Productivity, Growth and Quality Attributes of 10 Iranian Saffron Accessions under Climatic Conditions of Chahar-Mahal Bakhtiari, Central Iran

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Abstract

Saffron, a spice crop seemingly native to Iran, is mainly being grown in northeastern province, Khorasan. Researches have, mainly, been focused on productivity and agronomic performance of this crop in the latter region, with no major studies on its productivity, growth and quality aspects under other environmental conditions. Therefore, in order to evaluate growth, yield and quality attributes of 10 Iranian saffron accessions, Birjand, Ghaen, Gon-Abad, Torbat-Haydariah, Ferdous, Istahban, Kerman, Isfahan, Kashan and Shahr-Kord under environmental conditions of Shahr-Kord (Lat. 32º 19′ N; Long. 50º 51′ E and Alt. 2066m) at central Iran, a three-replicate RCBD field experiment is being run from summer 2001. Each plot consists eight 4m long rows, spaced 0.4 m apart, with corms planted 5 cm apart on each row in September, 2001. Flowers were collected and stigmas were picked out during November 2001 and 2002 for each plot, followed by drying under room conditions for five days. Four to six-week interval harvests on a 0.3 m long section of a single row in each plot was conducted on corms and aerial parts of the plants from January 2001 to April 2002 (first year) and February 2002 to May 2003 (second year). Leaf area index (LAI) total dry matter (DM) and then crop growth rate (CGR) during linear growth phase of the accessions was estimated at both years. Bitterness (picrocrocin), aroma (safranal) and coloring strength (crocin) were evaluated for dried stigma samples obtained from second year's collections.

While three accessions including Shahr-Kord, Birjand and Ghaen (with 3.62, 2.67 and 2.26 kg ha^{-1}) ranked first, second and third, respectively, in terms of dried stigma yield for the second year, the rest of the accessions indicated poor performance in this regard. The maximum LAI values for the three mentioned accessions were 0.60, 0.54 and 0.74 during the second year, respectively. While maximum CGR of the latter accessions was significantly higher than the rest, corm dry matter yield of these accessions at the end of active growth phase of the second year was 7033, 4742 and 3933 kg ha^{-1}, respectively. For these three accessions, measures for the bitterness were 100.2, 91.0 and 99.2, for the aroma 32.0, 25.0 and 28.8, and for the coloring strength 268.2, 248.2 and 260, respectively, all being well above the minimums set by ISO for Category I Saffron.

More feasible conclusion can be made after collecting more data from these accessions in years to come. Based on the results obtained so far, though, it may be concluded that the three latter accessions could be grown for obtaining satisfactory stigma yield, along with acceptable quality attributes in Shahr-Kord. Furthermore, it appears that these three accessions could out-yield the rest due, mainly, to their greater LAI, CGR and dry matter accumulation.

INTRODUCTION

Saffron (*Crocus sativus* L.) is a perennial spice species from Iridaceae family. While its origin is not exactly defined (Kafi, 2002), Greece and Iran have been mentioned as probable origins of this old crop. Saffron has been used by ancient Greeks, Egyptians and Romans and, therefore, cultivated for more than five millennia (Basker and Negbi, 1983). In addition to being the most precious spice in the world (Basker and Negbi, 1983; Kafi, 2002; and Leffingwell, 1999), saffron possesses a set of somewhat unique agrological and eco-physiological characteristics including a relatively low water use, growth and development during fall and winter, a very low harvest index, a generative phase which is followed by the vegetative phase of growth and an economic yield which is produced prior to a significant vegetative growth. Furthermore it has three exceptional quality attributes, *i.e.* aroma, flavor and yellow dye, a set of characteristics bringing about its uniqueness for pharmaceutical, food and textile industries, respectively.

Saffron is currently being cultivated in Morocco, Spain, India, Pakistan, Turkey, Italy, Swiss, Greece and central Asia, but Iran and Spain are known to be the principal producers (Kafi, 2002) and the latter countries account for more or less 80 percent of the world's saffron production. While the world's total annual saffron production is estimated at 205 tons per year, Iran with more than 47,000 hectares of land under saffron cultivation, is said to produce 80 percent of this total, *i.e.* 160 tons. Khorasan province alone accounts for 46,000 hectares and 137 tons of the above-mentioned totals, respectively. While there exist many gaps in terms of scientific data on productivity and a number of eco-physiological and growth aspects of saffron in the country, the limited studies conducted on Iranian saffron have been mainly dealing with its growth, productivity and quality under the climatic conditions of the northeastern province of Khorasan (Kafi, 2002). No information is available on the agronomic performance, growth and quality of this crop under climatic conditions of central Iran.

Rapid population growth in the dry climate regions of the world, along with irrigation water limitations (Rockstro and Falkenmark, 2000) necessitate exploring the possibility of cultivating crop plants with lower water uses. Iran is, mainly, an arid and semiarid country, whose agricultural water resources are becoming increasingly limited. Saffron is a water efficient crop that grows well in cooler climates with a water requirement lower than a number of traditional crops (Kafi, 2002). The west-central provinces of Iran with relatively cool semiarid climates lack a considerable saffron production. Encouragement of saffron production in the latter provinces may potentially lead to an improved management of water resources, in addition to increased farmers income.

An increased saffron production in central Iran has to be accompanied by studies on eco-physiological aspects of this crop under latter environmental conditions. Saffron is, traditionally, being produced in several areas in Iran, with soil and weather conditions naturally varying in these saffron-cultivating regions. Then several accessions exist which may differ in terms of growth characteristics, productivity and quality attributes. Therefore, the present experiment is aimed at evaluating productivity of saffron under the climatic conditions of Chahar-Mahal Bakhtiari province, west central Iran, along with relative performance of a number of saffron accessions originated from diverse areas across the country. Major quality attributes and growth parameters related to the potential differences in productivity of the accessions will be examined too.

MATERIALS AND METHODS

This experiment is being conducted at Shahr-Kord (Lat. 32º 19′ N, Long. 50º 51′ E and Alt. 2066m), Chahar-Mahal Bakhtiari province, central Iran in a clay-sandy soil. Five accessions local to Khorasan province at northeast Iran, i.e. Birjand, Ghaen, Torbat Hydariah, Ferdous and Gon-Abad, one from Fars province at central south of Iran, i.e. Istahban, one from Kerman province at southeastern Iran, i.e. Kerman, two from Isfahan province at central Iran, i.e. Kashan and Isfahan and one from Chahar-Mahal Bakhtiari province at central Iran, i.e. Shahr-Kord were used in this experiment. In August 2001 corms were obtained from saffron farms of local farmers at the mentioned areas, sorted for uniform size, transported to Shahr-Kord and maintained under dry cool conditions.

First Year

The soil was under fallow for the last two consecutive years and was prepared using a moldboard plow, disk harrow, leveler and furrower, respectively. No fertilizer was applied, though an equivalent of 70 tons/ha of animal manure was mixed with the soil during the seedbed preparations. Plots were prepared in eight 4-m long rows spaced 0.4m apart. The corms were planted 15-20cm deep on mid-September 2001, 5cm apart atop the ridges. The 10 accessions were used as the levels of the treatment in a 3-replicate randomized complete block design. Plots were irrigated 3 times, i.e. immediately after planting, after termination of flowering (late November 2001) and during linear phase of the growth (early April 2002). Weeds were mechanically controlled twice, at 20th October 2001 and early April 2002.

During the active vegetative growth phase, February-April 2002, leaf area and leaf and corm dry weight measurements were conducted four times on a 0.3m long section of one row per plot. Leaf areas were measured using leaf area meter and dry weights using oven drying at 72 ºc for 48 hours. Leaf area indices, total dry matter produced and crop growth rates, on a per week (w) basis, were determined using the data collected on leaf area and dry matter, respectively.

Second Year

While no action performed during spring-summer 2002, irrigation was done on early October 2002 and weeds were controlled mechanically on October 25th, 2002. During blooming from late October to late November 2002, flowers were handpicked at down every day and taken to the lab, where stigmas were separated and stored under room conditions for 7 days. Total economic yield, i.e. dried stigma, for each plot was determined by these harvestings. No considerable economic yield was obtained with the accessions except for Birjand, Ghaen and Shahr-Kord; therefore, measurements on quality attributes were restricted to the latter three accessions.

Dried stigma samples were ground to powder and prepared to photospectometry according to protocol LA-W-824-10. Readings were made based on the maximum absorption of the three chemicals in the saffron stigma, safranal, picrocrocin and crocin, which relate to aroma, flavor (bitterness) and color, respectively. Readings at 330 nm, 257 nm and 440 nm of the 1% solution were used for expressing aroma, bitterness and coloring strength of the samples, respectively.

Further irrigations were conducted twice, one on 22nd November and another, following mechanical weeding, on March 20th, 2003. Leaf area and dry matter samples were taken on a 0.3m section of a row per plot four times during active vegetative growth, Late February-May 2003. Leaf area indices, total dry matter and crop growth rates were determined as described for the first year. Number of corms per m^2 was determined for the final sampling, i.e. May 6th, 2003.

The data were subjected to logarithmic transformation and analyzed using the ANOVA procedure of SAS software. Correlation coefficients were calculated for all traits and the least significant difference test was applied for mean comparisons at the 0.05 level of probability.

RESULTS AND DISCUSSION

A synopsis of main meteorological parameters at Shahr-Kord Weather Station for the long-run average (1980-2000) and the two crop years during which the present experiment has been conducted is indicative of an annual precipitation of 321mm per long-term basis (Table 1). The first year was characterized by a lower than average precipitation during November, February and March, though precipitation was higher than average for December, January and April. Total precipitation was 8 percent higher than average at first year. The second year was characterized by a lower than average precipitation for January and March, though the reverse was true for November, February and to some extent April. Total precipitation at the second year did not considerably differ from its long-term average. Temperatures for the two years were not markedly different from the long-run average, except for early parts of the two seasons, where temperatures were 2 to 3º C higher than their long-run averages. It can be said that a major portion of the precipitations at this province falls normally after flowering and during the active vegetative growth phase of saffron, i.e. December, January, February and April, where average temperatures normally fall in the range of 0 to 11º C. Thus irrigation practices may, probably, be kept minimal and restricted to one to three supplementary irrigations during saffron active vegetative growth under climatic conditions of Shahr-Kord.

Data collected for different traits at the first year, in general, and for the stigma yield, in particular, were highly variable. Therefore, here analyses of variances and mean comparisons are restricted to the data collected at the second year of the experiment.

Treatment (accession) effects were statistically significant for stigma yield, LAI, CGR, total dry matter and corm weight and number (Table 2). For most of the above traits a majority of the variation due to the treatment effect arose from differences of the Birjand, Ghaen and Shahr-Kord with the rest of the accessions.

While the rest of the accessions did not produce a considerable stigma yield, Shahr-Kord, Birjand and Ghaen ranked first, second and third (Table3), with Shahr-Kord out-yielding the latter two accessions. The accessions local to Shahr-Kord, Birjand and Ghaen produced a larger LAI compared to the rest of accessions, indicating that these accessions owe their higher stigma yield, at least in a major part, to their higher photosynthetic areas. The accessions from Shar-Kord, Birjand and Ghaen indicated a higher CGR compared to the rest. A higher total dry matter production of the accessions from Shahr-Kord, Birjand and Ghaen compared to the rest (Table 3) could also be attributed to the differences in their LAI's and CGR's. A close relationship between LAI and the amount of light being intercepted by the crop plant is well established (Shibles and Weber, 1965; and Wilfong et al., 1967). Shahr-Kord, Birjand and Ghaen ranked first, second and third in terms of corm weight produced per unit area (Table 3). While Shahr-Kord and Birjand produced a larger number of corms, Shahr-Kord and Ghaen produced larger corms relative to the rest of the accessions (Table 3). Stigma yield was highly correlated with LAI, CGR, total dry matter and corm weight and size (Table 4), suggesting that with the accessions used in this experiment, a higher LAI, dry matter and corm weight and size may lead to a higher economic yield in saffron. While there is no report on growth factors of saffron, a close association between LAI and/or LAD and economic yield (Aase, 1978; Baker and Gebeyehou, 1982; Dunphy et al., 1984) and biological yield (Ehsanzadeh, 1999) has been reported for small grain cereal crops.

Analysis of main quality attributes indicated that the three accessions, Birjand, Ghaen and Shahr-Kord have numbers well above the minimums set by the International Organization for Standardization for Category I Saffron (Table 5). An analysis of data for the quality attributes was not possible, due to insufficient stigma yield for seven of the ten accessions, though, it appears that the accession local to Shahr-Kord is superior in terms of all three quality characteristics evaluated in this study.

Based on the results obtained with the ten Iranian saffron accessions during second year of our experiment, it could be concluded that saffron could be produced with minimal inputs under environmental conditions of Chahar-Mahal Bakhtiari, though a more definite conclusion could be made with data which will be collected for 3rd, 4th and even 5th year of the experiment. Since they out-yielded the rest of the accessions in one hand and proved acceptable in terms of quality characteristics, on the other, the three accessions from Shahr-Kord, Birjand and Ghaen may be recommended for saffron production in this part of the country. It appears that these accessions owe their higher agronomic performance to a higher LAI and CGR, relative to the other accessions.

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Tables

Table 1. A synopsis of temperature and precipitations data[1] at Shahr-Kord Weather Station (Lat. 32º 19′ N, Long. 50º 51′ E and Alt. 2066m).

	Average temperature (ºc)			Total precipitation (mm)		
Month	2001-2	2002-3	Long-term	2001-2	2002-3	Long-term
September	19.9	20.9	18.8	0.0	0.0	0.0
October	15.3	16.3	13.1	0.4	0.5	7.9
November	9.7	9.1	7.5	19.6	47.2	32.3
December	5.0	4.1	2.0	129.1	61.4	55.5
January	2.3	1.1	-1.7	80.5	22.0	59.3
February	1.4	0.4	1.0	14.4	97.4	50.1
March	6.3	5.4	6.0	12.4	30.1	57.7
April	9.1	10.0	11.2	91.5	49.6	39.2
May	14.1	13.3	15.9	0.8	22.2	15.5
June	18.9	18.6	20.8	0.0	0.1	0.7
July	22.7	24.0	24.1	0.0	0.0	2.3
August	22.6	24.1	23.1	0.0	0.0	0.4
Total	------	-------	--------	348.7	330.4	320.9
Average	12.3	12.3	11.8	--------	------	-------

[1] Long-run data are for 1980-2000.

Table 2. Analysis of variance (Mean Squares)[1] for stigma yield, LAI, CGR, total dry matter and corm weight, number and size of ten accessions of Iranian saffron.

Source of variation	DF	Stigma yield	LAI	CGR	Total dry matter	Corm weight	Corm number	Corm size
Replication	2	0.0437	0.1308	0.220	0.1429	0.1508	0.5859	0.1852
Accession	9	3.3442**	0.6097**	0.7150**	0.6031**	0.5877**	0.3400**	0.0601
Error	18	0.0202	0.0689	0.220	0.0501	0.0504	0.0606	0.0358
CV		15.3	22.5	35.0	5.5	7.2	6.0	9.7

[1] ** = F test significant at the 0.01 level of probability.

Table 3. Means[1] for stigma yield, LAI, CGR, total dry matter and corm weight, number and size of ten accessions of Iranian saffron.

Characteristic / Accession	Stigma ($kgha^{-1}$)	LAI	CGR ($gm^{-2}w^{-1}$)	Total dry matter (gm^{-2})	Corm weight (gm^{-2})	Corm number	Corm size (g)
Birjand	2.67[a]	0.54[a]	45.7 [a]	544.0[a]	474.2[a]	430.6[a]	1.07[ab]
Gon-Abad	0.02[bcd]	0.09[b]	5.5 [bc]	71.4[b]	64.2[b]	72.2[d]	0.99[ab]
Ghaen	2.27[a]	0.74[a]	31.7 [ab]	447.0[a]	393.3[a]	277.8[ab]	1.44[a]
Isfahan	0.01[de]	0.05[b]	3.4 [bc]	49.7[b]	45.8[b]	86.1[cd]	0.63[b]
Kashan	0.03[bc]	0.12[b]	6.1 [bc]	98.1[b]	88.3[b]	116.7[cd]	0.91[ab]
Shahr-Kord	3.62[a]	0.60[a]	71.9 [a]	787.3[a]	703.3[a]	469.4[a]	1.71[a]
Ferdous	0.03[b]	0.12[b]	9.7 [bc]	125.6[b]	115.0[b]	163.9[bcd]	0.81[ab]
Istahban	0.03[b]	0.09[b]	5.0[c]	69.4[b]	65.0[b]	116.7[cd]	0.84[ab]
Torbat-Haydariah	0.02[cde]	0.11[b]	4.6 [c]	59.4[b]	53.3[b]	86.1[cd]	0.91[ab]
Kerman	0.01[d]	0.12[b]	5.6 [bc]	94.5[b]	85.0[b]	163.9[bc]	0.69[b]

[1] Means with a same letter are not significantly different based on LSD at 0.05 level.

Table 4. Pair-wise correlation coefficients[1] for the characteristics of ten accessions of Iranian saffron.

	Stigma yield	LAI	CGR	Total dry matter	Corm weight	Corm number	Corm size
Stigma	1						
LAI	0.86**	1					
CGR	0.68**	0.67**	1				
DM	0.85**	0.77**	0.79**	1			
CormW	0.85**	0.76**	0.79**	0.99**	1		
Corm N	0.82**	0.74**	0.61**	0.84**	0.84**	1	
Corm S	0.48**	0.41*	0.48**	0.56**	0.56**	0.12	1

[1] * and ** significant at 0.05 and 0.01 levels of probability, respectively.

Table 5. Photospectometry results of coloring strength, aroma and flavor (bitterness) of three Iranian saffron accessions compared to ISO 3632-2-13 Standards for Category I saffron.

Accession	Birjand	Ghaen	Shahr-Kord	ISO 3632-2-13
Characteristic				
Coloring (crocin)	248	260	268	190
Aroma (safranal)	25	29	32	20
Bitterness (picrocrocin)	91	99	100	70