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A study on the effects of environmental factors on vegetative characteristics and corm yield of saffron (*Crocus sativus*)

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ABSTRACT
Saffron (*Crocus sativus* L.) is one of the most important economical crops in Iran. The present study was conducted to evaluate the morphological characteristics and yield of saffron corms in six regions of Talesh city, Guilin province (Iran) with different altitudes. The studied regions were considered as treatments and the obtained data were analyzed based on a nested design. The results showed significant difference among the cultivation areas in terms of number, diameter and dry weight of corm. The areas with altitudes of ~1250 and ~1400 m produced the maximum number of corm per plant (7.64 and 6.16, respectively). The highest corm diameter (15.7 mm) and dry weight (0.94 g) were produced in the plain region with ~30 m altitude. Direct associations were observed among environmental factors such as precipitation, relative humidity, annual mean temperature and saffron corm weight. According to the results of the present experiment, saffron corm can be efficiently produced in Talesh region of Guilan province.

Keywords: Altitude, dendrogram, morphological characteristics, saffron, yield.

مطالعه اثر عوامل محیطی روی ویژگی‌های رویشی و عملکرد بنه زعفران

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چکیده
زعفران یکی از مهمترین گیاهان زراعی ایران از نظر اقتصادی است. مطالعه حاضر به منظور ارزیابی ویژگیهای رویشی و عملکرد بنه زعفران در شش ناحیه با ارتفاع متفاوت از سطح دریا در شهر تالش واقع در استان گیلان انجام شد. نواحی مورد مطالعه به عنوان تیمار در نظر گرفته شد و داده‌های مورد اندازه‌گیری بر اساس طرح آشیانه‌ای مورد تجزیه و تحلیل قرار گرفت. نتایج حاکی از وجود اختلاف معنی دار بین نواحی مورد کشت زعفران از نظر صفات تعداد بنه، قطر بنه و وزن خشک بنه بود. نواحی با ارتفاع حدود ۱۲۵۰ و ۱٤۰۰ متر از سطح دریا بیشترین تعداد بنه در بوته (به ترتیب ۷/٦٤ و ٦/۱٦) را تولید نمودند. بیشترین قطر بنه (۱۵/۷ میلی‌متر) و وزن خشک بنه (۰/۹٤ گرم) در نواحی پست با ارتفاع حدود ۳۰ متر از سطح دریا بدست آمد. عوامل محیطی مانند میزان نزولات، رطوبت نسبی، میانگین دمای سالانه با وزن بنه زعفران دارای همبستگی بودند. بر اساس نتایج این آزمایش، تولید بنه زعفران در منطقه تالش از استان گیلان به‌طور کارآمد امکانپذیر است.

واژه‌های کلیدی: ارتفاع از سطح دریا، دندروگرام، ویژگی‌های ظاهری، زعفران، عملکرد.

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Introduction

Saffron (*Crocus sativus* L.), is a perennial, herbaceous and stemless crop, belonging to Iridacea family (Schmidt *et al*., 2007) and recognized as the most expensive spice in the world (Winterhalter & Straubinger, 2000; Fernandez, 2004). It has many other uses in industries pertaining to food, pharmaceuticals, cosmetics and perfumery as well as textile dyes (Kafi *et al*., 2006; Mir, 1992). Saffron has been employed in traditional medicine for centuries (Fernández, 2004). Recently, scientists have focused on investigating the cytotoxic, anti-carcinogenic and anti-tumor properties of this herb (Abdullaev, 2002; Fernández, 2004; Magesh *et al*., 2006). High economic values and job opportunities and high water use efficiency of saffron in contrast to other crops are the important reasons why this plant has gained such wide attention (Behnia, 1991). Saffron is an autumnal flowering geophyte characterized by a long summer rest in which the plant survives periods of drought by means of corms (Gresta *et al*., 2008). Its biological cycle commences with its above-ground vegetative growth at the first autumn rains with an almost immediate emission of leaves and flowers, ending with the production of replacement corms (Gresta *et al*, 2008). Saffron propagation is done by the cormlets (daughter corms) originating from main corm (Sharaf-Eldin *et al*., 2013). Kaushal & Upadhyay (2002) reported that both the production of daughter corms and the yield of flowers were dependent on the size of the mother corms. Saffron has been successfully grown apparently under different geographic locations throughout the world. Agro-climatically, this crop can be cultivated in temperate, semi-arid, and arid areas (Kumar *et al*., 2009). There are many factors conducing to the growth, development and yield attributes of saffron, the most important of which are environmental conditions and corm physiology (Galavi *et al*., 2008). Environmental and climatic conditions, e.g. temperature, soil and water content noticeably affect both the quantitative and qualitative traits of saffron (Amirnia *et al*., 2014). Temperature is the most important environmental factor as regards controlling the growth and flowering in *Crocus* species (Kumar *et al*., 2009). The optimum temperature for flower initiation and development of the corms has been reported to be in the range of 23–27°C (Molina *et al*., 2005).

Iran is the largest producer of saffron in the world (94% of the global productions) (Rezvani Moghaddam *et al*., 2016). Many attempts have been made to extend its cultivation to most parts of Iran. Talesh region in Guilan province has desirable climate features such as mild and cold temperatures during day and night, respectively, and loamy soils which are appropriate for the production of saffron corm. It is clear that the high relative humidity and rainfall in Talesh region is not helpful in producing flowers or stigmas based on plant habitat in Khorasan region with a dry climate.

Accordingly, in order to assess the influence of environmental factors on saffron vegetative stage, the present study was conducted to evaluate the morphological characteristics and yield of saffron corms under different regions with different altitudes in Talesh city (Iran).

Material and Methods

The experiment was carried out in Talesh city of Guilan province, Iran, in 2013 where six regions were considered in Talesh area to test the effects of environmental factors on saffron corms

(Table 1). One saffron-cultivated field was selected for each region and plots were created of 2×3 m (6 m^2 in size) inside each. The plants were two years old at the time of assessment. In each region, geographical and climatic factors including relative humidity (Figure 1), maximum and minimum temperatures (Figure 2), and rainfall (Figure 3) over a period of 20 years were obtained from the nearest meteorology stations.

Table 1. Geographical characteristics of the studied geographical regions

Region	Longitude (E)			Latitude (N)			Altitude (m)
Tularoud	48	56	02	37	44	47	30
Vazneh Sar	48	43	02	37	45	07	1130
Dizgah	48	38	30	37	51	31	1135
Hassan Dirmani	48	37	57	37	51	15	1150
Irboo	48	43	10	37	45	40	1260
Qalae-Chal	48	41	40	37	45	38	1390

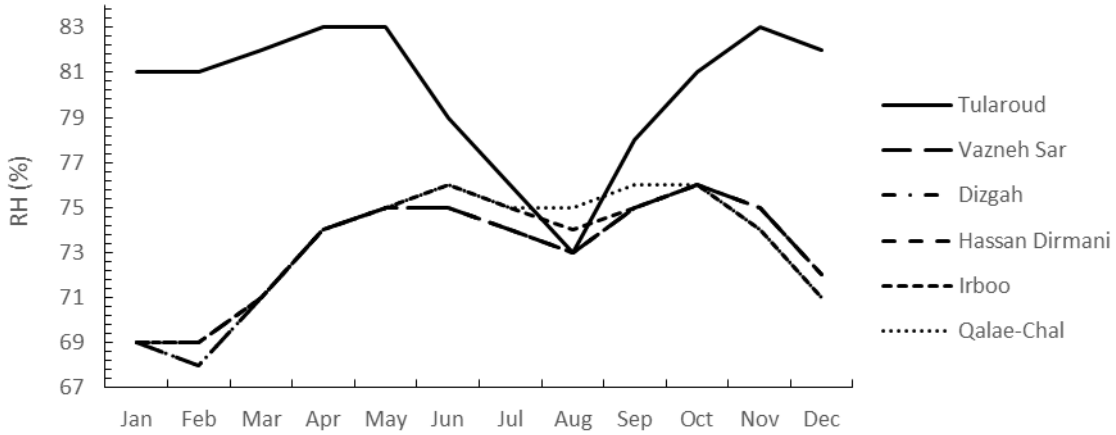

Figure 1. Average of relative humidity percentage of the studied geographical regions

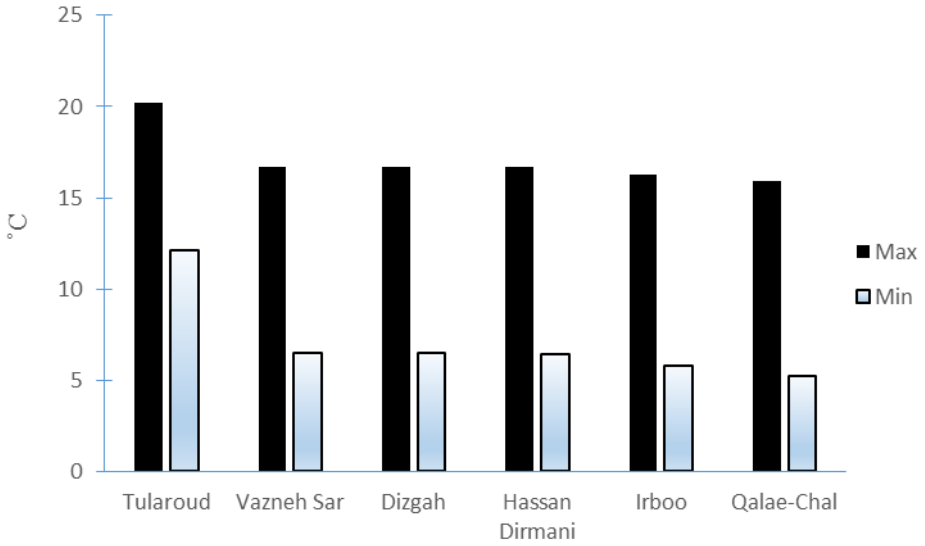

Figure 2. Annual maximum and minimum temperatures of the studied geographical regions

Vegetative characteristics and corm yield were measured and the obtained data was analyzed in a nested design with three replications and 10 observations for each replicate. The regions were considered as treatments. During the experiment (autumn, winter and spring), quantitative characteristics such as leaf length, leaf and spathe number and shoot fresh weight were measured; shoot dry weight was also recorded after drying fresh shoots at 60^{o}C for 48 h.

Leaf withering and senescence in the spring marked the time when corms were harvested from in each 1 m^2 plot of each field; further measured were the number, diameter and fresh and dry weight of corms with and without tunic. Soil characteristics were specified by the analysis of soil samples from the studied regions (Table 2). The statistical procedure was performed by SPSS V21 and means were compared with a Least Significant Difference (LSD) test at $P \leq 0.05$.

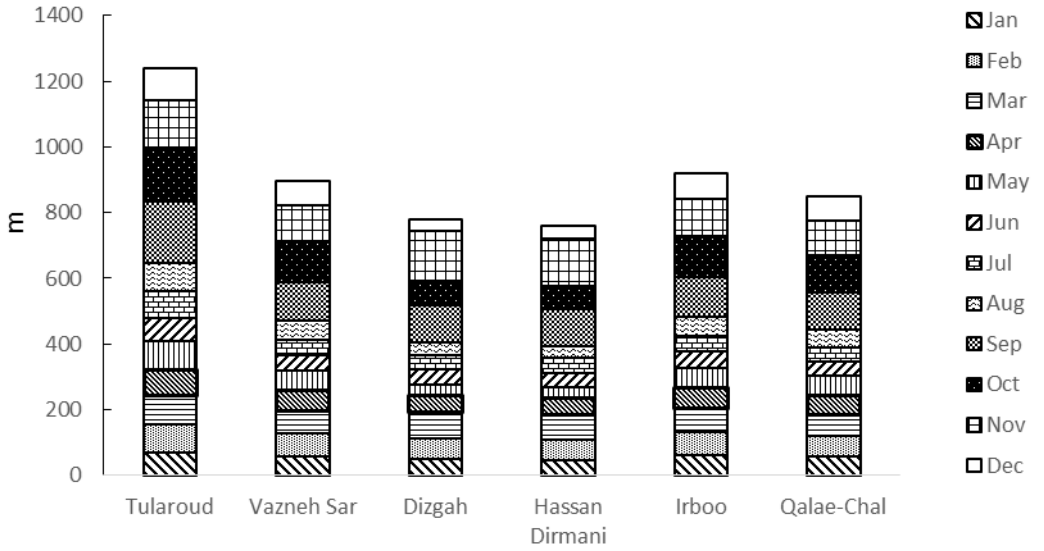

Figure 3. Average of total rainfall of the studied geographical regions

Table 2. Soil characteristics of the studied geographical regions

Region	EC dS/m	pH	OC* %	N %	P ppm	K ppm	Sand %	Silt %	Clay %	Soil texture**
Tularoud	1.25	7.21	1.95	0.178	139	390	34	38	28	CL
Vazneh Sar	1.08	6.54	2.1	0.147	9.8	134	20	44	36	SCL/CL
Dizgah	0.67	7.80	0.44	0.022	8.2	154	62	22	16	SL
Hassan Dirmani	1.25	7.34	1.7	0.148	32.7	216	66	22	12	SL
Irboo	1.17	7.14	0.80	0.072	12.1	154	16	48	36	SCL
Qalae-Chal	0.75	6.80	0.69	0.06	1.9	37	44	32	24	L

*Organic carbon ** S: silt L: loam C: clay

Results

According to the means of the studied traits (Tables 3 and 4), there were significant differences among cultivation areas concerning the number, diameter and dry weight of corm and all vegetative characteristics. The areas with altitudes of ~1250 m (Irboo) and ~1400 m (Qalae-Chal) produced the maximum number of corms per plant with 7.64 and 6.16 numbers, respectively. Tularoud with ~30 m altitude generated the maximum weight of corm with an average of 4 grams. The highest corm diameter (15.77 mm) and corm dry weight (0.94

g) were recorded in the plain region (Tularoud). The lowest corm diameter (8.79 mm) and dry weight (0.89 g) were observed in the altitude of ~1150 m (Hassan-Dirmani).

Table 4 illustrates the results obtained from the vegetative characteristics. The highest number of leaf /plant (23.26), and spathe number (5.06) and the lowest leaf length (10.03) were observed in Hassan-Dirmani. The maximum leaf length (33.17), and the most fresh and dry matter of leaves (3.14 and 0.82) were recorded in Qalae-Chal. Tularoud and Vazneh-Sar produced the lowest of these traits except for leaf length.

The results associated with the correlations between climate features and the measured traits (Table 5) indicated that there were significant positive correlations of precipitation, relative humidity and annual mean temperature with saffron corm fresh weight and tunic. Moreover, sand percentage had a positive correlation with leaf and spathe number while negatively correlated with silt and clay.

According to dendrogram diagram generated by Ward method based on Euclidean distance, the studied regions were classified into three separate groups (Figure 4). The first group was comprised of four regions (Irboo, Dizgah, Hassan-Dirmani, and Qalae-Chal). This group was divided into two sub-groups as regions of Dizgah, Irboo and Hassan-Dirmani were in a distinct sub-group. The region of Qalae-Chal with the highest altitude was in a separate sub-group. Vazneh-Sar and Tularoud were put in the second and third groups, respectively.

Table 3. Mean comparison of saffron corm attributes in different geographical regions

Region	Corm number/plant	Corm Diameter (mm)	Corm weight with tunic (mg)	Corm weight without tunic (mg)	Corm dry matter
Tularoud	4.85 b	15.77 a	4 a	3.09 a	0.94 a
Vazneh Sar	3.13 c	9.25 b	2.65 b	0.57 c	0.15 d
Dizgah	5.29 b	10.20 b	1.92 bc	1.85 b	0.67 b
Hassan Dirmani	5.76 b	8.79 b	0.89 c	0.81 c	0.31 cd
Irboo	7.64 a	13.44 a	1.96 bc	1.65 b	0.57 b
Qalae-Chal	6.16 ab	13.37 a	2.39 b	1.77 b	0.43 bc

Table 4. Mean comparison of saffron vegetative attributes in different geographical regions

Region	Leaf number/plant	Spathe number	Leaf length (cm)	Leaf fresh weight (mg)	leaf dry matter (g)
Tularoud	3.9 d	1.23 d	19.2 b	0.49 c	0.13 c
Vazneh Sar	3.1 d	1.4 d	15.66 bc	0.27 c	0.07 c
Dizgah	14.83 b	3.7 b	12.63 cd	1.23 b	0.37 b
Hassan Dirmani	23.26 a	5.06 a	10.03 d	1.48 b	0.42 b
Irboo	10.65 c	2.31 c	18.98 b	1.43 b	0.37 b
Qalae-Chal	12.8 bc	3.23 b	33.17 a	3.14 a	0.82 a

Table 5. Correlation between climate, soil characteristics and the studied traits in saffron. N=60

	Leaf number	Spathe number	Corm diameter	Corm fresh weight with tunic	Corm fresh weight without tunic	Corm dry matter
Sand	0.79*	0.84*	-0.40^{ns}	- 0.49	- 0.04^{ns}	0.03^{ns}
Silt	-0.75*	-0.81*	0.42^{ns}	0.47^{ns}	0.05^{ns}	-0.02^{ns}
Clay	-0.82*	-0.86*	0.3^{ns}	0.52^{ns}	0.03^{ns}	-0.05^{ns}
Rainfall	-0.72^{ns}	- 0.77*	0.78*	0.90**	0.71^{ns}	0.65^{ns}
Temperature	-0.48^{ns}	-0.51^{ns}	0.56^{ns}	0.76*	0.72^{ns}	0.71^{ns}
Humidity	-0.49^{ns}	-0.53^{ns}	0.69^{ns}	0.81*	0.80*	0.75*

*, ** significant at 0.05 and 0.01 probability levels, respectively.

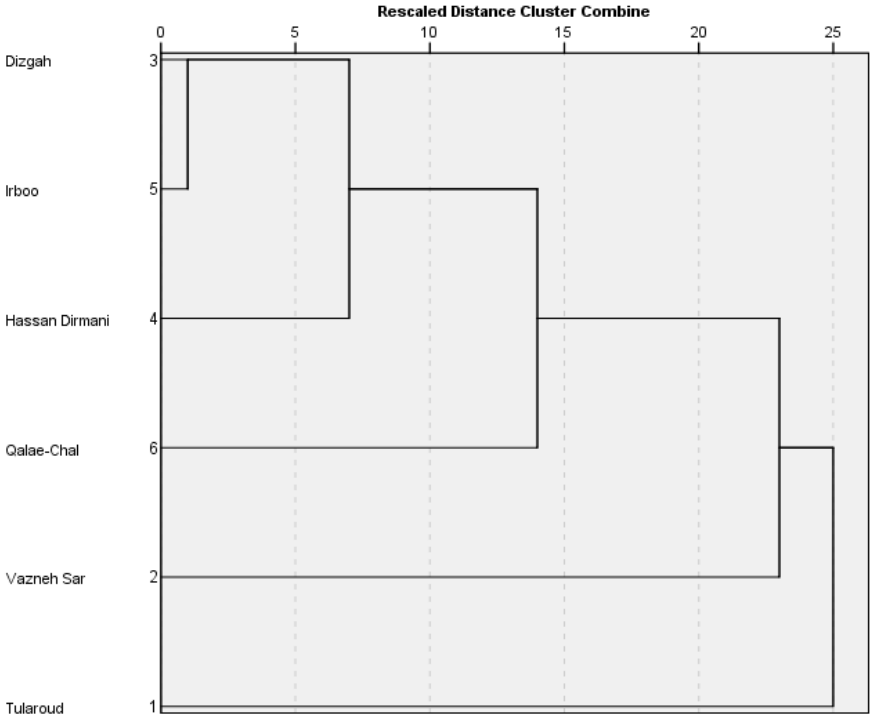

Figure 4. Dendrogram for the six studied regions produced by Ward's clusters analysis; based on standardized means of vegetative and corm yield characters of saffron (scale. squared Euclidean distance).

Discussion and conclusion

Saffron has been successfully grown under different geographic locations in the world (Gresta *et al*., 2008). This crop can be cultivated in temperate, semi-arid and arid areas with 1500–2800 m above sea level. Favorable climatic conditions for high yields of saffron are autumn rains, warm summers and mild winters (Fernandez, 2004). Temperature is the most important environmental factor controlling the growth and flowering in *Crocus* species (Kumar *et al*., 2009). Duke (1979) reported that the mean annual temperature and rainfall in 16 saffron growing sites of the world ranged from 5.9 to 18.6°C and from 420 to1370 mm, respectively. Molina *et al.* (2005) stated that the optimum temperature for flower initiation and development of the corms varies from 23 to 27°C, with 23°C being marginally better for a maximum number of flowers. Environmental conditions such as altitude may also affect saffron quality specially crocin (Lage & Cantrell, 2009).

However, saffron can also be cultivated with good yields in very different environmental conditions (Gresta *et al*. 2008); a combination of certain environmental factors can be important to reach the optimum qualitative and quantitative yield. Kamyabi *et al* (2014) reported that among environmental factors, precipitation and temperature had the highest impact on saffron cultivation. In the present research, saffron was cultivated in six regions from the plains to the mountains of Talesh city, Guilan province, Iran. The altitudes of the regions varied from 30 to 1390 m ASL with an average annual rainfall of 760 to 1240 mm and average annual temperatures of 10.6 to 16.1 ◦C. In other words, the environmental factors of the studied regions in this research were favorable for saffron cultivation as far as corm yield and other vegetative traits are concerned and in line with the findings of other researchers noted above. The regions of Irboo and Qalae-Chal with the highest altitude were the

most suitable for corm production, indicating that altitude can play a major role. Panwar *et al*. (1995) reported successful saffron cultivation between 1500 and 2000 m ASL.

Saffron can grow in various soils ranging from sandy to well-drained clay loams (Sheykhdavodi *et al*., 2010); however, it grows best in friable, loose, low-density, well-watered, and well-drained clay, calcareous soils having a high organic content. In the other words, it requires sandy to sandy loam soils. The results of the associations between soil and vegetative attributes in the present study validated that sandy soil was good for increasing the leaves and spath number. A pH range of 6.8 to 7.8 in the soil is considered optimum. Saffron water requirement is low and it can be cultivated under irrigated or rainfed conditions. In Greece, for instance, saffron growing areas have a 500 mm annual rainfall (Kumar *et al*., 2009).

Omidbaigi *et al*. (2001) studied the effect of cultivation sites on the quality of saffron in Iran and reported that the quantity and quality of saffron (except for aroma) in Neishabor (North Khorasan) region were superior compared with that produced in Ferdows region (South khorasan), Iran. Bulb and corm size are major factors determining the capacity of bulbous plants for flowering (Kaushal and Upadhyay, 2002). Corm size has a recognizable effect on the production of daughter corms, flowers and yield of saffron. A close relationship was observed between corm size and flowering time in *C. sativus* (DeMastro and Ruta, 1993). On the other hand, corm development directly depends on shoot or leaves because of photosynthesis. Irboo and Qale-Chal produced the highest corm size and the highest vegetative traits such as leaf number, length and dry weight, meaning they have appropriate environmental conditions including soil texture, temperature and altitude for saffron growth.

Finally, based on the results of the experiment, saffron corm can be efficiently produced in Talesh region. With regards to the capacity of different areas of Talesh region (such as Irboo and Qalae-Chal) to produce saffron as a valuable crop, efforts must be made to ensure optimal conditions for the cultivation and production of saffron corms in this region.

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