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INFLUENCE OF DELAYED HARVEST ON YIELD AND SOME QUALITY PARAMETERS OF SAFFRON (*Crocus sativus* L.)

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ABSTRACT

This study was conducted to determine influence of delayed harvests on yield and quality characteristics of saffron (*Crocus sativus* L.) under the Harran Plain conditions, on research fields of Faculty of Agriculture of Harran University, during winter growing seasons in 2006-2007 and 2007-2008. The trial was arranged in randomized complete block design with three replicates. For determining the effect of delayed harvests, three different flower harvest times were used in the research; full blooming, 1 day after full blooming and 2 days after full blooming. The following parameters were measured in the study, including plant heights (31.93-32.00 cm), corm numbers per plant (2.93-3.00 number plant^{-1}), corm yields (29038.00-29070.00 kg ha^{-1}) and marketable corm ratios (70.00-70.67%), stigma lengths (2.70-3.06 cm), stigma weights (6.91-7.40 mg), saffron yield (16.00-17.10 kg ha^{-1}), safranal ratio (35.73-39.97‰), crocin ratio (178.33-203.33‰) and picrocrocin ratio (83.57-89.53‰). The results of the study revealed that delay harvesting has caused a significant decrease at saffron quality parameters measured.

Keywords: saffron (*Crocus sativus*), ontogenetic variability, quality parameters, saffron yield.

INTRODUCTION

Saffron (*Crocus sativus* L.) is a member of *Iridaceae* family used for commonly as food spice obtained from its flower stigmas. It is also used as sweetener in food and beverage industry, used in medicine, cosmetic and dye industries due to its fragrance, color and taste (Mc Gimpsey *et al.*, 1997; Shen *et al.*, 2006; Carmona *et al.*, 2007; Soeda *et al.*, 2007). The most important bioactive compounds in saffron are crocin, picocrocin and safranal. The amounts of these main compounds are used to express the quality of saffron (Mc Gimpsey *et al.*, 1997; Carmona *et al.*, 2007; Lage and Cantrell, 2009). Amount of bioactive agents in saffron determine its price in trade. An economic saffron production is only possible with higher quality parameters. The main factor affecting the active ingredient of the saffron is the climate characteristics. Researchers have stated that some factors including temperature, relative humidity, day length, light intensity etc. were effective on saffron quality. Ortega *et al.* (2004) and Gresta *et al.* (2009) reported that saffron cultivation and location have important effects on the quality and this is caused by climate factors of the location and also the environmental factors during harvest time are effective on saffron quality (Ehsanzadeh *et al.*, 2004; Özel and Erden, 2005). Crocin and picrocrocin biochemical compounds reduce in the cells of stigmas during drying, storage, and extraction. The degree of degradation depends on temperature, humidity, light intensity and other compounds in the environment (Alonso *et al.*, 1990; Alonso *et al.*, 2001; Carmona *et al.*, 2005; Gregory *et al.*, 2005; Molina *et al.*, 2005; Douglas *et al.*, 2014). Alonso *et al.* (1990) noted that increase of temperature caused to oxidation of crocin and decomposition of picrocrocin of saffron stigma.

Harvesting of saffron is generally done during the full flowering stage. However, due to various reasons, harvesting of saffron can be delayed. There has been no study investigating effects of different harvest times or delayed harvests on quality parameters of saffron so far. Therefore, this study was conducted to be able to answer the question that how does delay in harvesting affect yield and quality parameters of saffron?

MATERIALS AND METHODS

This study was carried out to determine some yield and quality parameters of saffron (*Crocus sativus* L.) depending on tree different harvest times (full blooming, 1 day after full blooming and 2 days after full blooming), under the Harran Plain conditions, in randomized complete block design with three replicates for 2 years, between 2006 and 2008. Plant material of the study was Iran ecotype of saffron bulbs with 7-8 cm of circumference. The flowers were harvested by hand in the morning (at 8.00 o'clock).

The field was irrigated once before the planting and when the proper mellowness of soil was reached, deep ploughing was made. Subsequently, the field was ploughed with a cultivator and 100 kg ha^{-1} N and P_2O_5 composed fertilizer was applied and then the field was cultivated with a rotator. The bulbs were planted by hand with 10x10 cm density on 12 October 2006 for the first year and 14 October 2007 for the second year. Each plot was arranged in 4 rows of 6 m length. Certain maintenance processes like irrigation, weeding etc. were made during the trial. Flower harvest was made by hand by discarding 0.5 m both from the beginning and end of two middle rows at suitable times according to the application (every day, fully opened flowers in plots were determined and marked, and then were harvested by applications). After stigmata were removed from the harvested flowers, they were dried at 40 ºC for 2 hours. The dried stigmata were kept at room temperature for a day and measurement and weighting procedures were performed. Blooming date, blooming duration, flowering date, flowering period, vegetation duration, plant height, stigma length, stigma weight, saffron yield, corms number, corm yield and

marketable corm ratio were measured and observed according to the methods reported by Özel and Erden (2005). The safranal ratio, crocin ratio and picrocrocin ratio were determined by Anonymous (2010).

Saffron filaments were grounded, after drying. The powder was used for extraction following the ISO (3632-2) protocol. Samples were extracted with 50ml of pure water, and the extracts were filtered from 0.2 µm pore size filters and its absorbance read in a spectrophotometer using pure water as the control. Safranal, crocin and picrocrocin strength were expressed in absorbance units at 257 nm (picrocrocin), 330 nm (safranal) and 440 nm (crocin) respectively.

RESULTS AND DISCUSSIONS

Phenological characteristics

The phenological observation results were shown in Table-1.

Table-1. Phenological observations on different harvest time in saffron.

Harvest time	Sproutting date	Flowering date	Flowering period (day)	Vegetation period (day)
		2006-2007		
Full blooming	07.11.2006	09.11.2006	26	185
1 day after bloming	05.11.2006	07.11.2006	27	182
2 days after bloming	07.11.2006	09.11.2006	26	185
		2007-2008		
Full blooming	10.11.2007	13.11.2006	26	180
1 day after bloming	12.11.2007	15.11.2006	25	179
2 days after bloming	12.11.2007	15.11.2006	26	180

When the phenological observation values determined according to the delayed harvests in saffron were investigated, sprouting date were determined by years as 5-7 November and 10-12 November and flowering dates were 7-9 November and 13-15 November, respectively. The difference between flowering dates by years could be attributed to late plantation in the second year and ecological factors.

The flowering period determined for saffron considering the delayed harvests changed between 26 and 27 days in the first year and 25 and 26 days in the second year.

Plant characteristics

The effects of the delayed harvests on no statistically significant difference between years and applications considering plant height, stigma length, stigma weight, corm number per plant, corm yield and marketable corm ratio, expect saffron yield. The combined values of two years are given in Table 2.

Table-2. Mean values of plant heights (cm), stigma lenghts (cm), stigma weights (mg), saffron yield (kg.ha $^{-1}$), corm number (corm.plant $^{-1}$), corm yield (kg.ha $^{-1}$) and marketable corm ratio (%) of saffron for different harvest times.

Harvest times	Two years combined						
	Plant height	Stigma length	Stigma weight	Saffron yield	Corm number	Corm yield	Marketable corm ratio
Full Blooming	32.00	2.70	6.91	16.03 b*	3.00	29061.70	70.33
1 day After Bloming	32.00	2.96	7.05	16.29 b	2.98	29049.00	70.50
2 days After Bloming	32.00	3.06	7.40	17.09 a	2.97	29065.00	70.67
Mean	32.00	2.91	7.12	16.47	2.98	29058.60	70.50
Lsd (%5)	ns	ns	ns	0.73	ns	ns	ns

ns: Not significant

* Means followed by the same letter were not significantly different at the 0.05 probability level, according to the LSD test.

According to the combined values of two years, the values were obtained in trail as follows; the plant heights 32.00 cm, the stigma lengths 2.70-3.06 mm, the stigma weight 6.91-7.40 mg, the corm numbers 2.97-3.00

number.plant^{-1}, the corm yield 36646.7-36653.3 kg.ha^{-1} and the marketable corm ratios 71.00-71.62%.

Saffron Yield: In the study, saffron yield changed between 16.03 - 17.08 kg.ha^{-1} by the combined values of two years (Table-2). In addition, the highest saffron yield was determined with the harvest made 2 days after full flower opening, while the lowest saffron yield was determined with the harvest made on the same day with full flower opening. In generally, yield was increased in the late harvest. This situation could be caused by the increasing stigma height and weight. In fact, stigma height and weight were seen to increase with delaying flower harvest (Table-1). The obtained findings were higher than the results reported as 400-760 g.da^{-1} by Nehvi *et al.* (2007), while they were found lower than the result reported as 2780 g.da^{-1} by Özel and Erden (2005). These differences could be caused by different corm sizes used for propagation, storage conditions and climate factors.

Active ingredient and quality determination

The effects of different harvest times on safranal ratio, crocin ratio and picrocrocin ratio were found significant, while the years were not effective. The combined values of two years are given in Table 3.

Table-3. Mean safranal ratio (‰), crocin ratio (‰) and picrocrocin ratio (‰) in saffron for different harvest times.

Harvest times	Two years combined		
	Safranal ratio	Crocin ratio	Picrocrocin ratio
Full Blooming	39.92 a	203.17 a	89.50 a
1 day After Bloming	37.32 b	188.50 b	86.57 b
2 days After Bloming	35.77 c	178.67 c	83.57 c
Mean	37.67	190.11	86.54
Lsd (%5)	0.16	1.26	0.12

According to the combined values of two years, by delayed harvests, the safranal ratio were changed between 35.77-39.92‰, the crocin ratio were changed between 178.67-203.17‰ and the picrocrocin ratio were changed between 83.57-89.50‰. The highest safranal ratio, crocin ratio and picrocrocin ratio were obtained at the full blooming harvest, while the lowest ones were determined at the 2 days after blooming harvest (Table 3). In general, the safranal ratio, the crocin ratio and the picrocrocin ratio were found to decrease depending on the delaying harvest time of saffron flower.

The values obtained were higher than the findings (0.04-0.48%) reported by Lage and Cantrell (2009). Also, reported values for safranal varied from 3.22% to 8.64% Baghalian *et al.* (2010) and between 6.17-22.30 mg.g^{-1} dry weights Zarinkamar *et al.* (2011). This difference could be caused by genotypic and climate factors. It was reported that climate factors and genotype were effective on saffron yield and quality (Ortega *et al.*, 2004; Özel and Erden, 2005; Gresta *et al.*, 2009; Lage and Cantrell, 2009). Considering the ISO standard which states that safranal ratio has to be equal to or higher than 20‰, the values obtained in all applications of the study were higher than this level Anonymous (2010).

According to ISO standards, the samples with crocin ratios between 150-190‰ were classified as second class saffron, while the samples with higher crocin ratios were accepted as first class saffron. Accordingly, the delayed harvests in saffron were categorized within the second class saffron group, considering crocin ratio Anonymous (2010). The values obtained were similar the findings (154.2-200.0‰) reported by Siracusa at al. (2010). Also, reported values for crocin varied from 17.90% to 37.23% (Lage and Cantrell, 2009), from 21.30% to 36.10% (Baghalian *et al.*, 2010) and between 19.56-29.33 mg.g^{-1} dry weights (Zarinkamar *et al.*, 2011). This difference could be caused by genotypic and climate factors.

The picrocrocin values were obtained higher than the findings (51.6-81.1‰) reported by Siracusa *et al.* (2010). Also, reported values for picrocrocin ranged from 4.23% to 28.78% (Lage and Cantrell, 2009), from 9.83% to 15.35% (Baghalian *et al.*, 2010), from 0.79% to 12.94% (Alonso *et al.*, 1990) and between 5.28-7.07 mg.g^{-1} dry weights (Zarinkamar *et al.*, 2011). This difference could be caused by genotypic and climate factors. In fact, some researchers were reported that genotype (Alonso *et al.*, 1990; Ehsanzadeh *et al.*, 2004; Özel and Erden, 2005; Baghalian *et al.*, 2010) and climate factors (Ortega *et al.*, 2004; Gresta *et al.*, 2009; Lage and Cantrell, 2009; Siracusa *et al.*, 2010; Zarinkamar *et al.*, 2011) were affected on the yield and quality of saffron. According to the international ISO standards, the samples with picrocrocin ratio higher than 70‰ are classified as first class saffron. The saffron obtained in the study was included in the first class in terms of picrocrocin ratio Anonymous (2010).

CONCLUSIONS

The findings obtained in the study demonstrated that harvest of saffron flowers at the full flowering stage resulted in higher crocin, picrocrocin and safranal ratios compared to delayed harvest; however, the saffron yield was obtained from the last harvest (2 day after flowering). In this regard, it was concluded that delayed harvests decreased the quality of saffron.

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