Asian Journal of Plant Sciences

ISSN 1682-3974

science alert

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Asian Journal of Plant Sciences 7 (8): 747-751, 2008
ISSN 1682-3974

Effect of Planting Depth and Soil Summer Temperature Control on Growth and Yield of Saffron (*Crocus sativus* L.)

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Abstract: In order to study the effect of planting depth and summer temperature control on growth and yield of saffron (*Crocus sativus* L.), an experiment was conducted at Agricultural Research Station in Zabol University (Iran) during 2004-2005 growing seasons. The experiment was laid out in a split plot within a Randomized Complete Block Design (RCBD) with four replications. The main plots consisted of three planting depths (10, 15 and 20 cm) and three different methods for summer temperature control (check, mulching and irrigation) were arranged in subplots. The results revealed that by increasing the planting depth, corm propagation, contractile roots number, flowering time, leafing time and leaf number were decreased significantly, but leaf length and stigma were increased. Flowers number and corm weight were increased significantly by increasing planting depths from 10-15 cm, but both of them were decreased in 20 cm depth. In response to summer temperatures control treatments, flowering, leafing, leaf and stigma lengths were increased but corm propagation decreased significantly, due to decreasing temperature treatments. Leaves and contractile roots number were not affected by summer treatments. In response to temperature control and planting depth interaction, the most corm propagation and leaf number ware obtained at 10 cm planting depth and control treatments, also minimum corm propagation and leave number was obtained at 20 cm planting depth with mulching treatments. Minimum flower number was obtained at 10 cm planting depth with irrigation and its maximum number was obtained at 15 cm planting depth with mulching.

Key words: Corm, contractile root, mulch, dry matter, flower emergence, leaf emergence

INTRODUCTION

Domesticated saffron (*Crocus sativus* L.) is a herbal, fall-flowering perennial crop and a species of Crocus in the Iridaceae Family. Saffron has a special situation in Iranian export specialty. It is an expensive spice and medicinal plant. Iran is the largest producer of saffron in the world (65% of global production) (Koocheki *et al*., 2007). High economic values, make employment, make incomes and high water use efficiency in contrast to other crops are the important testimonies for special attention to saffron (Behnia, 1996). There are many factors contributing to growth and development process and yield of saffron, the most important factors are environmental conditions and corm physiology. Among environmental conditions, temperature and its range have an important effect on growth and development period, therefore growth period correlation to seasonal temperature changes (Kafi, 2002). The main plant phenomena's development such as flowers evolution and main reserve source for life resumption (corm), developing in soil, therefore soil temperature is more important than air temperature for saffron's growth and development. However soil temperature is relevant to air temperature, but fluctuations in soil temperature is lower than that in air temperature within a short time. In the autumn soil become(s) cold earlier and in the spring it becomes warm up later than air (Behnia, 1996).

Waithaka and Wanjao (1982) in the survey effect of cold duration treatment on growth and flowering of *Liatris spicatal*, reported that 3-5°C temperature is necessary for beginning growth and flowering, also by increasing cold period, emerging rate, vegetative growth and flowering rate accelerated. Scholars reported that duration from planting to flowering had an inverse relevance with cold course time. Lack or not enough cold

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periods has a negative influence on bud emergence and flowering branches length. In tuber crops it is necessary to take a moderate and low temperature for flowers emerging from soil (Rees, 1992). However, the extreme cold decrease growth and yield and delay flower formation (Molina *et al*., 2005). With leaves photosynthesis activity provided corms formation and strengthens during winter and early spring (Kafi, 2002). Meriam (1997) reported that final corms size of *Anemone coronarial* at controlled conditions, affected by day length and temperature, as 16 h day length in compare with 8 h day length increased corms growth rate, but high temperature and short day length decreased final corms size. Corm production amount was two third more in thermal regime, 27/22°C (day/night) than 22/17°C (day/night) (Koul and Faroog, 1984). De-Maestro and Rata (1993) reported that large corms had positive effect on flowering rate, but not affected on stigma weight. By large corm planting, first year's flower yield and also due to more corm proliferation (parturition) and daughter corm production next years yield increase (Koocheki *et al*., 2007). Saffron's corm and flower yield affected by corm weight and diameter. Accordingly, the corms with approximately 20 g weigh and more than 3 cm diameter were recommended (Sud *et al*., 1999). The purpose of present study was to evaluate the effect of planting depth and summer temperature control on saffron shoot and root growth.

MATERIALS AND METHODS

The experiment was carried out between June 2004 and May 2005 at the Agricultural Research Station in Zabol University, Sistan and Baluchistan Province, Iran, located in 61.31 longitude and 30.55° latitude and 480 m Altitude from sea level. The climate was arid and warm. Experiment was conducted in split plot within a randomized complete block design with 4 replications. The main plots included three planting depths (10, 15 and 20 cm) and sub plot were considered three summer temperature control (check, mulching with straw in summer and one irrigation in September). The previous crop was wheat (*Triticum aestivum* L.) in 2003. The field was plowed in 30 cm depth and all plots were fertilized uniformly with decayed animal manure (30 t ha^{-1}) and ammonium phosphate (150 kg ha^{-1}), before planting in the summer. The size of each main plot was 13.5×5 m and three subplots (4×5 m) were accommodated in them. The field was irrigated prior to planting on 10 October and corms were planted on 28 October 2004. Corms were planted in 40 cm wide rows with 15 cm spacing within-rows and also 4 corms were planted in each hole. The plots consisted of 12 rows of saffron. First irrigation was performed after leaves grow and next irrigations were performed at required time. Weeds were controlled manually when needed. Mulching and irrigation was applied on 20 June and 20 September 2004, respectively. All studied parameters were recorded on each time. In order to evaluate the temperature changes in soil, it was measured at the 10, 15 and 20 cm depths with soil thermometer on 30 June and 2 August 2004. Sampling of root and shoot parts were taken in March 2005. Flowers number, flowers and one-flower weight and stigma length were measured daily. Contractile roots (succulent form) that are in the base of root were measured on samples collected from three randomly selected holes at the middle of subplot in one square meter, the number of propagated corms (daughter corm) were also recorded. Corms weight, leaves length and number were measured in May 2005 (end of growing season).

Statistical analysis was conducted using MSTAT-C software and treatment means were compared by Duncan's new Multiple Range Test (DMRT). The probability level for determination of significance was 0.05.

RESULTS AND DISCUSSION

Flowering time: Results showed that, the days after irrigation to flower emergence significantly affected by planting depth ($p>0.05$) (Table 1). Table 2 shows that minimum days after irrigation to flowering observed in deeper planting depth. It seems that by increasing planting depth, due to decreasing the corm bed temperature site, it caused breaking buds dormancy and thereupon enhanced flower emergence (Kafi, 2002). Days after irrigation to flower emergence also were significantly influenced by summer temperature control treatments ($p>0.01$) (Table 1). Minimum summer temperature was obtained in mulching treatments and consequently the minimum days after irrigation to flowering were seen in mentioned treatment, thus it showed a positive correlation effect between decreasing temperature and flowering acceleration (Kafi, 2002). Planting depth and temperature control interaction weren't significantly affected on days after irrigation to flowering (Table 1), though minimum days after irrigation to flowering was obtained at 20 cm planting depth-mulching interaction (Table 3). It seems that treatments interaction, by decreasing corm bed temperature in deeper planting depth and summer temperature control treatments caused bud dormancy breaking and accelerate flower emerging (Kafi, 2002).

Table 1: ANOVA data about the effect of planting depth and summer temperature control on growth and yield characteristics of saffron

SOV	Flower emergence[1]	Leaf emergence[1]	Corm No. (h^{-1})	Contractile roots No. (h^{-1})	Corm dry weight ($g\ h^{-1}$)	Leaf No. (h^{-1})	Leaf dry weight ($g\ h^{-1}$)	Leaf length (cm)	Stigma length (cm)	Flower No. (m^{-2})
Planting depth (A)	7*	7*	1020.5*	14542.4**	27.27ns	9337.02*	1.59ns	112.92**	2.52**	90.52**
Summer temperatures control (B)	94.7**	112**	86*	1684ns	338.8**	590.19ns	14.05*	134.1**	0.52**	32.86**
A*B	4.6ns	2.5ns	68.5*	400.7ns	6.3ns	836.52*	0.69ns	6.47ns	0.04ns	11.52**
CV (%)	5.9	7.1	14.8	24.3	21.7	14.27	17.59	6.46	7.3	8.69

[1]Days after irrigation to leaf and flower emergence; ns: Non significant, **: p>0.01 and *: p>0.05

Table 2: Effect of planting depth and summer temperature control on saffron leaves and flower emergence (days after irrigation)

	Treatments					
	Planting depth (cm)			Summer temperatures control		
Traits	10	15	20	Check	Mulching	Irrigation
Leaf emergence[1]	24.2a	23.1ab	22.7b	26.0a	20.4c	23.7ab
Flower emergence[1]	20.2a	19.2ab	18.7b	22.0a	16.0c	20.0b

[1]Days after irrigation to flower or leaf emergence; Row means followed by the same letter are not significantly different at 0.05 or 0.01 probability level

Table 3: Effect of planting depth-summer temperature control interaction on saffron flower and leaf emergence (days after irrigation)

	Planting depth (cm)								
	10			15			20		
Traits	Check	Mulching	Irrigation	Check	Mulching	Irrigation	Check	Mulching	Irrigation
Leaf emergence[1]	26.7	20.2d	25.7	25.2	21d	23.2	26	20	22.2
Flower emergence[1]	22.7	16.2	21.2	21.5	16.5	19.7	22	15.5	18.7

[1]Days after irrigation to flower or leaf emergence

Also, as increasing planting depth, temperature were decreased and caused the corm proliferation reduced, so lead to produced sturdy corms with a high flowering potential.

Leaf emergence: Table 1 reveals that days after irrigation to leaf emergence were significantly influenced by planting depth (p>0.05) and it decreased by increasing planting depth (Table 2). Leaf emergence accelerated by decreasing corms bed temperature in deeper planting (15 and 20 cm). Also, leaf emergence time was significantly affected by summer temperatures control (p>0.01) (Table 1) and it decreased by mulching significantly (Table 2). Leaf emergence and flowering accelerated by mulching, because it decreased soil exposure at radiation and thereupon soil temperature decreased. A low temperature is necessary for breaking seed dormancy, flowering and growth the low temperature to break dormancy around five degree Celsius (Dole, 2003). Minimum days after irrigation to leaf emergence observed in 20 cm planting depth-mulching interaction (Table 2).

Root

Corm number: The number of daughter corms (propagated corms) showed significant reduction by increasing planting depth (p>0.05) (Table 1). The results showed that corm weight in low planting depth was less than deep planting depth (Table 4). There were statistically difference effects of temperature control on corm propagation (p>0.05). Corm propagation decreased by mulching because of decreasing soil temperature (Table 4), Corm propagation increased by increment daily temperature (Mashayekhi and Latifi, 1997). Planting depth-mulching interaction had a significant effect on corm propagation. Corm propagation limited by mulching and planting depth interaction and it decreased by mulching and deep planting depth (Table 5).

Contractile roots number: Results indicated that contractile roots number more significantly decreased by increasing planting depth (p>0.01); maximum and minimum contractile roots number were obtained in 10 and 20 cm planting depths, respectively (Table 1, 4). Increasing contractile roots at low planting depth is a reaction for corm preservation from temperature fluctuation (Azizbekova and Milyaeva, 1999; De-Maestro and Rata, 1993). There was no significantly effect of planting depth-temperature control treatments interaction on contractile roots number. Nonetheless maximum and minimum contractile roots number were obtained in 10 cm planting depth×check and 20 cm planting depth×mulching interactions, respectively (Table 1, 4, 5).

Corm dry weight: Planting depth treatments had not significantly effect on corm dry weight (Table 1). Minimum corm dry weight was obtained in 10 cm planting depth (Table 4). In shallow planting depth, corm weight

Table 4: Effect of planting depth and summer temperatures control on saffron root and shoot characteristics (h^{-1})

	Planting depth (cm)			Summer temperatures control		
Traits	10	15	20	Check	Mulching	Irrigation
Corm No.	41.0a	28.2b	23.0c	32.8c	27.7b	31.7a
Contractile root No.	73.7a	15.4b	11.6b	43.3	30.4	37.0
Corm d.wt. (g)	7.5	10.1	10.1	5.5b	15.3a	6.9b
Leaf No.	140.9a	100.6b	87.3b	112.0	101.7	115.1
Leaf d.wt. (g)	6.7	7.3	7.4	6.0b	8.4a	6.7b
Leaf length (cm)	24.6b	29.2a	30.4a	25.0c	31.8a	27.2b
Flower No. (per m^2)	11.2c	16.6a	13.1b	13.0b	15.5a	12.5b

Row means followed by the same letter(s) are not significantly different at 0.05 or 0.01 probability level

Table 5: Effect of planting depth-summer temperatures control interaction on saffron root characteristics (per hole)

	Planting depth (cm)								
	10			15			20		
Traits	Check	Mulching	Irrigation	Check	Mulching	Irrigation	Check	Mulching	Irrigation
Corm No.	45.7a	32.7b	44.5a	28.7bc	28.7bc	27.2bc	25.2bc	21.7c	22.2c
Contractile roots No.	73.7	48.7	68.7	18.7	6.2	21.2	17.5	6.2	11.2
Corm d.wt. (g)	4.2	12.7	5.6	6.5	15.5	8.5	5.8	15.8	6.7

Row means followed by the same letter(s) are not significantly different at 0.05 or 0.01 probability level

decreased because of increasing corm number, increasing preservative fiber around the corms and contractile roots. These agents reduced assimilate transfer to corm and thereupon decreases total corm dry weight (Koul and Faroog, 1984). Corm dry weight more significantly affected by summer temperature control treatments (p>0.01) and the most increase was obtained by mulching (Table 1, 4). Low corm propagation by summer temperature control treatments lead to increasing food resource to existing corm (Koul and Faroog, 1984).

Shoot

Leaf number: Results showed that leaf number per each corm (hole) decreased by increasing planting depth, maximum leaf number obtained in 10 cm planting depth (Table 1, 4). In response to temperature control treatments, the leaf number decreased by mulching but not significantly (Table 4). There were statistically significant effects of temperature control-planting depth interaction on leaf number per plant (hole) (p>0.05), (Table 1), maximum and minimum leaf number were obtained in 10 cm planting depth-check and 20 cm planting depth-mulching interactions, respectively (Table 6). Corm number and leaf number were more in shallow planting.

Leaf dry weight: There ware no significant differences between leaf dry weight in response to planting depth, but the trend showed increases by increasing planting depth (Table 1, 4). Leaf dry weight and leaf length increased in deeper planting. Leaf dry weight significantly increased by summer temperature control treatments (p>0.05) and maximum leaf dry weight was obtained in mulching (Table 1, 4) due to lower temperature. Also, corm propagation decreased in low temperature and thereupon it caused strongly corm with high leaf dry weight produced (Molina *et al*., 2004; Yanez and Ohkava, 2005).

Leaf length: Leaf length significantly increased by increasing planting depth (Table 1, 4). This increasing was reacted to strong corms that exist in ambient temperature. Molina *et al*. (2004) reported that temperature is important factor for flowering and vegetative growth in saffron and in deeper planting produced sturdy corm. The results showed that temperature control treatments had a significant influenced on saffron leaf length (p>0.01) and maximum leaf length was obtained in mulching (Table 1, 4) because of lower temperature. Soil temperature decreased by mulching and it caused shoots growth (Molina *et al*., 2004). The interaction of temperature control and planting depth treatments was significant on leaf length. Maximum leaf length was obtained at 20 cm planting depth-mulching interaction (Table 4).

Flower number: Flower number was affected by planting depth significantly (p>0.01). Maximum flower number per m^2 was obtained at 15 cm planting depth (Table 1, 4). Small corm flowering ability in shallow planting was no desirable (Sud *et al*., 1999). In summer temperature control treatments, mulching significantly increased flower number (Table 4). Soil temperature fluctuation controlled in mulching and it caused decreased soil temperature and reduced corm respiration, there by flowering ability was increased by increasing corm food resource (Han *et al*., 1991). Maximum and minimum flower number was

Table 6: Effect of planting depth-summer temperatures control interaction on saffron shoot characteristics (per h or m^2)

	Planting depth (cm)								
	10			15			20		
Traits	Check	Mulching	Irrigation	Check	Mulching	Irrigation	Check	Mulching	Irrigation
Leaf No.	151a	115b	156a	99bc	102bc	101bc	95bc	88c	97c
Leaf d.wt. (g)	6.1	7.6	6.6	6.2	9	6.8	6.8	8.5	6.9
Leaf length (cm)	23	28	30	27	32	28	26	35	30
Stigma length (cm)	3.25	3.37	2.87	3.5	3.87	3.37	4	4.25	4
Flower No. (m^{-2})	12cd	12cd	10d	13c	19a	17b	12cd	15b	11cd

Row means followed by the same letter are not significantly different at 0.05 or 0.01 probability level

obtained in 15 cm planting depth-mulching and 10 cm planting depth-irrigation interaction, respectively (Table 6). The results indicated that 15 cm planting depth and mulching interaction are best conditions for saffron flowering.

Stigma length: Results showed that stigma length significantly increased by increasing planting depth and temperature control treatments ($p>0.01$) (Table 1). Maximum stigma length was obtained at 20 cm planting depth-mulching interaction, but this increasing was not signification (Table 6).

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