The effect of lifting conditions, packaging and store temperature on saffron corm proliferation and stigma yield

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Abstract: Saffron is an herb plant and it is propagated by corm. After six or seven years, saffron corms should be picked up from the underground, graded and re-cultivated in the new field. Determination of appropriate lifting method, packaging and storage of saffron corms are necessary to reduce the falling of germination and maintained the corms quality. In this research, the effects of soil moisture content during lifting, packaging methods, storage temperature and storage period on saffron yield, dried leaves weight and corms proliferation were investigated. Statistical analysis was done on randomized complete block design applying the analysis of variance (ANOVA). The results showed that the increasing of soil moisture reduced functional factors, including the corm proliferation, dried leaves weight and yield by 38%, 49% and 48% respectively. Increasing of humidity increased the saffron corms waste during storage and it reduced the yield and the corm proliferation. The highest saffron yield was obtained from saffron corms which were kept in gunnysack or carton packaging, at storage temperature of 25°C during the 30-day storage period.

Keywords: saffron corm, digging, maintenance, packaging

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1 Introduction

Saffron (*Crocus sativus* L.) is one of the most expensive crops of the world. Saffron is auto triploid and probably has common origin with other saffron species that has been cultivated in the Mediterranean basin (Behdani and Fallahi, 2016).

In the Mediterranean basin the production of saffron has been decreased due to rising standards of living and, inevitably, the rise of labor costs. However, the Mediterranean saffron bears the best quality features worldwide, which is attributed to deep cultivation knowledge and careful treatment by all European producers (INTERREG IIIC, 2006).

Iran, with an annual production of about 360 tones of saffron, approximately 95% of the world production, is the main producer of this crop in 2016. Spain, India, and Greece, held the lower ranks as minor producers, respectively (Anon, 2017).

The appreciation for saffron as a food additive continues today and it has become the world’s highest priced spice (Winterhalter and Straubinger, 2000). There is also a long tradition of saffron use in the traditional medicine of many cultures (Abdullaev and Frenkel, 1999). More recently, there has been increasing interest in the biological effects of the components of saffron and their potential medical applications, particularly those based on their cytotoxic, anti-carcinogenic and anti-tumour properties (Abdullaev and Frenkel, 1999; Fernández Pérez and Escribano Martínez, 2000).

Saffron is an herb plant and it is propagated by corm. The useful period of saffron farm is functioning the plant density and it is variable from five to ten years. After this period, saffron corms should be picked up from underground, graded and then replanted in the new field (Behdani and Fallahi, 2016).

The life cycle of saffron is similar in all producing countries. At the beginning of the dry season (April-May),

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the leaves senesce and wither, and the bulbs go into dormancy. The transition from the vegetative to the reproductive stage occurs shortly after wards in the apex of the buds of underground corms. At this time, the farmers lift the saffron corms from underground during dry season (May-Sep) in Iran. After corms lifting, the mother corm parts should be removing and the replacement corms should be separated and graded. Then, the corms must be stored in optimum environments until new planting.

The farmers use moldboard plow for lifting saffron corms. They plow the saffron farm by a single bottom moldboard plow in 25 cm depth. Then, the saffron corms are gathered by labors. Fifty labor working days and 50 tractor working hours are required for lifting and gathering corms in one acre.

Molina et al. (2005a) investigated temperature effects on formation in saffron. They reported that incubation of the corms after lifting at a higher temperature (30°C), reduced flower initiation and caused the abortion of some of the initiated flowers. No flowers formed in corms incubated at 9°C. A variable proportion (20%-100%) of the corms forced directly at 17°C without a previous incubation at 23°C-27°C formed a single flower. The wide differences in the timing of the phonological stages in different locations that we found in this study, seemed related to the ambient temperature. Leaf withering was followed shortly by flower initiation, which occurred during late spring or early summer as the rising temperature reached 20°C.

The number of flowers per plant, and fresh and dry stigma yield decreased gradually as the duration of cold-stored corms increased to 28 days at 8°C during field and glasshouse experiments (Çavuşoğlu, 2010).

Molina et al. (2005b) reported that storage of saffron corms at 2°C after flower initiation resulted in a time-dependent abortion of those flowers already initiated. Also, these authors pointed out that no benefit resulted from cold-storing corms after flower initiation. The yield of spice saffron per corm depended on both the duration and the condition of the cold- storage. Storage at freezing temperatures (0°C or –1°C) damaged the corms. Flowering could be induced in corms stored between 1°C-2°C. Siracusa et al. (2010) evaluated the effects of different corm storage conditions on saffron production and qualitative parameters. They subjected corms to several storage condition sets. The results of their study clearly demonstrated the importance of monitoring the storage conditions to improve saffron samples in terms of yield and quality. The results of others' research showed that the bulb storage conditions are the important effective factors on flowering. Mark (2005) investigated the effect of bulb storage on growth, flowering of Lachenalia aloides 'Pearsonii. He reported that the flowering accelerated, and leaf length and floret number reduced when bulbs stored at 10°C, 12.5°C, or 15°C for 45 days compared with storing at 20°C or 25°C.

Distinguish of suitable soil moisture content during corm lifting, packaging and storage conditions were the aim of our research. Therefore, we investigated the effects of soil moisture content during corms lifting, packaging type, and temperature of store and storage periods on stigma yield and corm proliferations.

2 Materials and methods

This study was carried out at Khorasan Agricultural and Natural Resources Researchand Education Center, Torogh station, Mashhad, Iran.

In this study, 12 treatments were considered including soil moisture content during corms lifting (two level: dry and wet), corms packaging type (four levels: lace pack, nylon pack, carton pack and gunnysack), temperature store (three levels: 1°C, 10°C and 25°C) and storage period (three levels: 30, 60 and 90 days). Experiments were conducted as completely randomized block design with three replications.

Experiments were performed using saffron corms raised at Mashhad, one of the saffron-producing areas of Iran. The corms were lifted from two orchards with differential soil moisture contents (wet and dry) after leaf senescence. For this purpose and increasing the soil moisture contents, one part of each of the orchards was irrigated before corm lifting. The mother corm parts were removed and corms were separated and graded for each group (wet and dry). Some saffron corms of each group were planted in two plots with 100 corms per square meter density as testifier samples.

Each corms group was packaged in four different ways (lace pack, nylon pack, carton pack and gunnysack). The weight of each pack was 3000 grams. For each treatment (a set of soil moisture content during corms lifting and packaging type) nine packs were prepared. The corm packs were stored in three stores with different temperatures (1°C, 10°C and 25°C). The corms packs were transferred from stores and were planted in three times (30, 60 and 90 days). The planting density was 100 corms per square meter.

Eventually stigma yield, dried leaves weight and corms proliferations were measured as performance characteristics.

The statistical analysis was done on randomized complete block design by applying the analysis of variance (ANOVA) using SPSS 13 software. Duncan's multiple ranges test was utilized to separate means at a 5% level of significance.

3 Results

The variance analysis of data in Table 1 indicates that the soil moisture content during corms lifting created a significant effect on the stigma yield, dried leaves weight and corms proliferations ($P<0.01$). The packaging type had a significant effect on the stigma yield, dried leaves weight ($P<0.01$) and on the corms proliferations ($P<0.05$). Test results showed that the store temperature had a significant effect on the stigma yield, dried leaves weight ($P<0.01$) and did not have significant effect on the corms proliferations.

Table 1 ANOVA of parameters considered on stigma yield, dried leaves weight and corms proliferation (Mean of squares)

Variation source	DF	Stigma yield	Dried leaves weight	Corms proliferation
Soil moisture content	1	18.35**	265300.46**	55.00**
Packaging type	3	2.44 **	6452.16**	3.68 ns
Store temperature	2	2.26 **	5335.53**	0.61 ns
Storage period	2	24.69**	58365.39 **	121.39**
Soil moisture ×Packaging type	3	2.87 **	1066.20 ns	1.57 ns
Store temperature×Storage period	4	1.93 **	18435.18 **	1.03 ns
Packaging type ×Storage period	6	0.58 **	7187.46 **	1.62 ns
Soil moisture×Packaging type×Store temperature	6	0.98**	8570.72**	1.27 ns
Soil moisture×Packaging type×Storage period	6	1.13**	5059.14**	5.99**
Packaging type×Store temperature× Storage period	12	0.75**	3985.18**	0.35 ns
Error		0.019**	805.55	0.80

Note: ns: corresponding to no significant difference; * corresponding to significant difference at P=0.05; **corresponding to significant difference at P=0.01.

According Table 1, the combination effects of (soil moisture × packaging type), (store temperature × storage period), (packaging type × storage period), (soil moisture × packaging type × store temperature), (soil moisture × packaging type × storage period) and (packaging type × store temperature × storage period) were significant on the stigma yield and dried leaves weight (P<0.01).

In the following paragraphs, the effects of each factor on the rupture energy and force are comprehensively discussed.

3.1 Soil moisture content (during corms lifting)

Stepwise analysis of obtained data revealed that among three quantitative variable factors, the dominant factor on the stigma yield, dried leaves weight and corms proliferations is soil moisture content during corms lifting.

According to Table 2 as the soil moisture content increased from 6% to 14%, the stigma yield, dried leaves weight and corms proliferations values decreased 48%, 49% and 38%, respectively. This may be due to the fact that increasing of soil moisture content raised the waste and damage storage of saffron corms. Therefore, the flowering and proliferation of corms and thus the stigma yield was decreased.

Table 2 Means comparison of characteristics in different variations

Factors	Stigma yield ($kg\ ha^{-1}$)	Dried leaves weight ($kg\ ha^{-1}$)	Corms proliferation (Amount)
Soil moisture content (%)			
6	1.22a	141.90a	2.62a
14	0.64b	71.81b	1.61b
Packaging type			
Lace pack	0.77a	97.87a	2.15b
Nylon pack	0.73a	103.24a	1.74a
Carton pack	1.15c	122.78b	2.33b
Gunnysack	1.08b	103.52a	2.24b
Store temperature (°C)			
25	1.14a	115.00a	2.22a
10	0.85b	97.84b	2.07a
1	0.81b	107.70b	2.05a
Storage period (Day)			
30	1.55c	133.82c	3.00b
60	0.85b	109.65b	2.72b
90	0.39a	77.08a	0.65a
Testifier	2.41	215.00	3.00

Note: Means for the same factor and in the same column flowed followed by the same letter are not significantly different ($P<0.05$) according to Duncan's Multiple ranges Test.

3.2 Packaging type

There was significant difference between several types of packaging (P<0.05) as shown in Table 2. The most appropriate packaging for saffron corms was the carton pack. Maintaining saffron corms in gunnysack and carton packages resulted in the highest performance. This is possibly due to the fact that the saffron corms which were kept in Lace pack lose moisture increasingly and also keeping saffron corms in nylon packaging increases waste and decay. Using of the nylon pack, in comparison to the carton pack, caused a decrease in stigma yield and corms proliferation by 37% and 25%, respectively (Figure 2).

3.3 Store temperature

Considering the values presented in Tables 2, the most appropriate store temperature for saffron corms was ambient temperature (25°C). The results showed that the maintenance of saffron corms in stores with temperature less than 25°C decreased three quantitative variable factors namely stigma yield, dried leaves weight and corms proliferation. Stigma yield was related to store temperature and there was significant difference between 25°C store temperature and other store temperatures (10°C and 1°C) as shown in Table 2.

The saffron corms spend their dormancy period in summer and begin their vegetative growth at beginning of the cold season (early fall). Therefore, storing of saffron corms at lower temperatures than the ambient temperature causes the plant physiological growth before replanting. The starting of plant physiological growth of saffron corms harmed the corms and decreased their power of flowering and proliferation. A similar response has been reported by Molina et al. (2005b).

3.4 Storage period

Considering the values presented in Table 2, increasing of storage period from 30 to 90 days decreased stigma yield, dried leaves weight and corms proliferation by 75%, 42% and 78%, respectively. This is possibly due to the fact that it's better to immediately replant the saffron corms after lifting and grading. The stigma yield of testifier samples that were planted without delay was 2.41 kg per hectare. This amount is 36% and 84% more than stigma yield of stored samples after 30 and 90 days, respectively.

Considering the interaction effect of storage period and store temperature, the highest difference in stigma yield under three various storage periods was attributable to 10°C store temperature (Figure 1). The highest stigma yield was obtained from saffron bulbs that were stored in ambient temperature (25°C) for 30 days. This conclusion was consistent with the findings of Mark (2005), who reported that the flowering acceleration reduced when corms stored at 10°C or 15°C for 45 days compared with storing at 20°C or 25°C.

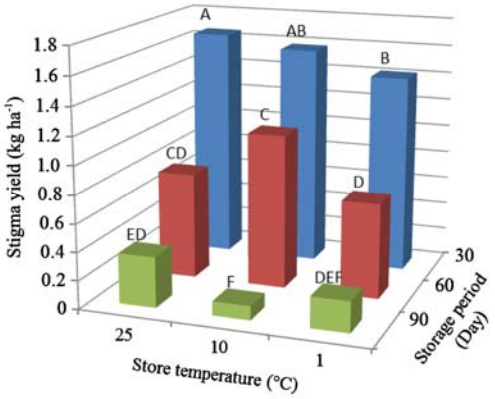

Figure 1 Effect of store temperature and storage period on the stigma yield

Note: Means with minimum common letter are not significantly different (P<0.05) according to Duncan's multiple ranges test.

Another characteristic that shows vegetable activity and corms proliferation is dried leaves weight in kilograms per hectare. Results showed that with increasing the shelf life of one month to three months, dried leaves weight that can cause yield loss is also reduced (Figure 3).

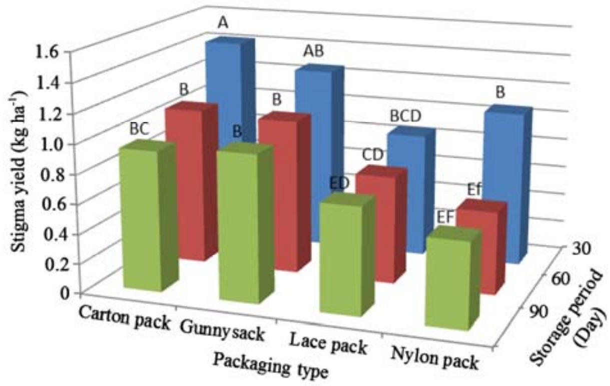

Figure 2 Effect of packaging type and storage period on the stigma yield

Investigating the triple interaction effects of storage period, packaging type and store temperature on stigma yield showed that saffron corms were stored at 25°C and carton packages for a one-month shelf life, has led to the highest performance.

Maintenance of corms in nylon pack or lace pack for three months resulted in a sharp decline in stigma yield. The reduction in stigma yield by reducing the store temperature has increased.

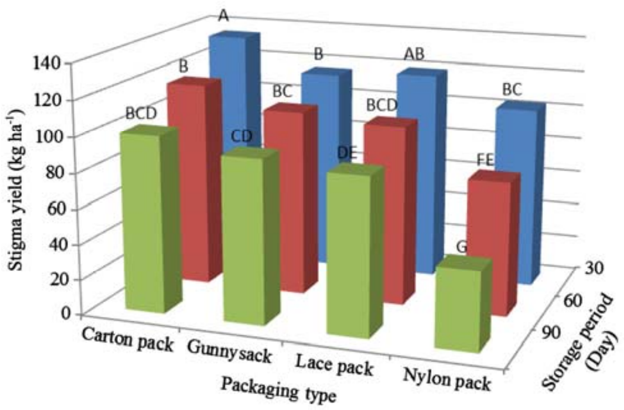

Figure 3 Effect of packaging type and storage period on the dried leaves weight

4 Discussion

Farm irrigation prior to saffron corms harvest and thus increasing of soil moisture reduced the performance characteristics, including the corms proliferations, dried leaves weight and stigma yield respectively by 38%, 49% and 48%. The moist soil increased the corms humidity, thus corms waste during storage increased. Therefore, the corms proliferation and flowering reduced. Molina et al. (2005b) reported the wide difference at different location both in the timing of flower initiation and in the time of flowering in plantings arising from a uniform batch of corms. They pointed out to climatic factors as the main cause of these differences.

Maintenance of saffron corms in gunnysacks and carton packs had the highest stigma yield. Saffron corms in lace packs lost their moisture and also by being held in nylon packs, waste and decay are increased. In both cases, the flowering and stigma yield will be reduced.

Storing saffron corms at lower temperatures than the ambient temperature causes the growth of plant physiology in store. This makes the corms more vulnerable at the time of planting and it will reduce corms germination after planting. So, saffron bulbs were stored at 25°C (ambient temperature) and storage period of one month will be the highest stigma yield. The release of bud dormancy and hence the time needed for flower formation could be accelerated by cutting the corms at 30°C for a short time (Molina et al., 2005a).

5 Conclusion

Based on this research, the following conclusions can be drawn:

1) The results showed that the increasing of soil moisture from 6% to 14%, stigma yield, dried leaves weight and corms proliferations values decreased 48%, 49% and 38%, respectively.

2) The most appropriate packaging for saffron corms was the carton pack. Using of the nylon pack, in comparison to the carton pack, caused a decrease in stigma yield and corms proliferation by 37% and 25%, respectively.

3) The maintenance of saffron corms in stores with temperature less than 25°C decreased three quantitative variable factors namely stigma yield, dried leaves weight and corms proliferation.

4) Generally, the highest saffron yield was obtained from saffron corms which were kept in gunnysack or carton packaging, at storage temperature of 25°C during the 30-day storage period.

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