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The saffron plant's generative corm generation and stigma yield are influenced by planting methods and corm depths

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ABSTRACT

Planting methods and corm depth may damage the underground corms of saffron during the dormant period in heavy rainfall areas. Consideration of proper planting methods and corm depth will lead to a higher yield of saffron. This research was conducted for two successive seasons (2020 - 2021 and 2021 - 2022) to study the influence of planting method and corm depth on the dry stigma and generative corm yield of saffron. The experiment was a factorial combination of two planting methods (ridge and flat) and three corm depths (10 cm, 15 cm, and 20 cm), laid out as a randomized complete block design (RCBD). Results revealed that dry sigma yield (DSY) and generative corm yield (GCY) were significantly influenced by the main and interaction effects of planting method and corm depth. In flat cultivation, both DSY and GCY were considerably higher than the ridge method in both years. In the case of corm depth, 15 cm and 20 cm produced the highest DSY. The interaction effects showed that the flat method in 15cm corm depth produced more DSY and GCY. Moreover, a strong positive correlation was obtained among the days to flowering (DTF) and flowering interval days (FID) first year, the number of flowers (NF) and DSY in both years and among the DSY and the number of generative corms (> 8 g). Hence, the flat method and 15 cm corm depth are recommended for optimum yield in the study area.

Keywords: *Crocus sativus* L., irrigation, planting method, corm weight and yield

INTRODUCTION

Saffron (*Crocus sativus* L.) is a perennial crop (Koocheki and Seyyedi, 2015; Ali et al., 2018; Azizi – Zohan et al., 2009; Askari-Khorasgan, 2019) which widely adopt in arid and semi-arid regions of the world (Lage and Cantrell, 2009; Sepaskhah and Kamgar-Haghighi, 2009; Alizadeh et al., 2009; Yarami et al., 2011). The dry stigma of saffron is the most expensive spice in the world because it contains the compounds crocin ($C_{44}H_{64}O_{24}$), picrocrocin ($C_{16}H_{26}O_7$) and safranal ($C_{10}H_{14}O$) (Cardone et al., 2019, Melnyk et al., 2010; Zeka et al., 2015). Although the use of Italy's saffron has a long history Iran produces 90% of the world's saffron (Vahedi et al., 2018). Saffron has been grown in Afghanistan for about 2000 years (DACAAR, 2007), but in the last two decades, the Afghan government has promoted it as a substitute crop for opium poppies in the agricultural sector to increase national GDP and women's engagement in economic activities (Minoia and Pain, 2016). Afghanistan produced 3.5 tons of saffron and had a 2000-hectare agricultural area in 2016 (MAIL, 2019). The Afghan saffron ranks first out of 300 samples tested by the International Taste and Quality Institute (ITQI) around the globe (Cardone et al., 2020).

Due to its triploid (2n = 24, x = 8 chromosomes) male sterility, saffron is unable to generate viable seeds (Skinner, 2017; Kothari et al., 2021; Renau-Morata et al., 2012). Asexual reproduction takes place by daughter corms. Breeders find it challenging to enhance this crop for better quality and greater output due to its sterility. Therefore, in order to produce the greatest number of flowers and corms during the growing season. So, it is important to develop a package of Agronomic practices to enhance saffron productivity in specific areas. The two basic cultural practices for saffron cultivation that differ from region to region are planting method and corm depth.

Each country in the world uses a different planting method. In Iran and Afghanistan, flatbed and ridge bed methods are common, and the furrow method is followed in Spain (Kumar and Sharma, 2018). The ridge bed approach prevents the corm from being submerged in water-logged soil, protecting it from breakdown. It also offers superior defense against high temperatures and insect diseases (DACAAR, 2007). Basin irrigation is a popular saffron irrigation technique in Iran. However, it is believed that the furrow approach reduces evaporation and increases the efficiency of water consumption (Aziz-Zohan et al., 2009). Furrow irrigation provides the ideal growing conditions for crops because it keeps the soil moisture, reduces evaporation, and prevents salt leaching (Quaniqi et al., 2102). On the other hand, Kumar and Sharma (2018) investigated tthe hat flatbed method had a higher yield of total corm than ridge approach.

Another crucial element for a good yield of saffron per unit area is corm depth. In Mashhad, Iran, Koocheki et al. (2011) conducted experiments. They found that a yield of 10 cm of corm depth per unit area outperformed yields of 15 and 20 cm. In the Hatay province of Turkey, research was undertaken by Sesveren et al. (2006) who reported that the development and yield characteristics of saffron were controlled by corm depth, climate, corm circumference, and soil temperature. For saffron blossoming, corm depth according to soil type is a crucial factor (Abrishamchi, 2003). These saffron-growing aspects are added to the task that needs to be done.

MATERIALS AND METHODS

Research area

The current study was carried out in 2020–2021 and 2021–2022 at the Agricultural Research Farm of Shaikh Zayed University (SZU), Khost. Afghanistan. Although it was extremely close to becoming semi-arid hot, the experimental region was in a semi-arid climate, or Köppen semi-arid cold (BSk) (BSh). Table 1, Figure 1, and Figure 2 provide the physicochemical parameters, study area, and metrological data, respectively.

Table 1. The soil physicochemical properties at the experimental farm

pH (water)	8.3
N (%)	2.2
P (mg/kg)	6.9
K (mg/kg)	190
OM (%)	0.91
Clay (%)	19.80
Silt (%)	21.80
Sand (%)	58.40
Textural Class	Sandy loam

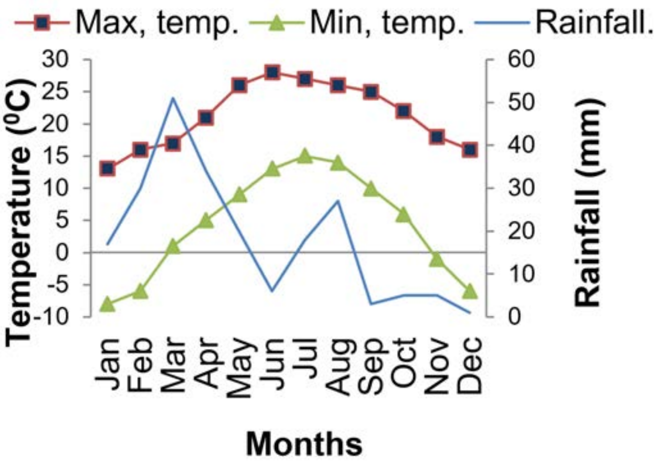

Figure 1. Meteorological data at the Khost Province, Afghanistan during 2015–2022 years. Source: Khost (2022)

Experimental design

The experiment was carried out based on a randomized complete blocks design arranged in two factors with three replicates. The factors for the study were, two planting methods (flat and ridge method) and three levels of corm depth (10 cm, 15 cm, and 20 cm; Table 2).

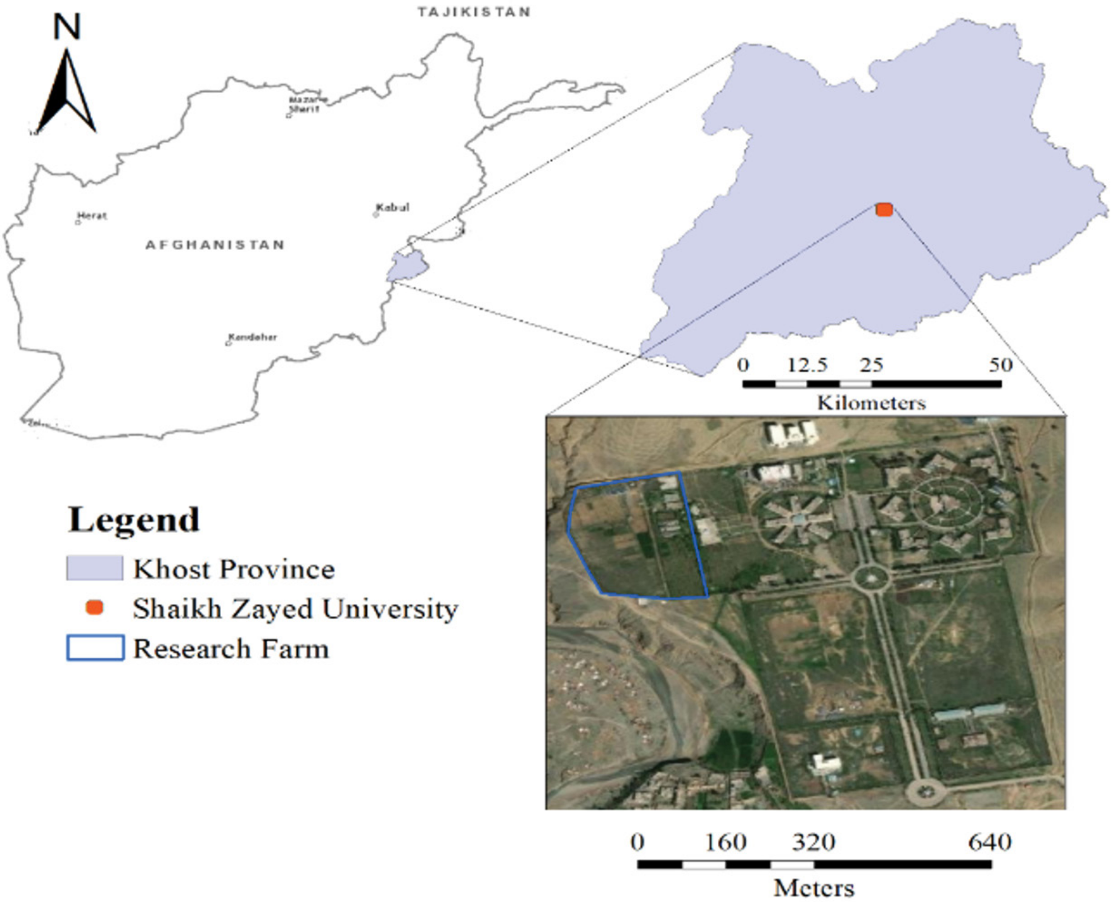

Figure 2. Map of research area

Agronomic practices

The experimental field was set up in accordance with the local saffron cultivation schedule (early September). Plots were established after spreading 18 tons/ha of well-decomposed sheep manure on top of the soil and incorporating well with soil using a plow. Each plot was 3 m^2 (1.5 x 2 m) and was spaced from the other by 1 m. In the ridge planting method, the ridges were manually created at a height of 30 cm, a distance of 50 cm between each ridge, and a width of 50 cm. When the flat method's row spacing was 30 cm. On both the flat and ridge, the distance between the two plants was 10 cm. Depending on the type of treatment, each plot was individually irrigated utilizing hand pipes, and the time of irrigation was considered depending on weather conditions, totally four and five times irrigation are applied for the first and second season, respectively. Throughout the entire growing season, weeds were carefully pulled out manually.

Table 2. Treatments description

Treatments	Description
FD1	Flat method and 10 cm corm depth
FD2	Flat method and 15 cm corm depth
FD3	Flat method and 20 cm corm depth
RD1	Ridge method and 10 cm corm depth
RD2	Ridge method and15 cm corm depth
RD3	Ridge method and 20 cm corm depth

Data collection and measurements

Days to flowering (DTF) are counted from corm cultivation to the initiation of flowering (4 October 2020 to 13 November 2020) and flowering interval days (FID) from the initiation of flowering to the end of flowering (13 November 2020 to 29 November 2020). Flowers were physically gathered from each plot's one-meter squares, and the dried stigma yield (DSY) and number of flowers (NF) per square meter were then computed. A 0.5 cm line was dug at the end of the first season (on June 1st, 2021) to harvest generative corms. Each group of corms (>8 g, 5 - 8 g, and 5 g in size) had a different number of generative corms (NGC), GCY (g), and their weight. Identical measurements were made during the second season.

Statistical analysis

Data collected were subjected to analysis of variance (ANOVA), using Statistical Tool for Agriculture Research (STAR) software (version 2.0.1). LSD ($P < 0.05$) was used to separate statistical differences between the treatments. To find out the relationships among the parameters, the R software (R i386 4.0.2) was used.

RESULTS

Saffron flower and dry stigma

According to the analysis of variance shown in Table 4, the planting methods had a significant influence on the DTF, FID, NF, and DSY parameters in both years. The flat method greatly outperformed the ridge method for the aforementioned characteristics (Table 3). The findings demonstrated that mother corm depths were only significant for DTF and FID in the first year but were significant for DTF, FID, NF, and DSY in the second year (Table 4). The highest means for DTF in the first year were obtained at 20 cm depth, whereas the highest means for FID were obtained for both years at 15 cm depth. The highest means for NF and DSY were significantly obtained highly in 15 and 20cm of corm depth (Table 3). DTF and FID showed significant interactions in the first year, but NF and DSY did so in the second year (Table 4). The highest DTF and FID values were generated by treatment FD3 (flat method with 20 cm corm depth). However, NF and DSY were greatest in FD2 treatments (flat method with 15 cm corm depth) (Figure 3).

Generative corm

Findings show that NGC and two types of corm weight that have been observed (> 8 g and 5 – 8 g) were affected by planting method and corm depth in both years, however, tiny weight corm numbers (<5 g) were only affected by corm depth (Table 4). In terms of planting methods, the flat method produced more NGC values, NGC > 8 g, and NGC 5-8 g than the ridge method in both two years (Table 5), and in terms of corm depth, 10 and 15 cm gave the highest NGC over 20 cm both years, while 15 and 20 cm produced significantly heavier NGC (>8 g) both years compared to 10 cm and the medium NGC (5-8 g) were produced in 15 cm first year but 20 cm for both years (Table 3 and Table 5). Similar to how the planting method affected the GCY, 10 and 15-cm corm depth only had a significant impact on it in the second year.

Table 3. Means values of days to flowering (DTF), flowering interval days (FID), number of flowers (NF), and dry stigma yield (DSY)

Treatments	DTF		FID		NF (m^2)		DSY (g/m^2)	
	1st year	2nd year	1st year	2nd year	1st year	2nd year	1st year	2nd year
Planting Method								
Flat	37.55^a	31.89^a	12.11^a	9.00^a	26.67^a	20.40^a	0.07^a	0.05^a
Ridge	35.44^b	29.56^b	8.00^b	5.89^b	20.66^b	9.00^b	0.05^b	0.02^b
Corm Depth (cm)								
10 cm	35.66^b	29.83^b	7.33^b	5.50^b	21.00	10.16^b	0.056	0.026^b
15 cm	36.00^b	30.50^b	10.16a^b	7.67^a	26.50	17.33^a	0.070	0.048^a
20 cm	37.83^b	31.83a	12.66^a	9.17^a	23.50	16.66^a	0.062	0.049^a

Note: Values followed by the same letter are not significantly different ($P < 0.05$)

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Table 4. Analysis of variance (ANOVA) to growth, yield and yield attributes for individual and combine of years

Source of Variance		DTF	FID	NF	DSY	NGC	NGC >8 g	NGC 5 - 8 g	NGC < 5 g	GCY
	df	MS	MS	MS	MS	MS	MS	MS	MS	MS
2020-2021										
Replication	2	0.17	2.72	20.17	0.0001	20.67	2.06	0.89	8.72	181.1
Planting Method (PM)	1	20.06**	76.06**	162.00**	0.0012**	760.50**	162.00**	46.72**	32.00	29120.9**
Corm depth (CD)	2	8.17**	42.72**	45.50	0.0003	249.50**	35.39**	12.06*	298.72**	1653.6
PM x CD	2	1.06*	14.39**	2.17	0.0000	57.17	15.17**	5.39	16.17	1394.9
Residual	10	0.17	0.32	12.83	0.0001	19.73	1.72	2.49	8.66	915.9
2021 – 2022										
Replication	2	3.39	1.72	0.39	0.0001	54.89	0.22	2.39	78.17	15.06
Planting Method (PM)	1	24.50**	43.56**	589.39**	0.0052**	392.00**	162.00**	64.22**	0.06	17860.50**
Corm depth (CD)	2	6.22*	20.39**	94.06**	0.0007**	159.39*	99.39**	17.06**	450.17**	2086.72*
PM x CD	2	0.67	5.06	82.39**	0.0006**	106.17	85.17**	1.72	174.06*	28.17
Residual	10	0.86	1.46	1.26	0.0001	28.69	0.69	1.66	40.57	424.19
Combine analysis (2020 - 2021 and 2021 - 2022)										
Year	1	7598.03	196.58	5041.88	30326.02**	8130.03**	49.00**	11520.44**	343904.05**	7008.48**
R within Year	4	0.94	1.54	8.23	27.44	10.44	2.22	39.53	11.83	96.26
Planting Method(PM)	1	61.36**	551.27**	84.20**	196.68**	812.25**	215.11**	25.00	9781.87**	46582.59**
Y * PM	1	2.25	124.23**	82.34**	195.32**	110.25**	11.11*	21.78	8263.42**	677.21
Corm Depth (CD)	2	25.69*	121.54**	20.38	79.69*	174.53**	29.86**	160.86**	1632.90	3754.12*
PM x CD	2	2.86**	15.85**	20.08	79.69*	174.36**	22.58*	301.36*	770.81	15.03
Y * CD	2	5.03**	56.18**	1.36	53.04*	68.25**	9.69**	115.58**	43.50*	854.96
Y * PM * CD	2	1.08	38.70**	1.32	53.13*	74.08**	7.19	63.86	2.03	564.82
Residual	20	0.81	0.91	6.31	14.34	10.21	1.69	21.53	218.37	668.67

* and**: statistical differences at $P < 0.05$ and 0.01, respectively; DTF: Days to flowering; FID: Flowering interval days; NF: number of flowers; DSY: dry stigma yield; NGC: Number of generative corms; GCY: generative corms yield.

Table 5. Means values of the number of generative corms (NGC) and it's different weights and generative corms yield for two years

Treatments	NGC (50 cm)		NGC> 8 g		NGC 5-8 g		NGC< 5 g		GCY (g/50 cm)	
	1st year	2nd year	1st year	2nd year	1st year	2nd year	1st year	2nd year	1st year	2nd year
Planting Method										
Flat	42^{a}	62.78^{a}	11.56^{a}	8.44^{a}	12^{a}	8.11^{a}	19.22	46.22	225.67^{a}	244.89^{a}
Ridge	29^{b}	53.44^{b}	5.56^{b}	2.44^{b}	8.78^{b}	4.33^{b}	16.56	46.11	145.22^{b}	181.89^{b}
Corm Depth (cm)										
10 cm	40.83^{a}	61.33^{a}	6.00^{b}	2.17^{b}	9.00^{b}	5.17^{b}	24.00^{a}	52.67^{a}	183.33	210.00^{a}
15 cm	37.33^{a}	60.33^{a}	10.83^{a}	10.00^{a}	10.33^{ab}	5.33^{b}	19.50^{b}	49.50^{a}	203.00	233.50^{a}
20 cm	28.33^{b}	52.17^{b}	8.83^{a}	4.17^{ab}	11.83^{a}	8.17^{a}	10.17^{c}	36.33^{b}	170.00	196.67^{b}

Note: Values followed by the same letter are not significantly different ($P < 0.05$)

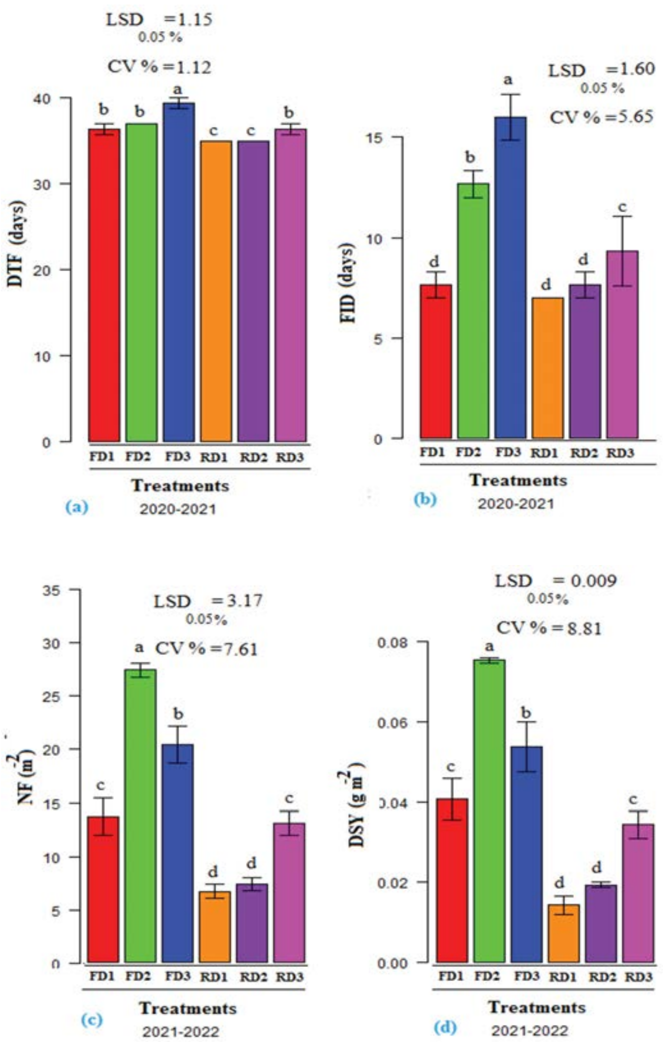

Figure 3. Interaction effects of planting method and corm depth for DTF: Days to flowering; FID: Flowering interval days; NF: Number of flower and DSY: Dry stigma yield (values followed by the same letter are not significantly different at $P < 0.05$)

GCY in both years was higher when using the flat method as compared to the ridge method, and when using 15 and 10 cm of corm depth as compared to 20 cm of corm depth (Table 4 and Table 5). Additionally, the weight of corms was significantly influenced by the interaction of the factors, with weights of > 8 g in both years and <5 g only in the second year (Table 4). In contrast, treatment FD1 produced the smallest weight of corm (NGC 5 g) oval in the second year (Figure 4, (a), (b), and (c), respectively). Treatment FD2 consistently produced the largest NGC (>8 g) in both years.

Relationship among growth, yield corms-related traits

The findings indicate that the parameters were correlated (Figure 5). There were substantial positive and significant relationships between DTF and FID in the first year (r = 0.87***), NF and DSY in the second year (r = 1.00*** and 0.99***), NF and GCY in the second year (r = 0.87***), and DSY and GCY in the fourth year (r= 0.86***). Additionally, it was observed that FID and NGC (5 g) first and second years had negative correlations (r = -0.48* and r = -0.54*), respectively.

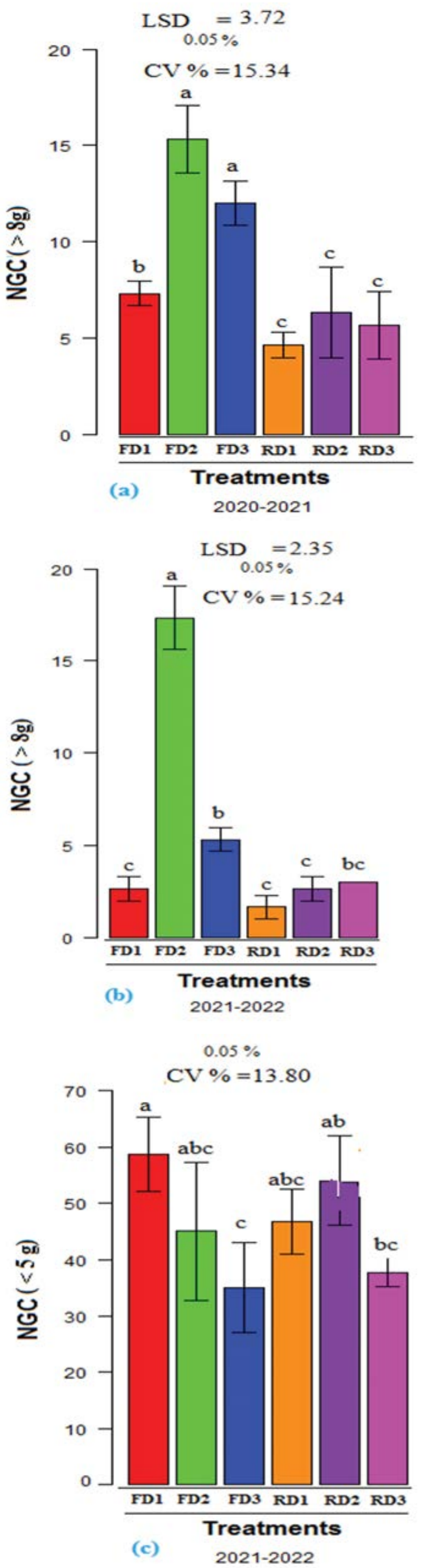

Figure 4. Interaction effects of planting method and corm depth for NGC (number of generative corms). Values followed by the same letter are not significantly different ($P < 0.05$)

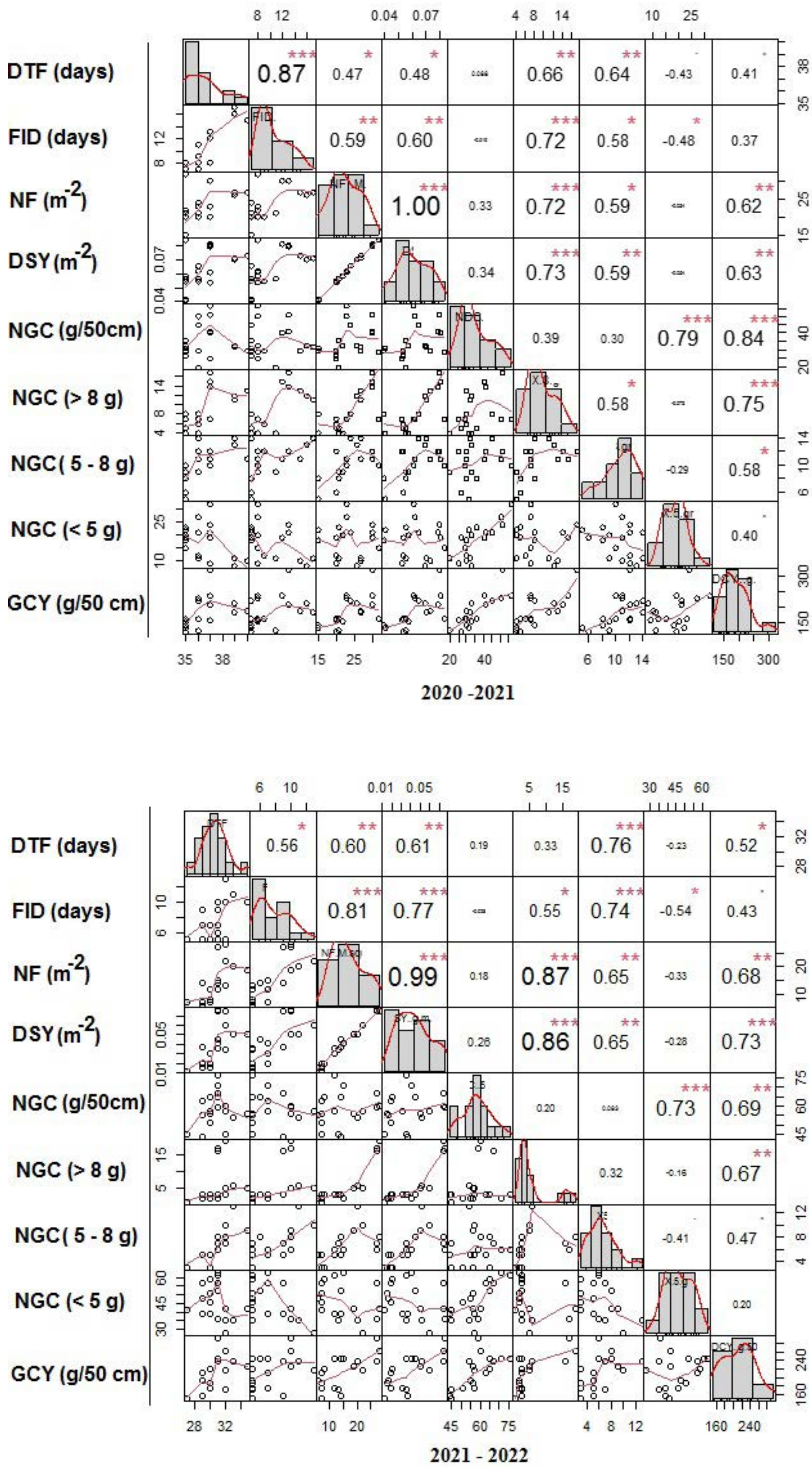

Figure 5. Relationship among the DTF: Days to flowering; FID: Flowering interval days; NF: number of flowers; DSY: dry stigma yield; NGC: Number of generative corms; GCY in the first and second seasons (*, ** and ***: statistical differences at $P < 0.05$, 0.01 and 0.001, respectively)

DISCUSSION

The growth, yield, and development of generative corms influence by a number of agronomic practices. The planting method and corm depth are the two that have a great influence on saffron production since they change depending on the soil and temperature. The current study found that the planting method and corm depth had a significant influence. In both years, the flat method produced the highest values of DTF (37.55 and 31.89), FID (12.11 and 9.00), NF/m^2 (26.67 and 20.40), and DSY/m^2 (0.07 and 0.05), respectively (Table 3). In contrast, fewer of these characteristics were observed when saffron was grown using the ridge method. The thinner soil layer above corms, which inhibited corm growth throughout dormancy and growing periods, maybe the cause of the decreased yield in the ridge method. Our results are in line with the findings of Aziz-Zohan et al. (2009) and Pazoki et al. (2013), who found that the flat method with basin irrigation produced a higher yield of saffron than the furrow irrigation method. In the case of corm depth, the maximum mean value in Table 3 showed that 20 cm depth of corm cultivation required more DTF (37.83 and 31.83) and FID (12.66 and 9.17), respectively, in both years than did 10 and 15 cm depth, but the highest values of NF/m^2 (17.33 and 16.66) and DSY/m^2 (0.048 and 0.049) were recorded in the second year at 15 and 20 cm corm depth, respectively. The minimal values of NF/m^2 and DSY/m^2 were achieved when corms were grown at depths of 10 cm, regardless of corm depth in the second year (10.16 and 0.026, respectively). In the current study, the maximum NF/m^2 and DSY/m^2 at 15 cm planted may be the best corm depth. Because deeper soil may cause a delay in the development of flowers and leaves, saffron's growth and fresh weight may finally decline. Otherwise, temperature changes may be impacted by the soil depth for corms lowering. Galavi et al. (2008), De Juan et al. (2009), and Gerdakaneh et al. (2017) reported the best yield of saffron in corms with a depth of 15 cm, supporting this finding. According to the significant planting method and corm depth interactions on DTF and FID in the first year, the flat method at 15 corm depth had the highest value for these parameters (Figure 3, (a) and (b), respectively). The interactions between planting methods and corm depth also demonstrated that when compared to the other interactive effects of planting method and corm depth, the saffron cultivation on flat method with a 15 cm depth produced the highest NF/m^2 and DSY g/m^2, respectively. The flat method of saffron cultivation produced the highest values of NGC, corms number > 8 g, corms number (5 – 8 g), and total GCY in both years (Table 5). While in the case of corms depth, corms at depths of 10 and 15 cm produced the greatest values of NGC in both years, while corms at depths of 15 and 20 cm produced the highest numbers of NGC (> 8 g) in both years but for the NGC (5 – 8 g), both mentioned depths (15 and 20 cm) in the first year and just 20 cm in the second year produced the high values. The high value of NGC (<5 g) was recorded at a depth of 10 cm in both years and 15 cm only in the second year. The GCY was at its peak in depths between 10 and 15 cm in the second year. The interaction of the factors was significant in the first year for NGC (>8 g) and the highest values produced by treatment consist of the flat method with 15 cm corm depth (FD2), and treatment FD2 in the second year for the observed of NGC (>8 g), are shown in Figure 4(a) and (b), respectively. The flat method with 10 cm corm depth (FD1) produced the most corms in the small-weight NGC (<5 g) (Figure 4c).

According to the relationships from Figure 5, DTF and FID in the first year, NF and DSY in both years, NF/m^2 and GCY in the second year, and DSY with GCY had statistically significant and positive relations at the level of 0.001% probability. The main reasons for these positive relations between the DTF, FID, NF, DSY, and GCY may be due to the more number of flowers from the more generative corms. It was also found that there was a statistically significant and negative relationship at the level of 0.05% probability among the NF and NGC (<5 g). For this reason, it shows that the small weight of corms in many cases develop just on germination and formation of leaves. A linear relationship was reported by Yarami and Sepaskhah (2015) for saffron; Ahmadi and Arian (2021) for common bean and by Ahmadi and Salari (2022) for wheat.

CONCLUSION AND FUTURE PERSPECTIVES

There were significant differences among planting method and corms depth with respect to all considered parameters. The results showed that all the measured parameters of saffron increased by the flat method compared to the ridge method in both years. In comparison to the ridge method, the main values of DSY and GCY in the flat method were high 44.4% and 43.83% in the first year and 42.85 and 29.52% in the second year, respectively. According to the findings, DTF and FID values were highest at a depth of 20 cm, while DSY and GCY values were highest at a depth of 15 cm.

The interaction effect between the planting method and corm depth was also significant and the highest NF, DSY and NGC (<8 g) were produced by flat method in 15 cm corm depth. Furthermore, it was found that there was the most positive relationship among the NF, DTF, DSY and GCY. Farmers and producers should adhere to sound agronomic practices, including planting methods, corm depth, corm weight, and time of cultivation in a particular soil and climate, in order to increase sustainable saffron growth and yield. Because in the second year, we observed various yield values and features. In order to fully understand these behaviors, more research must be done on many locations and epochs in the Khost Province and other regions of Afghanistan.

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