentage was found highest in culture 'f'. The soil plays a significant role in the vegetative growth of *Crocus sativus* in indoor cultivation. In culture 'f', the vegetative growth was found significantly higher than other Culture Variables. The total average length of the plant after 35 days of flowering was 12.3, 16.3, 21.1, 18.9, 18.7 & 28.2 in culture a, b, c, d, e, & f respectively indicates the significance of soil culture in indoor saffron cultivation.

Keywords: *Crocus sativus, Culture Variable, Vegetative Growth*

INTRODUCTION
Saffron (*Crocus sativus*) is known as the most expensive spice with diverse uses as: Food, Medicine, Perfume, Cosmetics and Textile Dye (Basker & Negbi 1983). As an antioxidant it has gained importance in pharmaceutical and health sector. This plant belongs to family iridaceae having 24 numbers of chromosomes, it is a sterile triploid geophyte which cannot produce seed and propagates through mother corms (Gresta *et al*., 2008a & b and kumar *et al*., 2009). During each session the daughter corm develop on mother corms by budding for which the photosynthetic activity and reserved food plays a vital role (Kumar *et al*., 2009, Renau-morata *et al*., 2012). The flowering capacity of the plant depends upon the weight/ size and the age of the corm. Omidbaigi *et al*., (2002) reported that the higher number of flowers and daughter corms are obtained from corm with 11 gm. of weight or more.
In India presently saffron is cultivated in 3785 ha of land in four districts; namely Pulwama, Badgam, Kistwar and Srinagar of Jammu & Kashmir with a production of about 16 metric tons (Ajaz Ahmad &

Sneha Deshpandae, 2017). About 86% production comes from Pampore town of Pulwama district where farming is conducted in 3200 ha area. In Kashmir the total available cultivated land for saffron was 5707 ha during 1969-1997 which has declined due to factors like irregular rain fall, minimum use of technology, no proper management of disease & pests and anthropogenic pressure.

The total demand of saffron in India is about 100 metric tons while its production is only 16 metric tons thus there is a vast gap between production and demand resulting in the import of saffron from other countries. To fill this gap, we need to increase per ha production in existing areas and to search new areas and techniques of its cultivation. Some successful attempts to grow saffron in Kargil (Munshi *et al*., 2003) and in some other states of India like Uttar Pradesh and Himachal Pradesh are reported (Dhar & Mir 1997; Kaushal and Upadhyay 2002) but they contribute negligible amount of saffron as compare to the total production. In India the production of saffron can be increased by expending the area of its cultivation in Kashmir and similar geoclimatic regions in India or by exploring nontraditional areas by adopting novel technologies such as indoor farming, Aeroponics, Hydroponics and through some other controlled environmental agriculture activities. By micro-propagation and nursery management module mass production of quality planting material can be obtained to meet the demand of new cultivation areas. Kanwalpreet *et al*., (2022) provided systematic literature review of all artificial approaches which can be used for saffron cultivation and focused primarily on hydroponics approaches.

During the present study an attempt was made to study the vegetative growth and flowering performance of *Crocus sativus* under controlled environment system where besides Aeroponic, various culture were used to grow saffron and to find out the most suitable medium for its propagation. Field experiments are also under way to observe the possibility of its propagation in climatically opposite geographical region in the Thar Desert.

MATERIALS AND METHODS

Study Area

The study was conducted during 2023 in Sardarshahar located in Churu district of Rajasthan state at 28.44° N latitude & 74.49° E longitude comes under Thar Desert of India. It has hot summer with highest temperature up to 50°C and cold winter with minimum subzero temperature, annual precipitation remains 35.98 millimeter.

Collection of Corms

The Corms of *Crocus sativus* were collected from Pampore town of districts Pulwama which is the most cultivated place in India with its cultivation history of 500 BC. The corms were collected and transported by air and road ways to the experimental site during the month of July, 2023.

Indoor Saffron Cultivation

During present study the size of the culture room was 15*15*9 ft. provided with metallic racks of 3*2*8 ft. with 4 sections each to place 84 wooden trays of 24*20*3 inches vertically. The culture variables were prepared by using various proportion of: Vermicompost, Cocopeat, Sand and Clay to study their impact on flowering performance and vegetative growth of *Crocus sativus*. The corms were disinfected before planting by fungicidal solution (0.1%) to ensure their health and viability. Prior to planting the extra peels were removed from all the saffron corms, they were segregated and classified as per their weight. i.e. 2 to 6.9 gm., 7 to 10 gm., 10.1 to 15 gm., 15.1 to 20 gm. and 20.1 to 25 gm. for study. Weight class of 7 to 10 gm. was selected as an Experimental group; the result of this group was compiled for detailed study for flowering performance and vegetative growth of *Crocus sativus* under controlled environment system. Three replicate of 200 corms each of this experimental group were carefully placed in 18 trays for following six culture variables.

a) Soil less culture (Aeroponic)
b) Vermicompost 100%
c) Vermicompost, Sand & Cocopeat (2:1:1)
d) Vermicompost, Sand & Clay (2:1:1)

e) Vermicompost, Sand & Clay (2:2:1)
f) Vermicompost, Sand & Clay (1:1:2)

Remaining groups of corms were placed in the culture room in variable "f" in 66 trays.

The temperature of the room was maintained at 17°C ± 2°C and humidity 80% during start of the experiments. The corms were kept in dark for initial 20 days till the shoot emerge out afterwards the photoperiods were maintained as 12 hours dark and 12 hours light of 7000 to 7500 lux. The dark phase is necessary for the corms to undergo physiological changes and prepare for sprouting and flowering (Rifatun *et al*., 2023). At the time of flowering a cold shock was given by reducing the temperature to 10°C during night while the day temperature remained 17°C. The flowers were plucked and stigmas were collected from 2 Oct. 2023 to 23 Oct. 2023. The total average Weight of 200 Corms/ Plants in different culture variables before start of the experiment and after 35 days of last flowering was estimated. Vegetative growth was also recorded by random sampling from various cultures.

The experiment was started on 17.08.2023, flowering occurred between 02.10.2023 to 27.11.2023. After 35 days of last flowering all the plants were shifted to ¼ ha of agriculture field, the clay soil and vermicompost were mixed in the sandy soil. Fungicide treatment was given to the corms before sowing. Besides this, 65 gardening bags of 3 ft. diameter and 1.5 ft. height were used to sowing the corms @100 per bag; these bags were kept in shad in variable soil compositions for further studies.

Statistical analysis

Mean and Standard Deviation for all measured parameter were calculated and differences among the culture variables were tested using an analysis of variance (ANOVA, 95% confidence level). In instances where the ANOVA indicated rejection of null hypothesis, the Tukey test was used as a posteriori test.

Result and Discussion

The experiments were conducted under controlled environment system to study the variation in the flowering performance and vegetative growth of *Crocus sativus* under various cultures 'a' to 'f' (Fig- 1). The corm weight class 7 to 10 gm. were selected as experimental group for detailed study while the remaining were placed in culture room in variable 'f' for general observations. Rifatun *et al*., (2023) stated that by embracing indoor farming techniques, saffron cultivation can be extended beyond its traditional geographic boundaries.

The flowering and vegetative growth of *Crocus sativus* was found influenced by the weight of the corms and composition of various cultures. The corms weight <7 gm. do not flower at all in soilless culture and in 100% vermicompost, but in variables 'c', 'd' & 'e' it flowers between 5% to 8% and in 'f' culture 12%. Fredric & Pamela (2000) and McGimpsey *et al*., (1997) reported that the smaller corms <6.9 gm. do not flower with in two seasons after planting. Aghhavani-Shajari *et al*., (2015) reported that the number of shoots and flowering depends upon the size of corms in all media tested. Samira *et al*., (2015) stated that the large corms produce big flowers which has stigma with more length and weight.

The corms with 15 gm. to 25 gm. of weight produce average 3 shoots with flowers in soil culture 'f', the corms size 10 to 14.9 gm. produce average 2 shoots with flowers while the corms < 10 gm. mostly produce one shoot with flower in soil culture and Aeroponic. In 15% of the cases the corms between 7 to 10 gm. also produce 2 shoots in soil culture while in Aeroponic only one shoot produce flowers. De Mastro and Ruta (1993) reported that corm size has a positive effect on saffron flowering. Omidbaigi *et al*., (2002) reported the maximum number of flowers and daughter corms are obtained from the corms with 11 gm. of weight. They further reported that the mother corms has limited life span and after maximum flowering, aging will start, therefore this hypothesis should be rejected that by increasing corm, the number of flowers will increase without limitation. Mashayekhi & latifi (1998) reported that big corms are weak for flowering due to high vegetative growth but during present study we have observed positive correlation between number of flower and corm size under soil culture (d & f). Omidbaigi (2005) reported that from corms weight 15 gm. produce high quality saffron stigma. Sadeghi (1994) reported that the bigger corms increase the yield in the following years via production of bigger daughter corms. Flowering can be limited when mother corms below 8 gm. of weight are used, while the stigma yield and

percentage of flowering increase significantly with enhanced corm weight. During present study it was observed that the size of flower and stigma was larger when the corm weight was >15 gm. In two flowers of corm weight class 20 to 25 gm. five stigmas were reported during present study in culture 'f' (Fig 2). In the present study the weight of the fresh stigma ranged between 32 to 41 mg. in culture 'f' and its average stigma weight was higher than Aeroponic culture. Raina *et al*., (1996) reported that the average weight of fresh stigmas varied from 26 to 37 and length varied from 28 to 35 mm. Fredric & Pamella (2000) observed no difference in the stigma in hydroponic, Aeroponic and soil culture. Plessner *et al*., (1989) reported the stigma weight in plants growing in the nutrients and in soil culture were slightly lower than that of stigmas harvested from field plants. The size and weight of the corm was significantly reduced under Aeroponic as compare to the soil culture (d & f).

The vegetative growth of *Crocus sativus* 35 days after flowering in various cultures 'a' to 'f' under controlled environment system is summarized in Table 1. The biomass of the plants was significantly reduced after 35 days of flowering in culture variables 'a', 'b', 'c' & 'e' as compare to their initial weight. While in culture variables 'd' & 'f' the biomass was increased by 9.53% & 18.8% respectively. The shrinkage in corms were observed in culture 'a' after flowering and during shoot elongation and its biomass was reduced by 29.98 % probably due to the use of reserved food and discontinuous supply of required nutrients. The results indicate that the growth is influenced by the composition of culture variables which may help in the propagation of saffron in nontraditional areas and in controlled environment system. Saffron grows on a wide range of soil; Skrubis (1990) reported that the best growth performance of saffron is achieved on well drained clay calcareous & deep soil. Fernandez (2004) suggested that clay is good soil for saffron cultivation while Sampathu *et al*., (1984) reports that the saffron requires a well ploughed sand-clay loamy soil or a drained clay soil. Saffron is also cultivated on sandy soil in Azerbaijan (Azizbekova and Milyaeva (1999).

In the present study it was observed that composition 'f' shows the best results for flowering performance and vegetative growth of *Crocus sativus* in the culture room. Fredric and Pamela (2000) observed that the dry weight of the corms grown in Aeroponic and hydroponic was significantly higher as compared to soil culture. Negbi *et al*., (1989) observed that the rate of emergence of saffron plants shoot was inversely related to the planting depth. Mohammad *et al*., (2015) reported that the total corm dry weight showed a decreasing trend up to 120th days of plant growth and then increased until the end of life cycle (Mid May). Root & leaf dry weight increased up to 120th and 150th day of the plant growth cycle followed by decreasing trends. The total length of roots and leaf area increased up to the middle of growth cycle (Feb 10) and then decreased with a slower trend during the second flowering phase.

In the present study the average length of the plant in various culture variables were recorded 35 days after last flowering in the culture room, it was 12.3, 16.3, 21.1, 18.9, 18.7 and 28.2 cm in culture variables 'a', 'b', 'c', 'd', 'e' & 'f' respectively, the maximum plant length in culture 'f' (33.0 cm) was significantly higher than in culture 'a' (13.5 cm) indicates the impact of culture types on the vegetative growth of saffron (Fig. 3). The number of leaves per shoot remained 7 or 8 in all variables. Fredric & Pamela (2000) observed no significant difference in the number of shoot leaves produced per corm between the soil culture & soil less of saffron culture.

The results indicate that the soil culture plays a significant role in the flowering and vegetative growth of saffron in controlled environment system and may influence the future growth & multiplication of the corms in the field. The length of the leaves produced by corms grown in soil culture was 30% higher than Soilless culture. In culture 'f" this increase was as high as 65% of Aeroponic. A significant variation in length of the leaves in various soil cultures was also reported. Mohammad *et al*., (2015) reported that in the early growing session, leaves and root system were developed using mother corm reservoir, but at the end of the growth cycle replacement corm were grown by translocation reservoir from the saffron organs.

In soilless culture a few short, curlier roots were observed and their growth stops after attaining 0.3 cm length however in variables 'b', 'c', 'd', 'e' & 'f' the average length were 0.46 cm, 0.8 cm, 3 cm, 0.5 cm & 7 cm respectively and average number of root recorded were 23, 22, 47, 37 & 67 respectively, thus the

number of roots and their length also vary in different cultures. Unlike our observation Fredric and Pamela (2000) observed that the number of roots and their length was significantly greater in Aeroponic as compared to soil culture. Light is known to have an inhibitory effect on root growth (Poovaiah and Reddy 1991). A reduced root system could have negative effect on nutrient and water uptake leading to reduction in plant growth, probably accounting for the significant decrease in fresh biomass of corm observed in the nutrient culture system (Fredric and Pamela 2000). Inhibition of root development has been thought to be due to insufficient oxygen supply to the roots and lead to hypoxia and depressed root growth (Drew, 1997). Zobel (1991) reported the unusual root morphology observed in Aeroponic and Hydroponic culture is probably related to the mechanically resistance impeding the growth of the roots. Mechanically impeded roots have been reported to be shorter, thicker and more irregularly shaped than root grown in soil (Bennie 1991).

Figure 1: Showing Saffron Cultivation in Control Environment System.

Figure 2: Flower with Five Stigma.

Figure 3: Vegetative Growth of *Crocus sativus* in Culture Variabels after 35 days of flowering.

Table 1. The Vegetative growth and development of Crocus Sativus L. in Culture Variables under controlled environment system

		Aero	Vermi	V:Co:S	V:S:Cl	V:S:Cl	V:S:Cl
				2:1:1	2;1;1	2;2;1	1;1;2
Culture Variables*		A	B	C	D	E	F
Biomass							
	Avrg. Initial Weight in gm	9.34	8.9	8.52	9.13	9.36	9.68
	Avrg Weight after 35 days of last flowering	6.54	7.26	7.26	10	7.61	11.5
Leaf development							
	Shoots (No.)	1	1 to 2	1	1 to 3	1 to 2	1 to 3
	Leaves (No.)	0	7	7	7	8	7
	Leaf length (cm)	12.34	16.33	21.1	18.99	18.74	28.2
Root development							
	Roots (No.)	0	17.2	22.9	46.8	37.6	68.4
	Length (cm)	0	0.46	0.81	3	0.52	7

* *As mesured after 35 days of last flowering*
(3 Months 10 Days growth)

CONCLUSION

Flowering and vegetative growth of saffron is possible in a controlled environment in any geoclimatic region which may expend the area of saffron propagation in nontraditional area. The soil culture plays a significant role in the flowering and vegetative growth of saffron, as compared to soilless culture the soil culture gives better results, further the composition of soil again plays a vital role in its propagation, in this study, soil culture "f" showed the best results, so the composition of soil need some more composition to find the most suitable one, it may also help to find right composition of soil in the field. The size of corms plays a vital role in the flowering and vegetative growth of saffron. Further studies are needed to find out the most suitable soil composition for its propagation in controlled environment system and in nontraditional area.

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