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Study of diversity in some Moroccan population of saffron (*Crocus sativus* L.)

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To study Moroccan saffron germplasm variability relating to different agro-morphological and phenological traits, 969 saffron corms (accessions) were collected from thirteen different sites located in traditional saffron area of Taliouine-Taznakht. The study confirmed a wide range of phenotypic variability within and between populations. The variance analysis revealed that the mother corm weight (MCW), taken as covariant, has significant effect on all studied traits. The difference within and between origins (Provenances) was highly significant for all traits, which showed highly significant correlation. The flowers number (NF) as well as the number of daughter corms weighing above 7 g per plant (NDC≥7) turned out to be the most determinant parameters of saffron yield. The produced FN per corm varied from 1 to 9 with an average of 2.2 flowers. P1 population recorded a flowering rate of 65.5% with a maximum average of NF (2). Stigmat length (SL), which is an important yield trait, showed wide variation between origins from 32 to 38 mm. The mean stigma dry weight (DSW) varied from 4.2 to 6.2 mg with a maximum of 7.1 mg per flower recorded in P1. The PCA revealed 5 homogeneous main groups inside the studied populations. The first one was monoorganogenic and consisted of P1 population only, a group characterized by high values of MCW, NF, NDC≥7 and DSW. This study confirms as well a noticeable influence of corm origin on saffron yield, explained by the genotypic profile and/or the epigenetic effects of the different origins. These results proved a variability which should be useful to the selection program aiming the improvement of saffron productivity in Morocco.

Key words: Variability, agro-morphological traits, phenological traits, saffron corms, Morocco.

INTRODUCTION

Saffron (*Crocus sativus* L.) is one of the most important spice plants because of the pistil high value that grow inside its flowers. Growing in different countries under various soil-climate conditions, during many centuries, saffron has been influenced by various stressful factors and has undergone different sorts of mutations. Every changes and became a unique genotype, a new clone. Clones within a population grow together as a mixture, but they never combine into the same genetic structure because of their sterility (Agayev et al., 2012). Most

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Table 1. Details of saffron germplasm lines collected from 13 locaions of Morocco.

Origin code	District	Location (Douar)	Altitude (m)
P1	Askaouen	Askaouen	1900 - 2200
P2	Tawyalt	Assaka	1900 - 2200
P3	Tawyalt	Anrouz	1900 - 2200
P4	Sidi Hssaein	Tasgna	1450 - 1650
P5	Zagmouzen	Darf	1450 - 1650
P6	Zagmouzen	Darf	1450 - 1650
P7	Assaysse	Assaysse	1650 - 1900
P8	Zagmouzen	Darf	1450 - 1650
P9	Agadir melloul	Tamlakout	1650 - 1900
P15	Askaouen	Askaouen	1900 - 2200
P16	Askaouen	Askaouen	1900 - 2200
P17	Askaouen	Askaouen	1900 - 2200
P18	Askaouen	Askaouen	1900 - 2200

operating mutations and other genetic changes are preserved in the local populations (Singh et al., 2015). Such a process led to diverse clones with a high, medium or low viability potential. High potential clones are prospering but have small extent whereas the medium ones prevail in majority. The third group is exposed to a genetic decline leading to a partial disappearance and replacement by the first and the second group. That is the natural selection, self-renewal selection (Agayev and Zarifi 2010).

Saffron biological characteristics make its breeding too complicated (Agayev et al., 2012). Studies of the divergence are of great importance in the variation estimation and the potential of its future utilization in crop improvement programs (Salwee and Nehvi, 2014). Corm multiplication in saffron does not induce genome variation, except some natural mutations which are not easily detectable in triploid saffron specie (Salwee and Nehvi, 2014).

Moroccan saffron cultivation development depends mainly on the improvement of yields which appear to be relatively small and variable compared with other producing countries. The increase of yields requires an efficient cultivars selection. However, an evaluation of the existing population from different provenances is primordial as a preliminary step. Hence, the present work aims to study the genetic diversity of the Moroccan saffron populations relating to some agro-morphological and phenological traits.

MATERIALS AND METHODS

The saffron corms were collected in August 2014 from 13 representative villages of the main traditional saffron cultivation areas in Morocco (Table 1). Individual corm samples were identified through an access code, the name of the farmer, and plot location, and they were characterized through their diameter (cm) and weight (g). In the first year, all the collection was planted at the National Institute for Agricultural Research (NIAR) in the experimental station of Annoceur. This site is located in the province of Sefrou, in southern Fes-Meknes Region at an elevation of 1350 MAMSL and characterized by an annual average temperature ranging from -7 to 40°C and annual precipitation of 500 mm. Uniform cultural conditions were maintained for raising a good crop. Germplasm lines were planted in early October 2014 for their multiplication. In July 2015, daughter corms of each accession were harvested separately. Then, their number and weight were recorded. For a second multiplication cycle, the daughter corms were planted in September 2015 in a completely randomized design in Berrechid area, located on south of Casablanca at an altitude of 350 MAMSL with an annual temperature ranging from 5 to 32°C and annual precipitation of 365 mm. The soil is clay to sandy with an alkaline pH (8.35), a normal electric conductivity (0.15 mmhos/cm) and a high content of organic matter (2.78%).

The collection involved 969 corms from 13 origins. The number of accessions per population varied from a minimum of 16 corms to 155 as maximum. Corms were planted in rows at a depth of 10 cm with inter and intra row distance of 40×40 cm. During the growing season, twelve agro-morphological traits were studied; mother corm weight (g) (MCW), flowers number (FN), fresh stigma length (cm) (FSL), stigma dry weight (mg) (DSW), number of days to anthesis (days) (DA), flowering duration (days) (FD), number of days to 100% flowering (FED), number of sprouts (NS), plant height (cm) (PH), number of daughter corms (NDC), number of daughter corms over 7 g (NDC≥7), and number of daughter corms below 7 g (NDC<7).

Statistical analysis were carried out using descriptive statistics, analysis of variance (ANOVA) and principal component analysis (PCA) using Past 3.10 software and Minitab 17.1.0 software. Data was square root transformed to ensure normal distribution and homogeneity in variance and they were further analyzed by ANOVA. To study the structure of Moroccan saffron germplasm, distances between populations were computed using the Euclidean distances using previously standardized data. Clustering of the genotypes was performed using UPGMA clustering method.

RESULTS AND DISCUSSION

Descriptive analysis

The saffron accessions collected from 13 traditional saffron areas of Morocco were evaluated through twelve

Table 2. Descriptive statistical analysis of agro-morphological traits in Saffron (*Crocus sativus* L.).

Trait	N	MCW (Units)		FN (Units)		NS (Units)		PH (Units)		NDC (Units)		NDC<7 (Units)		NDC≥7 (Units)	
Orig.		Avg	CV	Avg	CV	Avg	CV	Avg	CV	Avg	CV	Avg	CV	Avg	CV
P1	58	22.3	25.8	**2.0**	107.0	7.2	40.3	**31.0**	22.5	8.2	31.4	5.1	54.3	**3.1**	50.4
P15	42	12.6	30.1	0.4	154.9	6.4	34.4	29.2	19.7	6.9	31.5	6.0	35.2	0.9	91.1
P16	64	14.1	28.5	0.6	178.9	5.8	**50.9**	28.2	27.6	5.9	40.1	4.2	58.7	1.7	89.7
P17	32	13.1	37.5	0.4	**251.2**	4.7	43.2	26.1	**35.1**	4.6	**47.9**	3.7	60.2	0.9	**107.6**
P18	15	12.7	34.1	0.5	139.4	4.7	44.8	27.9	23.0	5.8	34.0	4.4	49.2	1.3	96.8
P2	87	16.8	32.7	0.5	230.5	5.4	39.6	28.9	23.0	6.3	37.0	4.2	53.7	2.1	78.8
P3	16	12.8	35.5	0.4	165.1	5.5	49.7	30.3	21.0	5.8	39.3	4.9	46.1	0.9	82.3
P4	116	17.3	33.4	0.7	149.9	6.1	34.2	**31.0**	16.2	6.6	34.5	4.2	56.6	2.3	77.9
P5	127	**22.9**	34.0	0.7	195.1	7.4	44.1	28.6	26.6	8.5	38.4	5.9	50.8	2.7	78.7
P6	**155**	18.8	31.7	0.7	215.5	6.3	40.6	28.9	27.2	7.6	35.1	5.0	56.5	2.6	79.8
P7	60	19.5	31.2	0.9	179.2	5.8	30.7	28.9	20.7	6.1	33.3	3.9	53.4	2.2	81.9
P8	148	22.5	**38.9**	1.3	156.9	**7.8**	43.8	29.5	20.0	**8.9**	39.3	**6.5**	54.3	2.3	89.0
P9	49	19.1	36.7	1.4	140.9	5.0	45.2	27.4	28.8	6.7	44.7	4.6	**72.2**	2.0	78.1
Gen	969	18.9	38.4	0.9	180.7	6.4	44.2	20.1	23.8	7.3	40.7	5.0	57.7	2.2	84.5

Maximal values are bolded and minimal values are underlined.

Table 3. Contribution of mother corm weight towards total variance.

Factor	DF	SS%	F
Origin	12	20.98	21.15***
Error	956	79.02	-
Total	968	100.00	-

*, **, ***: significant at 0.05, 0.01 and 0.001, respectively.

agro-morphological traits. The mean values were subjected to descriptive statistics to evaluate the extent of the diversity within different sampled populations (Table 2).

The NF is the most polymorph character which recorded the highest CV (180%) whereas the plant height was less variable between populations (CV = 23.8%). Daughter corms number (NDC) representing a determinant productivity factor in the first year of saffron cultivation exhibited average CV over different populations to the extent of 40.7%.

Study confirmed a wide range of variability of agro-morphological traits between populations. The flowers number, the shoots number per corm and the daughter corms number ranged, respectively from 0.4 (P15) to 2.0 (P1), 4.7 (P17, P18) to 7.8 (P8), and 4.6 (P17) to 8.9 (P8). P1 recorded the maximum flower number and daughter corms number weighing above 7 g (3.1), whereas the least number of corms was recorded by P15 (0.9) (as shown in Table 2).

The behavior of different accessions from each provenance shows a different profile. Especially, P17 which recorded the highest CV for most of the characters. Thus, enhances a phenotypic variation inside P17. P1 recorded the lowest CV and less diversity between its accessions.

Previous studies about saffron diversity have shown variability in agro morphological traits. In fact, Sheikh et al. (2014) revealed significant genotypic differences for FN (0.8-1,96), NS (15.4-26.6), PH(23.2-35.6) and NDC (3.46-9.3) and highlighted the environment effect on the character expression. Singh et al. (2015) has studied 28 accessions from Cachemire and has reported a NF per corm ranged between 2 and 4.

Variance analysis

The variance analysis showed highly significant difference for MCW (Table 3). Results indicate the existence of specificities of each origin. The residual variation accounted for 79% of the total variance, showed high level of variation within the same origin, while the locations accounted for 21% of the total variance (Table 3). This high level of MCW variation can be explained by the difference within origins. In fact, MCW ranged from

Table 4. Analysis of covariance for different agro-morphological traits in saffron (*Crocus sativus* L.).

Factor	DF	FN	NS	PH	DCN	DCN < 7	DCN≥ 7
MCW	1	107.7***	164.0***	24.0***	174.1***	9.7**	228.5***
ORIGIN	12	4.4***	4.6***	2.2**	6.6***	6.8***	3.1***

*, **, ***: significant at 0.05, 0.01 and 0.001 respectively.

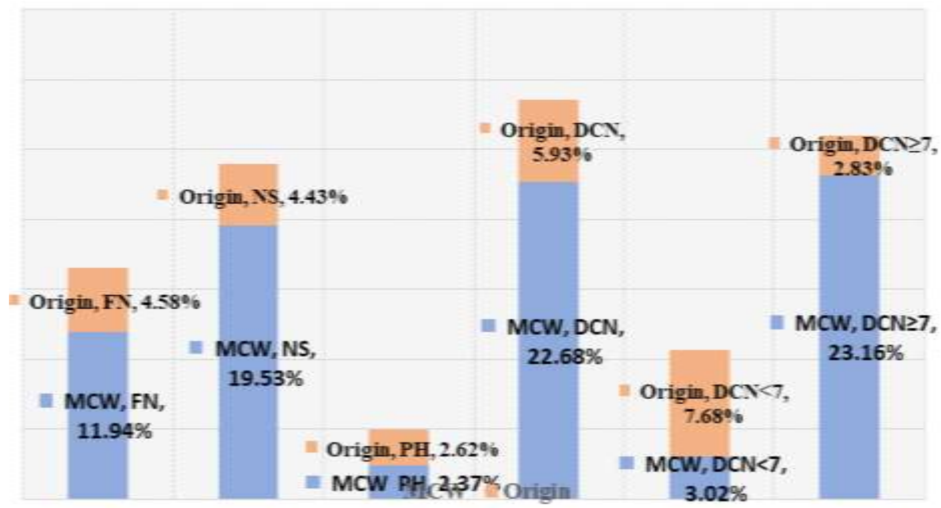

Figure 1. Contribution of mother corm weight and origin to total variance.

22.9 g for P5 to 12.5 g for P15.

Mother corm weight taken as covariant showed very high significant effect on most of the traits studied (Table 4).

Mother corms weight and origins effect

Contribution of the mother corm weight to the total performance of the daughter corms depends on the evaluated traits. The results confirmed a greater contribution of the mother corm weight to the total variability particularly the number of the daughter corms weighing above 7 g (Figure 1). In fact, the mother corm weight contributed by 23.16% to the total variance while the provenance contributed only by 2.83%. Similar results have also been confirmed by Soheilivand et al. (2007), which can be explained by the total reserves available to the production of new corms. For the number of shoots, MCW contributed 19.53% to the total variance while only 4.43% of the variance can be explained by the origin. Similar high contribution of the MCW compared to the origin has been observed for the total number of daughter corms and the number of flowers with 22.68% against 5.93% and 11.94% against 4.58%, respectively. On the other hand, the influence of the mother corm weight was relatively equivalent to that of the origin for the plant height, whereas, the influence of the origin on the total variability was pre-dominant for number of daughter corms weighing less than 7 g (7.68% vs. 3.02%). Several studies have highlighted the importance of the weight of the mother corms on the saffron production parameters like the number of flowers and the number of large daughter corms which are the two most economically important traits (Soheilivand et al., 2007; Agayev et al., 2012).

The differences between the origins were also highly significant for all the studied traits (Table 4). P1 population recorded an average more than 3 flowers per flowering corm coupled with 8 daughter corms (DCN) and 3 daughter corms weighing above 7 g/corm (DCN≥7) (Figures 2 to 5). The populations P5, P6, P8 and P9 were also close to P1. On the other hand, P3, P15, P17 and P18 populations were less productive. P3 produced a very low flower number (less than one flower/3 planted corms) with only 1 corm weighing above 7 g/mother corm.

The classification and grouping of the origins based on productivity traits (flowers number and daughter corms number) revealed the superiority of P1 and P8 (Tables 5 and 6). In terms of flowers number, P9 was observed to be as productive as P1, whereas for daughter corms number, P5 and P1 are observed to be as efficient as P8 (Tables 5 and 6). On the other hand, P17 and P3 were

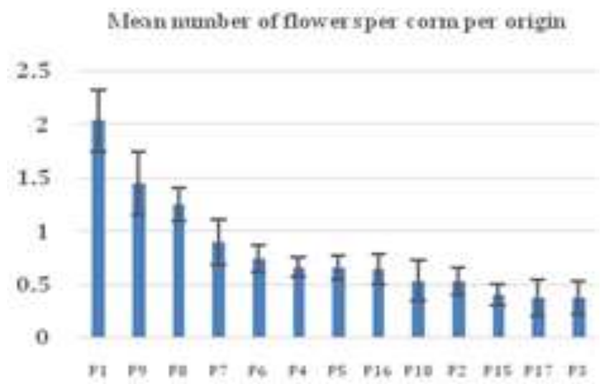

Figure 2. Distribution of flowers number (± standard deviation).

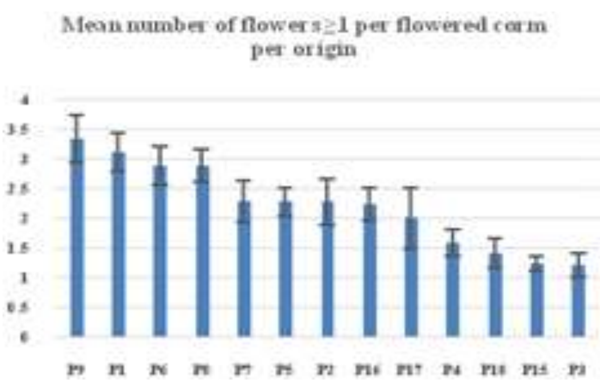

Figure 3. Distribution of flowers number ≥1 (± standard deviation).

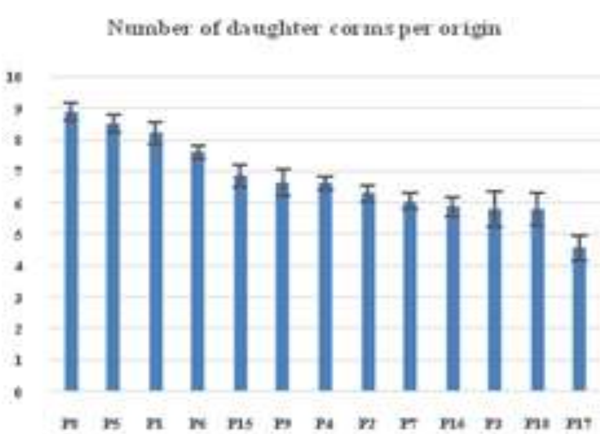

Figure 4. Distribution of daughter corm number (± standard deviation).

observed to be the less productive origins in terms of the flowers number and P17, and P18 in terms of the corms number produced

Ben El Caid et al. (2018) reported that regardless of number daugther corms, positive correlation was stated

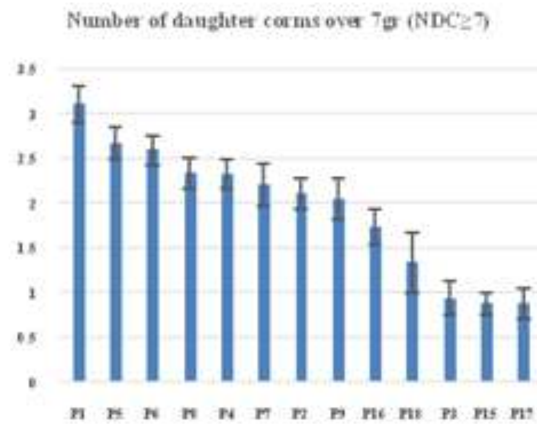

Figure 5. Distribution of daughter corm number ≥ 7 g(± standard deviation).

Table 5. Origins classification by the flowers number in saffron.

Original	Mean	Grouping
P1	**2.03**	**A**
P9	1.45	AB
P8	1.25	B
P7	0.90	BC
P6	0.74	BC
P4	0.66	BC
P5	0.65	BC
P16	0.64	BC
P18	0.53	BC
P2	0.53	BC
P15	0.40	BC
P17	0.38	BC
P3	0.38	BC

Values followed by a common letter within each column are not significantly different at $P < 0.05$ using the Duncan's Multiple Range Test (DMRT).

between the studied agro-morphometric traits and provenance Agadir Melloul in FSA planting site.

Correlations between traits

All the studied traits exhibited a highly significant correlation except the correlation between the corms number below 7 g and the flowers number (FN) per mother corm (Table 7). Apart from the correlations between dependent traits, NDC≥7 g, NDC<7 g and NDC, the sprouts number (NS) was also highly correlated to the corms number produced (0.61), since the daughter corms develop at the leaf base. As confirmed by ANCOVA, the MCW was positively correlated to all the production parameters (NF, NS, NDC and NDC≥7) and their R values were 0.35, 0.44, 0.48 and 0.48, respectively.

Table 6. Origins classification by the daughter corms number in saffron.

Original	Mean	Grouping
P8	**8.89**	**A**
P5	8.53	AB
P1	8.21	ABC
P6	7.61	BCD
P15	6.86	CDE
P9	6.65	CDE
P4	6.62	DE
P2	6.31	EF
P7	6.05	EF
P16	5.88	EF
P3	5.81	CDEF
P18	5.80	CDEF
P17	4.56	F

Values followed by a common letter within each column are not significantly different at P < 0.05 using the Duncan's Multiple Range Test (DMRT).

Table 7. Pearson correlation Matrix among agro-morphological traits in saffron.

Number of flowers (FN)	0.35***						
Number of shoots (NS)	0.44***	0.17***					
Plant heigth (PH)	0.15***	0.22***	0.38***				
Number of dauther corms (NDC)	0.48***	0.10**	0.61***	0.14***			
Number of dauther corms (NDC<7)	0.17***	-0.04^{NS}	0.40***	-0.12***	0.79***		
Number of dauther corms (NDC≥7)	0.48***	0.22***	0.35***	0.41***	0.35***	-0.29***	
-	MCW	FN	NS	PH	NDC	NDC<7	NDC≥7

*, **, ***: significant at 0.05, 0.01 and 0.001 respectively.

Table 8. Flowering percentage in Saffron over different origins.

ORI.	P1	P15	P16	P17	P18	P2	P3	P4	P5	P6	P7	P8	P9
FLOW (%)	**65.5**	31.0	20.3	18.8	33.3	21.8	31.3	20.7	28.3	25.8	41.7	41.2	42.9

Negative correlations were identified between NDC<7 and NDC≥7 (-0.29) and PH (-0.12) (Table 7).

Flowering potential and productivity

The first-year evaluation at Berrechid experimental station, showed that only 32% of the corms produced flowers. The flowering rate varied between origins and ranging from 1 to 3 flowers/corm (Table 8). P17 was the least productive population with less than one flower produced per 5 corms, while 65.5% of P1 corms exhibited flowers.

Saffron is known as a low volume and high value crop with the number of flowers per plant being the most determinant parameter for saffron yield, contributing directly to the production volume. Results revealed a wide variability for this trait ranging from 1 to 9 flowers produced per corm with an average of 2.2 flowers.

The stigma length and weight, two important yield contributing traits, recorded a wide range of variation for different regions, ranging between 32 and 38 mm and 4.2 and 6.2 mg, respectively. Maximum stigma weight (7.1 mg per flower) was recorded among accessions of P1 origin and the lighter DSW was recorded among P18 accessions.

Table 9. Descriptive analysis of saffron.

Ori.	N	MCW		FN		DA		FD		FED		FSL		DSW	
		AVG	CV	AVG	CV	AVG	CV	AVG	CV	AVG	CV	AVG	CV	AVG	CV
P1	38	24.00	20.4	3.1	63.4	58.7	6.5	3.2	79.5	60.9	5.5	**3.7**	10.1	**6.2**	17.6
P15	13	12.60	19.4	1.2	35.6	59.2	9.8	1.8	115.7	59.9	8.6	3.6	15.9	5.1	**25.8**
P16	13	16.20	13.9	2.2	45.4	57.6	4.9	**3.7**	74.5	60.3	3.5	**3.7**	11.4	5.4	24.8
P17	6	15.70	30.3	2	63.3	57.8	6.8	2.3	120.2	59.2	3.5	3.5	9.8	4.9	12.3
P18	5	15.10	32.5	1.4	39.1	61	4.5	1	0	61	4.5	3.2	14.4	4.2	19.1
P2	19	18.80	30.1	2.3	74.9	59.8	5.8	2.7	121.7	61.5	5.8	3.5	12.8	5.1	19.5
P3	5	10.20	34.3	1.2	37.3	61	**10.8**	1.8	99.4	61.8	**9.7**	3.7	12.1	5.6	12.9
P4	24	18.80	**42.9**	1.6	66.9	**61.5**	4.9	2	101.6	**62.4**	4.7	3.6	13.6	5.6	22.6
P5	36	25.60	32	2.3	62.6	58.8	4.9	2.9	83.7	60.7	4.7	3.5	**16.2**	4.7	20.6
P6	40	21.50	20	2.9	70.5	59.6	6.3	3.3	87.5	61.8	5.2	3.7	9.9	5.9	18.3
P7	25	21.70	29.4	2.3	**78.6**	60.2	8.3	2.8	**125.2**	62	7.7	3.6	14.3	5.8	18.9
P8	61	**26.40**	25.8	2.9	74.9	59.1	6.7	3.1	79.8	61.2	6	3.6	11	5.2	25.4
P9	21	19.60	32.2	**3.3**	55.6	58.8	7	**3.7**	79.2	61.5	6.8	**3.8**	8.1	5.6	18
-	-	18.94	27.94	2.21	59.08	59.47	6.71	2.64	*89.85*	61.09	**5.86**	3.59	12.28	5.33	19.68

MCW: Mother corm weight, FN: flowers number of flowered corms, DA: number of days to anthesis, FD: flowering duration, FED: number of days to 100% flowring. FSL: fresh stigma with style lenghtt, DSW: dray stigma with style weight, AVG: average, CV: variation coefficient, N: sample size, Ori: origin.

Table 10. Variance analysis of flowering traits.

Source	DF	FN	DA	FD	FED	FSL	DSW
MCW	1	39.9***	3.6	26.2***	2.6	0.0	9.7**
ORIGIN	12	2.6**	1.4	1.9*	1.0	1.8*	4.9***
Total	305	-	-	-	-	-	-

*, **, ***: significant at 0.05, 0.01 and 0.001 respectively.

The study confirmed the minimum variability for phenological and yield characters in saffron compared to agro-morphological traits (Table 9). Among different origins, the flowering duration period fluctuated between 15 and 21 days. The least variable trait was the number of days to the last flower emission (CV 5.98%). In contrast, flowering duration (CV 89.85%) as a phenological trait and the number of flowers (CV 59.08%) as a saffron production trait were the most variable.

Among agro-phenological traits, the MCW taken as a covariate had a very significant effect on the flowers number per corm (FN), the flowering duration (FD) and the stigmas weight (DSW) (Table 10). The differences between origins were on the other hand, very significant for the number of flowers per corm, the dry stigmas weight (DSW) and just significant for the flowering period duration (FD) and the fresh stigmas length (FSL). The differences between origins were not significant for the first and last days of flowering

Table 11. Pearson correlation matrix among phenological traits in saffron

Number of flowers (NF)	0.41***						
Day to anthesis (DA)	-0.11*	-0.45***					
flowering duration (FD)	0.29***	0.64***	-0.46***				
Number of days to 100% Flowering (FED)	0.10	-0.01	0.75***	0.24***			
fresh stigma length (FSL)	0.01	0.14*	-0.22***	0.12*	-0.16**		
Dry stigma weight (DSW)	0.13*	0.17**	0.03	0.08	0.09	0.46***	
-	MCW	NF	DA	FD	FED	FSL	DSW

*, **, ***: significant at 0.05, 0.01 and 0.001 respectively.

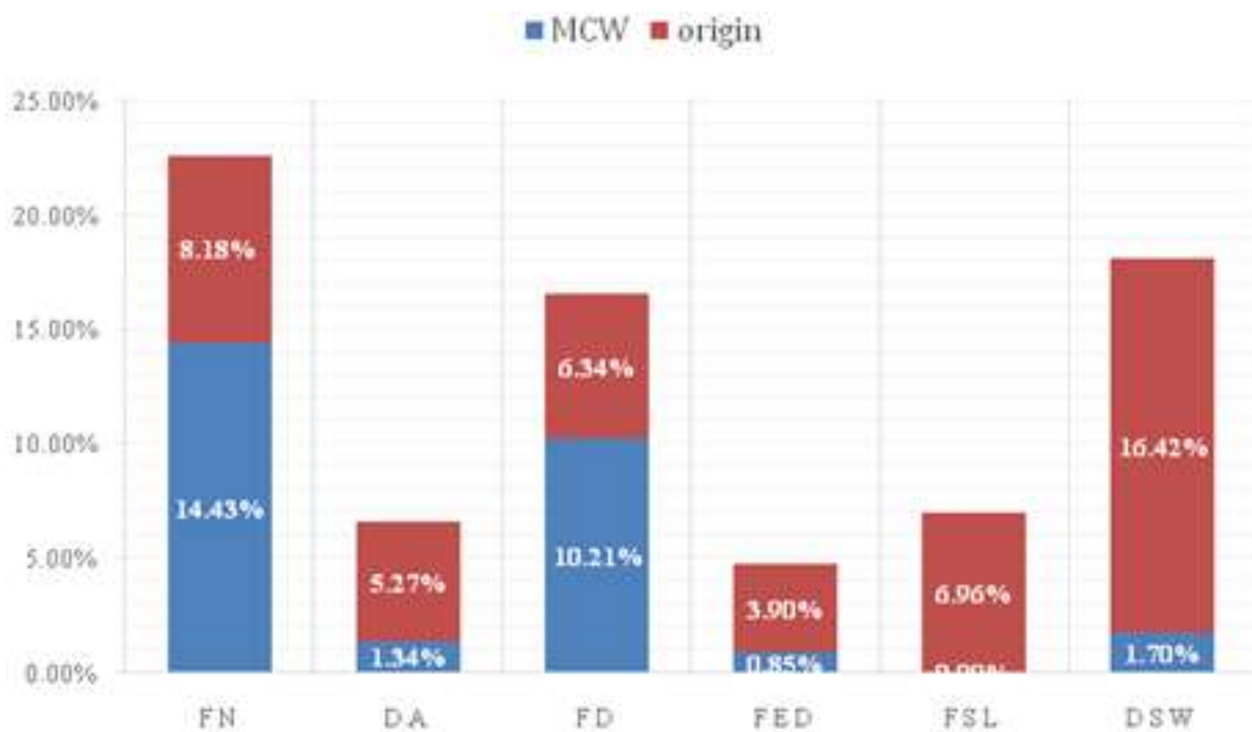

Figure 6. Contribution of the mother corm weight and the origin to total variance.

(DA, FED); this suggests that for the studied saffron collection, the phenological stages are mainly controlled by environmental factors.

The results showed that the contribution of mother corm weight to the total variance depends on the studied character. The highest variance rate explained by the mother corm weight was the flowers number (FN) (14.18%), followed by the flowering period duration (FD) (10.21%). High weight corms produce more flowers and therefore exhibit a longer flowering duration (Table 11). It is therefore concluded that the corm origin has a significant effect on saffron yield; this can be explained by the genotype profile and/or by the epigenetic effects of the provenances.

Soheilivand et al. (2007) reported differences in the flowers number produced by heavy and light corms and emphasized the fact that the heavier mother corms produce more flowers compared to the lighter corms. Planting corms weighing 3 to 7 g does not show any differences in the flowering rate or yield increasing. Mahdi et al. (2016) reported that corms with ≤6 g are not recommended for saffron cultivation.

The total variance due to origin was high for the fresh stigma length (FSL; 6.96%), dry stigma weight (DSW; 16.42%), and the flowering period duration (FED; 3.9%) (Figure 6). It is therefore concluded that the corm origin has a significant effect on saffron yield; this can be explained by the genotype profile and/or by the epigenetic effects of the provenances. Also, De-Mastro and Rota (1993) demonstrated that the corm size has a positive effect on the flowering rate but not on the stigma weight.

Table 12. Principal components for saffron populations.

PC	Variance (%)	Cumulated variance (%)
1	63.51	63.51
2	20.93	84.44
3	8.22	92.66
4	5.06	97.72
5	1.24	98.95
6	1.03	99.99
7	0.01	100.00

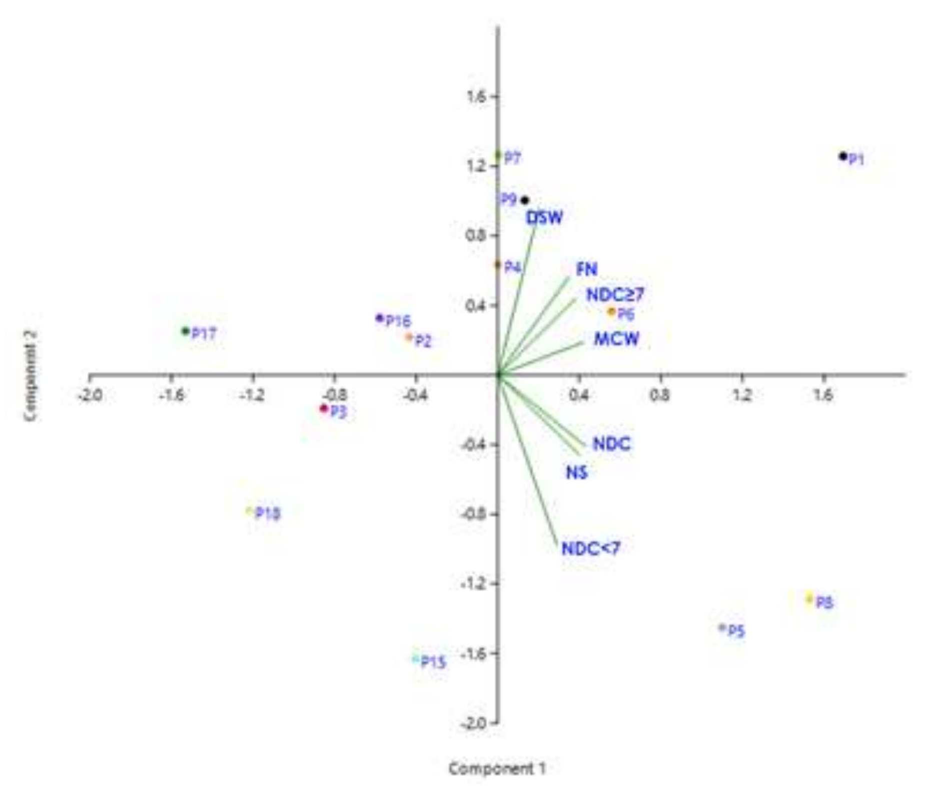

Figure 7. Principal Component biplot PC1 and PC2.

Principal component analysis

The principal components analysis revealed that the two first components had a cumulative variance of 84.44%, with the first PC cumulating 63.51% of the variance and the PC2 20.93% of the variance (Table 12).

The first component presented a positive strong loading from all the studied traits. The main contribution was from MCW, NS, NDC, NDC≥7 and FN, whereas it has a smaller contribution from NDC<7 and DSW. In contrary, the second component is mainly composed of a positive loading from DSW and a negative loading from NDC<7 (Figure 7).

The PCA biplot of the two first components have grouped studied populations into 5 homogeneous groups (Figure 8). The first group composed only of P1, as this population gathers individuals with a higher corm weight, NF, NDC≥7 and stigmas weight. The populations P5 and P8 form a second group and were projected on the positive side of PC1 and the negative side of PC2. The reason being a high MCW and the highest number of corms below 7 g associate with low stigma weight. Populations P17 and P18 were grouped together and are located on the negative side of the PC1 having a poor mother corms weight, number of flowers, shoot size and number, and number of daughter corms. P3 and P15

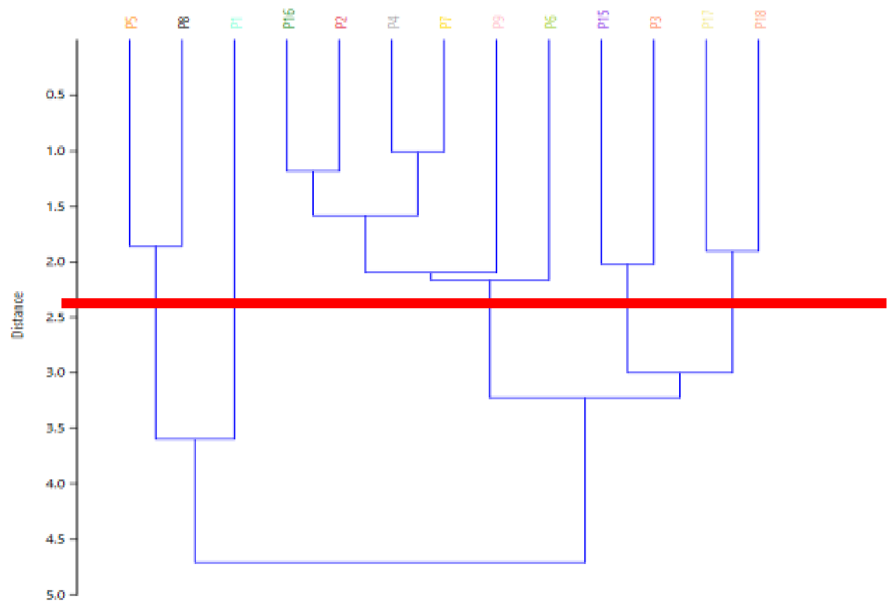

Figure 8. Populations clustering using UPGMA linkage and Euclidean distance.

populations belong to the fourth group located at the negative sides of both first and second principal components. This fourth group recorded the least mother corm weight, flowers number, number of daughter corms over 7 g and stigma weight. The remaining six populations, P2, P4, P6, P7, P9 and P16, were grouped into the fifth group in the middle of the biplot representing intermediate values of all the evaluated traits (Figure 7).

Cluster analysis did not reveal any clear relationship between diversity pattern and geographical origins (Different provenances). This can be explained by corm exchange between districts, villages and farmers (Birouk, 2009). The group III (P12, P2, p7, P9, P4, and P6) gathered several origins from different altitudes. The pattern of grouping indicated that geographical diversity was not an essential factor to group the genotypes from a particular source. Similar findings have been reported by Maqhdoomi et al. (2010) and Qadri et al., (2013).

Based on the results of the correlation coefficients, NF, NDC and NDC≥7 g traits are the most important traits to improve yield components and subsequently can increase the saffron yield. Saffron is indeed a perennial plant; its agronomic traits have high positive phenotypic and genotypic correlation with each other. Therefore, selecting an appropriate size quality saffron corm guaranteed a large NF and NDC≥7 g, and high DCW that will ensure high saffron yield in the first and the subsequent years. Mahdi et al. (2016) and Molina et al. (2005) reported that the limiting factor for the flowering is the small size of the corms. Soheilivand et al. (2007) reported that planting 3 to 7 g corms does not make any difference in the flowering rate or on the yield.

Conclusion

The present study which aims to show the genetic diversity of Moroccan saffron, has demonstrated a great variability of almost the studied traits. It could be assumed that the combination of more than one factor could explain the variation observed. The obtained results may bring valuable information to initiate saffron improvement program. Thus, selection of productive cultivar is possible and is the fastest way to improve saffron productivity.

CONFLICT OF INTERESTS

The authors have not declared any conflict of interests.

REFERENCES

Agayev YM, Akperov Z.A, Zarifi E (2012). New research challenges on clonal selection of saffron (*Crocus sativus* L.). In: Proceedings of 4th International saffron symposium. Advances in saffron biology technology and trade 22-25 October, Kashmir, India. P 18.

Agayev YM, Zarifi E (2010). Peculiar Evolution of Saffron (*Crocus sativus* L.): Prosperity and Decline Proc. 3r dIS on Saffron Eds.: M.Z. Tsimidou et al. Acta Horticulturae850, ISHS pp. 29-32.

Ben El, Caid M,Salaka L, Lachheb M, Lagram K, Atyane H, | El Mousadik A, Serghini MA (2018). Provenance and site effects on progeny Saffron corms (*Crocus Sativus*) productivity. American Journal of Innovative Research and Applied Sciences 7(4):198-207

Birouk A (2009). Renforcement des capacités locales pour développer les produits de qualité de montagne - Cas du safran. Rapport Projet: FAO/TCP/MOR/3201.

De Mastro G, Rute C (1993). Relative between corm size and saffron (*Crocus sativus* L.) flowering. Acta Horticulturae 344 :512-517.

De-Los-Mozos-Pascual M, Santana-Meridas O, Rodrigues-Conde MF, Sanchez-Vioque R, Pastor-Ferriz T, Fernandez J, Santaella M, Sanchez RA, Renau B, Sanchis E, Garcia-luis A, Guardiola JL, Molina RV (2010). A preliminary characterization of saffron germplasm from the CROCUSBANK collection. In: Proceedings of 3rd International Symposium on Saffron 20-23 May, Krokos, Kozani, Greece P 8.

Mahdi B, Mehdi R, Mehdi R (2016). Determining the most effective traits to improve saffron (*Crocus sativus* L.) yield. Physiology and Molecular Biology of Plants 22(1):153-161.

Maqhdoomi MI, Nehvi FA, Wani SA (2010). Genetic divergence in Saffron (*Crocus Sativus* L.). Acta Horticulturae 850 :79-84.

Molina R, Valero M, Navarro Y, Garcıa-Luis A, Guardiola J (2005). The effect of time of corm lifting and duration of incubation at inductive temperature on flower formation in saffron (*Crocus sativus* L). Scientia Horticulturae 103:361-379.

Salwee Y, Nehvi FA (2014). Structural Variations and Biology of Kashmir Saffron-A Study. Vegetos 27:376-381.

Sheikh FA, Makhdoomi MI, Gowhar A, Nehvi FA,. Lone AA, Zaffar G, a Iqbal AM (2014). Genetic variability in saffron (*Croccus sativus* L.) clones. Medicinal Plants 6(3):185-188.

Soheilivand S, Agayev YM, Shakib AM, Fathi M, Rezvani E (2007). Comparison of diversity in flowering rate of two saffron (*Crocus sativus*) populations of Iran. In: Proceedings of 2nd International Symposium on Saffron Biology and Technology pp. 317-321.

Singh AK, Chandra N, Bhakta N (2015). Extent and pattern of diversity in saffron germplasm of Indian Kashmir. Bangladesh Journal of Botany 44(4):635-642.