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Cost-effective saffron production system module for corm weight and planting density

Bashir A. Alie[1], Mudasir H. Khan[1*], Niyaz A. Dar[1], Ghulam H. Mir[1], Sher A. Dar[2], A. A. Lone[2], Azra Khan[1], Uzma Fayaz[1], Mohammad T. Ali[1], Arif H. Bhat[1]

[1]Advanced Research Station for Saffron and Seed Spices, SKUAST-Kashmir, India.
[2]Dryland Agriculture Research Station, SKUAST-Kashmir, India.

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***Correspondence**
Mudasir H. Khan
drmhkhan@skuastkashmir.ac.in

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Production of Saffron (*Crocus sativus* L.) is expanding in both the traditional and non-native areas of Jammu and Kashmir, India. A study was carried out to develop a cost-effective production system module at ARSSSS, SKUAST-Kashmir, Pampore to determine suitable corm weight and planting density for saffron. The treatments in the current study includes 3 levels of corm weight (W_1= < 8g, W_2= 8-12g and W_3 = >12g) and 5 levels of corm densities viz., 15 lakh corm density/ha, 12 lakh corm density/ha, 10 lakh corm density/ha, 05 lakh corm density/ha and 03 lakh density/ha (farmers practice). Economically, saffron corms were sown in ditches plant geometry to accommodate 04 saffron corms, irrespective of densities. The observations were recorded on percentage of plant emergence, number of flowers per unit area, rod length, stigma length, fresh weight and dry weight of flower, stigma fresh and dry weight, total stigma yield, corm multiplication ratio, the onset of the flowering and flowering period. The results showed that all the factors mentioned above other than rod length and stigma quality were significantly affected by corm weight and planting density. Corms with higher weight started flowering earlier and their flowering time was longer than other treatments. Four years of evaluation of the experiment confirms marked superiority in yield by planting corms weighing >7g with a plant population of 12 lakh corms/ha on a raised bed for a duration of 4 years.

Key words: *saffron, Crocus sativus, corm density, geometry, yield, quality*

INTRODUCTION

Saffron (*Crocus sativus* L.) is a perennial, medicinal, non-stemmed plant with chromosome number of 2n = 3x = 24 that belongs to the family Iridaceae. It is a triploid sterile plant and is vegetatively propagated through corms. It grows well in open, low, and well-drained soils. Saffron is one of the most expensive spice of the world composed of large number of bioactive molecules chiefly crocin, picrocrocin and safranal that are responsible for its colour, aroma and flavor. The chemical composition of saffron is believed to have anti-carcinogenic, cytotoxic, and anti-tumor properties. Quality and quantity of saffron is largely determined by various factors such as soil, climate, corm weight, planting time, corm size, planting depth, crop density, nutrient management, weed management, harvesting and post-harvest management. Production and yield of saffron is largely governed by size and weight of the saffron corms. The saffron corms usually have a globular shape with 0.5 to 5.0 cm in diameter that bears 6 to 14 small, needle shaped leaves about 29-40 cm in length and 2.1-3.5 mm in width around 4 to 5 scales with glabrous or ciliates in the lower region. Depending on the weight of the corm, each corm contains 1-4 apical buds from which the flowers and leaves appear. Apart from the apical bud the corm also contains many lateral buds from which small cormlets originate. Depending on the nutrient management and soil health, the corm weight varies between 1-20 g. Usually mixed grade corms (big and small sized corms) are planted in a ratio of 60:40 so as to increase the productivity per unit area in 4 years of planting cycle. Nehvi et al. (2004) reported that planting corms with >3 cm diameter and 8 g weight resulted in the increased number of flowers and leaves per unit area and were more productive as compared to small corms. A positive association between the planting of bigger corms and the formation of bigger daughter corms in the following season was reported by Sadeghi (2010); Ali et al. (2013). Similarly, Omidbaigi et al. (2002) reported that corms weighing >11 g produced the maximum number of flowers and daughter corms as compared to corms weighing >6 g.

Suitable corm density is another important aspect for improving productivity per unit area. Behdad (2001) reported that planting 2 corms/hill showed high performance with regard to productivity per unit area as compared to 1 corm/hill. Similar results were also reported by Behnia & Mokhtarian (2009) and Mollafilabi (2004) who concluded that planting corms at high density showed high B:C ratio in comparison to lower density in 4 years of planting cycle. Kochaki et al. (2012) observed that planting of saffron corms at higher densities increased the yield during 1st three years of planting after which a decreasing trend in saffron production was noticed and thereafter a decrease in yield was observed. Keeping in view all the above facts, the current study was therefore attempted with the aim to determine the effect of corm weight and planting density on the yield and quality of saffron under temperate production system.

MATERIALS AND METHODS

The present investigation was carried out at the Research Farm of ARSSSS, SKUAST-Kashmir, Pampore during kharif seasons of 2017-2020 on flat karewa land. The experimental site was located at 34°01′N and 74°56′E with an average elevation of 1574 m amsl. The soil of the experimental plot was silty clay, acidic (pH 6.45) and low in organic carbon (0.61%). Available nitrogen, phosphorus and potassium in the soil were 276, 16 and 312 kg/ha, respectively. The treatments consisted of three levels of corm weight (W_1= < 8g, W_2= 8-12g and W_3 = >12g) and 5 planting densities viz., 15 lakh corm density ha^{-1}, 12 lakh corm densityha^{-1}, 10 lakh corm densityha^{-1}, 05 lakh corm density ha^{-1}and 03 lakh density

ha^{-1} (farmers practice). Economically, saffron corms were sown in ditches plant geometry to accommodate 04, irrespective of densities.

The treatments were 15 combinations of 3 corm weights and 5 densities. A factorial randomized block design with three replications was used for the conduct of the experiment. Spacing between two adjacent plots and blocks was kept as 0.25 m and 0.75 m, respectively. The corms were treated with carbendazim (50% WP) for twenty minutes before planting. Planting of the corms was done in August at different densities as per treatment. For the preparation of the field, first the cross ploughings were done which was followed by crushing soil clods with the help of disc harrow and then the soil was brought to a fine tilth by using a power tiller and then leveled. FYM @ 15 t/ha was mixed with the soil at the time of final land preparation. Vermicompost @ 5q/ha along with ½ dose of nitrogen (30 kg N) and full dose of phosphorus (60 kg P_2O_5) and potassium (40 kg K_2O) were applied as basal dose and the rest 60 kg N/ha was applied in two equal split doses in December and February when moisture was available. All recommended production technologies were adopted for raising and maintaining a healthy crop.

For the recording of observations, 10 plants were randomly selected from each plot and were studied for growth, yield attributes, corm yield and quality traits. Data was also collected on plant stand percentage and expressed at harvest as percentage of corms planted. Irrigation was given/applied through sprinkler system and flowers were picked at 4th week of October to 10th of November during each year of experimentation. Data recorded were statistically analyzed as per the method suggested by Cochran and Cox (1963). Mean differences between and among the treatment were tested by F-test and when the F-test was found to be significant, critical difference (C.D) at 5 % level of significance was calculated. Relationship between different parameters was calculated by correlation and regression analysis and the following prediction equation used was $Y=a+b_1X_1+b_2X_2$; where Y= saffron yield; a=intercept; b_1-b_2= regression coefficients; X_1 plant height; X_2=Number of flowers/corms. Relative economics was also worked out under temperate conditions.

Weather

The climate of the study area is temperate and usually remains under snow cover for about three months (December to February). The annual rainfall of the area is about 650-750 mm, temperature ranges from -3°C in January to 30.6°C in summer and relative humidity varies from 50 to 82%, respectively. The ambient temperature varies between a minimum of -11°C during 1st week of January to a maximum of 34°C in the month of July. The mean daily temperature varied from 16-32°C and the mean daily radiation from 11-27 MJ/m^2. These ranges of variation define the limits of the applicability of the study.

RESULTS AND DISCUSSION

Growth parameters

All aspects of growth and yield attributing traits except length of rod, stigma length and quality parameters were significantly influenced by the corm weight and corm density, which highlights the importance of agronomic factors under study. Corm density and corm weight showed significant effect on the flowering period. Corm sprouting percentage was also significantly affected by the weight of the corms. Corms weighing 8 to 12g and >12g exhibited the highest sprouting percentage (166.23 & 174.75) (Table 1). Koocheki et al., 2019 reported that flower yield in large and medium sized corms is twice than small sized corms. Sadeghi (2010) reported that the sprouting percentage of corms with diameter 8 to 10 (cm) was more than medium and small corms. Buds that appear early produce stronger plants and high percentage of flowers.

Table 1. Corm weight and density influence on growth and yield parameters of saffron (Pooled Data)

Treatment	Emergence percentage	Number of flower per m^2	length of rod (cm)	Leaf length (cm)	Stigma Length (cm)	Fresh stigma yield (g/m^2	Flowering period (days)	Quality Parameters (E$^{1\%}$) Crocin	Picrocrocin	Safranal
Corm weight (g)										
W1: <8	92.35	52.12	12.20	18.52	3.1	1.00	16.9	308.9	107.4	47.7
W2: 8-12	166.23	112.33	15.65	24.65	3.7	2.03	27.2	310.2	109.3	48.3
W3: >12	174.65	121.85	17.45	26.87	3.8	2.21	24.7	309.9	108.6	47.9
SEm±	1.8	2.3	2.7	0.65	1.10	0.027	1.41	1.8	2.6	1.3
CD (P=0.05)	5.8	6.6	NS	1.70	NS	0.084	3.10	NS	NS	NS
Corm density (Lakhs/ha)										
15	143.20	82.56	16.55	24.65	3.6	1.72	25.3	309.2	110.6	48.2
12	151.45	91.10	16.25	25.75	3.7	1.88	26.7	310.1	111.3	48.4
10	136.70	78.85	15.75	24.25	3.6	1.62	24.8	309.3	110.9	48.9
05	84.70	53.70	16.80	27.60	3.6	1.11	25.5	310.3	109.5	47.8
03	62.85	41.85	15.40	28.25	3.5	0.85	24.9	308.9	108.9	47.5
SEm±	2.1	1.18	1.9	0.089	1.7	0.10	0.04	3.2	2.8	1.9
CD (P=0.05)	6.2	3.65	NS	0.301	NS	0.29	0.15	NS	NS	NS

Yield Parameters

Number of flowers per unit area

The average comparison of the number of flowers in each unit area at different levels of corm size within rows showed that the density of the upper corm has more flower numbers per m^2 compared to the smaller corm size (Figure 1 & 2).

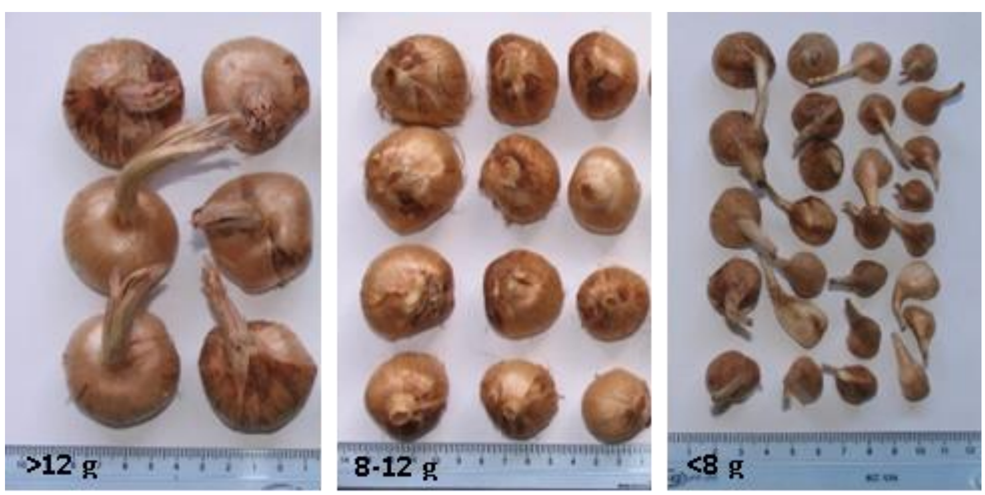

Figure 1. Grades of corms used in the study

Increasing the density of saffron corms has a positive effect on flower numbers and pollination. Rostami & Mohammadi (2013) reported that with the increase in corm abundance, flowers in each area are developed sequentially.

Figure 2. Number of flowers per unit area

Bigger corm and high planting density showed significant effect on number of flowers per m^2 over other treatments while the lowest number of flowers were noticed in the control treatment (Table 1). Ramazani (2000) pointed out that larger corm that produce more flower and have more stored food, are able to produce more daughter corms with bigger size. Molina et al., (2005) reported that size and weight of corm is a major factor that determines the ability of flowering in saffron. It was also noticed that there was a positive relationship between rate of leaf photosynthesis and mother corm size as bigger corms exhibited higher leaf area as compared to the smaller corms which leads to a high accumulation of stored food in alternate corms and thereby produced more flowers and higher stigma yield during the following years. The maximum number of flowers/m^2 is attributed to planting corm density of 12 lakh/ha. These results are in conformity with the earlier reports of Douglas et al. (2014), Ali et al. (2018) and Kumar & Sharma (2018). High plating density seems to favour more number of sprouts and subsequent more number of small baby corms, but this advantage out-weighed by overcrowding of corms and less flower raising index due to small size corms.

With regard to the effect of corm density on comparison of no. of flowers in per unit area it was noticed that higher corm density produced more number of flowers per m^2 as compared to the lower corm density. Gresta et al. (2009) reported that high corm density of saffron corms showed positive association with the number of flowers and stigma yield. Rostami and Mohammadi (2013) reported that flowers per unit area increased linearly with increased corm density.

Length of rod

Corm weight and corm density showed non-significant effect on length of rod (Figure 3). However, higher mean values of the parameter were recorded at higher levels of the treatments (Table 1). Sadeghi (2010) reported that corm size significantly affected the length of rod from the 2nd year of planting as corms of larger size showed longer rods.

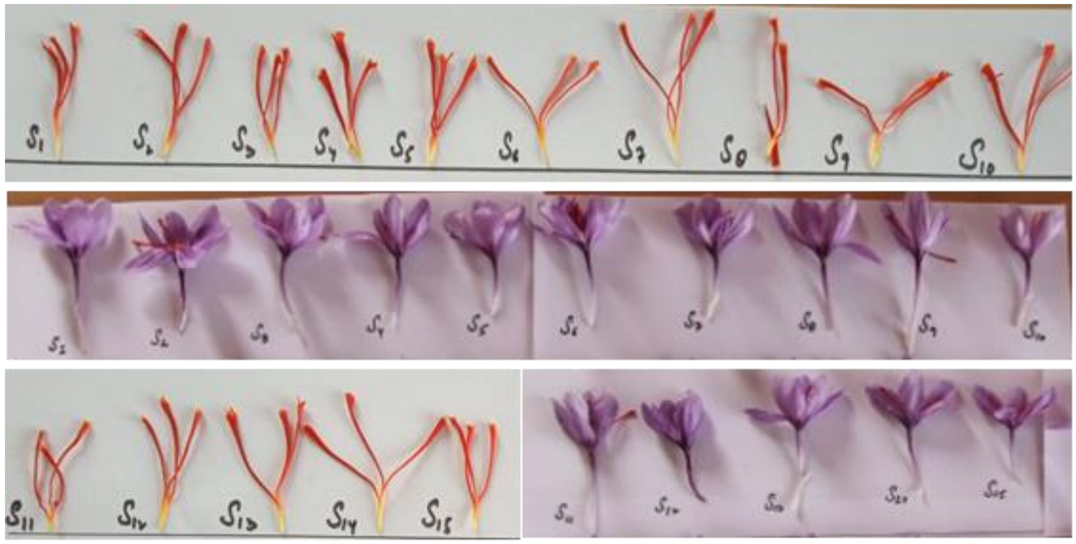

Figure 3. Length of rod and stigma

Length of stigma

The association between the length of the stigma and the corm weight was significant, however, corm density didn't affect significantly on the stigma length. It was noticed that the flowers obtained from the corms weighing <7 g produced short stigmas as compared to the corms weighing >8 grams (Table 1). This might be due to the fact that the bigger corms contain more stored food as compared to the small corms and the flower emergence in saffron occurs before the vegetative phase of the crop when the roots are not fully developed. These findings are in line with the observations of Rostami & Mohammadi (2013) and Mahdi et al. (2019) who reported length of stigma showed significant variation at different planting densities. They further reported that the higher plant density of saffron showed negative effect on the length of stigma due to more competition between saffron plants for nutrients, moisture etc. which is in contrast with the present findings.

Fresh weight of the flower

Results showed that corm weight and corm density significant influenced the fresh weight of flowers (Table 1). Flowers obtained from corms weighing >8g corms showed more fresh weight as compared to the other treatments. Similar findings were also reported by Mahdi et al. (2019) and Douglas et al. (2014) who observed that flower weight was significantly affected by corm weight. Bigger corms produced flowers with higher weight as compared to the smaller corms and the decrease in the corm weight was associated with the decrease in flower weight.

Fresh and dry weight of stigma

Results of the data as indicated in Table 1 showed that corm weight and corm sowing density significantly affect the fresh and dry weight of stigma. Interaction between that corm weight and corm density treatments also revealed that stigmas of flowers obtained from smaller corms with less corm density showed the less fresh and dry weight of saffron (Table 2). These results are in conformity with the findings of Gresta et al. (2009) and Rostami & Mohammadi (2013) who revealed that corm density is negatively correlated with dry and fresh weight of stigmas. The results were further confirmed by the study of De Juan et al. (2009) who reported negative relationship between corm density and dry and fresh weight of stigmas, however, Mahdi et al. (2019) reported that the fresh and dry weight of stigmas increased with the increase in corm weight. Bigger corms produced flowers with high fresh and dry weight of stigma as compared to the small corms. The reasons might be that bigger corms contain more stored food as compared to small corms which helps in formation of stigmas with higher weight. Since the dry or fresh weight of stigma has direct positive relationship with the total yield, they believe that optimum corm density depends on the yield comparison unit in a way that if yield is expressed in terms of corm weight then less corm density is desirable while if yield is expressed on the basis of planting area then high corm density will be better.

Table 2. Interaction effect of Corm weight and density influence on dry stigma yield, flower yield and corm yield of saffron

Treatment	**Corm density (Lakhs)**					
	15	**12**	**10**	**05**	**03**	**Mean**
Corm Weight (g)	**Saffron flower yield (kg/ha)**					
<8	124.5	147.8	112.0	057.0	032.0	94.66
8-12	218.4	239.2	196.8	127.1	099.0	176.10
>12	229.5	257.5	213.5	136.5	114.5	190.30
Mean	190.80	214.83	174.10	106.87	81.83	
Corm weight SEm± =11.60 Density SEm± = 14.20 Corm weight x Density SEm± = 21.6						
CD (P=0.05) = 21.6 CD (P=0.05) = 24.6 CD (P=0.05) = 41.8						
	Saffron dry stigma yield (kg/ha)					
<8	2.85	3.05	2.45	1.30	0.95	2.12
8-12	7.75	8.25	6.60	4.15	2.80	5.91
>12	7.95	8.45	6.85	4.75	3.05	6.21
Mean	6.18	6.58	5.30	3.40	2.27	
Corm weight SEm± =1.70, Density SEm± = 1.24, Corm weight x Density SEm± = 2.35						
CD (P=0.05) = 3.8 CD (P=0.05) = 2.6 CD (P=0.05) = 4.5						
	Saffron corm yield (kg/ha)					
<8	12275	9920	8375	4365	2875	7562
8-12	25800	24735	22220	11065	6930	18150
>12	27255	26595	24635	12121	7605	19642
Mean	21777	20417	18410	9184	5803	
Corm weight SEm± =161.40, Density SEm± = 176.30, Corm weight x Density SEm± = 212.50						
CD (P=0.05) = 298.50 CD (P=0.05) = 314.25 CD (P=0.05) = 410.80						

Total yield

The total yield of saffron as affected corm weight and density are presented in Table 1&2. Data revealed that planting corms with >8.0 g and above weight have significant effect on total yield of saffron over other treatments including control (farmers practice). Molina et al. (2005) reported that bigger corms have more cell division, earlier leaf growth and longer growing period than smaller corms and which makes bigger corms to grow better and produce heavier daughter corms that support higher yields. Interaction of corm weight and higher corm density also exhibited significant effect on the total saffron yield (Table 1 and 2). These findings are in conformity with the earlier reports of Iqbal et al. (2012), Andabjadid et al. (2015) and Mahdi et al. (2019) who are of the opinion that planting bigger saffron corms >12 g weight at higher density increases the saffron yield which results from the increase in number of plants and flowers. High planting density lead to big flower size with high weight of stigma and thereby increases the total yield. Yau & Nimah (2004), Behnia (2008) Gresta et al. (2008) reported that high weight in mother corms leads to increase in number and weight of daughter corms. Our findings are further supported by

Çavuşoğlu & Erkel (2009) who reported that large sized corms gave higher yield of saffron. The current results are in contrast with the earlier reports of Mohamad-Abadi et al. (2007) who reported non-significant association between planting density and saffron yield.

Flowering period

Data presented in Table 1 showed significant effect of corm weight had on the flowering period. Further, flowering of big corms began five days earlier and last for longer period as compared to the smaller corms (Table 1). These results are in accordance with the earlier studies of Çavuşoğlu & Erkel (2005) who observed that larger corms have longer flowering period as compared to smaller corms. This may probably due to the low physiological functions of smaller corms which ultimately lead to the production of smaller flowers (Renau-Morata et al., 2012). On the other hand Rostami & Mohammadi (2013) revealed that higher plant density trigger earlier flowering and also decreases flowering period which may be due to high emergence of flower tube due to high density. Planting corms at 12 lakh/ha significantly enhanced the flowering period of saffron crop. High plating density seems to favour more number of less productive sprouts and ensuring more number of small daughter corms, but this advantage out-weighed by overcrowding of corms and less flower raising index in coming years due to small size corms.

Quality Parameters

A perusal of the data presented in Table 1 showed that plant density and corm weight had no significant effect on Crocin, Picrocrocin and Safranal contents, however, as per ISO specification, the mean values of these traits were in the Grade I category. These results are in line with the observations of Koocheki & Seyyedi (2016) and Hajj et al. (2019).

Response analysis

In saffron, correlation analysis among important parameters (Table 3) revealed that Saffron flower yield (0.987**), Stigma Length (0.782**), Fresh stigma yield (0.962**), Saffron corm yield (0.738*) and Flowering period (0.894**) showed significant association with saffron dry stigma yield. Among all, two important parameters i.e. Saffron flower yield and Flowering period are strongly correlated with Saffron dry stigma yield. Their regression revealed that 84% of total variation in Stigma yield can be accounted by linear function involving Saffron flower yield and Flowering period. The model for predicting stigma yield on the basis of these two parameters is Y= -5.58+264.65 SFY+27.78 FP (Where, Y= Yield (kg); SFY= Saffron flower yield and FP Flowering period (days). Partial regression coefficients revealed that flowering period caused only 12% influence on stigma yield. However, saffron flower yield caused 75% influence. So appropriate plant density is prerequisite to get desired saffron yield.

Relative economics

Cost of cultivation and net returns analysis (Table 4) indicated that saffron cultivation provided higher returns. The net return and the net return per rupee invested varied from Rs. 66870 to Rs. 4426114 and -0.09 to 1.91 in different treatment combinations. Comparatively higher net returns of Rs. 4426114 were obtained when medium sized corms (8-12g) were planted at 12 lakh density. It could be even more remunerative if market for dispersal of saffron could be established. Thus, it was concluded that saffron corms weighing 8-12g should be planted at density of 12 lakh corms/ha to get optimum saffron yield and consequently higher return under prevailing climatic conditions of Pampore area of Jammu and Kashmir.

Table 3. Correlation Co-efficient among growth, yield and quality parameters as influenced by corm weight and density

Variables	Leaf length (cm)	Saffron flower yield (kg/ha)	Stigma Length (cm)	Fresh stigma yield (g/m²)	Saffron dry stigma yield (kg/ha)	Saffron corm yield (kg/ha)	Flowering period (days)
Leaf length (cm)	1.000	0.678*	0.789*	0.674*	0.756*	0.878**	0.542
Saffron flower yield (kg/ha)		1.000	0.788*	0.893**	0.987**	0.865**	0.887**
Stigma Length (cm)			1.000	0.734*	0.782**	0.637*	0.587
Fresh stigma yield (g/m²)				1.000	0.962**	0.673*	0.923**
Saffron dry stigma yield (kg/ha)					1.000	0.738**	0.894**
Saffron corm yield (kg/ha)						1.000	0.534
Flowering period (days)							1.000

*Correlation is significant at the 0.05 level (2-tailed)
** Correlation is significant at the 0.01 level (2-tailed)

CONCLUSION

The different weights and densities had a strong impact on the yield and yield attributing traits of saffron. Bigger sized corms had more food reserves which led to early sprouting and thereby increased number of plants and flowers per unit area which ultimately results higher total yield. Further bigger corms start early flowering due to the high physiological ability of the corm. Thus, the study leads to the conclusion that planting of mixed grade corms (60:40, Big: Small) at medium densities (8-18 lacs/ha) would be appropriate for yield gains in saffron, however, more trials needs to be planted at multi-locations to arrive at the final conclusion/ recommendations.

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AUTHOR CONTRIBUTIONS

Bashir A. Alie, Mudasir H. Khan: Conceptualization, methodology, interpreted the results, writing original draft preparation; Niyaz A. Dar, Ghulam H. Mir: Conducted the field trials, formal analysis; Sher A. Dar, A. A. Lone: Writing-review and editing; Azra Khan, Uzma Fayaz: Quality analysis of saffron; Mohammad T. Ali, Arif H. Bhat: Collected the field data.

INTERESTS

The authors declare that there is no conflict of interest among each other.

ETHICS APPROVAL

Not important for this work

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