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Study on Yield and Corm Regeneration of Saffron through Different Planting Geometry Patterns

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A B S T R A C T

A field experiment was conducted in order to examine the effect of different plant geometries and spacing between the pits on corm regeneration and yield. The experiment was laid out in a randomized block design with three replications at the Research Farm of Saffron Research Station, SKUAST-Kashmir, Pampore for 3 years viz., 2012-13, 2013-14 2014-15. The treatments consisted of three planting methods viz., 15 corms per pit (P_1), 10 corms per pit (P_2) and 5 corms per pit (P_3) and two spacing from pit to pit viz., 30x20 cms (S_1) and 25x10 cms (S_2). The statistical data and details from the second and third year of the experiment were evaluated and analyzed. Analysis of variance showed significant variation among all the treatments. The highest number of daughter corms/plot was obtained from the highest density (15 corms/pit) and wider spacing (30x20cms). It was also noticed that highest number of total corms/row weighting >10g, 5-8 g, <5 gram were recorded under the same treatment (P_1-15 corms/pit) as 9.00, 7.59 and 49.02 corms, respectively. Further, the total corm weigh /pit was significantly highest (158.55gms) in P_1 (15 corms per pit) treatment as compared to other treatments. With regard to the floral traits viz., no. of flower/plant, flower fresh weight (gm), flower dry weight (gm), stigma fresh weight (gm) and stigma dry weight (mg), the treatment P_1 (15 corms per pit) and spacing S_1 (30x20cms) produced significantly highest mean values for these traits. Significantly highest saffron yield (5.80 kg ha^{-1}) was recorded in the treatment P_1 (15 corms per pit), while the lowest yield (3.89kg ha^{-1}) was recorded in treatment P_3 (5 corms per pit), similarly the spacing treatment S_1 (30x20cms) produced the highest saffron yield (5.09 kg ha^{-1}) as compared to S_2 (25x10 cms) treatment (4.58 kg ha^{-1}).

Introduction

Saffron (*Crocus sativus* L.) a perennial herb belongs to Iris family Iridaceae is the most expensive spice in the world known for its aroma and colour and used for flavouring and colouring in medicinal and pharmaceutical industries. It is derived from the dry stigmas of the plant popularly known as the "Golden Condiment". The colour, flavour and aroma of saffron are mainly due to crocin, picrocrocin and safranal, respectively. Main constituents for intense colour of saffron are lipophilic and hydrophilic carotenoids. These are β-crocetin, γ-crocetin, α-carotene, β-carotene, lycopene, zeaxanthin. A glycosidic form of crocetin digentiobioside (crocin 1) is most abundant by weight and soluble in water. In saffron pigments, crocetin portion is common with different sugar moieties which are gentiobiose, D-glucose, and neapolitanose- a trisaccharide. The bitter taste of saffron is due to monoterpene aldehyde picrocrocin ($C_{16}H_{26}O_7$). For aroma, main constituent responsible is safranal and its hydroxyl derivative formed by hydrolysis of picrocrocin during drying. Besides, many other trace compounds also contribute to aroma of saffron. Due to very high crocin content and rich aroma, the Kashmiri saffron is famous worldwide and commands a premium price over the saffron available from Spain or Iran. It is principally used as food additive in dairy products, vegetarian and culinary dishes and gives pleasant flavour, distinctive colour and delicate aroma and is an irreplaceable spice. Besides, it is used in colouring industry, paintings and staining of histological sections. It is also used in cosmetic preparations due to antioxidant and probably anti-aging activity. Crocin, picrocrocin, safranal and crocetin also contribute to health-promoting properties. In small doses it is used as sedative, expectorant, stimulant, aphrodisiac and antispasmodic. Picrocrocin has a sedative effect on spasms.

Saffron is a legendry crop of Jammu and Kashmir produced on well drained karewa soils of Kashmir and Kishtwar where ideal climatic conditions are available for good growth and flower production. It grows at an elevation of 1500-2000 m amsl. Photoperiod and temperature exerts a profound influence on the flowering of saffron. An optimum period of 11 hours illumination and moderate temperature of about 18-20^{0}C during flowering is found optimum. Unusually low temperature coupled with high humidity during flowering season affects flowering. Spring rains boost production of new corms. Slightly acidic to neutral, gravelly, loamy, sandy soils are suitable for saffron cultivation. The cultivated saffron being a triploid, fails to produce seeds upon selfing or crossing. Because of this sterility, work on breeding saffron for better quality and higher yield is very difficult (Mathew, 1982). There is also a very rare genetic variation for increased number of stigmas, anthers and perianth parts in saffron (Estilai, 1978). Therefore, there are less possibilities for improving the produce quantitatively and qualitatively through conventional methods of selection and breeding. Thus leaving a room to improve yield and quality by agronomic manipulations for which a thorough knowledge of the growth stages and developmental behaviour of the saffron is considered a pre-requisite. Among other agronomic factors responsible for low yield of saffron under valley, planting geometry and spacing has a great role to play in increasing saffron yield and quality. Planting technique and spacing not only ensures proper adjustment and optimum plant population in the field but also enables the plants to utilize the land and other input resources more efficiently towards growth and development. Suitable planting density in saffron will increase the period of exploitation (Abrishami, 1997). Behdad (2001) studied plant density in both single and double corms and reported that single corm cultivation had lower performance. Behnia and Mokhtarian (2010) stated that 10 corms with 30 (cm) spacing between rows had maximum yield. The planting of saffron at higher densities led to increase in the yield during first three years of planting (Kochaki *et al.*, 2012).Spacing usually has a large effect on crop yield, however, so far little research on saffron spacing has been reported internationally. One-year study reported that the most-dense planting gave the highest stigma yield per unit area as expected (Bullitta *et al.*, 1996). However, planting at an intermediate density (inter-row spacing of 20 cm with intra-row spacing of 10 cm) was recommended by McGimpsey (1993). The objective of this study was to examine the effect of different plant geometries and spacing between the pits on corm regeneration and yield.

Materials and Methods

A field experiment was laid out in a randomized block design with three replications at the Research Farm of Saffron Research Station, SKUAST-Kashmir, Pampore for 3 years viz., 2012-13, 2013-14 2014-15. The treatments consisted of 3 planting methods viz., 15 corms/pit (P_1), 10 corms/pit (P_2) and 5 corms/pit (P_3) and 2spacing's (pit to pit) viz., 30x20 cms (S_1) and 25x10 cms (S_2). Recommended package of practices were followed for raising a healthy crop. Ten plants were randomly selected in each plot in each replication for obtaining the data on 5 corm traits viz., daughter corm/plot, total corm weight, number of corms (>10 g, 5-8 g and <5 g) and 6 floral and yield traits(for 100 flowers) viz., no. of flower/plant, flower fresh weight (gm), flower dry weight (gm), stigma fresh weight (gm), stigma dry weight (mg) and yield (kg/ha). Flowers were picked each day or each alternate day. The red part of the stigmas were cut by fingernails from the flower and dried in an oven at 50°C for 3 hours to a constant weight. Flower numbers were recorded separately for each plot. Weight of red stigmas was recorded on 100 flower basis. In order to monitor corm multiplication, 10 corm clusters (each derived from one planted corm) were randomly dug up. The diameter and weight of the largest corm were measured, and the number of smaller corms was also recorded. Corms were dug up from one-third of each plot. The diameter and weight of the largest corm from 30 random samples were measured, and the number and total weight of smaller corms were also recorded. The corms were sorted according to weight and re-planted. The data obtained in respect of various observations were statistically analyzed by the method described by Cochran and Cox (1963). The significance of "F" and "t" was tested at 5 % level of significance.

Results and Discussion

Floral traits and saffron yield

Analysis of variance for individual as well as interaction effects showed significant variation among all the treatments except flower dry weight, stigma fresh weight and stigma dry weight where effect were found non-significant (Table 1). These results are in agreement with the earlier reports of Mollafilabi *et al.,* (2014). The perusal of data (Table 2) indicated that planting densities and spacing produced significant difference on number of flowers/plant. The treatment P_1 (15 corms/pit) produces significantly highest number of flowers (1.97) while least number of flowers (1.64) were produced by treatment P_3 (5 corms/pit). Similarly, spacing of S_1 (30x20 cms) produced significantly higher number of flowers (1.95) as compared to S_2 (25x10 cms) spacing (1.60). Previous studies have shown that in the second experimental year, absorbing foods through roots and photosynthesis by leaves resulted in producing corms with more weights compare to the first year (Badiyala and Saroch, 1997), which had a positive effect on the number of saffron leaves and produced more assimilates (Pandy and Srivastava, 2000). On the other hand, larger corms increased flowering capacity and yield during next years through producing more daughter corms (Sadeghi, 1993). With regard to flower fresh weight, planting density showed significant increase from P_1 (15 corms/pit) to P_3 (5 corms/pit) and same trend was also noticed with regard to the spacing with significantly highest flower fresh weight in S_1 (30x20 cms) and lowest in S_2 (25x10 cms). The results also revealed that planting density of P_1 (15 corms/pit) exhibited significantly highest flower dry weight (6.14

g) which was followed by P_2 (10 corms/pit) (6.06 g) and P_3 (5 corms/pit) (5.94 g), however, spacing didn't produced any significant effect on flower dry weight. Similar trend was also noticed with regard to the stigma fresh and dry weight with significantly highest stigma fresh and dry weight in planting density of P_1 (15 corms/pit) and lowest in P_3 (5 corms/pit). These results are in agreement with the earlier reports of Nazarian *et al.,* (2016) who reported that highest number of flowers, flower fresh weight and (stigma + style) dry weight were obtained in high density plantation, while lowest values of these traits were obtained in low density plantation. Mohammadi *et al.,* (2013) observed that different planting densities have a significant impact on length of stigma. They mentioned that the length of stigma was reduced by increasing plant density due to competition among saffron plants. Gresta *et al.,* (2009) and Rostami and Mohammadi (2013) reported that there is a negative relationship between corm density and dry weight of stigma that is inconsistent with the present study. Juan *et al.,* (2009) observed that dry weight of stigma was decreased by increasing corm density. Since dry weight of stigma has effect on total yield, they believed that optimal density of corms depends on the yield comparison unit in such a way that if yield is expressed in terms of corm weight, less corm density will be more appropriate and if it is expressed based on area planted, more corm density will be better. Spacing treatments didn't showed any significant effect on the stigma fresh and dry weight, however, highest mean values for these traits were noticed in spacing treatment S_1 (30x20 cms). The present findings are in contrast with the earlier reports of Andabjadid *et al.,* (2015) who reported that length of stigma, dry weight of flower, fresh and dry weight of stigma were significantly affected by lesser spacing within rows. Yield of crop is the most important criterion for comparing and judging the efficiency of different treatments. The data regarding the effect of different treatments on saffron yield are presented in Table 2. Planting densities showed significant effect on saffron yield. The planting density of P_1 (15 corms/pit) recorded significantly higher yield (5.80 kg ha^{-1}) as compared to (4.89 ha^{-1}) and (3.89 ha^{-1}) at planting densities of P_2 (10 corms/pit) and P_3 (5 corms/pit), respectively. Similarly, spacing treatment S_1 (30x20 cms) showed significantly higher yield (5.09 kg ha^{-1}) as compared to 4.58 kg ha^{-1} in spacing treatment of S_2 (25x10 cms). It seems that increasing corms density and reducing corms distances between and within rows, cause enhancement in yield. Results of the present study are in accordance with the earlier reports of Behnia (2008) and Kochaki *et al.,* (2012) who concluded that yield increased significantly by increasing plant density. Galavand and Abdollahian-Noghani (1994) reported that planting pattern of corms in 30 (cm) distance between lines and 10 (cm) space within rows had more performance. Alavi-Shahri *et al.,* (1994) stated that by increasing corm density, saffron yield increased. They believed that more spacing between rows and within rows were appropriate in terms of performance increase. Yau and Nimah (2004) indicated that more planting distances is superior than lesser distances. Results of the present study is in conflict with results of Mohammad-Abadi *et al.,* (2007) who reported planting density had no significant effect on the saffron yield. Probably interaction of planting density with numerous factors such as planting depth and method can contain different effects and therefore different results can be attributed to these cases. High planting density increases the yield in the unit area and limits the exploitation period of saffron. Researchers concluded that the highest yield and the exploitation period of saffron can be obtained in the highest planting density (Naderi Dar BaghShahi *et al.,* 2008).

Table.1 Analysis of variance of corm traits of saffron

Source	df	Mean squares				
		Daughter corm/plot	Total corm weight	>10 g	5-8 g	<5 g
Replications	2	70.45	362.71	1.68	1.45	39.17
Factor A	2	2054.80**	18419.23**	18.50**	6.50**	1075.17**
Factor B	1	112.60**	264.65*	12.52**	2.00**	98.09**
Factor A X B	2	10.49*	15.49	0.50*	0.50**	9.51*
Error	10	1.54	13.43	0.02	0.01	0.82
Total	17					

Table.2 Influence of planting density and spacing on corm attributes of saffron

Treatments	Daughter corm/plot	Total corm weight	>10 g	5-8 g	<5 g
P_1 (15 corms/pit)	66.52	158.55	9.00	7.59	49.02
P_2 (10 corms/pit)	43.02	110.04	7.00	6.91	32.51
P_3 (5 corms/pit)	30.01	48.02	5.50	5.50	22.53
SE(m)±	0.716	2.116	0.077	0.043	0.523
CD	1.595	4.712	0.172	0.097	1.164
S_1 (30x20 cms)	49.02	109.37	8.00	7.00	37.01
S_2 (25x10 cms)	44.01	101.70	6.33	6.33	32.34
SE(m)±	0.585	1.728	0.063	0.036	0.427
CD	1.302	3.848	0.140	0.079	0.950

Table.3 Analysis of variance for floral traitsand yield (100 flowers) of saffron (100 flowers)

Source	df	Mean squares					
		No. of flower/plant	Flower Fresh weight (gm)	Flower dry weight (gm)	Stigma fresh weight (gm)	Stigma dry weight (mg)	Yield (kg/ha)
Replications	2	0.10	49.82	1.18	0.05	11308.10	0.76
Factor A	2	0.13**	72.34**	0.06**	0.07*	1775.55*	5.44**
Factor B	1	0.60**	4.50*	0.00	0.00	0.50	1.21**
Factor A X B	2	0.64**	95.68**	0.11**	0.14*	4479.25*	0.03*
Error	10	0.00	0.12	0.00	0.01	247.03	0.00
Total	17						

Table.4 Influence of planting density and spacing on floral traits and yield of saffron (100 flowers)

Treatments	No. of flower/plant	Flower Fresh weight (gm)	Flower dry weight (gm)	Stigma fresh weight (gm)	Stigma dry weight (mg)	Yield (kg/ha)
P_1 (15 corms/pit)	1.95	42.87	6.14	3.48	698.23	5.80
P_2 (10 corms/pit)	1.76	39.26	6.06	3.30	676.73	4.82
P_3 (5 corms/pit)	1.64	35.21	5.94	3.22	664.22	3.89
SE(m)±	0.016	0.203	0.007	0.042	9.074	0.039
CD	0.035	0.452	0.016	0.094	20.208	0.087
S_1 (30x20 cms)	1.97	40.61	6.08	3.41	681.89	5.09
S_2 (25x10 cms)	1.60	37.42	6.01	3.26	676.56	4.58
SE(m)±	0.013	0.166	0.010	0.045	7.409	0.055
CD	0.028	0.399	NS	NS	NS	0.071

Corm and corm attributes

Analysis of variance for planting density, spacing and their interaction showed significant effects on all the traits related to corm (Table 3). The data on daughter corms/plot as influenced by planting densities and spacings are presented in Table 4.

Significantly the highest daughter corms (66.52) were recorded in planting density P_1 (15 corms/pit) and the lowest (30.01) was noticed in planting density P_3 (5 corms/pit). These results are in line with the earlier reports of Behnia and Mokhtari (2009) who reported that maximum density of saffron corms produced the highest number of corms per row.

The results of Torabi and Sadeghi (1994) showed that by dwindling maternal corms, daughter corm roots don't have any role in absorbing food and to make larger daughter corms, it depends on the food transferring from mother to the daughter and also photosynthesis process.

It seems that in the second year, the cell division in corms and growth of leaves occur sooner which provides greater use of environmental conditions and finally results in more photosynthetic material to be transferred into root and producing corms with more weight at the end of the growth year (Moolina *et al.*, 2005).

In another 5-year research, Alavi-Shahri *et al.*, (1994) stated that increasing plant density significantly increases saffron yield and they recommended the higher density with close spacing for achieving higher yields. Significantly highest daughter corms/plot (49.02) were recorded in spacing S_1 (30x20 cms) as compared to 44.01 daughter corms/plot in S_2 (25x10 cms). The data pertaining to total corm weight (Table 4) revealed that planting density P_1 (15 corms/pit) produced significantly high total corm weight (158.55 g) while the lowest corm weight was recorded in treatment P_3 (5 corms/pit) (48.02). These results are in accordance with the earlier reports of Juan *et al.*, (2003) who reported that planting at high density m^{-2} gave the highest corm yield. Pandey and Srivastava's study (2000) showed that increase in the weight/density of corm has a positive effect on number of daughter corm formation and saffron yield during the next years.

Spacing S_1 (30x20 cms) showed significantly more total corm weight (109.37 g) as compared to S_2 (25x10 cms) (101.70 g). It was also noticed that significantly highest number of total corms/row weighting >10g, 5-8 g, <5 g were recorded in treatment P_1 (15 corms/pit) as 9.00, 7.59 and 49.02 corms, while lowest number of corms/row were recorded in treatment P_2 (10 corms/pit) as 5.50, 5.50 and 22.53, respectively.

Similarly, spacing treatments also produced significant effects on number of corms/row. The treatment S_1 (30x20 cms) produced significantly highest number of corms/row (8.00, 7.00 and 37.01) as against of 6.33, 6.33 and 32.34 in S_2 (25x10 cms) treatment, respectively.

The study of Naderi-Darbaghshahi *et al.*, (2008), showed that plant method and density showed significant effect on the number of corn per unit of area. The number of corm produced in furrow cultivation method (391.8 corms per square meter) was significantly more than the number of corms in basin method (334.1 corms per square meter). They stated that this appropriate number of corms can be attributed to the less soil density around maternal corms and better growth possibility, which can have significant effect on yield during the next years. Since daughter corms are formed on the maternal corms (Behnia, 1990), and their production depends on attributing additional assimilates of maternal corms, and density effects on this property through making production resource restriction, this research tried to analyze the effect of plant density on the amount of saffron corm regeneration.

In the present research different plant density and spacing's were used in order to improve corm and saffron yield and it was noticed that both these treatments showed significant effect on corm and saffron yield. Thus, the study lead to the conclusion that for realizing higher number of daughter corms and saffron yield, the corm density should be 15 corms per pit with a spacing of 30x20 cms from pit to pit. But such studies require more critical testing at various locations over a longer period before final recommendations are made.

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