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SPACING EFFECTS ON CORM AND FLOWER PRODUCTION OF SAFFRON (*CROCUS SATIVUS*)

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ABSTRACT

Saffron is a valuable condiment that may have the potential to invigorate economically the Bekaa Plain, especially the Baalbeck - Hermel area, which has suffered after the crack down on illicit crops. However, no research on the optimal cultural practices for saffron has been conducted locally. The objective of this study is to investigate the effects of spacing on saffron corm and flower production. Corms were planted by hand at three spacing densities: 20 cm x 20 cm, 20 cm x 10 cm, and 10 cm x 10 cm in October of 2000 at the Agricultural Research and Education Center (AREC). The field experiment was in a randomized complete block design with three replicates. Flowers were counted and picked in October and November, and the stigmas collected, dried, and weighed. Corms were dug up in July 2002 and measured. Density of planting had no effect on numbers of corms produced per corm cluster, but it had a significant effect on corm weight, which had a large effect on flower production. By 2002, the 20 cm x 20 cm spacing gave heavier corms, and higher flower numbers and red stigma yield per corm cluster than the 20 cm x 10 cm and 10 cm x 10 cm spacing. Unless corms can be purchased at markedly lower prices, farmers are recommended to maximize flower production per corm by planting at 20 cm x 20 cm spacing.

Keywords:, saffron, planting density, corm weight, red stigma yield, Bekaa

INTRODUCTION

The Bekaa Plain, especially the Baalbeck - Hermel area, has suffered economically after the crack down on illicit crops. This has caused increased emigration of the rural population to towns and cities. So far, no new replacement crops have been successfully introduced.

The crops that can replace illicit crops need to be of high value and saffron is one of them. Saffron is the most expensive condiment. Prices quoted on wholesale market usually range between US$220-1600/kg depending on quality, although retail prices are always much higher (McGimpsey, 1993; Garcia, 1997). The average yield in Spain, a major world producer, is around 10-12.5 kg/ha.

Saffron is expected to have good adaptation to the cool Mediterranean environment of the Bekaa. Most probably it originated from eastern Mediterranean (McGimpsey, 1993; Negbi, 1999). According to Grieve (1995), wild forms still exist in Italy, Greece, Asia Minor, and Iran (West Persia to Kurdistan). It was extensively grown in the Near East and Mediterranean basin in classical times (Zohary and Hopf, 1988). At present, it is cultivated in

France, Greece, Iran, Italy, Morocco, and Spain.

In order to introduce saffron successfully into Lebanon, knowledge of optimal cultural practices needs to be available. Spacing usually has a large effect on crop yield, however so far little research on saffron spacing has been reported internationally. A one-year study reported that the most-dense planting (67 corms/m^2) gave the highest stigma yield per unit area as expected (Bullitta *et al*., 1996). However, planting at an intermediate density (inter-row spacing of 20 cm with intra-row spacing of 10 cm) was recommended by McGimpsey (1993). It was pointed out that if the corms were planted in higher densities, saffron yield would be increased in the first one or two years, but would soon become overcrowded and need to be dug up and replanted earlier (McGimpsey, 1993; Ait-Oubahou and El-Otmani, 1999). In Nivelli, Italy, corms are dug up annually, so they are planted densely. The best yield of flowers and corm was obtained by leaving a space of 2-3 cm between corms in the row (Tammaro, 1999). This result was partially substantiated by a single-year field study in Spain, which reported that planting at 300 big corms/m^2 gave the highest corm yield (Juan *et al*., 2003).

No research on saffron has been conducted in Lebanon. In order to introduce saffron successfully into the country, information on optimal conditions to multiply the costly corms, and to produce flowers to get the stigmas for sale is needed. The objective of the present study was to investigate the effects of spacing on corms and flower production in saffron.

MATERIALS AND METHODS

Saffron corms were purchased and shipped by airfreight from the Hoog & Dix Export B.V. in the Netherlands. Field experiments were conducted at the Agricultural Research and Education Center (AREC) of the American University of Beirut in Lebanon over three seasons (2000-2002). The Center (33° 56’ N, 36° 05’ E, 995 m above sea level) is located in the semi-arid Bekaa Valley. The long-term annual precipitation is 503 mm, 60% of which falls during December to February. The long-term mean annual temperature is 13.9 °C. The soil is an alkaline (pH 8.0), clayey, Vertic Xerochrept formed from fine-textured alluvium derived from limestone (Ryan *et al*. 1980).

Corms were planted on 4 October 2000 by hand about 15 cm deep in two spacing densities: low (20cm x 20cm) and medium (20cm x 10cm). The experiment design was a randomized complete block with three replicates. In addition, one plot of corms was planted at a high density (10cm x 10 cm). Plot size was 10m by 1m.

Weekly irrigation (2-4 hours each application) was provided after planting and from September 15 in subsequent years until it started to rain. Weekly irrigation was also applied in April. Total irrigation of 140, 210, and 130 mm was applied in 2000/01, 2001/02, and early in the season of 2002/03, respectively. All plants dried up by beginning of May. Weeding was done by hand. No fertilizers were applied.

Flowers were picked each day or each alternate day. The red part of the stigmas were cut by fingernails from the flower and dried in an oven at 50°C for 3 hours. Flower numbers were recorded separately for each plot. In 2002, weight of red stigmas was recorded on a plot basis.

In order to monitor corm multiplication, 10 corm clusters (each derived from one planted corm) were randomly dug up on September 18, 2001. The diameter and weight of the largest corm were measured, and the number of smaller corms was recorded. In July 2002, corms were dug up from one-third of each plot. The diameter and weight of the largest corm from 30 random samples were measured, and the number and total weight of smaller corms were recorded. The corms were sorted according to weight and re-planted in September 2002.

RESULTS

Weather - Figure 1 shows the daily minimum temperatures from October 1 to November 30 in 2000 and 2001. In general, October and November were cooler in 2000 than in 2001. Both 2000/01 and 2001/02 seasons received below average rainfalls (Table 1), but the rainfall distribution was better in 2001/02 with 172 mm of rain in March and April. October of 2002 received unusually low rainfall.

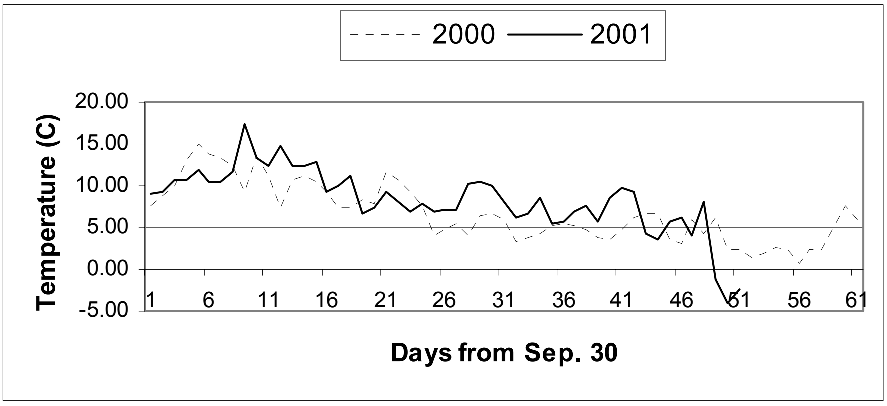

Figure 1. Daily minimum temperatures from October 1 to November 30 in 2000 and 2001.

Flower Numbers - In 2000, only 47 flowers were produced from the 3500 corms that had been planted. Flowering took place in a short 10-days period from Nov 7 to 17. This could be due to late receiving and planting of the corms, and to the cooler temperature in 2000 (relative to 2001).

In 2001, spacing had a large effect on flower production on the basis of per unit area (Table 2). The ratio of actual flower production for low to medium to high density was 1.0: 2.0: 4.0 as expected. However, spacing had no effect on flower production when expressed as per corm cluster. Flowering lasted from October 27 to November 28.

Unlike 2001, planting at the low density gave a higher number of flowers per corm cluster than the medium density in 2002. Relative to the two lower densities, the high density had the lowest flowers per corm cluster. Plant density did not have a significant effect on flower production per unit area. The ratio of actual flower production for low to medium to high density was 1.0: 1.4: 1.5. This was markedly different from the expected 1: 2: 4 ratio. Similar to 2001, flowering lasted from October 28 to November 29.

TABLE 1

Annual Rainfall (mm) and Distribution at the Experimental Site from 2000/01 to 2002

Season	Sep	Oct	Nov	Dec	Jan	Feb	Mar	Apr	Season's total	May-Aug	Annual total
2000/01	0	31	26	110	47	159	16	3	392	33	425
2001/02	1	14	36	75	87	52	124	48	437	4	441
2002/03	7	7	57	209							
Mean*	1.2	18.8	54.9	106.8	111.3	86.1	76.8	31.0	486.9	16.1	503.0

* long-term mean (1956/57-2001/02)

TABLE 2

Number of Flowers Produced per Unit Area or per Corm Cluster under the Different Planting Densities in 2001 and 2002

	2001		2002	
Density	m^{-2}	corm $cluster^{-1}$	m^{-2}	corm $cluster^{-1}$
Low (20cm x 20cm)	23	0.9	150	5.9
Medium (20cm x 10cm)	47	0.9	207	4.0
High (10cm x 10cm)	92	0.9	226	2.2
l.s.d.[1]	15.7	0.44	58.3	0.93

[1] only for comparison between the low and medium density

Red stigma production - In 2002, the low-density treatment gave a higher stigma yield per 100 corm clusters than the medium-density treatment (Table 3). Relative to the two lower densities, the high density had the lowest stigma yield per 100 corm clusters. Spacing did not have a significant effect on stigma production per unit area. The ratio of stigma production per square meter for low to medium to high density was 1.0: 1.3: 1.7, similar to that of flower production. There was no significant difference in stigma yield per 100 flowers between the low and medium densities. The high-density treatment gave the highest yield per 100 flowers.

Effect of corm weight on flower production - Corm weight had a large effect on flower production in 2002 (Table 4). Corms smaller than 4 g in weight practically did not give any flowers. Corms >8 g in weight were the most productive, yielding on average more than two flowers per corm.

Corm production and size - The random sampling in 2001 showed that on average 5.1 (3 – 7) corms of different sizes were produced from each planted corm. The average diameter and weight of the largest corm from each corm cluster was 21 mm (13 - 28) and 5.1 g (1.5 - 9.3), respectively.

In 2002, effect of planting density was not significant on total numbers and weight of corms produced per corm cluster, but was significant on the basis of per unit area (Table 5). The ratio of corm number per square meter (1.0: 2.0: 4.1) for low to medium to high density was very close to the ratio planted, but not for the ratio for corm weight per square meter (1.0: 1.9: 2.8). Average weight per corm produced under the low density was not significantly different from that under the medium density. However, weight of corms was 33% lower under the high-density treatment. The average corms produced under the three treatments weighed < 4 g per corm.

Effect of planting density on numbers and weight of big corms produced in 2002 was given in Table 6. Numbers of corms larger than 8 g were less than initially planted under all the treatments. This decrease was much larger under the high density of planting than under the low and medium densities, which were not significantly different. The numbers of corms larger than 6 g also did not differ significantly under the low and medium density, and the number of corms under the high density was markedly lower. On average, corms larger than 8 g or 6 g from the low density were higher in weight than those from the medium density of planting, and those from the high density recorded the lowest weight.

TABLE 3

Weight of Stigma Produced per Unit Area, per 100 Flowers, and per 100 Corm Clusters under the Different Planting Densities in 2002

Density	mg m^{-2}	mg 100 $flowers^{-1}$	mg 100 corm $cluster^{-1}$
Low (20cm x 20cm)	578	385	2248
Medium (20cm x 10cm)	773	375	1499
High (10cm x 10cm)	958	425	929
l.s.d.[1]	263.2	91.9	638.0

[1] only for comparison between the low and medium density

DISCUSSION

This study demonstrated clearly that under the Bekaa conditions, over crowding effect on flower production was displayed by saffron corms under the high and medium densities as early as the third production year. Corm clusters under the three densities were yielding the same number of flowers in 2001. However, corm clusters under the high and medium densities yielded less flowers and red stigma than those under the low density in 2002. This difference probably was due to the heavier 8-grams or 6-grams corms produced under the low density, although the two densities gave similar numbers of corms. This result was unexpected for the medium-density planting, which was recommended by McGimpsey

(1993). Such a recommendation might be based on production per unit area when corm supply and cost is not a constraint but availability of land is.

TABLE 4

Effect of Corm Weight on Flower Production, 2001-02

Corm weight (g)	>8	6-8	4-6	2-4	<2
First lot					
Corms planted	275	193	273	261	540
Flower/corm	1.8	0.8	0.2	0.0	0.0
Second lot					
Corms planted	123	331	810	747	288
Flower/corm	2.7	0.7	0.2	0.0	0.0
Mean flower/corm	2.2	0.7	0.2	0.0	0.0

TABLE 5

Effects of Planting Density on Average Corm Number and Weight, 2001-02

Density	Number of corms		Weight of corms (g)		Ave. weight per corm
	corm cluster^{-1}	m^{-2}	corm cluster^{-1}	m^{-2}	(g)
Low (20cm x 20cm)	16.0	401	44.3	1108	2.8
Medium (20cm x 10cm)	15.8	792	43.1	2154	2.7
High (10cm x 10cm)	16.5	1645	30.5	3053	1.9
l.s.d.[1]	2.76	75.0	8.34	183.1	0.67

[1] only for comparison between the low and medium density

TABLE 6

Effects of Planting Density on Number and Weight of Big Corms, 2001-02

Density	Number of corms > 8 g (10 corm cluster^{-1})	Number of corms > 6 g (10 corm cluster^{-1})	Ave. weight of corms (g)	
			> 8 g	> 6 g
Low (20cm x 20cm)	6.3	11.9	11.6	9.3
Medium (20cm x 10cm)	6.2	10.9	10.6	9.0
High (10cm x 10cm)	1.3	5.3	9.8	7.7
l.s.d.[1]	4.78	7.99	0.76	0.25

[1] only for comparison between the low and medium density

The finding that the effects of planting density differed when expressed on per corm cluster or per unit area basis would have important implication to farmers when they initiate saffron cultivation in Lebanon. Since corms are expensive, farmers should initially maximize flower production from each planted corm, instead of maximizing production per unit area. Keeping in mind that digging up the corms and replanting them every one or two years is labor intensive and costly, they should plant the corms in a low density, at least 20 cm by 20 cm. Later, they may plant at higher densities to maximize stigma yield per unit area when the corms become relatively inexpensive and in abundant supply.

In the initial stage of saffron cultivation in Lebanon, multiplication of corms by the farmers themselves will be as important or even more important than flower and stigma production. This is because corms are expensive and need to be imported from overseas. As a cheaper alternative, farmers may multiply corms for the expansion of their cultivation areas. They may also sell the corms to other farmers. Whether farmers aim to produce flowers or corms, results of this study suggest that they should plant the corms at the low density.

The finding that the average weight of the largest corms produced was lower than the original corms was unexpected since the experiment was irrigated. Short periods of low humidity in the spring might have induced early senescence of the foliage and cessation of corm growth. It was observed in pot-grown saffron that as early as March, once the foliage start to senesce, watering the pots will not stop the process. The present study should be continued in order to get extra years of data to substantiate the findings. Studies on techniques to prevent early senescence may also need to be carried out.

CONCLUSION

In the initial stage of saffron cultivation, since imported corms are expensive, farmers in the semi-arid Bekaa are recommended to maximize flower, red stigma, and corm production per planted corm rather than maximizing yield per unit area. They should plant corms at a low density (20 cm x 20 cm).

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