Iran Agricultural Research (2015) **34**(**1**) 46-55

Shiraz University

The effect of 10-year continuous saffron cultivation on physical and chemical properties of soil

M. Khozaei*[1], A. A. Kamgarhaghighi[1], A. Sepaskhah[1], N. A. Karimian[2]

[1] Department of Water Engineering, College of Agriculture, Shiraz University, Shiraz, I. R. Iran
[2] Department of Soil Science, College of Agriculture, Shiraz University, Shiraz, I. R. Iran

* Corresponding Author: khozaei61@yahoo.com.

ARTICLE INFO

***Article history*:**

Received **3 October 2012**
Accepted **4 February 2013**
Available online **29 June 2015**

***Keywords*:**

Basin and furrow irrigation
Potential evapotranspiration
Undesirable change in soil

ABSTRACT- The effect of 10-year continuous saffron cultivation on physical and chemical properties of a silty clay loam soil was investigated in a research farm of College of Agriculture, Shiraz University, Shiraz (52 º 33′ E Longitude and 29º 36′ N latitude), Iran. This farm was irrigated with different regimes (100% of saffron's potential evapotranspiration (ETp), 75%ETp, 50%ETp) including rain fed treatment under two irrigation methods (basin and furrow irrigation). The results showed that the values of electrical conductivity, sodium adsorption ratio, Arsenic, Boron and soil bulk density of soil in the root zone increased significantly, but the final infiltration rate decreased significantly compared to the original soil. The value of pH in 100%ETp and 75%ETp treatments decreased and in 50%ETp and rain fed treatments increased compared to the original soil. Corms under high irrigation treatment had more weight up to a 6-year cultivation. However, after that, the corm weight declined to levels equal to or less than the low irrigation treatment cases. The number of total corms increased up to 6 years of cultivation and decreased after that. So, the continuous saffron cultivation causes some undesirable change in soil chemical and physical properties, which become pronounced after 6 years of cultivation.

INTRODUCTION

Saffron (*Crocus sativus L.*), is the most expensive spice widely used for its aroma and coloring properties (Rangahau, 2003). It has been used as a sedative and analgesic drug in traditional medicinal preparations (Riffaldi et al., 1994). Recently, it has been shown that saffron has distinct anti-cancer activities (Nair et al., 1991). Saffron is grown in several countries including France, India, Iran, Italy, Spain and Pakistan. In Iran, saffron is grown in the eastern part of the country, primarily in Razavi Khorasan, and Southern Khorasan, provinces. This plant is reproduced by corm. Corms are 3 to 5 cm in diameter and each corm produces 6 to 9 leaves. Saffron plant dormancy occurs in summer and it flowers in autumn. Flowering period is 20 to 30 days. After flowering, saffron's green leaves appear. Saffron is a semi- tropical plant and is adapted to a mild winter and hot dry summer. Saffron is resistant to the cold climate and prefers fertile land with loamy soil texture and a pH level between 7 and 8 (Sampathu et al., 1984). Saffron is irrigated only during the winter months; therefore, it does not compete with other crops for water when they usually need irrigation during the summer. By continuous saffron cultivation, saffron yield is decreased and usually the field is not used again for saffron cultivation. This phenomenon is called allelopathy that is an issue which requires additional research. In this case, change in soil physical and chemical properties should be investigated. Many scientists investigated the effects of different crops on physical and chemical properties of soil. For example, Chalak Haghighi (2002) considered the effect of Lentiformis cultivation on soil properties in two regions of Fars province in Iran (Chalak Haghighi, 2002). The results showed that cultivation of this plant increased potassium, phosphorus, nitrogen, and organic matter of soil and also increased soil fertility. Bowman et al. studied the salt meadow in Fort Collins, USA, and the results showed that the vegetation density was related to soil physical characteristics (Bowman et al., 1985). Biswas et al. (1957) studied the physical, chemical and morphological properties on cultivable and non-cultivable saffron's soil (Biswas et al., 1957). Results showed that the amount of calcium carbonate of the soil that was under saffron cultivation was lower and the values of manganese and copper in cultivable soil surface layer were higher than the same layer of non cultivable soil. Qarai and Beigi (1995) reported that the probable reason for the soil becoming unsuitable after a period of saffron cultivation can be a change in physicochemical and biochemical properties of soil or the major change in the population of microorganisms of soil (Qarai and Beigi, 1995). Azizi Zohan and Sepaskhah (2002) stated that the unsuccessful saffron cultivation after one cultivation period can be due to allelopathic effects or accumulation of special salts in the root zone (Azizi Zohan and Sepaskhah, 2002). Jalali stated that after one period of cultivation, saffron cannot be cultivated in the same soil for several years (Jalali, 1962). The objective of the present study was to investigate the effect of 10-year continuous saffron cultivation under different irrigation treatments on physical and chemical properties (bulk density, water infiltration rates, electrical conductivity (EC), acidity (pH), sodium absorption ratio (SAR), concentration of carbonate, bicarbonate, Arsenic and Boron) of a silty clay loam soil. Also, the change in weight and number of saffron corms under different irrigation treatments at 10-year saffron cultivation was investigated.

MATERIALS AND METHODS

Study Area

Fars province is located in the southern part of I. R. Iran, at 50º 30′ to 55 º 38′ E Longitude and 27º 30′ to 31 º 42′ N latitude, with an arable land area of 1.32 million km^2 (Fig. 1). The Zagros mountain range, with a north-west to south-east direction, extends towards the central parts of the province. Elevations in the north are higher than 3900 m above MSL, but in the southern region generally elevations are usually lower than 500m above MSL. Shiraz is located in the central part of Fars province at 52 º 33′ E Longitude and 29º 36′ N latitude. Shiraz has arid and semi-arid climate, the average annual rainfall of which is about 380 mm and its mean annual temperature is 18 ºC.

This study was conducted for 2 years, which followed the 9th and 10th years of saffron cultivation at Badjgah Agricultural Experiment Station, College of Agriculture, Shiraz University (I. R. of Iran). Badjgah is located at 16 km north of Shiraz at 52 º 46′ longitude, 29 º 50′ latitude, elevation is 1810 m above MSL and mean annual rainfall is approximately 420 mm. This region is semi-arid and the mean air temperature for the months January to December is shown in Table 1.

The soil texture is silty clay loam. Some of the chemical and physical properties of uncultivated soil are shown in Table 2. The total area of the experimental field was 768 m^2 consisting of 24 m^2 plots.

Fig. 1. Study site location

Table 1. The mean air temperatures in Badjgah

Month	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Mean temperature (°C)	3.4	3.5	6.9	10.7	15.7	20.3	23.8	23.8	20.5	15.4	10.2	5.9

Table 2. Some chemical and physical properties of uncultivated soil

EC (dS/m)	pH	Organic Matter	CO_3^{2-} (mg kg^{-1})	HCO_3^- (mg kg^{-1})	Phosphate (mg kg^{-1})	AS (mg kg^{-1})	B (mg kg^-)	B (-gr cm^3)	F.C	PWP
0.5	8	1.9(%)	0	4.2	0.239	8	0.576	1.34	0.39	0.135

Two irrigation methods (basin and furrow irrigation), under different amounts of irrigation water (100% of saffron's potential evapotranspiration (ETp), 75% ETp, 50% ETp and rain fed), with random experimental design blocks in a factorial experiment with four replications were used. Fig. 2 shows the schematic diagram of the experimental field. Basin and furrow irrigation methods were shown with A1 and A2, respectively. Different amounts of irrigation water including 100% ETp, 75% ETp, 50% ETp and rain fed were shown with B1, B2, B3 and B4, respectively.

Saffron corms were planted in late October and early November 2000 by using 3.8 gr corms at a rate of 4.8 t ha^{-1}. The cultivation depth was 15 to 20 cm. In two years of study (2008 and 2009), growing period started at late October and ended at early May. Animal manure was added to each plot at the rate of 22.5 t ha^{-1} .The animal manure contained approximately75% moisture, 28% organic carbon, 12% ash (DW), 5.9 pH, 0.78% Ca, 0.5% K, 1.3% P, 0.4% Mg, 32 ppm Cu, 340 ppm Fe and1 ppm As.

A2B4	A1B3
A2B3	A1B1
A2B2	A1B2
A2B3	A1B4
A2B4	A2B1
A1B1	A1B3
A2B3	A1B3
A1B4	A2B1
A2B2	A2B4
A1B2	A1B1
A1B2	A2B1
A1B4	A2B3
A1B1	A2B4
A2B2	A1B3

Fig. 2. Schematic diagram of the experimental field

First irrigation was applied on 12 October followed by additional irrigations at 24 days intervals. Some chemical properties of irrigation water are shown in Table 3.

Determination of the weight and number of saffron corms

Previous studies measured the weight and number of saffron corms under different irrigation treatments for the 1 to 8 years cultivation and the 9^{th} and 10^{th} years measurements were made in this study. The weight of corms was measured by digital balance; then, they were divided into the weight groups of less than 4gr, between 4gr and 8gr and more than 8gr and the number of corms in each group were determined.

Soil sampling and analyses

In July 2008 and 2009, two different soil depths (0-30 and 30-60 cm) were sampled from all plots and also from non-cultivated soil around the experimental plots as a control treatment. Soil samples were air-dried, and sieved through a 2-mm sieve before the analysis.

Dry bulk density

The undisturbed soil samples were taken by using a core sampler of a 150-cm^3 volume; then, dry bulk density was determined by using the core method (Blake and Hartge, 1986).

Table 3. Some chemical properties of irrigation water

C (ds m^{-1})	pH	CL (meq L^{-1})	Phosphate (mg L^{-1})	CO_3^{2-} (mg L^{-1})	HCO^{3-} (mg L^{-1})	AS(mg L^{-1})	B(mg L^{-1})
0.679	7.65	1.7	9.88	0	4.7	1.2	0.576

Dry bulk density

The undisturbed soil samples were taken by using a core sampler of a 150-cm^3 volume; then, dry bulk density was determined by using the core method (Blake and Hartge, 1986).

Soil infiltration equation

Knowledge of soil infiltration equation is essential for solving problems involving irrigation, drainage, and ground water recharge. Soil infiltration equation in basin irrigation was measured with double ring infiltrometers consisting of two concentric rings. The rate of water infiltration was measured in the inner ring while the level of water was maintained at approximately the same level in the outer ring to reduce the amount of lateral flow from the inner ring. The diameter of the inner ring was 340 mm and the outer diameter was 560 mm. The ring height was 300 mm and was driven into the ground to 50 mm depth. The water level was kept at or above 60 mm depth; the difference in height between the inner and outer rings was kept to a minimum. The rate of fall of the water level in the inner cylinder was measured at 1, 5, 10, 15, 30, 45 and 60 minutes and at 30-minute intervals thereafter. The process was stopped once a steady state infiltration rate had been achieved. The duration of each test was from 6.5 to 8.5 hours. Then, the measurement data were fitted to the Kostiakov equation (Kostiakov, 1932) for each plot in the study area which was irrigated by basin irrigation method.

The double ring infiltrometer method is not suitable for measuring infiltration in a furrow. Infiltration from a furrow occurs around the wetted perimeter, and a significant portion of the total infiltration moves laterally through the furrow sides rather than vertically downward. Recognizing this problem, Bondurant developed a blocked furrow method for measuring water intake (Bondurant, 1957). In that study, Bondurant used the blocked furrow method for determining the furrow infiltration equation (Bondurant, 1957). Then, the measurement data were fitted to the Kostiakov–Lewis equation (Kostiakov, 1932; Lewis, 1937) for each plot in the study area which was irrigated by furrow irrigation method. Kostiakov-Lewis and Kostiakov equations for furrow and basin irrigations are as follow, respectively:

$$Z1 = kt^{\alpha} + bt \quad \text{Kostiakov- Lewis equation} \quad (1)$$

$$Z2 = kt^{\alpha} \quad \text{Kostiakov equation} \quad (2)$$

Where Z1 is the infiltrated water in the unit of furrow length (cm^{-3} cm^{-1}), Z2 is the infiltration water in basin (cm^3), t is infiltration time (min), k and α are experimental coefficients and b is final infiltration rate (cm^3/cm^{-1} min^{-1}).

Soil pH and electrical conductivity (EC)

The pH was determined using a 1:5 (v/v) soil-water suspensions according to USDA method. The electrical conductivity was measured with a conductivity meter using a 1:5 (v/v) soil-water suspension (Rhoades, 1982).

Determining soil sodium absorption ratio (SAR)

The soil sodium absorption ratio (SAR) was calculated by the following equation:

$$SAR = Na^{+}/[(Ca^{++} + Mg^{++})/2]^{0.5} \quad (3)$$

Where Na^+, Ca^{++}, and Mg^{++} are the concentrations of Sodium (Na), Calcium (Ca), and Magnesium (Mg) in saturation extract of soil, meq L^{-1}.

The concentration of Na was determined by flame photometer model. The concentrations of Ca, and Mg were determined by titration with EDTA (Chapman and Pratt, 1961).

Determining soil bicarbonate

The concentration of bicarbonate was determined by titration with sulfuric acid 0.01 normal in the presence of methyl orange (Chapman and Pratt, 1961).

Determining the arsenic concentration of soil

The soil was sun dried for 4 days and dried in closed oven at 105°C for 24 hr. Then 5 ml of 65% Nitric acid was added to 0.5 g of soil samples and were placed on heating block and the temperature was raised to 70 º C. After being heated for 50 minutes at this temperature, the samples were allowed to get cool. Then, 2.2 ml of concentrated perchloric acid and 3 ml of H_2SO_4 were added and the tubes were heated again at 155°C. Heating was stopped when the dense white fumes of perchloric acid appeared. The samples were cooled and diluted to 25 ml with distilled deionized water and filtered through filter paper (Whatman, No.1). Total arsenic was determined by atomic absorption spectrophotometer (HG-AAS, PerkinElmer, Germany) by using matrix-matched standards (Welsch et al., 1990). The concentration of arsenic in saturation extract of saffron corms, animal manure and irrigation water was also determined in this research.

Determining the boron concentration of soil

The soil samples were air dried and then passed through a 100 mesh sieve. About 1 g of powdered samples of soil was taken and ignited for 40 min. About 6 g Na_2CO_3 was added and then this mixture was ignited for 40 min again. After that, the samples were cooled to room temperature and 50 ml water was added. Then, 20 ml of 4 N H_2SO_4 was added in order to complete dissolution of solid. This solution was diluted with ethanol to 100 ml and evaporated to 20 ml in a water bath. About 2 ml of buffer solution (25 g ammonium acetate, 1.5 g EDTA disodium salt, 40 ml distilled water, and 12.5 ml acetic acid) and 2 ml of azomethine-H solution (0.45 g azomethine-H in 100 ml 1% ascorbic acid) were added to 1 ml of this solution. The mixture was kept at room temperature for 40 min. The absorbance of solution was measured at 420 nm by UV/vis spectrophotometer. The quantitative determinations were obtained using calibration curve. A calibration curve was prepared using different concentrations of aqueous boron standards.

RESULTS AND DISCUSSION

Final soil infiltration rate and soil bulk density

In this study, the effect of different amounts and methods of irrigation in soil final infiltration rate (f_0) and soil bulk density were studied. As Table 4 shows, the value of f_0 in furrow irrigation was significantly less than that under basin irrigation due to more saffron corms under furrow irrigation and; therefore, more soil compaction in this treatment. In both methods of irrigation, the value of f_0 in 100%ETp treatment showed a sharp decrease. Soil bulk density in furrow irrigation was higher than that under basin irrigation and significantly increased by increasing irrigation water. Similarly, Ranjan et al. analyzed the results of an 8-year experiment on a silty clay loam soil to determine the influence of fertilizer application on some soil properties (Ranjan Bhattacharyya et al., 2007). Their results showed that steady state infiltration rate under fertilized soil was higher than under unfertilized. Celik showed that bulk density in cultivated soil was higher than that in uncultivated soil (Celik, 2005).

Table 4. The effect of different amounts and methods of irrigation on soil final infiltration rate (f_0), (cm sec^{-1}) and soil bulk density (ρb), (gr cm^{-3})

method		Irrigation amount				
		Control	Dry land	50%ETp	75%ETp	100%ETp
Furrow	f_0	0.018 c	0.017 c	c 0.015	0.012 c	0.004 d
Basin		0.040 a	0.036 a	0.03 b	0.028 b	0.012 c
Furrow	ρ_b	1.4 e	1.543 d	1.655 c	1.790 b	1.95 a
Basin		1.321f	1.422 e	1.533 d	1.692c	1.87 b

In each row and column and for each factor, values with different letter(s) are significantly different ($p<0.05$)

Fahong, et al. expressed that in furrow irrigation, the porosity of soil under wheat cultivation is higher than that in basin irrigation (Fahong et al., 2004). Therefore, the bulk density of soil in furrow irrigation is less than that in basin irrigation. However, Masri and Ryan declared that the bulk density of soil which is cultivated by Mediterranean wheat under furrow irrigation is higher than that under basin irrigation (Masri and Ryan, 2006).

Soil infiltration equation

The Kostiakov–Lewis and Kostiakov equations were used to determine the soil infiltration for different irrigation treatments in furrow and basin irrigation,

The results are shown in Table 5. The results show that the coefficient of equation (k) in both Kostiakov and Louis Kostiakov equations increased by decreasing the amount of irrigation water due to more crack in soils with low applied irrigation water and caused increased soil infiltration in such a treatment at the beginning of infiltration measurement.

Soil pH

The pH of soil was significantly lower in 100% ETp and 75% ETp treatments when compared to non-cultivated soil (Table 6). The decline in soil pH at these treatments may have been caused due to the addition of animal fertilizers that contained organic forms of N or ammonium and the resulting nitrification that released H^+ ions (Brady and Weil, 2002). At 50% ETp and dry land, the soil pH values increased significantly when compared to original soil pH. It also increased significantly with increased soil depth for both 100%ETp and 75%ETp treatments. This increase in pH was associated with increased carbonate level of soil and less weathering as soil depth increased. In this case, Riffaldi et al. showed that long term maize cultivation did not appear to have caused any adverse effect on soil pH (Riffaldi et al., 1994). Malo et al. showed that long term cultivation caused significant reductions in surface soil pH and also soil pH increased significantly with increasing soil depth (Malo et al., 2005).

Table 5. The Kostiakov and Louis Kostiakov equations for basin and furrow irrigation treatments.

Irrigation method	Irrigation amount				
	Control	Dry land	50% ETp	75% ETp	100% ETp
Basin	$Z=5.31\ t^{0.38}$	$Z=4.63\ t^{0.35}$	$Z=3.81\ t^{0.40}$	$Z=2.54\ t^{0.37}$	$Z=1.33\ t^{0.32}$
Furrow	$Z=3.36t^{0.55}+0.018t$	$Z=3.2t^{0.47}+.017t$	$Z=2.42t^{0.488}+0.015t$	$Z=2.17t^{0.69}+0.012t$	$Z=1.19t^{0.4}+0.004t$

Table 6. The effect of different soil sample depth and different amount of irrigation on chemical properties of soil

		Irrigation tretment				
Property	Depth of soil	100%ETp	75%ETp	50%ETp	Dry land	Original soil
pH	0-30 (cm)	f7.35	d7.6	a8.2	a8.35	b7.93
	30-60 (cm)	e7.5	c 7.82	a8.25	a 8.4	b7.96
EC (ds/m)	0-30 (cm)	d2.3	c2.87	b3.57	a4.73	e0.566
	30-60 (cm)	d2.36	c2.93	b3.49	a4.68	e0.56
SAR	0-30 (cm)	c3.23	c3.8	b4.88	a5.91	e1.204
	30-60 (cm)	c3.6	c3.9	b5.3	a5.51	e0.966
$HCO3^-$ ($mg\ kg^{-1}$)	0-30 (cm)	a4.8	b4.5	c4.25	d 4.0	c4.3
	30-60 (cm)	a5.1	b 4.52	c 4.3	d 4.1	c4.42

In each row and column and For each factor, values with different letter(s) are significantly different ($p<0.05$)

Electrical conductivity

The agricultural system greatly affects soil's electrical conductivity (EC) with irrigated soils having a higher EC than soils maintained as dry land (Kiriiwa et al., 1998). The water applied in irrigation system adds some electrolytes to the soil and also irrigated agriculture uses large quantities of fertilizer; therefore, they cause a major salinization (Corwin et al., 2006). The results obtained in this study indicate that the EC of cultivated soil was higher than that of original soil and by decreasing the irrigation water, the EC of soil significantly increased. The value of ECs increased with increased soil depth, but the results were not significant (Table 6).

Sodium absorption ratio

As shown in Table (6), the sodium absorption ratio of cultivated soil was significantly higher than that of non-cultivated soil (original soil) due to the use of fertilizer and because of an increase in sodium concentration of soil, which also reflects one of the main environmental impacts of irrigation in cultivated soil. However, by increasing the irrigation water which led to an increase in soil leaching, the SAR of soil decreased significantly. By increasing soil depth, the values of SAR increased although the differences were not significant. Increase in sodium concentration of soil causes undesirable effects in soil physical properties such as reduction in soil permeability, aeration, porosity, soil hydraulic conductivity (Tedeschi and Dell'aquilla, 2005) and increased runoff and erosion (Masri and Ryan, 2006).

Soil bicarbonate

The amount of HCO_3^- shows the degree of soil alkalinity. In this study, by decreasing the amount of irrigation, the bicarbonate level of soil decreased and the differences were significant. However, the values of bicarbonate increased by increasing soil depth and the differences were not significant. Biswas et al. studied the physical, chemical and morphological properties on cultivable and non-cultivable saffron soil (Biswas et al., 1957). The results showed that the amount of calcium carbonate in the soil that was under saffron cultivation was less and the value of manganese and copper in cultivated soil surface layer was more than the similar layer of non cultivated soil (Table 6).

There was no significant difference between the values of pH, EC, SAR and HCO_3^- in different irrigation methods (basin and furrow). Therefore, these values were not shown in Table 6.

Arsenic and boron

As it is shown in Table 7, the concentration of soil arsenic was about 9 mg/kg, and increased significantly by increasing the irrigation water. However, the differences between the values of arsenic by increasing soil depth were not significant. By increasing the amount of irrigation, the density of saffron corms also increased. Therefore, corms of saffron could play an important role in aggregation of arsenic contents in soil under saffron cultivation. In this study, the concentration of arsenic in saturation extract of saffron corms in the tenth year of cultivation and in animal manure and irrigation water were 1.2 microgram per gram, 0.6 and 1.2 (ppb), respectively. The concentration of AS in saturation extract of corms can verify their role in aggregation of arsenic contents in soil. The concentration of boron increased by increasing the irrigation water; however, these differences were not significant. Arsenic and boron are toxic environmental pollutants. According to previous research, long term irrigation with AS and contaminated groundwater increased its concentration in crops (Imamul Huq et al., 2003). At higher concentration levels, AS is toxic to most crops. It has been shown that AS decreased in shoot growth (Abedian and Meharg, 2002) and caused lower fruit and grain yield (Carbonel Barrachina et al., 1995; Ullah, 1998). Weiping Chen et al. also showed that after 100 years of continuous cultivation, the soil Cd content of the plow layer increased from the background level (Weiping et al., 2009). Riffaldi et al. also showed that after one year, fertilization increased the available P and soluble S contents as well as the heavy metal level, without causing toxic concentration in soil (Riffaldi et al., 1994).

Table 7. The effect of different soil sample depths and different values of irrigation on Arsenic (AS) and Boron (B) of soil (mg kg^{-1})

		Irrigation treatment				
Property	Depth of soil sample	100%ETO	75%ETO	50%ETO	Dry land	Original soil
	0-30 (cm)	a16.8	b15	c13.64	d11.85	e9.16
As	30-60 (cm)	a 17	b 15.28	c 13.73	d 11.94	e 8.83
	0-30 (cm)	a 0.995	a 1.139	a 0.961	b 0.651	b 0.576
B	30-60 (cm)	a 0.657	a 0.886	b 0.644	b 0.688	b 0.605

In each row and column and for each factor, values with different letter(s) are significantly different ($p<0.05$)

Number and weight of saffron corms at different cultivation periods

Fig. 3 and 4 show the total weight of saffron corms (heavier than 8 gr, between 4-8 gr and less than 4gr) at different cultivation periods. Production of saffron corms with weigh greater than 8 gr needs more space and soil nutrient. Furthermore, reproduction of saffron corms in different years of cultivation increases competition for growing space and attracting soil nutrient. Therefore, the number and weight of saffron corms with weight more than 8gr decreased from the first to the tenth years of cultivation. However, after 6 years of cultivation, this decrease was sharp since the adverse effect of undesirable change in soil physical and chemical properties was added to the above mentioned reasons. The number and weight of saffron corms between 4-8 gr and less than 4 gr increased up to 5 and 6 years of cultivation and after that decreased due to some undesirable change in soil physical properties.

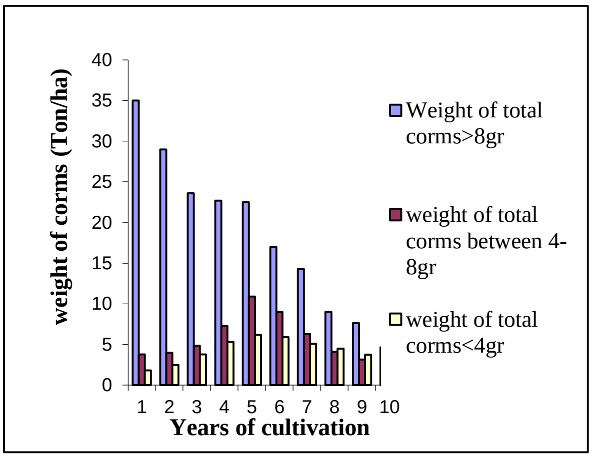

Fig. 3. Total weight of saffron corms at different cultivation periods

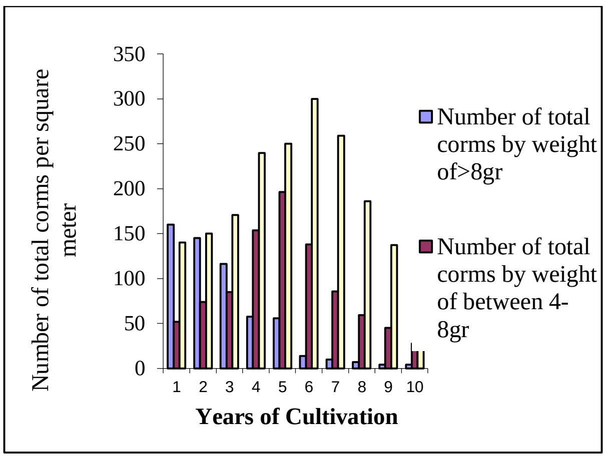

Fig. 4. Total number of saffron corms at different cultivation periods

Fig. 5 shows the relationship between weights of total corms at different years of cultivation under different irrigation treatments. As this figure shows, the weights of total corms decreased from the first to the tenth years of cultivation. Additionally, the weight of corms, under high irrigation treatment up to 6 years of cultivation, was more than that in low level of irrigation treatment and after that, it was equal to or for some cases, it was less. The weight of total corms under 100%ETp, 75%ETp, 50%ETp and dry land treatments decreased each year with averages of 7%, 5%, 6% and 11%, respectively, compared with the previous year up to 6 years of cultivation. However, after that, the weight of corms showed sharp decline (23.8%, 16.9%, 12.7% and 9.8%, respectively, for 100%ETp, 75%ETp, 50%ETp and rain fed treatments) each year compared to the previous year. Fig. 6 shows the relationship between the numbers of total corms at different years of cultivation under different irrigation treatments. The number of saffron corms under 100%ETp, 75%ETp, 50%ETp and dry land treatments increased each year with the average of 14%, 11.3%, 6.4% and 8.4%, respectively, compared with the previous year up to 6 years of cultivation. However, after that, it decreased each year with averages of 26.6%, 17.3%, 8% and 2%, respectively, compared with the previous year. These results indicate that the continuous saffron cultivation causes some undesirable change in soil chemical and physical properties. These changes, up to 6 years of cultivation, cannot play an important role in decreasing the saffron yields; however, after that these changes are significant.

Fig. 7 and 8 show the number and weight of total corms under furrow and basin irrigations, respectively. As these figures show, total number of corms under furrow irrigation is higher than that under basin irrigation; however, the weight of total corms under furrow irrigation was lower than that under basin irrigation. The results show that under furrow irrigation, the production of saffron corms is higher than that under basin irrigation; however, in furrow irrigation, the weight of saffron corms is low and these corms cannot play an important role in the flowering and production of saffron.

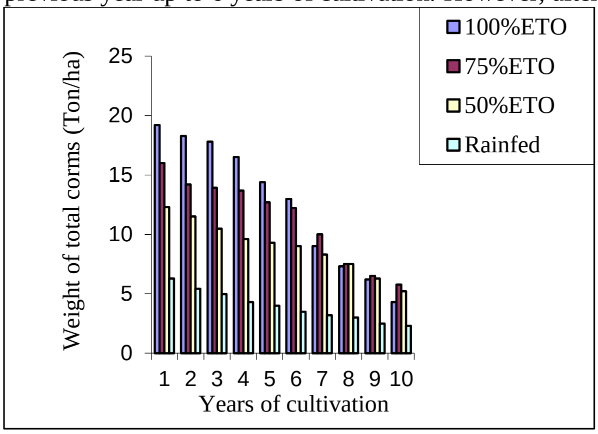

Fig. 5. Relationship between weights of total corms at different years of cultivation under different irrigation treatments

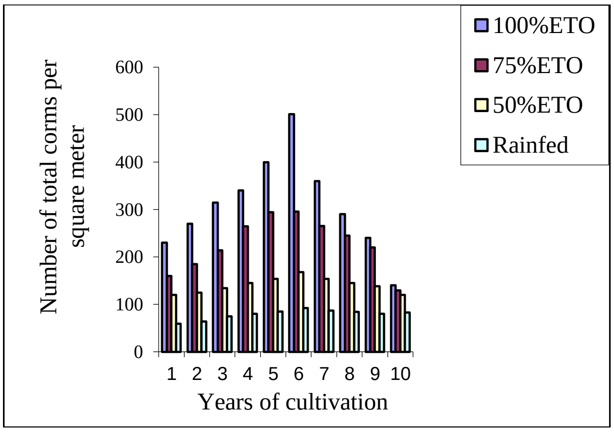

Fig. 6. Relationship between numbers of total corms at different years of cultivation under different irrigation treatments

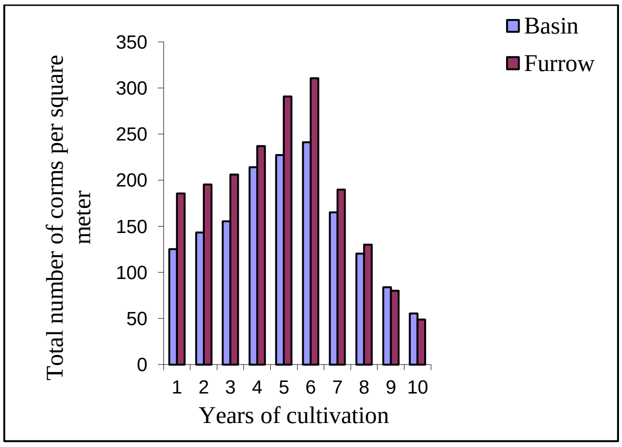

Fig. 7. Number of total corms under furrow and basin irrigations

CONCLUSIONS

The value of f_0 in furrow irrigation was less than that under basin irrigation. In both methods of irrigation, the value of f_0 in 100%ET_p treatment decreased sharply in comparison with other treatments. By increasing irrigation water, the bulk density of soil increased significantly. Soil bulk density in furrow irrigation was higher than that under basin irrigation. The pH of soil was significantly lower in 100% ETp and 75% ETp treatments when compared with non-cultivated soil. At 50% ET_p and dry treatment, the soil pH values increased significantly when compared with the original soil. The EC of cultivated soil was higher than that of the original soil and by decreasing the irrigation water, the EC of soil significantly increased. The sodium absorption ratio of cultivated soil was significantly higher than that of the non-cultivated soil. The bicarbonate in soil decreased by decreasing the amount of irrigation and the differences were significant. The values of bicarbonate increased by increasing soil depth; however, the differences were not significant.

Concentration of soil arsenic increased significantly by increasing irrigation water. By increasing irrigation, the density of saffron corms also increased. Therefore, corms of saffron could play an important role in aggregation of arsenic contents in soil under cultivation of saffron. The concentration of boron also increased by increasing the irrigation water; however, the difference was not significant. The number of saffron corms under 100%ETp, 75%ETp, 50%ETp and dry land treatments increased in each year compared with the previous year up to 6 years of cultivation; however, after that it decreased. The weight of total corms under 100%ETp, 75%ETp, 50%ETp and dry land treatments decreased in each year compared with the previous year up to 6 years of cultivation; however, after that the weight of corms showed sharp decline compared with the previous year. These results indicate that the continuous saffron cultivation causes some undesirable change in soil chemical and physical properties. These changes cannot play an important role in decreasing the saffron yields up to 6 years of cultivation; however, after that these changes are significant.

REFERENCES

Abedian, M.J., & Meharg, A.A. (2002). Relative toxicity of asenite and arsenate on germination and early seedling growth of rice (Oryza sativa L.). *Journal of Plant Nutrition and Soil Science*, 243, 57–66.

Azizi Zohan, A., & Sepaskhah, A.R. (2002). The effect of leaching on soil improving and recultivation of saffron. The article abstract at Iran Seventh Congress of Agronomy, Karaj. P. 228. (In Persian)

Biswas, N.R., Datta Raychaudhuri, S.P., & Dakshinamurthi, C.D. (1957). Soil conditions for growth of saffron at Pampore (Kashmir). *Indian Journal of Agricultural Sciences,* 27(4), 413-418.

Blake, G.R., & Hartge, K.H. (1986). Bulk density. In: Klute, A. (Ed.), Methods of Soil Analysis. Part 1. Physical and Mineralogical Methods, second ed. Agronomy Monographs, 9. ASA-SSA, Madison, WI, 363–375.

Bondurant, J.A. (1957). Developing a Furrow Infiltrometer. *Agricultural engineering,* 602-604.

Bowman, R.D., & Mc Ginnies, W.J. (1985). Soil and vegetation relationship in central plants salt grass meadow. *Journal of Range Management*, 38, 325-328.

Brady, N.C., & Weil, R.R. (2002). The Nature and Properties of Soils, 13[t]h ed. Prentic –n Hall, upper saddle River, NJ 07458.

Carbonel Barrachina, A.A., Burlo-Carbonel, F., & Mataix Beneyto, J. (1995). Arsenic uptake, distribution and accumulation in tomato plants: effect of arsenic on plant growth and yield. *Journal of Plant Nutrition,* 18, 1237–1250.

Celik, I. (2005). Land-use effects on organic matter and physical properties of soil in a southern Mediterranean highland of Turkey. *Soil and Tillage Research,* 83, 270–277.

Chalak Haghighi, S.M. (2002). Investigation of some Atriplex lentiformis cultivation effect on soil and plant cover properties in Fars. M. Sc. thesis. College of Natural Resources. Tehran University, Tehran, I. R. Iran, 200p.

Chapman, H.D., & Pratt, P.F. (1961). Methods of analysis for soil, plant and water, University of California, Division of Agricultural Sciences. Riverside, California.

Corwin, D., Lesh, S., Oster, J., & Kaffka, S. (2006). Monitoring management induced spatial-temporal changes in soil quality through soil sampling directed by apparent electrical conductivity. *Geoderma*, 131 (3–4), 369–387.

Fahong, W., Xuging, W., & Sayre, K. (2004). Comparison of conventional flood irrigated flat planting with furrow irrigated raised bed planting for winter wheat in china. *Field Crops Research*, 87, 35– 42.

Imamul Huq, S.M., Rahman, A., Sultana, S., & Naidu, R. (2003). Extent and severity of arsenic contamination in soils of Bangladesh. In: F. Ahmed, M.A., Ali, Z.A., (Eds.). Fate of arsenic in the environment. BUETUNU Int. Symp. Dhaka, Bangladesh, 69–84.

Jalali, A.K. (1962). Saffron in Kashmir. *Prajna: Banaras Hindu University Journal*, 7, 205-211.

Kiriiwa, Y., Ozawa, K., Yokota, H., Zaitsu, Y., Miyoshi, H., & Oishi, A. (1998). Effect of irrigation water quality on salt accumulation in soil and mineral contents of alfalfa in the United Arab Emirates. *Japanese Journal of Soil Science and Plant Nutrition*, 69, 348–354.

Kostiakov, A.N. (1932). on the dynamics of the coefficients of water percolation in soils and on the necessity of studying it from a dynamic point of view for purpose of amelioration." Transactions of the 6th Comm. Int. Society of Soil Science, Part A (pp. 17–21).

Lewis, M.R. (1937). The rate of infiltration of water in irrigation practice. *Trans., Am. Geophys. Union,* 18, 361–368.

Malo, D.D., Schumacher, T.E., & Doolittle, J.J.M. (2005). Long-term cultivation impacts on selected soil properties in the northern Great Plains. *Soil and Tillage Research,* 81, 277–291

Masri, Z., & Ryan, J. (2006). Soil organic matter and related physical properties in a Mediterranean wheat-based rotation trial. *Soil and TillageResearch*, 87, 146–154.

Nair, S.C., Pannikar, B., & Pannikar, K.R. (1991). Anti tumor activity of Saffron (*Crocus sativus* L.). *Cancer Letter*, 57, 109-114.

Qarai, H., & Beigi, M. (1995). The study of changes in physicochemical and mineralogical properties of soil under saffron cultivation in Estahban. Report of Research, Department of Iran Scientific and Industrial Research, Shiraz, 37 p.

Rangahau, M.K. (2003). Growing saffron-the world's most expensive spice. *Crop and Food Research*, 20, 1-4.

Ranjan Bhattacharyya, S., Chandra, R.D., Kundu, S., Srivastva, H.S., & Gupta, A.K. (2007). Long-term farmyard manure application effects on properties of a silty clay loam soil under irrigated wheat–soybean rotation. *Soil & Tillage Research*, 94, 386–396

Rhoades, J.D. (1982). Soluble salts, In: Page, A.L., Miller, R.H., Keeney, D.R. (Eds.), Methods of Soil Analysis. Part 2. Chemical and Microbiological Properties, 2nd ed. *Agronomy*, 9,167–179.

Riffaldi, R., Aviozzi, A.S., Levi Minzi, R., & Menchetti, F. (1994). Chemical characteristics of soil after 40 years of continuous maize cultivation, *Agriculture, Ecosystems and Environment*, 49(3), 239-245.

Sampathu, S.R., Shivashankar, S., & Lewis, Y.S. (1984). Saffron (*Crocus Sativus* L.) - Cultivation, processing, chemistry and standardization. *Critical Reviews in Food Science and Nutrition*, 20(2), 123-157.

Tedeschi, A., & Dell'aquilla, R. (2005). Effects of irrigation with saline waters at different concentration, on soil physical and chemical characteristics. *Agricultural water management*, 77 (1–3), 308–322.

Ullah, S.M. (1998). Arsenic contamination of groundwater and irrigated soils of Bangladesh.In: International conference on arsenic pollution of groundwater in Bangladesh: causes, effects and remedies. DCH, Dhaka, Bangladesh (pp.133).

Weiping, C., Laosheng, Wu, Andrew, C., & Chang zhenan, H. (2009). Assessing the effect of long-term crop cultivation on distribution of Cd in the root zone. *Ecological Modeling*, 220, 1836–1843.

Welsch, E.P., Crock, J.G., & Sanzolone, R. (1990). Trace-level determination of arsenic and selenium using continuous-flow hydride generation atomic absorption spectrophotometry (HG-AAS). In: Arbogast, B.F., (Ed.), Quality assurance manual for the branch of geochemistry. Open- File Rep. 90–0668. U.S. Geological Survey, Reston, VA, 38– 45.

تحقیقات کشاورزی ایران (۱۳۹۴) ۳۴(۱) ۴۶-۵۵

اثر ده سال کشت مستمر زغفران بر خصوصیات فیزیکی و شیمیایی خاک

مریم خزاعی [۱*]، علی اکبر کامگارحقیقی[۱]، علیرضا سپاسخواه[۱] و نجفعلی کریمیان[۲]

[۱] بخش مهندسی آب، دانشکده کشاورزی، دانشگاه شیراز، شیراز، ج. ا. ایران
[۲] بخش علوم خاک، دانشکده کشاورزی، دانشگاه شیراز، شیراز، ج. ا. ایران

* نویسنده مسئول

اطلاعات مقاله

تاریخچه مقاله:
تاریخ دریافت: ۱۳۹۱/۷/۱۲
تاریخ پذیرش: ۱۳۹۲/۱۱/۱۵
تاریخ دسترسی: ۱۳۹۴/۴/۸

واژه های کلیدی:
آبیاری کرتی و جویچه ای
تبخیر –تعرق پتانسیل
تغییرات نامطلوب در خاک

چکیده– اثر ده سال کشت مستمر زعفران بر خصوصیات فیزیکی و شیمیایی خاک ماسه- رسی- شنی در مزرعه تحقیقاتی دانشکده کشاورزی دانشگاه شیراز (طول جغرافیایی ۳۳ °۵۲ و عرض جغرافیایی ۳۶ °۲۹) مورد بررسی قرار گرفت. این مزرعه با رژیم های مختلف آبیاری (۱۰۰٪ ، ۷۵٪ ، ۵۰٪ تبخیر و تعرق پتانسیل زعفران) و تیمار دیم و تحت دو روش آبیاری کرتی و جویچه ای آبیاری می شد. نتایج نشان داد که مقادیر هدایت هیدرولیکی، نسبت جذبی سدیم، آرسنیک، بور و چگالی ظاهری خاک در منطقه ریشه افزایش معنی دار ولی سرعت نفوذ نهایی کاهش معنی داری در مقایسه با خاک بدون کشت داشت. میزان اسیدیته خاک در تیمار ۱۰۰٪ تبخیر و تعرق پتانسیل و ۷۵ ٪ تبخیر و تعرق پتانسیل کاهش و در تیمار ۵۰٪ تبخیر و تعرق پتانسیل و تیمار دیم در مقایسه با خاک بدون کشت افزایش یافت. پداژه ها تحت تیمار با آبیاری زیاد تا سال ششم کشت وزن بالایی داشتند در حالی که بعد از آن وزن پداژه ها به مقدار برابر یا کمتر از سطح آن در تیمار با آبیاری کم، کاهش یافتند. تعداد کل پداژه ها تا سال ششم کشت افزایش و سپس کاهش یافت. بنابراین کشت مستمر زعفران سبب تغییرات نامطلوبی در خصوصیات فیزیکی و شیمیایی خاک می گردد که بعد از سال ششم کشت خود را نشان می دهد.