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Full Length Research Paper

Evaluating the possibility of saffron and chamomile mixed culture

Mohammadreza Naderi Darbaghshahi[1]*, Alireza Banitaba[2] and Babak Bahari[1]

[1]Agronomy and Plant Breeding Department, Islamic Azad University, Khorasgan (Isfahan) Branch, P.O. 81582-158, Isfahan, Iran.
[2]Agronomy and Plant Breeding Department, Islamic Azad University, Golpayegan Branch, P.O. 81582-158, Golpayegan, Iran.

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Mixed culture is a simultaneous culture of two or more plants in one farm and has many advantages which increase in yield is the most important one of them. This study was conducted to evaluate possibility of chamomile and saffron (*Crocus sativus* L.) mixed culture during 2008 to 2010 years. Three chamomile kinds (*Matricaria chamomilla, Tanacetum parthenium* and *Anthemis nobilis*) at two sowing dates (autumn and spring) were examined in a three years old saffron farm. The experimental layout was split factorial in a randomized complete block design with four replicates. Saffron and pure chamomile plots were two main plots and Factorial of two sowing dates (November 2008 -after saffron flower harvesting- as autumnal sowing date and late February 2008 as spring sowing date) and three kinds of chamomile (*M. Chamomilla*, *A. nobilis* and *T. parthenium*) were sub plots. According to the results, there was no competition between saffron and chamomile in all mixed culture treatments. Various treatments did not show significant differences in saffron yield and top treatment (saffron and autumnal *M. Chamomilla*); it produced 1.83 kg/ha saffron flower and 1354 kg/ha chamomile flower (LER = 1.69). Also, there was no significant difference between yield of chamomile in mixed culture and the yield of *M. Chamomilla* in pure chamomile cultivation. Chamomile cultivation significantly reduced soil electrical conductivity (EC). According to the results, we can announce that cultivation of all three chamomile kinds is possible in saffron farms of all similar regions of the world either immediately after flower harvesting of saffron in late November or February.

Key words: Mixed culture, saffron, chamomile, land equivalent ratio, soil electrical conductivity.

INTRODUCTION

Mixed culture is one of the most effective methods in sustainable agriculture. Intercropping systems have many advantages like better use of resources, control of weeds pests and diseases and also yield stability in different environments (Sobkowicz, 2006; Nargis et al., 2004). Following the increase in world population, destruction of agroecosystems will be continued, so, raising crop production plus protecting the environment is a necessity. Many strategies like biotechnology, plant breeding, chemical fertilizers, and pesticides have been used to increase agricultural crops yield, but these strategies have been useful only in regional scale and have provided part of our need to food. Also, some of these methods are not compatible to natural environment. Thus, food providing plus protection of natural environment must be the main goal of researchers. One

*Corresponding author. E-mail: mnaderi@khuisf.ac.ir, mnmpsvr@gmail.com. Tel: 0098-311-5230640. Fax: 0098-311-5224556.

Abbreviations: EC, Electrical conductivity; **LER,** land equivalent ratio; **SAAn,** saffron and autumnal *Anthemis nobilis*; **SAMc,** saffron and autumnal *Matricaria chamomilla*; **SATp,** saffron and autumnal *Tanacetum parthenium*; **SSAn,** saffron and spring *A. nobilis*; **SSMc,** saffron and spring *M. chamomilla*; **SSTp,** saffron and spring *T. parthenium*.

Table 1. Some of the physicochemical properties of soil site.

Soil depth (cm)	Ec (ds/m)	Acidity	Organic carbon (%)	Absorbable phosphorus (ppm)	Absorbable potassium (ppm)	Total nitrogen (%)	Soil texture
0-40	3.5	7.8	0.8	17.5	280	0.09	Silty loam

way is mixed culturing of crops because it has been seen that mixed culturing has higher yield than mono culturing. Also, land is used well in mixed culture because soil is covered better by shoot and root of plants, then, erosion of soil will be minimized (Sobkowicz, 2006). Another advantage of mixed culturing is more efficient use of soil. A mixture of various crops provides better soil coverage which causes less growth of weeds. Using legumes in mixed culture improves soil fertility (Nargis et al., 2004). Of course, maximum yield of mixed culture will be gained if needs of accompaniment plant to water and nutrients will be very close to main plant (Farhoodi et al., 2003).

Saffron is a crop that is dormant in summer and part of spring, and it does not have any vegetative organ in this time, so, culturing plants with similar needs can be a good idea for better use of field in saffron dormancy period (Farhoodi and et al., 2003), but because water need of saffron is little in this time and extra irrigation will certainly damage it, selecting crops with similar needs to water is very important (Farhoodi and et al., 2003). Chamomile is a crop with shallow root system that has many horizontal roots (Omidbeigi, 2002). This plant has a simple growth and prefers cool climates. Evaluating ecological characteristics of chamomile indicates that mixed culture of saffron and chamomile must be possible (Azizi, 2006). Although, there is no scientific and practical record for saffron and chamomile mixed culture, but because of similarities in their ecological characteristics, study of their mixed culture can be a good idea which was our reason of this study.

MATERIALS AND METHODS

Site location

The experiment was conducted from October 2008 to July 2010 at the Research Station of Islamic Azad University-Isfahan (Khorasgan) branch located in Isfahan's east (32˚ 40' N, 51˚ 48' E, 1555 m above sea level). Long time means of annual precipitation and temperature are 120 mm and 16℃, respectively. The climate is dry and very warm with dry summers (Bwhs), according to Koppen method.

Soil properties

In order to determine soil properties, soil samples were collected from 0 to 40 cm depth. Results of soil analysis are reported in Table 1.

Field experimental design

In this study, mixed culture of three chamomile kinds (*Matricaria chamomilla*, *Anthemis nobilis* and *Tanacetum parthenium*) at two sowing dates (autumn and spring) were examined in a three years old saffron farm. The experimental layout was split factorial based on a randomized complete block design with four replicates. Pure saffron and without saffron plots were main plots and factorial of two sowing dates (November 2003, after saffron flower harvesting, and late February) and three kind of chamomile (*M. chamomilla*, *T. parthenium* and *A. nobilis*) were sub plots. Every plot of saffron had five rows with 5 m length. Inter row distances were 30 cm and plants had been sown on rows with 20 cm distances. Chamomile seeds were sown between saffron rows with 1 cm depth and 5 cm distance. In "without saffron" plots, chamomile seeds were sown in rows with 30 cm inter-row distance. It is obvious that in pure saffron plots, chamomile was not sown. The method of irrigation was floating and weeds were controlled by hand.

Sampling and measurements

Samples were taken (harvested) from three middle rows of saffron plots to avoid marginal effects. The yield of saffron (dried stigma) in 2009 autumn, mean of corm numbers per area unit and size classification of corms in 2010 spring, dry weight of saffron shoot in 2010 spring, yield of chamomile's dried flower in spring 2009 were measured. Electrical conductivity of soil was measured after chamomile harvesting for pure saffron from all the mixed plots. LER was calculated from the following equation (Koocheki et al., 2009):

$$LER = \Sigma Y_i / Y_{ij} \quad (1)$$

Where Yi is the yield of every crop per unit area in mixed culture and Yij is the yield of the same crop in monoculture.

Statistical analysis

A split factorial design was used for data analysis and also saffron traits were analyzed according to completely randomized block design. Analysis of data was performed using S.A.S program and means were compared using Duncan's multiple range tests at 5% probability level. Graphs were drawn using Excel 2007.

RESULTS AND DISCUSSION

Weather condition of site

Long time means of monthly maximum temperature, monthly minimum temperature,

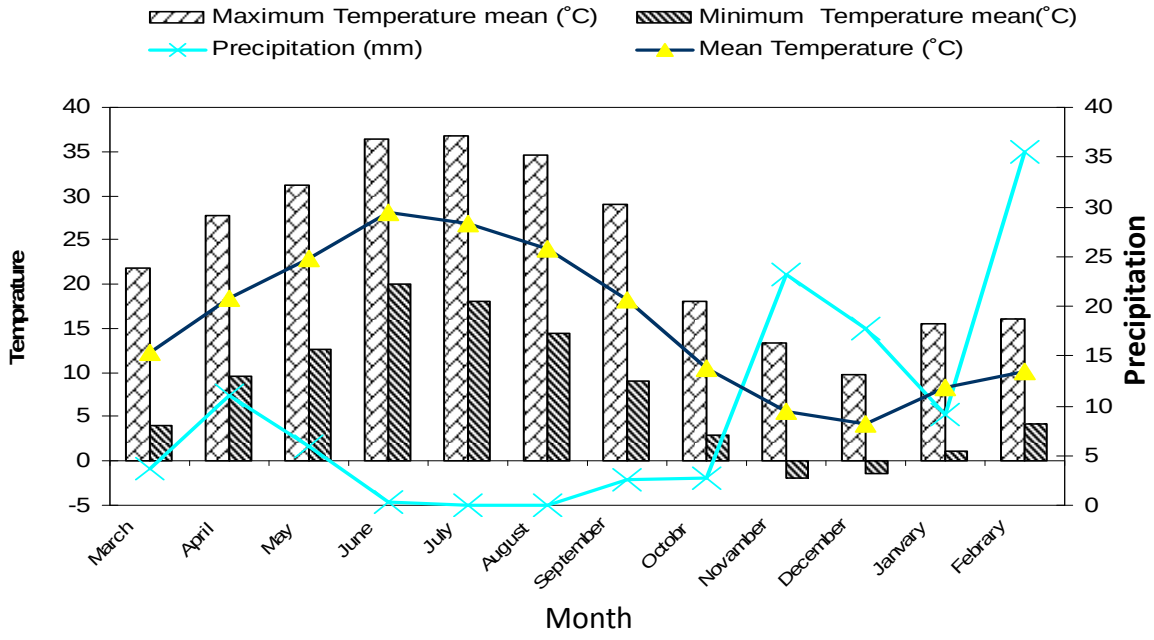

Figure 1. Long time means of some meteorological data.

monthly temperature and monthly precipitation are presented in Figure 1.

Corm numbers

There were no significant differences between corm numbers of various treatments per unit area. All treatments were located in one statistical group (Table 2) with a range from 401.7 corms per square meter in SSAn to 582.7 corms per square meter in pure saffron. Considering that corm numbers per unit area show the growth amount of saffron shoot and the rate of assimilation transferring to corms, the aforesaid result confirms that there has been no competition between chamomile and saffron plants. Koocheki et al. (2009) reported also that mixed culture of some plants with saffron did not affect saffron corms significantly, and plants which had more ecological and agronomical conformity to saffron, affected it less than the others. It seems that high ecological and agronomical conformity of all three chamomile kinds to saffron is the reason of non significant differences between corm numbers of all treatments.

Corm size

According to the results, percentage of tiny corms (smaller than 1 cm) in pure saffron and SSMc were significantly less than saffron mixed to *T. parthenium*. Also, percentage of average corms in SATp was significantly less than the other treatments except SSTp. Pure saffron with 4% large corms was the only treatment with large corms (Table 2). Apparently, decreasing in corm size was the only competitive feature of mixed culture in this study. This may be due to the fact that the presence of chamomile root around the saffron root supplies a bad condition for the growth of saffron corms. Similar results have also been presented in Unal and Cavusoglu (2005). Corm formation of saffron is one of its important traits because corm is the only source for propagation. In saffron cultivation, the quality of produced corms (that is, size and emergence capacity) is very important, as well as the number of them. Earlier studies revealed that mature bigger corms produced more flowers and daughter corms (Omidbaigi, 2005).

Total dry matter of saffron shoots

There were no significant differences between total dry matters of saffron shoots in all treatments and they were located in one statistical group with a range from 86.30 g/m^2 in SAMc to 127.90 g/m^2 in pure saffron (Table 2). On the whole, the results show that although mixed culture reduced the dry matter of saffron in both sowing dates and all of chamomile species, but this reduction was not significant. It seems that the mentioned equal corm number of treatments is the reason of non significant differences between total dry matters of all treatments.

Table 2. Results of means comparison effects of experimental treatments on saffron traits*.

Treatments	Saffron yield (kg/ha)	Saffron dry matter (g/m^2)	Corm number per m^2	Corm size (%)			LER	Soil EC (Ds/m)
				<1cm	1-3cm	>3cm		
Saffron + A.Mc	1.83^{a}	86.30^{a}	498.00^{a}	34.33^{ab}	65.67^{a}	0.01^{b}	1.69^{a}	2.06^{bc}
Saffron + A.Tp	1.16^{a}	92.77^{a}	451.00^{a}	32.67^{ab}	67.22^{a}	0.01^{b}	1.98^{a}	2.16^{bc}
Saffron + A.An	1.76^{a}	98.47^{a}	480.30^{a}	45.33^{a}	54.67^{b}	0.01^{b}	1.78^{a}	2.03^{bc}
Saffron + S.Mc	1.20^{a}	106.20^{a}	422.30^{a}	28.00^{b}	72.00^{a}	0.01^{b}	1.77^{a}	1.93^{c}
Saffron + S.Tp	1.43^{a}	82.04^{a}	401.70^{a}	35.67^{ab}	64.33^{a}	0.01^{b}	1.85^{a}	2.30^{b}
Saffron + S.An	1.76^{a}	101.40^{a}	484.00^{a}	37.67^{ab}	62.33^{ab}	0.01^{b}	1.89^{a}	2.26^{b}
Pure saffron	1.93^{a}	127.90^{a}	582.70^{a}	30.67^{b}	65.33^{a}	4.00^{a}	1.00^{b}	2.60^{a}

Means with similar letters in each column are not significantly different at the 5% level of probability according to DMRT. * A.Mc (Autumnal *Matricaria chamomilla*), A.Tp (autumnal *Tanacetum parthenium*), A.An (autumnal *Anthemis nobilis*), S.Mc (spring *Matricaria chamomilla*), S.Tp (spring *Tanacetum parthenium*) and S.An (spring *Anthemis nobilis*).

Saffron yield

There was no significant difference between saffron yield of mixed culture treatments (with a range from 1.16 kg/ha in SAAn to 1.83 kg/ha in SAMc) with pure saffron treatment (1.93 kg/ha) (Table 2). This results show that the existence of chamomile plants beside saffron plants did not have any bad effect on growth of saffron and dry matter accumulation in corms. Also, extra moisture of soil (due to additional irrigations for chamomile) did not make any trouble to corms in summer, because if additional irrigations of mix treatments had bad effects on corms, rottenness of corms would reduce next year's yield of saffron, certainly. Results of previous studies about mixed culture of saffron and other plants (Banitaba, 2008; Koocheki et al., 2009) shows that similar needs (agronomical and ecological) of companion plant will reduce bad effects of these plants on saffron yield. It seems that similar ecological and agronomical needs is the reason why chamomile did not show any bad effect on saffron in both sowing dates of all the three kinds. Chamomile plants have only a primary growth and are in rosette stage when saffron has great need to water, light and nutrients in winter. So, there is no light competition and also competition for water and nutrients is little. On the other hand, from late March that chamomile starts to grow quickly, growth of saffron is slow and about ending, and there is no noteworthy competition between them.

The lack of growth interference and competition was more obvious in late February sowing that chamomile growth started from late April. Also, considering that ripening stage of chamomile was from June 1st to July 1st depends on species and sowing date and it needed watering in that time while growth period of saffron was heading to end; it seems that water need interference in mentioned period did not have any considerable negative effect on saffron's yield. This interference was less in autumnal sowing and specifically for *M. Chamomilla* that matured early and was harvestable in late May, but it was more obvious in late February sowing and specifically for *T. parthenium* which matured late in proportion to two other species. In general, the reason of no significant difference between two sowing dates and also between three kinds of chamomile is probably that earlier competitive effect of chamomile in autumnal sowing and interference effect of longer irrigation in spring sowing acted against each other and counteracted the negative effects of one another.

Chamomile yield

There was no significant difference between means of chamomile yield in pure chamomile treatment and mixed culture treatment (617 and 603 kg/ha, respectively) and they were located in one statistical group but chamomile yield in autumnal sowing (821 kg/ha) was significantly higher than spring sowing (399 kg/ha) (Table 3). Mean comparison of sowing date and chamomile kinds of interaction showed that in autumnal sowing, *M. Chamomilla* significantly ranked higher than the other two kinds but it did not have any superiority in spring sowing date where *M. Chamomilla* and *A. nobilis* had similar yields (Figure 2).

Land equivalent ratio (LER)

All treatments had significantly higher

Table 3. Means comparison effect of experimental treatments on chamomile yield.

Treatment	Yield (kg/ha)
Cultivation method	
Chamomile + saffron	603.00[a]
Pure chamomile	617.00[a]
Sowing date	
Autumnal	821.00[a]
Spring	399.00[b]
Kind chamomile	
M.c	1027.00[a]
T.p	473.00[b]
A.n	329.00[b]

Means with similar letters in each column are not significant difference at the 5% level of probability according to DMRT.

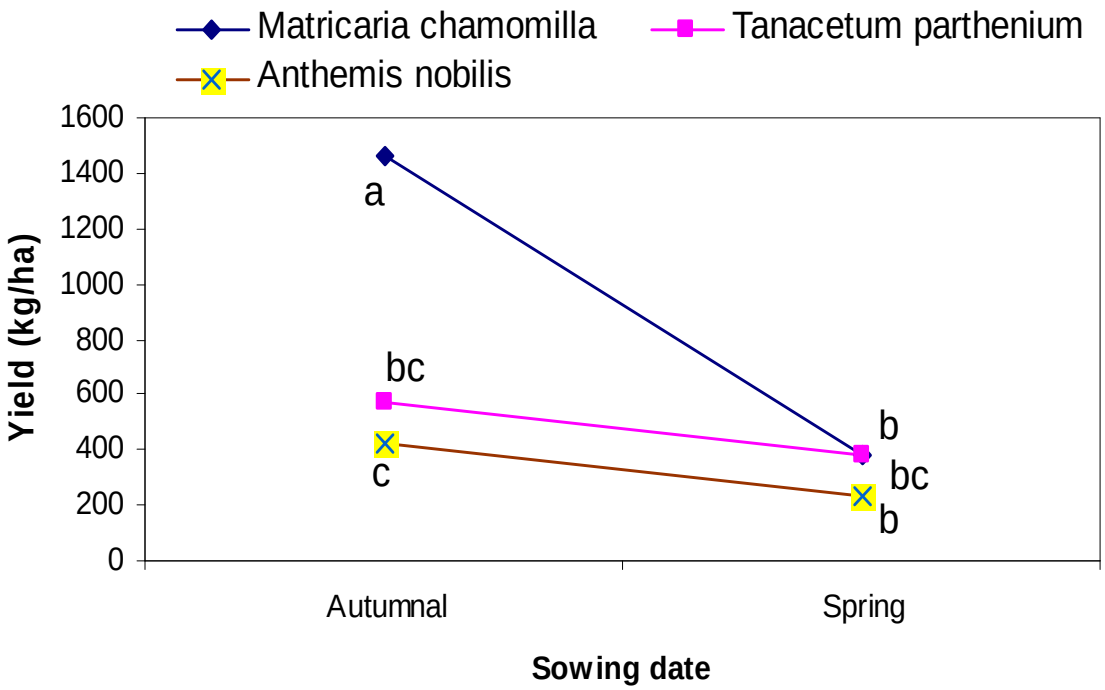

Figure 2. Interaction effects of sowing date and chamomile type on chamomile yield.

LER than pure saffron and SAAn had the greatest one (1.95). Also, all the mixed culture treatments had LER more than 1 without any significant difference (Table 2). Considering that all the mixed treatments had LER more than 1 in this study, it seems that mixed culture of saffron and chamomile has had better use of soil and the other agricultural inputs. Banitabaa et al. (2009), Farhoodi et al. (2003), Kaafi (2002) and Koocheki et al. (2009) reported similar results.

Soil electrical conductivity (EC)

According to the results (Table 2), cultivation of all chamomile kinds in both sowing dates significantly decreased EC in proportion to pure saffron and SSMc had the least EC (1.93 ds/m). It seems that chamomile has been absorbing a great deal of soil's salts (Salamon, 1994) and decreased EC which is a good feature of chamomile and saffron mixed culture and considering

relative sensitivity of saffron to salinity (Ait-aubahou and Ei-otmani, 1999), can play a useful role in saffron sowing in saline soils.

Conclusion

According to the results of this study, our hypothesis (possibility of chamomile sowing in saffron farm) is proven and we can surely announce that cultivation of all the three chamomile kinds is possible in saffron farms of all similar regions, either immediately after flower harvesting of saffron in late November or February. This can be a great revolution in saffron farmers' economy.

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