Turkish Journal of
Field Crops
2013, 18(2), 198-204

INFLUENCE OF CORM PROVENANCE AND SOWING DATES ON STIGMA YIELD AND YIELD COMPONENTS IN SAFFRON (*Crocus sativus* L.)

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Received: 29.04.2013

ABSTRACT

In order to study effect of different sowing dates on stigma yield and yield components in saffron. Field trials were arranged in split plot design was sowing dates (05-May, 05-Jun, 05-Jul, 05-Aug, 05-Sep and 05-Oct) as main plot and four ecotypes as sub plots (Mashhad, Torbat-jam, Gonabad, Birjand) in Mashhad at three distinct years (2009-11). The results from analysis of variance indicated significant differences between ecotypes and sowing dates in individual years, at last it is distincted that two Mashhad and Torbat-jam ecotypes had the highest stigma yield (98.6 and 92.5 mg/m^2) in Mashhad climate. Also the best sowing dates were 05-Jun to 05-July in Mashhad. It revealed that climate had significant effects on stigma yield and yield components, so that delaying in cultivation leads to decrease all agronomical traits of saffron. In other hand, results from metereological data indicated that average of temperature and average of sunny hours in comparison with average of percipitation and average of relative humidity, showed maximum effects on stigma yield and yield components, positively. Finally, results from phenotypic correlation indicated that stigma yield showed significant and positive correlation with all studied traits and results from step by step regression indicated that daughter corm number and corm fresh weight had positive and maximum direct effects to improve stigma yield. Therefore, it can be concluded that increasing cultivation density and selecting bigger corms are useful factor to increasing stigma yield.

Keywords: Direct and indirect selection, Saffron ecotypes, Step by step regression

INTRODUCTION

Saffron is one of the oldest and most expensive spices in the world (Winterhalter and Straubinger, 2000). It obtains from the dried stigmas of *Crocus sativus* L., a member of the large family Iridaceae, and has been cultivated in several countries such as Iran, India, Greece, Morocco, Spain and Italy (Ghorbani, 2006). Iran is the greatest producer saffron in the world and 75 % of the production is coming from Iran (Amirnia et al., 2012). Nowadays, saffron has attracted much attention to food science due to the demand for natural food colors and additives which could replace the synthetic colorants, flavor enhancers and aromas (Kafi, 2006) and also used in dyes and perfumes (Basker and Negbi, 1983). The novel use of saffron in recent years has been associated in cancer cure. There has been increased interest in the biological effects and potential medical applications of saffron, particularly those based on their cytotoxic, anticarcinogenic and antitumour properties (Abdullaev, 2002; Abdullaev and Espinosa-Aguirre, 2004; Fernandez, 2004; Magesh et al., 2006; Chryssanthi et al., 2009; Dalezis et al., 2009). Under this perspective, there is an increasing interest by producers and consumers in high quality product with clear geographical origin (Anastasaki, et al., 2010).

From an agronomic point of view, saffron is well adapted to different environmental conditions ranging from dry sub-tropical to continental climates (Azizbekova and Milyaeva, 1999; Mollafilabi, 2004; Sampathu et al., 1984). Anastasaki et al., (2010) and Luana Maggi et al., (2011) reported that price of saffron strongly depends on its country of production as many factors interfere to saffron's quality such as edaphoclimate conditions (soil, climate, rainfall), harvest time and postharvest treatment. During the last 40 years, the intensive manual labor required for daily flower picking and the separation of stigmas has significantly reduced the cultivated area of saffron in many European countries that traditionally produced the crop (Fernandez, 2004; Gresta et al., 2009).

For all the previously mentioned reasons, this study was undertaken to evaluate the influence of corm provenance and sowing dates on dry stigma yield and quantitative characteristics of saffron in order to explore the best saffron ecotype and sowing date for establishing a new farm in Mashhad condition.

MATERIALS AND METHODS

To study effects of sowing dates on yield and yield components in saffron an experiment performed in the experimental fields in Mashhad-Iran. Mashhad region locate in 36'15" latitude, 59'28" longitude and 985 meters above sea level and soil in experimental field was silt-clay and pH=7.8. In this study different ecotypes of saffron evaluated in three distinct years (2008-09, 2009-10 and 2010-11) so that at the end of each year, we through out pervious corms and cultivated new corms in the same farm. In each arable year, the experiment was conducted as split-plot in BCRD which different sowing dates (05-May, 05-Jun, 05-Jul, 05-Aug, 05-Sep, 05-Oct) used as main plots and different saffron ecotypes (Mashhad, Torbat-jam, Gonabad and Birjand) as sub plot. Four saffron samples from different regions of Iran, traditional saffron production areas, were studied in this work. Samples 1, 2 and 3 were obtained from the zone of Torbat-Jam, Mashhad and Gonabad in Razavi Khorasan province of Iran. Sample 4 was obtained from the area of Birjand in the south Khorasan province of Iran. To prevent Fusarium and Penicillium infestations, corms were dipped in a prochloraz solution (0.1%) and dried under forced ventilation for 5–7 h to remove the surface water.

In each year after preparing the field in April, 75 kg ha^{-1} pure nitrogen, 75 kg ha^{-1} pure phosphorous, 50 kg ha^{-1} pure potassium were used. The cultivation practices used were those commonly used for this crop, and an organic fertilizer (mature manure) was applied. Each plot contains 8 culture lines with 3 meter length and 25 cm distances from another line (the plot area was 6 m^2). Corm distances on lines were 8 cm and 15 cm depth (density was 50 corms/m^2). To avoid marginal effects and minimizing errors, plots situated beside each other by 50 cm distances. To enhance accuracy, margins considered as two lines at beginning and at the end of plots as well as 50 cm at two another sides of plots. All agronomical operation (ecotypes and infield preparation, traits measuring and experimental design) in three years were similar, and at the end of each year, the infield was plowed and corms were harvested for measuring. Rainfed conditions met the water requirements at the start of growth (October to November), and plants were drip irrigated from December to April. Meteorological data in show in below Table 1.

Table 1. Meteorological statistics of Mashhad field station during 2009-2011

Month	Temperature (ºC)			Relative humidity (%)			Precipitation (mm)			Number of sunny hours		
	2009	2010	2011	2009	2010	2011	2009	2010	2011	2009	2010	2011
April	21.84	17.71	20.12	41.24	64.69	54.76	12.40	38.70	35.10	286.90	226.00	220.20
May	26.17	23.94	25.94	34.82	43.98	30.44	10.20	5.10	3.50	340.50	337.40	367.30
June	27.70	27.02	29.35	26.95	30.29	23.81	0.00	1.30	1.00	367.40	365.90	377.60
July	27.45	27.95	26.68	20.87	33.23	22.19	0.00	2.90	0.00	380.00	361.10	376.60
August	23.85	22.16	22.67	25.31	40.26	24.92	0.00	21.30	2.40	330.60	331.40	329.60
September	18.91	17.26	20.68	40.87	37.58	38.07	0.00	0.00	0.50	262.60	295.10	285.10
October	8.19	12.09	12.28	57.38	50.55	46.18	10.30	5.80	8.60	177.50	206.30	233.50
November	6.83	5.50	9.47	67.48	70.63	42.03	12.50	22.20	0.00	130.30	136.80	236.90
Desember	3.42	7.04	3.58	67.67	62.08	54.32	29.20	4.20	13.10	160.10	148.10	183.70
January	6.60	4.89	4.50	68.50	67.88	64.67	28.80	22.60	48.00	132.20	137.60	145.10
February	10.85	11.82	5.37	60.23	69.28	67.81	40.20	50.50	22.40	196.90	127.80	116.60
March	11.50	13.74	14.78	71.27	58.48	45.08	102.10	27.60	10.10	161.30	176.60	245.10
Average	16.11	15.92	16.29	48.55	52.41	42.86	20.48	16.85	12.06	243.86	237.51	259.78
Sum	2202.3	2201.1	2206.4	2591.6	2638.9	2525.3	2254.7	2212.2	2155.7	4935.3	4860.1	5128.3

Data were collected on the following 13 characters in each pot: Number of Flower (NF), Fresh Weight of Flower (mg) (FWF), Dry Weight of Flower (mg) (DWF), Fresh Weight of Stigma (mg) (FWS), Dry Weight of Stigma (mg) (DWP), Number of daughter Corm (NDC), Fresh Weight of daughter Corm (mg) (FWDC), Dry Weight of daughter Corm (mg) (DWDC), Length of Leaf (cm) (LL), Dry Weight of Leaf (mg) (DWL), Biomass (BIO), Harvest Index (HI) and Stigma Yield per m2 (mg m^{-2}) (SY). Then the averages of the traits were used to statistical calculations in SAS ver. 9.12.

RESULTS AND DISCUSSION

Year Effects

Results from analysis of variance (Table 2) indicated FWF, DWF, FWS, DWS and DWL did not show significant differences at different years, so it can be stated environmental changes did not affected these traits, while NF, NDC, FDWC, DWDC, LL, BIO, HI and SY affected. These results are supported by previous findings (Mollafilabi, 2004; Unal and Cavusoglu, 2005; Gresta, et al., 2008). The results from means comparisons of these traits (Table 3) were maximum and minimum in 2011 and 2009, respectively. For instance, SY was 98.8 mg m^{-2} in 2011, while 80.8 mg m^{-2} in 2009. Also, NF ،NDC ، FWDC ،DWDC and LL traits, as major factor to improve stigma yield in next year were enhanced 4.8, 0.4, 0.9, 0.5 and 2.4 mg m^{-2} in 2011 in comparison to 2009, respectively. Analysis of metereological data in 2009-11 (Table 1) indicated in 2011 the parameters include average of temperature, average of sunny hours were upper, while average of relative humidity and average of precipitation were lower. According to these results it can be stated that meteorological parameters include average of temperature, average of sunny hours had maximum and positive effects on yield and yield components in saffron. Koocheki et al., (2006) stated that flowering and growth seasons of saffron are in autumn and winter seasons that have maximum precipitation, so saffron has not need for irrigation, necessary. On the other word, Saffron has low water requirements and is typically cultivated under rainfed conditions because it is well adapted to the rainfall pattern of diverse Mediterranean areas (Alizadeh, 2006). Zhang (1994) after study the precipitation and temperature effects on winter wheat stated temprature changes are more important on wheat seed yield in comparison with precipitation.

Table 2. Variance analysis of studied traits in saffron genotypes

SOV	df	NF	FWF	DWF	FWS	DWS	NDC	FWDC	DWDC	LL	DWL	BIO	HI	SY
Year	2	432.9 **	129.4	2.6	49.1	1.6	4.4 **	17.2 **	5.4 **	115.4 *	0.1	6017265.3 **	0.002 **	5973.2 *
E_1	6	8.5	51.8	1.2	13.0	0.4	0.1	0.1	0.1	12.7	0.1	98980.9	0.000	784.4
Month	5	1440.5 **	1057.8 **	122.5 **	121.6 **	12.8 **	9.3 **	37.1 **	24.8 **	401.2 **	1.6 **	38381266.5 **	0.001 **	67660.8 **
Year×Month	10	46.5 **	112.8	1.7	5.2	0.2	0.5 **	1.3 **	0.7 **	11.8 *	0.1 *	670373.2 **	0.000	1089.8
E_2	30	7.7	64.8	0.8	2.7	0.5	0.1	0.1	0.2	5	0.0	208471.5	0.000	533.8
Ecotype	3	44.1 **	2497.1 **	42.3 **	55 **	1.8 **	14.1 **	8.5 **	3.5 **	177.6 **	2.0 **	10799168.9 **	0.0001 **	3346.6 **
Year×Ecotype	6	32.4 **	431.4 **	3.5 **	9.7 **	0.3 **	0.4 **	1.4 **	0.3	10.2 0	0.3 **	460823.7	0.0001 *	644.7 *
Ecotype×Month	15	41.7 **	52.2	2.6 **	2.9	0.1	0.1	0.9 **	0.5 *	12.4 **	0.1 **	393396.5	0.0001 **	1311.4 **
Year×Ecotype×Montl	30	26.9 **	43.1	1.6 **	1.7	0.1	0.2 **	0.9 **	0.6 **	18.1 **	0.1 **	722014.1 **	0.0001 **	889.5 **
E_3	108	6.9	34.1	0.7	1.9	0.1	0.1	0.1	0.3	3.7	0.0	269103.7	0.0000	219.9
CV%	---	15.6	3.7	3.9	6.9	6.9	13.2	6.5	14.6	10.5	5.9	8.0	7.8	16.6

[a] - Abbreviations are described in materials and methods

Table 3. Mean comparison of studied traits in saffron genotypes

		NF	FWF	DWF	FWS	DWS	NDC	FWDC	DWDC	LL	DWL	BIO	HI	SY
Year														
	2009	14.7 c	350.8 a	42.9 a	28.5 a	5.2 a	2.6 a	5.5 c	3.2 c	18.5 ab	148.5 a	6178 c	0.09 a	80.8 b
	2010	16.3 b	353.5 a	43.3 a	28.6 a	5.2 a	2.2 b	6.1 b	3.5 b	16.8 c	151.1 a	6576.3 b	0.08 b	84.6 ab
	2011	19.5 a	352.1 a	43.2 a	27.1 a	4.9 a	2.2 b	6.4 a	3.7 a	19.2 a	149.7 a	6740.1 a	0.07 b	98.8 a
Month														
	05-May	17.8 b	353.3 bc	44.2 a	27 b	5.1 b	2.2 bc	5.7 b	3.2 b	16.5 c	151.1 b	6223.3 b	0.084 ab	90.8 b
	05-Jun	24.1 a	355.9 ab	44.8 a	29.9 a	5.9 a	3 a	7.2 a	4.5 a	22.3 a	160.6 a	7761.1 a	0.077 b	142.2 a
	05-Jul	24 a	359.7 a	44.8 a	30.8 a	5.8 a	2.8 a	7.2 a	4.5 a	22 a	161.5 a	7770.2 a	0.075 b	138.9 a
	05-Aug	14.5 c	350.5 bc	43.2b	27.6 b	4.7 bc	2.3 b	5.7 b	3.1 b	18.1 b	149.2 b	6111.0 bc	0.078 ab	68.6 c
	05-Sep	12.0 d	349 cd	41.6 c	26.8 b	4.6 c	1.9 c	5.4 c	2.9 b	16.4 c	142.5 c	5824.6 c	0.079 ab	55 cd
	05-Oct	8.7 e	344.3 d	40.3 d	26.4 b	4.5 c	1.7 d	4.7 d	2.6 c	13.9 d	133.8 d	5298.7 d	0.087 a	39 d
Ecotype														
	Gonabad	16 b	345.1 b	42.3 b	27 d	4.9 d	1.7 d	5.6 d	3.2 b	15.8 c	139.9 c	6030.3 b	0.083 a	82.2 b
	Mashhad	17.7 a	358.4 a	44 a	29.3 a	5.3 a	2.9 a	6.4 a	3.7 a	19.8 a	159.2 a	6942 a	0.078 b	98.6 a
	Torbat-Jam	17.5 a	357.4 a	43.8 a	28.4 b	5.2 b	2.5 b	6.2 b	3.6 a	19.4 a	156.9 a	6813.3 a	0.077 b	92.5 a
	Birjand	16.1 b	347.5 b	42.5 b	27.7 c	5.0 c	2.1 c	5.7 c	3.3 b	17.7 b	143.1 b	6207 b	0.082 a	83 b

[a] - Abbreviations are described in materials and methods

As last, it can state to saffron plant is a winter crop and the most growth of this plant occurred in autumn and winter months, on the other hand the mount of precipitation (rain and snow) usually is more but the evaporation is less in these months. So no water shortage would be seen and saffron will respond to increase temperature and sunny hours positively to improve yield components. Also researchers such as Molina et al., 2005a, 2005b; Gresta, et al., 2008; Lundmark, et al., 2009; Luana Maggi et at., 2011 pointed out that environments and climatic conditions (e.g. temperature, soil water content) effect severely on quantitative and qualitative traits of saffron.

Sowing Dates

The results from analysis of variance (Table 2) indicated different sowing dates affected all studied traits and they can have an important role in saffron production. Means comparisons of studied traits in different months (Table 3) indicated to decline in studied traits following to delaying in sowing date. These scholars in their studied observed that almost all of traits decreased with delayed sowing time. At last, according to the results of this study, it is revealed that sowing dates 05-Jun. and 05-Jul. were the best months to culture in Mashhad due to positive effects on yield components and stigma yield, while 05-Oct. was the worst month for culturing due to negative effects on yield components and stigma yield. For instance, delaying from 05-Jun. and 05-Jul to 05-Oct. lead to reduce NF from 24 to 9 numbers in per square meter, respectively. Also delaying in culture lead to reduce NDC, FWDC and DWDC traits. These traits as the main yield components had major roles in increase of stigma yield in next year. On the other hand, it is revealed that the amount of SY at 05-Jun and 05-Jul sowing dates and 05-Oct. sowing date were 142.2 and 138.9 and 39 mg/m^2, respectively. Gresta et al., (2009) observed soil temperature and moisture in sowing date (Jun. and Jul. months) were important factors in flowering and stigma yield of saffron, so lower soil temperature (in sowing date) lead to more stigma yield. At last, these investigators stated that soon sowing date is better than late. On the other hand, Molina et al., (2004) reported that the most favorable temperature to differentiate flowers in saffron is 23-25 ºC for growing corms at summer; these conditions observed from June to July in Mashhad.

Overall, it revealed delaying in sowing date would reduce SY and FN as well as vegetative yield (leaves and daughter corm production). The reason of these unfavorable effects in delaying sowing dates is that saffron corms is in dormancy period from Aug. to Oct. seemingly, but they are very active physiologicaly, so translocating of mother corms to new farm in these months lead to readuce flowers and leaves buds severly, and subsequently it will reduce stigma yield specially at the first cultivation year, (Benschop, 1993). Mollafilabi (2004) and Kafi (2006) suggested we can culture saffron corms from early Jun. to mid Sep. month. But it should avoid cultivating in mide summer (Aug. and Sep. months) due to hot weather and lowering humidity; because it would damage corms due to losing its humidity during transition.

Ecotype

Results from analysis of variance (Table 2) indicated significant differences between ecotypes in all studied traits. Although saffron is sterile and reproducted in asexual method (corm) but if saffron corms cultivated in a ragion for several decades, undergo morphological and genetical changes. Results from means comparisons (Table 3) revealed there were maximum differences between ecotypes due to FWS, DWS, NDC, FWDC, LL and DWL traits. These traits are as selective traits for stigma yield at current year and important yield components in next year. Therefore Mashhad and Birjand ecotypes were the best and worst from those traits respectively, so it can predicted that these ecotypes would have maximum and minimum stigma yield at current year, and even next years respectively. Finally, in Mashhad climate, it can be stated ecotypes Mashhad and Torbat-jam that produced 98.6 and 92.5 mg/m^2 dry stigma are the most adapted ecotypes, while two ecotypes Gonabad and Birjand that produced 82.2 and 83 mg/m^2 dry stigma are the least adapted ecotypes in Mashhad climate. So as it would be predicted, Mashhad ecotype adapted to Mashhad climate- as testifier could achieve maximum yield and then Torbat-jam ecotype, because of meteropological similarity between two regions Mashhad and Torbat-jam. On the other hands, declining yield in ecotypes Gonabad and Birjand in Mashhad climate is caused by climate variations between two regions. Ehsanzadeh et al., (2004) reported extraordinary differences between saffron ecotypes. At last, they stated that among ten studied ecoptyes in Shahrkord region, three ecotypes Birjand, Qaen and Shahrkord had maximum yield and quality because of climatic similarity between three regions. Freeman (1973) reported saffron is adapted to different environments that affect quality and quantity characteristics, but subtropical weather is the best conditions. Siracusa et al., (2010) stated that flower number and stigma yield were significantly affected by environment and corm provenance.

The main point in this study is that difference between ecotypes becease of I) meteropological changes amonge Mashhad and original regions which corms gathered, II) different qualities between saffron corms. Therefore, it can be stated that saffron is a sensitive plant to environmental conditions, so it is necessary to pay attention to corm quality and meterological similarity between origin and destination climate for establishing new farms and at last it is essential to evaluate different ecotypes to select the best one for each region. Laidiaw (2005) in a study on pastural plant introduced some factors include light, temperature, humidity and nutritions as important parameters to plant productions, so it is necessary to attention to climate condition for selecting appropriate ecotype. Dhar et al., (1988) stated that stigma yield is dependent to factors include soil characters, cultivation methods, density, corms weight, geographical situation, climate, agronomical management and harvesting period. It has been shown that the size of the mother corm has a significant effect on vegetative development and the production of daughter corms (Negbi, 1999; De Mastro and Ruta, 1993; De Juan et al., 2003).

Intractions between Ecotypes and Soweing Dates

Results from analysis of variance (Table 2) indicated significant differences between ecotypes and sowing dates intractions for studied traits. This result indicated that studied ecotypes in different sowing dates were not similar. The results from means comparisons between ecotypes and sowing dates intractions (Table 4) indicated Mashhad ecotype at 05-Jun and Birjand ecotype at 05-Oct were the best and the worst ecotpyes for majority of traits espectialy for stigma yield. Comstock and Moll (1963) stated that regard to interactions between genotype and environment, selection of variants upon only one environmental condition is not appropriate; hence it is better to evaluate genotypes in range of places, years and environmental changes, these help us to estimate adaption and stability of genotypes yield achieving a constant criteria to select the best and most efficient variants (Johnson et al., 1995).

Table 4. Mean comparison of interactions between studied traits in saffron genotypes

Ecotype	Month	NF	FWF	DWF	FWS	DWS	NDC	FWDC	DWDC	LL	DWL	BIO	HI	SY
	05-May	15.3 f-h	359.9 a-c	45.1 a-d	28.4 c-g	5.4 d-f	2.8 b-d	6.6 e-f	3.7 c-f	18.5 d-f	161.6 a-e	6944.8 d-g	0.078 c-e	82.5 e-g
	05-Jun	28.4 a	361.0 a-c	45.9 a	31.2 a-b	6.1 a-b	3.4 a	7.5 b	4.8 a-b	22.8 a-b	168.4 a-b	8246.4 a-b	0.075 e	173.7 a
Mashhad	05-Jul	25.2 a-c	366.2 a	45.4 -c	33.4 a	6.2 a	3.5 a	8.0 a	5.1 a	24.6 a	165.9 a-c	8500.5 a	0.074 e	158.3 a-b
	05-Aug	16.4 e-g	355.2 b-f	43.9 c-g	28.2 d-g	4.8 g-j	2.8 b-d	6.3 f-g	3.3 d-g	18.6 d-f	157.9 c-f	6515.3 e-h	0.075 e	79.6 f-h
	05-Sep	13.7 f-j	356.2 a-e	43.1 f-i	27.5 e-i	4.7 g-k	2.5 d-g	5.3 i-j	2.8 f-h	18.4 d-g	152.6 d-i	5891 h-k	0.081 b-e	63.9 g-k
	05-Oct	7.3 k	352.0 c-g	40.6 k-m	27.1 e-i	4.7 g-k	2.4 d-g	4.8 k-l	2.5 g-h	15.7 f-j	148.7 f-j	5553.8 h-k	0.084 b-e	33.6 l
	05-May	21.2 b-d	355.7 b-e	44.3 b-f	26.7 f-i	5.1 e-g	2.4 d-g	5.9 g-h	3.3 d-g	16.9 e-i	155.4 d-h	6466.1 f-i	0.080 b-e	107.7 d-e
	05-Jun	21.7 b-d	360.0 a-c	44.7 a-e	30.7 b-c	6.0 a-c	3.3 a-b	7.4 b-c	4.8 a-b	25.5 a	162.7 a-d	8084.3 abc	0.076 e	131.7 c-d
Torbat	05-Jul	24.3 a-c	364.2 a-b	45.6 ab	31.1 a-b	5.8 b-d	3.1 a-c	7.3 b-c	4.4 a-c	23.2 a-b	169.8 a	7883.9 abc	0.075 e	140.6 b-c
	05-Aug	14.9 f-i	357.1 a-d	44.1 b-g	28.0 d-h	4.8 g-k	2.5 d-f	5.6 h-i	3.1 e-h	17.8 d-g	154.3 d-h	6254.1 g-j	0.078 d-e	70.8 f-i
	05-Sep	12.9 g-j	355.4 b-e	42.4 h-j	27.0 e-i	4.6 h-k	2.1 f-i	5.9 g-h	3.2 e-h	17.8 d-g	152.2 e-i	6277.3 g-j	0.074 e	59.4 g-l
	05-Oct	10.0 j-k	352.1 c-g	41.7 h-j	26.9 f-i	4.6 h-k	1.6 i-l	5.2 i-k	2.9 f-h	15.3 f-j	146.7 g-k	5914 h-k	0.078 c-e	44.5 j-l
	05-May	18.0 d-f	351.2 c-g	43.4 e-h	26.5 g-i	5.0 e-h	2.0 f-j	5.1 i-k	2.8 f-h	17.0 e-h	145.8 h-k	5793.9 h-k	0.087 a-d	90.7 e-f
	05-Jun	20.8 c-e	355.3 b-f	44.9 a-e	29.3 b-e	5.8 b-d	2.7 c-d	7.0 b-d	4.2 b-c	22.3 a-c	156.7 c-g	7391.2 b-e	0.078 c-e	119.6 c-d
Gonabad	05-Jul	22.6 b-d	356.6 a-e	44.4 a-f	29.7 b-d	5.6 d	2.6 c-e	7.0 c-e	4.4 a-c	21.0 b-d	151.8 e-j	7493.8 b-d	0.075 e	125.1 c-d
	05-Aug	14.9 f-i	344.7 g-i	42.3 h-j	27.4 e-i	4.7 g-k	2.0 f-i	5.3 i-j	3.0 f-h	18.3 d-g	142.2 i-k	5876.7 h-k	0.081 bcde	70.3 f-j
	05-Sep	10.9 h-k	341.9 g-i	40.0 l-m	26.8 f-i	4.6 h-k	1.9 g-k	5.3 i-j	2.8 f-h	15.0 g-k	136.3 j-k	5621.8 h-k	0.082 b-e	49.7 i-l
	05-Oct	9.4 j-k	335.1 i	39.6 l-m	26.3 g-i	4.5 j-k	1.5 j-l	4.6 l	2.5 g-h	12.7 j-k	125.8 m	5064.8 k-l	0.090 a-b	42.7 k-l
	05-May	16.4 e-g	346.3 e-h	43.7 d-h	26.2 g-i	5.0 f-i	1.4 k-l	5.0 j-l	2.8 f-h	13.5 i-k	141.7 j-k	5688.4 h-k	0.089 a-c	82.2 e-g
	05-Jun	25.4 a-b	347.3 d-h	43.6 e-h	28.5 c-g	5.6 c-d	2.5 d-g	6.8 e-d	4.2 b-d	18.5 d-f	154.4 d-h	7322.3 c-f	0.077 d-e	143.6 b-c
Birjand	05-Jul	24.0 a-c	351.7 c-g	43.8 d-h	29.1 b-f	5.4 d-e	2.1 d-g	6.6 e-f	4.0 b-e	19.2 c-e	158.6 b-f	7202.4 c-f	0.076 d-e	131.7 c-d
	05-Aug	11.7 h-k	345.1 f-i	42.7 g-i	26.7 g-i	4.6 i-k	1.7 h-l	5.6 h-i	2.9 f-h	17.7 d-g	142.2 i-k	5798.2 h-k	0.079 b-e	53.6 h-l
	05-Sep	10.7 i-k	342.4 g-i	40.9 j-l	25.7 h-i	4.4 j-k	1.3 l	5.3 i-j	2.9 f-h	14.2 h-k	128.8 l-m	5508.2 j-l	0.080 b-e	47.1 i-l
	05-Oct	8.0 k	337.8 h-i	39.2 m	25.5 I	4.4 k	1.2 l	4.1 m	2.3 h	11.9 k	114.0 n	4662 l	0.097 a	35.2 l

[a] - Abbreviations are described in materials and methods

Correlation Coefficient

Results from phenotypic correlation coefficient (Table 5) indicated that there were positive and significant correlations between SY and all studied traits that the maximum correlation belonged to FWF and DWF (r = 0.77** and 0.75** respectively) and minimum correlation belonged to NF and HI (both r= 0.64**). Also Katar et al., (2012) in their study stated that there were high positive and significant correlations between yield and yield components.

Table 5. Correlation coefficient between studied traits in saffron genotypes

	NF											
FWF	0.45 **	FWF										
DWF	0.70 **	0.81 **	DWF									
FWS	0.54 **	0.60 **	0.63 **	FWS								
DWS	0.71 **	0.59 **	0.75 **	0.91 **	DWS							
NDC	0.53 **	0.66 **	0.67 **	0.67 **	0.69 **	NDC						
FWDC	0.53 **	0.66 **	0.67 **	0.67 **	0.69 **	0.99 **	FWDC					
DWDC	0.71 **	0.60 **	0.70 **	0.66 **	0.73 **	0.54 **	0.55 **	DWDC				
LL	0.70 **	0.61 **	0.71 **	0.66 **	0.72 **	0.55 **	0.54 **	0.98 **	LL			
DWL	0.72 **	0.58 **	0.69 **	0.70 **	0.79 **	0.59 **	0.58 **	0.96 **	0.96 **	DWL		
BIO	0.71 **	0.59 **	0.70 **	0.71 **	0.78 **	0.58 **	0.59 **	0.95 **	0.95 **	0.98 **	BIO	
HI	0.62 **	0.56 **	0.62 **	0.62 **	0.67 **	0.74 **	0.74 **	0.71 **	0.71 **	0.70 **	0.70 **	HI
SY	0.64 **	0.75 **	0.77 **	0.65 **	0.68 **	0.68 **	0.68 **	0.66 **	0.66 **	0.65 **	0.65 **	0.64 **

[a] - Abbreviations are described in materials and methods

Step by Step Regression

To determine the most effective traits on stigma yield, step by step regression method was used (Table 6) and stigma yield as dependent variable and other traits as independent variables were spoted. On the other hand, to achieve the real understanding of traits effects on stigma yield, we used step by step regression for each year individually, and for three years overall. So results from step by step regression analysis indicated FWS and DWF accounted for 71% of total variance of stigma yield in arable 2009; the regression coefficient was SY = -143.2 + 5.1 DWF + 2.5 FWS. Results from step by step regression analysis indicated FWDC and DWF accounted for 80% of total variance of stigma yield in arable 2010; the regression coefficient was SY = -2.2 + 14.9 DWF + 2.8 FWDC. Results from step by step regression analysis indicated FWF accounted for 76% of total variance of stigma yield in arable 2011; the regression coefficient was SY = -226.2 + 1.0 FWF. Finally, results from step by step regression for all years indicated FWF, NDC and NF accounted for 68% of total variance of stigma yield. Low amount of Standard deviation for NF, FWF and NDC (0.17, 0.14 and 0.04) as well as low amount of Durbin Watson Index (1.7) indicated well propriety and confidency of model; the regression coefficient was SY = -135.1 + 0.09 NDC + 0.75 FWF + 0.68 NF.

Table 6. Regression coefficients of saffron yield using stepwise method

Year	Model	Unstandardized Coefficients B	Std.Error	Unstandardized Coefficients Beta	t	R2	Durbin Watson
2009	Intercept	-143.2	47.2		-3.0 **		
	DWF	5.1	1.5	0.55	3.5 **		
	FWS	2.5	1.1	0.37	2.3 *		
						0.71	1.2
2010	Intercept	-2.2	36.9		-0.06		
	DWF	14.9	2.9	0.63	5.23 **		
	FWDC	2.8	0.9	0.36	6.02 **		
						0.80	1.5
2011	Intercept	-226.2	43.94		-5.15 **		
	FWF	1.07	0.13	0.88	8.56 **		
						0.76	1.9
Total	Intercept	-135.1	47.78		-2.83 **		
	NDC	0.09	0.04	0.21	2.19 *		
	FWF	0.75	0.14	0.47	5.21 **		
	NF	0.68	0.17	0.32	3.93 **		
						0.68	1.7

[a] - Abbreviations are described in materials and methods

Overall, from results of step by step regression, it can be stated FWDC and NDC are the most effective and important factors for increasing stigma yield in saffron. According to reproduction of saffron by corms, increasing NDC and FWDC not only can improve yield components (include NF, FWS FWF DWF) but also improve dry saffron yield via more production of daughter corms and high NDC at the next years extremely.

CONCLUSION

According to present study, it can be concluded beside that saffron is a sterile crop and reproduce only by asexual method, it was affected climate severely. So it is necessary to select appropriate ecotypes to each region. We indicated two ecotypes Mashhad and Torbat-jam as more fitted ecotype to Mashhad climate. Then it revealed delaying in cultivation not only reduced yield and component yield at the first year, but also affected saffron yield in next years. Both sowing dates 05-Jun. and 05-Jul. also were selected as the best sowing dates in Mashhad region as well as the traits NDC and FWDC were selected as the main triats for increasing dry saffron yield; so high-weight corms (up to 8 g) are appropriate and necessary for producing dry saffron especially at the first year. Anyway according to this study, to establish new saffron farms, it is better to pay attention to corm quality and climate accordance between the region have produced mother corms and the region will be established new farm. Finaly we have concluded that the major component of well-establishing new farm in new climate is to select most suitable ecotypes based on proper analysis.

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