Compare the effect of horizontal and vertical culture system on growth and yield of saffron (*Crocus sativus* L.)

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Abstract:

This experiment was conducted at at Research Field of Tarbiat Modares Universityin Tahran. The growth and productivity of saffron were compared under the horizontal and vertical cultivation. Land area intended for the vertical culture was a similar area of each plot in the horizontal culture. The experiment was analyzed as an unbalanced completely randomized design. The results of the first growth year showed that the time and period of germination and flowering in horizontal and vertical culture was similar. The number of flowers, flower and stigma dry weight in the vertical planting system was significantly higher than the horizontal culture. In contrast, the numbers and dry weight of the mother and girl corms in the horizontal system was significantly greater than the vertical system. Dry weight of leaf and root, and the total number of buds and leaves were significantly greater in the horizontal culture. The results of the second growth year showed that germination in vertical culture was later than horizontal culture and vertical planting corms were not able to flowering. The number of leaves, number of buds and number of the girl corms in the horizontal culture was significantly greater than the vertical culture.

Keywords: saffron, horizontal culture, vertical culture, corm, dry weight.

Introduction:

Saffron(Crocus sativus L.) is a perennial, subtropical and psychrophilic plant (Behnia, 1991). This plant mainly is expanding in Mediterranean and West Asia areas and Iran arid areas that have a cold winter and warm summer (MoayediShahraki *et al*., 2010). Saffron is one of the important species, because its dried red stigma is the most expensive spicein the world with numerous applications in medicine and foodindustries (Abdullaev, 2002; Fernandez, 2006; Akhondzadeh-Basti *et al*., 2007). Saffron as the most expensive agricultural and pharmaceutical product in the world (Koochaki *et al*., 2011) has the therapeutic properties such a soothing and the anti-cancer and anti-inflammatory effect (Tavakkol-Afshari *et al*., 2008). Cultivation of saffron as the most important pharmaceutical and spicy plant in Iran (Javadzadeh, 2011) is conducted mainly in arid and semi-arid areas of country (such as Khorasan and Kerman)(Sepaskhah, 2009).

It has been anticipated that in the near future because of the problems caused by global population growth and climate changes, arable lands will be limited.This has caused that the construction design of large farms that are built as the tower is considered. This type of farms is said so-called, vertical farms. The optimal use of space, especially in areas with the sufficient light intensity causes to increase further yield and profitability of farmers in this cultivation system

.Many objectives such as sustainability of the planting products, creating new job opportunities, saving in resources and increasing yield and income are earned by using the vertical farms strategy.Decreasing the existing stresses in the natural ecosystem and producing more products with high quality and without the use of pesticides and herbicides in a small space are including the advantages of vertical cultivation (Morgan, 2002). The verticalcultivation is appropriate for commercial production of plants such as strawberry with low leaf surface area and canopy(Despommier, 2009).The planting density can be tripled in the vertical system compared with the horizontal system; it results in increase the yield per square meter (Morgan, 2006). The research results that were conducted by De Villiers (2008) on the yield, properties of growth and quality of strawberry, showed that the highest yield was obtained in the vertical systems but fruits quality was slightly better in the horizontal system.The number of fruits and leaves and fresh weight of leaf per plant were higher in the conventional system compared with vertical systems. However, two horizontal and vertical cultivation systems of strawberry with the same density were compared with each other in Perez (2004)'s experiment. The results showed that the vertical cultivation had far lower yield than the horizontal cultivation that its cause was no reaching the enough light to plants in lower parts of the column.

Although, two horizontal and vertical cultivation systems have been studied about some plants but this hasn't been about the saffron. Thus, the aim of this experiment was to compare the morphological changes, growth and yield of saffron in vertical cultivation system than the horizontal cultivation.

Materials and methods

This experiment was conducted at the Agricultural Faculty Research Farm of Tehran Tarbiat Modarres University located in 16 km of Tehran-Karaj autobahn. Before saffron horizontal cultivation, operations of preparing land including initial plowing and disc were conducted in October and after land clearing, three plots with dimensions of 1.5 m × 1.5 m were created. 7 rows existed per plot with distance of 20 cm from each other. A cube was made in eight sides for the vertical cultivation (Figure 1). The area of each cube side was 1.5 m × 1.5 m. The intended land area for the vertical cultivation was similar to area of each plot in the horizontal cultivation with this difference that earth upper space was also used for production. For conducting this cultivation, cloth bags were used in each side of this cube. For each side, 8 rows with distance of 20 cm and 8 bags in each row were placed (density in the vertical cultivation was 3 times of the horizontal cultivation density in the same area). Bags were filled with a soil from surface soil of the farm earth and livestock manure. Each 4 sides of the cube were considered as a replicate to specify traits such as the number of flower per unit of area, the dry weight of flower and stigma and their data were collected together. For the other traits, each side of the cube was considered as a replicate to being calculated average of the measured data. The planting was conducted in October 23 and by using the corms of 4 to 6 grams. Corms were sterilized by 5% copper sulfate Fungicide before planting for 3 minutes and were cultured at a depth of 10 cm with 10-cm interval. Irrigation was conducted as trickle.

First irrigation was conducted as heavy immediately after planting and second irrigation was carried out one week after planting as light with aim to facilitate exit of saffron flower buds and leaf from soil and then by the end of the growing season due to the rainfall condition based on plant need, the irrigation was conducted. Crust breaking operations and weeding were conducted manually during the growing season. Weed was much greater in the horizontal than vertical cultivation.

Figure(1): Vertical culture system of saffron

The germination and flowering were simultaneous and durations of the germination and flowering period were identical in the first year of growth in horizontal and vertical cultivation. The appeared flowers on a daily basis were collected and counted and then the dry weights of flower and stigmas were measured after drying the samples in free space by balance with precision of 0.0001 gr. The sum of the dry weight for the harvested stigma during the flowering period was recorded as saffron yield at each replicate. Time of appearing leaf also was identical for both horizontal and vertical cultivations but yellowing leaves was earlier in the vertical cultivation. During the growing season, the maximum leaf length, number of buds and leaves on corm were measured in both cultivation systems in two times (stages). With yellowing completely leaves of the vertical cultivation, the dry weights of leaf and the main and secondary corms and its numbers on corm in two horizontal and vertical cultivation systems after drying the samples in an oven at 70 °C for 24 hours were measured. Therefore, the dry weights of root and the main and secondary corms and number of the secondary corms of two cultivation systems were also measured in May month. Measuring light was conducted by a solarymeter photometer device (watts per square meter) in vertical cultivation. In the second year of growth, the germination and emergence of leaf was later in vertical cultivation in comparison with horizontal cultivation and the corms of vertical cultivation were not able to flower. After the end of the flowering stage in the horizontal cultivation at the end of December, the maximum leaf length, number of buds and leaves on corm were measured in two cultivation systems. Also, the dry weights of leaf and the main and secondary corms and number of secondary corms on corm were measured in two horizontal and vertical cultivation systems after drying the samples in an oven at 70 °C for 24 hours.

Statistical Analysis

Comparing between the means of two horizontal and vertical cultivation systems was conducted by using t-test in the first year of growth for traits of flowering (number of flowers per unit area, the dry weights of flower and stigma). The numbers of replicates were equal to 3 and 2 respectively, for the horizontal and vertical cultivations (each replicate including 4 sides). For morphological traits (number of buds per corm, number of leaf in the corm and the maximum length of corn leaf), the dry weight of mother and daughter corms, the number of the daughter corms and the dry weights of root and leaf in experiment was analyzed as multi-observational unbalanced completely randomized design. 3 and 8 replicates existed respectively for the horizontal and cultivation systems. 12 samplings were conducted at two stages for morphological traits in each replicate. In relation to the dry weight of the mother and daughter corms, number of the daughter

corms and the dry weights of root and leaf, number of samplings wasn't identical at replicates and varied between 4 to 6 samplings. For the morphological traits, the logarithmic conversion and for four traits of the dry weight of mother and daughter corms, number of the daughter corms and the dry weight of root, the radical conversion were conducted. For comparing eight sides of the vertical cultivation, variance analysis of the related data to the morphological traits and the measured dry weight of leaf in these sides was conducted as a split plots experiment with time in a completely randomized design block with 9 to 12 replicates. Sides of the cultivation and time (the sampling stages) were considered respectively as the main and secondary factors in this analysis. In the second year of growth for morphological traits (number of bud in corm, number of leaf in corm and the maximum leaf length of corm) in both cultivation systems and for two years of growth, the variance analysis of the related data to these traits was conducted as test of the compound analysis in a completely randomized design block with 5 and 12 samples respectively for the vertical and horizontal cultivations and the logarithmical conversion was carried out. Two cultivation system of experiment were analyzed as a multi-observational completely randomized design with 5 samples for traits' number of bud per corm, the number of leaf in corm and the maximum length of corm leaf and traits' the dry weight of mother and daughter corms, the number of daughter corms and the dry weight of leaf and the logarithmic and radical conversions were conducted, respectively.

Analysis of variance was conducted through a generalized linear model (GLM) and after ensuring the normality of residuals distribution by using SAS 9.1 software and drawing graphs by using Excel software. Means were also compared by using test of the least significant difference (LSD) and at level of five percent possibility.

Results and discussion

The yield indicators of flower in the first year

Comparing the means number of flower and the dry weights of flower and stigma showed that the number of flower and the dry weights of stigma and flower was greater per unit area in the vertical than horizontal cultivation and was approximately three times (Table 1). This can be due to more density of the vertical than horizontal cultivation system (3 times) so that there was a direct relationship between the stigma yield and density of the corm and the corm yield significantly increased with increasing the density of planting. The results of most researchers also showed that the stigma yield also increased with increasing the density of planting (Koocheki *et al.*, 2009; Tammaro, 1999).

Table (1) :Effect of culture system on mean of flower yield indexes

Culture system	Dry weight of flowers ($mg.m^{-2}$)	Dry weight of stigma ($mg.m^{-2}$)	Number of flowers ($mg.m^{-2}$)
Vertical culture	347.34 a	56 a	**10 a**
Horizontal culture	121.78 b	17.62 b	**3.26 b**
t Test	*	*	*

In each column, means with different letters are statistically significantly different. *Significant at the 5% level of probability.

The dry weight of leaf in first year

Effect of the planting system on the dry weight of leaf was significant(Table 2). The comparison of mean showed that the dry weight of leaf was higher in horizontal than vertical cultivation (Figure 2). Leaves were yellow earlier in the vertical than horizontal cultivation, therefore, will have less photosynthetic capacity. The amount of receiving light was identical for all

plants in the horizontal cultivation (611 watts per square meter) but was not identical in the vertical cultivation. The upper rows had received more light than the middle and lower rows in the vertical cultivation (Figure 3).

Table (2): Mean squares and a significant level of analysis of variance the effect of culture system on dry weight of leaf

Sources of variation	Degrees of freedom	leaf dry weight (gr)
Culture	1	**0.11***
Culture*replication (error)	9	**0.01**
Error of sample	88	**0.008**
Coefficient variation		**36.78**

**&* ns represent significant at 1% & 5% level of probability,respectively

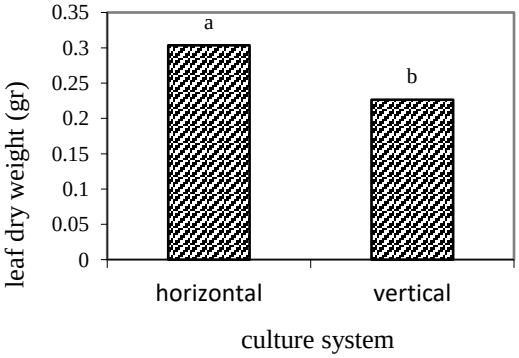

Figure (2): Effect of culture system on mean of leaf dry weight. Columns with same letters are statistically non significantly different.

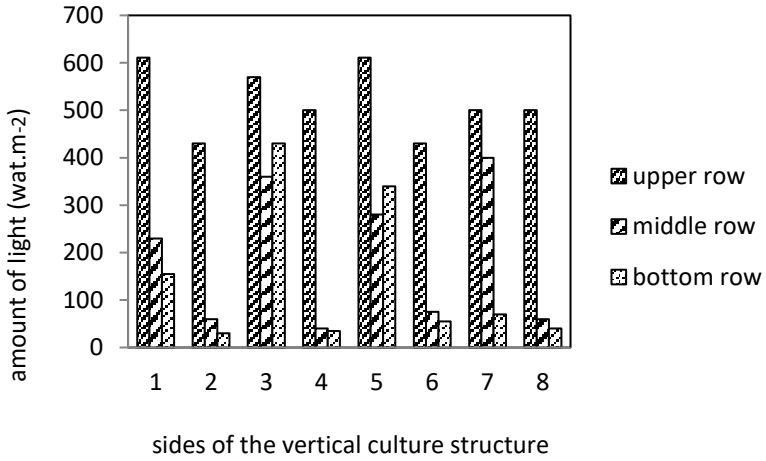

Figure (3):Amount of light received in sides and rows of vertical culture.

Morphological traits in the vertical cultivation

The results showed that the values of morphological traits were significantly different in structure sides of the vertical cultivation and different stages of sampling (Table 3). the total number of bud in corm, the total number of leaf in corm and the maximum leaf length increased respectively with the amounts of 1.16, 2.81 and 5.95 due to increasing growth at the second stage (four months after cultivation) than the first stage (two months after cultivation) (Table 4). Also, the sides effect of the vertical cultivation structure on the dry weight of leaf was significant (Table 5). The number of corm buds, the total number of corm leaf and the dry weight of leaf were more in sides of 1, 3 and 5 of the vertical cultivation. According to Figure 3, we observe that these sides have received more light. It was observed in terms of the maximum length of leaf that sides of 6 and 8 had received less light and thus, the competition increased for light and elongation of leaf became

more (Table 6). Rostami and Mohammadi reported that increasing density has caused that the saffron leaves have more elongation for more absorption of light (Rostami &Mohamadi, 2013).According to a study conducted by Takeda (2003) the amount of light that reaches the lower parts of the vertical columns of light intensity is only 10% of the upper part of the column and the resulting, inappropriate light conditions for normal growth of plants that are in the lower and middle column causes a delay in their development.

Table (3): Mean squares and a significant level of analysis of variance the morphological traits in vertical culture structure.

Sources of variation	Degrees of freedom	Maximum leaf length	Leaf number	Bud number
side	7	0.15*	0.04*	**0.04***
Side*sample(error a)	88	0.06	0.01	**0.01**
stage	1	2.51**	1.07**	**1.32****
Side*stage	7	0.01 ns	0.007 ns	**0.009 ns**
Error b	88	0.01	0.009	**0.01**
Coefficient variation(%)		10.97	11.06	**24.09**

**&* ns represent significant at 1% & 5% and non signficant at 5% level of probability, respectively

Table (4): Effect of the stage of sampling on morphological traits mean in vertical culture

stage of sampling	Maximum leaf length	Leaf number	Bud number
1	8.09 b	5.20 b	1.28 b
2	14.04 a	8.01 a	2.44 a

.In each column, means with different letters are statistically significantly different.

Table(5): Mean squares and a significant level of analysis of variance the leaf dry weight in vertical culture structure.

Sources of variation	Degrees of freedom	leaf dry weight (gr)
side	7	**0.02***
error	64	**0.009**
Coefficient variation(%)		**42.81**

* represent significant at 5% level of probability.

Table (6): Morphological traits mean in sides of vertical culture structure.

Sides of vertical culture	leaf dry weight (gr)	Maximum leaf length	Leaf number	Bud number
1	0.3 a	12.43 ab	7.54 a	**2.2 a**
2	0.18 bc	10.93 abc	5.91 b	**1.54 bc**
3	0.24 ab	10.1 bc	7.04 ab	**2 ab**
4	0.11 c	10.66 abc	6 b	**1.7 bc**
5	0.25 ab	9.95 abc	7.75 a	**2.37 a**
6	0.22 ab	13.29 a	6.08 b	**1.75 bc**
7	0.23 ab	7.91 c	6.7 ab	**1.83 abc**
8	0.2 bc	13.37 a	5.83 b	**1.5 c**

Columns with same letters are statistically non-significantly different.

The yield indicators of corm in the first year

Effect of cultivation system on the number of daughter corms and dry weight of mother and daughter corms was significant (Table 7). The comparison of means showed that the yield

indicators of corm were more in the horizontal than vertical cultivation at the first stage (after yellowing leaves of the vertical cultivation) and the second stage (after yellowing leaves of the horizontal cultivation) (Table 8). It seems that the possibility of growing and developing the daughter corms has decreased in vertical cultivation due to space constraint as well as existence of the competition for resources and unequal distribution of light. In fact, the non-proper lighting conditions for the natural growth of plants that were placed in the lower and middle parts of column, cause the delay in their growth. Plants that have received the amount of more light can conduct more photosynthesis and the obtained substances of photosynthesis will be produced with more amounts and finally transferred to tanks, thus, percentage of their dry substance increases (Seiedi et al, 2010). Benschop (1993) emphasizes on it that existence of the sufficient moisture is essential in the soil for the growth of daughter corms.

Table (7): Mean squares and a significant level of analysis of variance the effect of culture system on corm yield traits.

Degrees of freedom	Daughter corm dry weight(gr)	Daughter corm number	Mother corm dry weight(gr)	Sources of variation
1	0.26**	3.33**	3.96**	**culture**
9	0.003	0.34	0.02	**Culture*replication (error a)**
1	0.01 ns	0.51*	0.51**	**stage**
1	0.01 ns	0.03 ns	0.54**	**Culture*stage**
9	0.006	0.06	0.006	**Culture*replication*stage(error b)**
81	0.01	0.13	0.01	**Error of sample**
	10.33	25.75	9.39	**Coefficient variation(%)**

**& ns represent significant at 1% and non signficant at 5% level of probability, respectively

Table (8): Effect of culture system on the mean of corm yield traits in first and second stage.

Culture stage	Daughter corm dry weight(gr)	Daughter corm number	Mother corm dry weight(gr)
Stage 1			
Horizontal culture	0.36 a	2.4 a	**0.88 a**
Vertical culture	0.03 b	0.93 b	**0.2 b**
Stage 2			
Horizontal culture	0.21 a	1.66 a	**1.87 a**
Vertical culture	0.02 b	0.59 b	**0.21 b**

Columns with same letters are statistically non significantly different.

The dry weight of root in the first year

The dry weight of root was significantly affected by the cultivation system (Table 9). The dry weight of root was better in the horizontal cultivation compared with the vertical cultivation where soil moisture is depleted rapidly due to space limitation (Figure 4).Benschop (1993) emphasizes on it that existence of the sufficient moisture is essential in the soil for the development of root.

Table (9): Mean squares and a significant level of analysis of variance the effect of culture system on root dry weight.

Sources of variation	Degrees of freedom	root dry weight(gr)
culture	1	**0.04****
Culture*replication (error)	9	**0.0001**

Error of sample	33	**0.0001**
Coefficient variation(%)		**1.1**

** represent significant at 1%

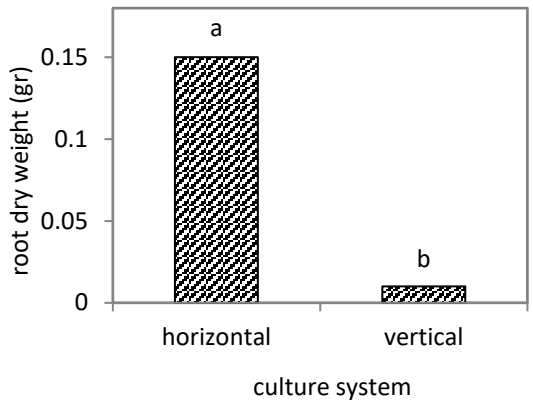

Figure (4): Effect of culture system on mean of root dry weight. Columns with same letters are statistically non significantly different.

The results for the second year of growth

In the second year of growth, percentages of the germination were in the horizontal and vertical cultivations, respectively, 13.79 and 84.30%. The germination occurred later in vertical than horizontal cultivation. The vertical cultivation corms weren't able to flowering but flowering took place in the horizontal cultivation. The number of less buds was removed from the soil in the summer and due to more heat in the vertical than horizontal cultivation and the rest didn't achieved the emergence stage and exit of the soil.

The results of affecting two temperatures of 23 and 33 °C on the enzyme activity in the terminal bud and saffron corm from July to October in an experiment showed that the temperature of 33 °C in the environment of cultivation causes to continue asleep in saffron corms by creating interference in the enzymatic activity and in contrast, the enzymatic activity concurrent with beginning growth of root, the terminal bud and leaf in saffron corms increases in 23 °C (Nasirian*et al*, 2014).

Morphological traits in the horizontal and vertical cultivation in the first and second year of growth

Analysis of variance shows the year of growth has a significant effect on the number of buds per corm, the total number of leaves and the maximum length of corm leaf. Interaction of the growth year had a significant effect on the number of bud per corm and the total number of leaf in the cultivation system but wasn't significant for the maximum length of leaf. Thus, the analysis of variance for two years should be separated for the number of bud per corm and the total number of leaf (Table 10). The number of bud, the total number of leaf and the maximum length of leaf were more in the second year of growth compared with the first year (Table 11).

Table(10): Mean squares and significance in the combined analysis of the effects of culture system and growth year on morphological traits

Sources of variation	Degrees of freedom	Maximum leaf length	Leaf number	Bud number
Year	1	0.50*	1.18**	**4.73****
replication*year	14	0.07	0.06	**0.03**
Culture	1	0.50 ns	1.88**	**0.90****
Culture*year	1	0.18 ns	1.69**	**0.91****

Culture*replication*year (error)	4	0.07	0.01	**0.02**
Error of sample	130	0.02	0.01	**0.01**
Coefficient variation(%)		15.03	14.19	**23.16**

**&* ns represent significant at 1% & 5% and non signficant at 5% level of probability, respectively

Table (11): Effect of culture year on mean of morphological traits in two years .

year	Maximum leaf length	Leaf number	Bud number
1	7.71b	5.64b	1.39b
2	10.55a	12.11a	5.78a

Columns with same letters are statistically non significantly different.

The morphological traits in the first year of growth

The analysis of variance shows in the first year that the planting system and its interaction at the sampling stage have a significant effect on the number of bud in corm and the total number of leaf (Table 12). Effect of the planting systems on the number of bud and the total number of leaf at the first stage (two months after planting) was not significant(Table 13). At the second stage (four months after planting), the number of bud and the total number of leaf were more in the horizontal than vertical cultivation(Table 13). Plants compete for receiving light in the vertical cultivation and plant that can overcome on the rest, produces more foliage and Shades on other plants. Thus, the number of leaf and bud became less in comparison with horizontal cultivation.

Table (12): Mean squares and a significant level of analysis of variance the effect of culture system on morphological traits

Sources of variation	Degrees of freedom	Leaf number	Bud number
Culture	1	0.31*	**0.23***
Culture*replication (error a)	9	0.03	**0.04**
Stage	1	2.07**	**2.55****
Culture*stage	1	0.11**	**0.13****
Culture*replication*stage (error b)	9	0.006	**0.008**
Error of sample	242	0.01	**0.01**
Coefficient variation		14.22	**28.07**

**, *& ns represent significant at 1%, 5% and non-significant at 5% level of probability, respectively.

Table (13): Effect of culture system on mean of morphological traits in different stages.

	Leaf number	Bud number
Stage 1		
Horizontal culture	5.8 a	**1.38 a**
Vertical culture	5.2 a	**1.28 a**
Stage 2		
Horizontal culture	11.11 a	**3.58 a**
Vertical culture	8.01 b	**2.44 b**

In each column, means with same letters are statistically non significantly different.

Morphological traits in the second year of growth

Effect of the planting system on the number of bud and the total number of leaf was significant in the second year (Table 14). The comparison of means showed the number of bud and the total number of leaf were more in the horizontal cultivation compared with vertical cultivation (Table 15). Increasing heat led to continue asleep of the corms and thus, the number of bud and leaf decreased. The effect of different temperatures (from 9 to 30 °C) in period of the saffron asleep on

its flowering was investigated in an experiment, the number of fewer bud was formed at 30 °C and this temperature was associated with the abortion of some flowers (Molina *et al*., 2005).

Table (14): Mean squares and a significant level of analysis of variance the effect of culture system on morphological traits in second year

Sources of variation	Degrees of freedom	Leaf number	Bud number
Culture	1	4.19**	**2.01****
Culture*replication (error)	9	0.09	**0.05**
Error of sample	44	0.02	**0.02**
Coefficient variation(%)		15.62	**23.44**

** represent significant at 1%

Table (15): Effect of culture system on mean of morphological traits in second year.

Culture system	Leaf number	Bud number
Horizontal culture	23.20a	**9.13a**
Vertical culture	5.22b	**2.97b**

Columns with same letters are statistically non significantly different.

The yield indicators of corm and the dry weight of leaf in the second year of growth

Effect of the planting system on the dry weight of leaf, the number of daughter corms and the dry weight of mother and daughter corms was significant (Table 16). The comparison of means showed that the dry weight of leaf and the yield indicators of corm were higher in the horizontal than vertical cultivation (Table 17). Lower growth of leaves with its little number cause lacking the desirable use of environmental factors to produce the photosynthetic substances and for this reason, lower number of the daughter corms is produced (NassiriMahallati *et al*., 2014).

Table (16):Mean squares and a significant level of analysis of variance the effect of culture system on corm yield traits and dry weight of leaf in second year.

Sources of variation	Degrees of freedom	leaf dry weight (gr)	Daughter corm dry weight(gr)	Daughter corm number	Mother corm dry weight(gr)
Culture	1	0.25**	0.17**	3.67**	**0.22****
Culture*replication (error)	9	0.0008	0.0005	0.11	**0.004**
Error of sample	44	0.0005	0.0009	0.13	**0.001**
Coefficient variation(%)		2.21	2.97	23.19	**3.39**

**& ns represent significant at 1% and non signficant at 5% level of probability, respectively

Table (17): Effect of culture system on the mean of corm yield traits and dry weight of leaf in second year.

Culture system	leaf dry weight (gr)	Daughter corm dry weight(gr)	Daughter corm number	Mother corm dry weight(gr)
Vertical culture	0.39a	0.31a	3.20a	**0.51a**
Horizontal culture	0.05b	0.03b	1.25b	**0.18b**

In each column, means with same letters are statistically non significantly different.

Conclusion:

It seems that shading leaves and the difference of light amount between rows cause to reduce the soil temperature to more amounts and also lower the ability to produce the daughter corms in conditions of planting saffron vertically. Moreover, since existence of the sufficient moisture especially in early spring is necessary for developing the daughter corms, the soil moisture is depleted more quickly in the conditions of vertical planting due to being limited size of the planting bags and this has led to a reduction in the number of daughter corms. Also, it was observed in the first year of growth that the stigma yield linearly increased in vertical cultivation with increasing the planting density.It was observed in the second year of growth that flowering wasn't conducted in the vertical cultivation because of continuing asleep of corms and the yield indicators of corm and the morphological traits was better in the horizontal than vertical cultivation.

Recommendations

- Since our aim is to investigate the possibility of vertical cultivation with higher density to achieve the favorable economic yield.
- It is necessary to replicate the supplementary experiments of vertical cultivation and consider further density, the number and size of daughter corms, distance between the different sides in structure of the vertical cultivation and different beds of cultivation, type and shape of structure in the vertical cultivation as well as the type and size of planting bags.
- It is recommended to continue the research for the fourth season and conduct a chemical analysis of the active substances in saffron stigmas to determine the quality of saffron.

References:

Abdullaev, F.I(2002). Cancer chemopreventive and tumoricidal properties of saffron(Crocus sativus). Exp. Biol. Med. 227: 20–25.

Akhondzadeh-Basti, A.; E. Moshiri; A.A. Noorbala; A.H.Jamshidi; S.H. Abbasi; S.Akhondzadeh(2007). Comparison of petal of Crocus sativus L. and fluoxetine inthe treatment of depressed outpatients: a pilot double-blind randomized trial.Prog. Neuropsychopharmacol. Biol. Psychiatry. 31: 439–442.

Behnia, M.R(1991). Saffron Cultivation. University of Tehran Press, Iran 285 pp. (InPersian)

Benschop, M(1993). Crocus. In: De Hertogh, A., and Le Nard, M. (Eds.). The Physiology of Flower Bulbs. Elsevier Science Publishers, Amsterdam, The Netherlands. p. 257–272.

De Villiers, J.J(2008). Acomparison between yield, growth and quality factors of unshaded strawberry plants grown hydroponically in three different production systems.Thesis presented infulfilm of the Stellenbosch University,88pp.

Despommier, D (2009). The rise of vertical farms. Scientific American. 301(5): 80-87.

Fernandez, J.A(2006). Anticancer properties of saffron, Crocus sativus Linn. Adv.Phytomed. 2: 313–330.

Javadzadeh, S. M(2011). Prospects and problems for enhancing yield of saffron (*Crocus sativus* L.) in Iran International Journal of Agriculture Research Review. 1: 21–25.

Koocheki, A.; A. Siahmarguee; G. Azizi and M. Jahani(2011). The effect of high density and depth of planting on agronomic characteristic of Saffron (*Crocus sativus* L.) and corms behavior. Journal of Agroecol. 3: 36–49. (In Persian with English abstract).

Koocheki, A.; L. Tabrizi;M. Jahani;A.A. Mohammad-Abadi; and A. Mahdavi Damghani(2009). Peformance of saffron (*Crocus sativus* L.) under different planting patterns and high corm density. 3rd International Symposium on Saffron. Forthcoming Challenges in Cultivation, Research and Economics. 20-23th May, Korokos, Kozani, Greece.

MoayediShahraki, E.; M. Jami Al-Ahmadi; and M. A. Behdani(2010). Study of energy efficiency of saffron (*Crocus sativus* L.) in Southern Khorasan. Journal of Agroecol. 2: 55–62. (In Persian with English abstract).

Molina, R.V.; M.Valerro;Y. Navarro;J.L. Guardiola; and A. Garcia-Luis (2005). Temperature effects on flower formation in saffron (*Crocus sativus L.).* Jurnal of ScinceHorticulture. 103: 361-379.

Morgan, L(2006). Hydroponic strawberry production. A technical guide to the hydroponic production of strawberries. Suntec(NZ) ltd, Tokomaru, Newzealand.

Morgan, L(2002). Guide for growing hydroponic strawberries. Presentation prepared for 3rd International Hydroponic Conference in Toluca, Mexico, April 18-20.

Nasirian, F.; A. Sorooshzadeh;F. Ghanati; and H.Oraki (2007). The Effect of Root-Zone Temperature on Antioxidant Activities in Saffron corm. Saffron Agronomy and Technology. 2(2): 55-70. (In Persian with English Summary)

NassiriMahallati, M.; A. Koocheki;Z. Boroum; Z. Rezazadeh; and L. Tabrizi, L(2007). Effects of corm size and storage period on allocation of assimilates in different parts of saffron plant (*Crocus sativus* L.). Iranian Journal of Field Crops Research. 1: 155-166. (In Persian with English Summary)

Perez, D.C(2004). Effect of plant density and initial crown size on growth, development and yield in strawberry cultivars Elsanta and Bolero. Journal of Horticultural Science and Biotechnology. 79:739-746 .

Rostami, M.; and H. Mohamadi (2013). Effects of planting date and corm density on growth and yield of saffron (*Crocus sativus* L.) on climate MalayerDistrict . Journal of Agroecology. 5(1): 27-38. (In Persian)

Seiedi, A.; A.Ebadi;M. Babalar;and B.Sayidi(2010). Effect of planting density on yield and fruit quality of strawberries Selva in soilless culture vertical. Journal of Horticultural Science. 24(1): 1-6. (In Persian)

Sepaskhah, A. R.; and A.A.Kamgar-Haghighi(2009). Saffron irrigation regime. International Journal Of Plant Prod. 3: 1–16.

Takeda, F.; and S.C.Hokanson(2003). Strawberry fruit and plug plant production in the greenhouse. Acta Horticulturae. (ISHS). 626:283-285 .

Tammaro, F(1999). Saffron (*Crocus sativus* L.) in Italy. In: M. Negbi, Editor, Saffron: Crocus sativus L., Harwood Academic Publishers, Australia, pp. 53–61.

Tavakkol-Afshari, J.; A. Brook;S.H. Mousavi (2008). Study of cytotoxic and apoptogenic properties of saffron extract in human cancer cell lines. Food Chem Toxicol. 46:3443-3447.

مقارنة تأثير نظام الزراعة الأفقي والعمودي في نمو وإنتاجية الزعفران. (*Crocus sativus* L.)

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الملخص:

أجريت هذه التجربة في مزرعة جامعة (تربيت مدرس) في طهران، تم مقارنة نمو وإنتاجية الزعفران المزروع ضمن نظامي الزراعة الأفقي والعمودي. كانت مساحة الأرض المخصصة للزراعة العمودية مماثلة لمساحة القطعة التجريبية في الزراعة الأفقية. تم تحليل النتائج وفق تصميم عشوائي تام غير متوازن. أظهرت نتائج الموسم الأول أن موعد وفترة الإنبات والإزهار في الزراعة الأفقية والعمودية كان متشابهاً. فيما تفوق عدد الأزهار والوزن الجاف للأزهار, والوزن الجاف للمياسم في نظام الزراعة العمودي معنوياً مقارنة بالزراعة الأفقية. بالمقابل، أيضاً تفوق عدد الكورمات الأم والكريمات ووزنها الجاف في النظام الأفقي معنوياً على النظام العمودي. كان الوزن الجاف للأوراق والجذور وعدد البراعم والأوراق أعلى معنوياً في الزراعة الأفقية. أظهرت نتائج الموسم الثاني أن الإنبات في الزراعة العمودية كان متأخراً عن الزراعة الأفقية وأن كورمات الزراعة العمودية لم تكن قادرة على الإزهار. فيما تفوق عدد الأوراق وعدد البراعم وعدد الكريمات في الزراعة الأفقية معنوياً على الزراعة العمودية.

الكلمات المفتاحية: الزعفران، الزراعة الأفقية،الزراعة العمودية، كورمة، الوزن الجاف.