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Saffron response to irrigation water salinity, cow manure and planting method

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ABSTRACT

Saffron (*Crocus sativus* L.) is the most strategic and expensive crop in the Islamic Republic of Iran. Shortage and salinity of irrigation water are two major constraints that influence saffron production in arid and semi-arid regions. The objective of the present study is to investigate the effects of irrigation water salinity, cow manure levels and different planting methods as strategies for coping with the impacts of salinity on yield and growth of saffron. Experimental design was a split–split plot arrangement in randomized complete block design with salinity levels of irrigation water as the main plot, cow manure levels as the subplot and planting method as the sub-subplot in three replications. The salinity levels consisted of 0.45 (well water, S_1), 1.0 (S_2), 2.0 (S_3), and 3.0 (S_4) dS m^{-1}. The fertilizer levels were 30 (F_1) and 60 (F_2) Mg ha^{-1} of cow manure for the first growing season and 15 and 30 Mg ha^{-1} for the second growing seasons. The planting methods were basin (P_1) and in-furrow (P_2). Saffron (stile/stigmas) yield declined by about 38% by increasing water salinity to highest level. Saffron yield in the in-furrow planting method was higher than 3.5 times that in the basin planting, which indicates that the in-furrow planting method can be recommended as a highly efficient method for saffron planting, by providing a probably appropriate soil temperature condition for corms growth. Higher cow manure application (60 Mg ha^{-1}) increased saffron yield by about 23%, due to improving soil fertility and supplying the nutrient requirements of plant. Maximum threshold EC_e for saffron yield was 1.1 dS m^{-1} that occurred under in-furrow planting method and cow manure application rate of 60 Mg ha^{-1} and saffron yield reduction coefficient was on average 40% per unit soil salinity increase. Finally, saffron can be considered as a salt-sensitive crop. High salt sensitivity of saffron could be remediated by using the in-furrow planting method and cow manure application.

1. Introduction

Increasing demand for water in the world, especially in the arid and semiarid regions, has forced farmers to use poor-quality water such as saline water for irrigation. Salinity is one of the serious environmental problems that causes osmotic stress and reduction in plant growth and crop productivity in irrigated areas (Katerji et al., 2003; Asgari et al., 2012). In the arid and semi-arid regions, the main water resource for irrigation is well water, which suffers increasing salinity and, because of limited water resources, more effective use of this resource is emphasized.

When saline water is used for irrigation, new approaches are needed that address the production sustainability. Greater attention should be given to minimize salinity in the root zone (Oster, 1994; Shalhevet, 1994; Gideon et al., 2002; Katerji et al., 2003, 2004). Several authors have indicated the need to select appropriate irrigation systems and practices that will provide sufficient water to meet the evaporative demand and minimize salt accumulation in the soil (Bresler et al., 1982; Munns, 2002). Several strategies can be used for reducing the effects of irrigation water salinity on crop yield, such as: cultivation of salinity resistant cultivars (Ahmadi and Niazi-Ardakani, 2006; Zamani et al., 2010), leaching the soil to prevent salt accumulation and changing the planting method such as cultivating plants in furrows (Dong et al., 2010; Zhang et al., 2007; Shabani et al., 2013). Furrow irrigation with saline water causes salt accumulation on ridges and decreased soil salinity in the furrows (Wadleigh and Fireman, 1949). Proper conditions for plant growth are provided with in-furrow planting method, due to higher soil moisture, reduction in evaporation from the soil surface, and higher salt leaching (Zhang et al., 2007; Li et al., 2008, 2010; Quanqi et al., 2012). Shabani et al. (2013) examined the effects of deficit irrigation with different salinity levels and planting methods (in-furrow and on-ridge), as strategies for coping with

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water and salinity stresses on yield and yield quality of rapeseed. They indicated that planting in-furrow increased yield by 5.3% and 13.7% in the first and second years, respectively, relative to on-ridge planting.

Soil amendments such as manure also can mitigate the impacts of water salinity stress on crop production. Manure improves soil conditions, such as increasing the pH in acid soils, increasing soil water-holding capacity, hydraulic conductivity and infiltration rate, and reducing soil bulk density. Manure also is a good source of plant nutrients and improves soil structure (Barbarick, 1996; Mkhabela, 2006; Mahmoodabadi et al., 2010). Ould-Ahmed et al. (2010) suggest that farmyard manure is an efficient amendment for sandy soil with saline water irrigation. However; poultry manure is not appropriate for use in conjunction with saline water irrigation, as it accentuates salinity stress.

Saffron (*Crocus sativus* L.) is a strategic export crop and the most expensive spice in the Islamic Republic of Iran. It is produced largely in the Khorasan and Fars Provinces that have arid and semi-arid climates, respectively (Abrishami, 1987). Although saffron does not contribute directly to food security, its low water requirement and high income generate interest when considering sustainable agriculture. Effects of planting methods and corm density (Behnia, 2009; Naderi-Darbaghshahi et al., 2009), chemical and organic fertilizers (Arslan et al., 2009; Omidi et al., 2009), corms weight and size (Nassiri Mahallati et al., 2007) on saffron have been investigated. Saffron is traditionally planted and irrigated by basin irrigation method in Iran. Azizi-Zohan et al. (2006) indicated that, in a semi-arid region of Fars Province of Iran, basin irrigation at intervals of 24 days was superior to furrow irrigation (planting on ridge) with more frequent irrigation intervals. Sepaskhah and Yarami (2009) examined the interaction effects of salinity and irrigation regime in a pot experiment, finding that saffron yield and corm production are most sensitive to soil water salinity and least sensitive to soil moisture depletion. At present, no research has been conducted to investigate the effect of irrigation water salinity, manure application, and planting methods on saffron under field conditions. Thus, in our study, we endeavor to examine the effects of irrigation water salinity, cow manure levels and planting methods on yield and growth of saffron (*C. sativus* L.) plant in a silty clay loam soil.

2. Materials and methods

2.1. Site description

This research was conducted during two production seasons from 2011 to 2013 at the Experimental Station of Agricultural College, Shiraz University, in Badjgah region at 29°56′N, 52°02′E and 1810 m above the mean sea level, in southwest of Iran. The climate is semi-arid, with long-term average air temperature, relative humidity, and precipitation values of 13.4 °C, 52.2% and 387 mm, respectively. The soil at the experimental site is silty clay loam up to 0.9 m depth (Table 1). Chemical analysis of the fresh and saline irrigation water is shown in Table 2.

Reference evapotranspiration (ET_o) was calculated using modified Penman–Monteith equation for semi-arid environments in the study area (Razzaghi and Sepaskhah, 2012). Meteorological data were obtained from standard weather stations at the Agricultural College, located near the experimental field.

2.2. Experimental design and treatments

We used a split–split plot arrangement in randomized complete block design with salinity levels of irrigation water as the main plot, cow manure levels as the subplot and planting method as the sup-subplot in three replications. The salinity treatments of irrigation water consisted of 0.45 (well water, S_1), 1.0 (S_2), 2.0 (S_3), and 3.0 (S_4) dS m^{-1}. The fertilizer levels were 30 (F_1) and 60 (F_2) Mg ha^{-1} of cow manure for first growing season and 15 and 30 Mg ha^{-1} for the second and third growing seasons which were applied at the beginning of each growing season. Some chemical properties of the cow manure are presented in Table 3. The planting methods were basin (P_1) and in-furrow (P_2) planting.

The first irrigation in the first growing season was done with well water for plant establishment. Subsequently, saline water treatments were applied. Saline water was obtained by addition of NaCl and $CaCl_2$ to the fresh water, in equal proportions.

In the first growing season, after deep plowing and field leveling in early September 2011, plots were constructed manually with dimensions of 1.5 × 2 m and 1.0 m distance between two adjacent plots. The cow manure levels and 100 kg ha^{-1} triple superphosphate as chemical fertilizer were added to the soil at plot construction time. Saffron corms were planted with 15 Mg ha^{-1} density on September 9 in five rows with 30 cm spacing in 15–20 cm soil depth in each plot. In the second and third growing seasons, the cow manure was added to the plots before the first irrigation.

All plots were irrigated on October 27 in the first growing season (2011) with fresh water. The amount of first irrigation water

Table 1
Physico-chemical properties of the soil at experimental site.

Characteristic	Soil depth (cm)		
	0–30	30–60	60–90
Field capacity (%)	32	33	35
Permanent wilting point (%)	17	19	19
Bulk density (g cm^{-3})	1.40	1.47	1.51
%Sand	11	10	16
%Silt	56	51	50
%Clay	33	39	34
Texture	SCL*	SCL	SCL
EC (dS m^{-1})	0.74	0.51	0.49
Cl^- (meq l^{-1})	5.31	3.05	2.90
Na^+ (meq l^{-1})	3.29	1.97	1.91
Ca^{2+} (meq l^{-1})	5.43	4.16	4.07
Mg^{2+} (meq l^{-1})	3.50	2.88	2.84

* Silty clay loam.

Table 2
Chemical analysis of the fresh and saline irrigation water used in the experiment (average of two years).

Characteristic	Fresh water	Saline water		
EC (dS m^{-1})	0.45	1.0	2.0	3.0
pH	7.31	7.24	7.12	7.00
Cl^- (meq l^{-1})	3.75	15.00	24.25	38.25
Na^+ (meq l^{-1})	0.57	5.67	11.60	18.17
Ca^{2+} (meq l^{-1})	3.00	5.40	11.80	18.20
Mg^{2+} (meq l^{-1})	2.80	2.60	3.40	3.70
HCO_3^- (meq l^{-1})	6.2	2.20	1.60	1.40
SO_4^{2-} (meq l^{-1})	0.45	0.65	0.85	1.45

Table 3
Chemical properties of the cow manure.

Characteristic	Value
EC (dS m^{-1}) in 1:5 solution	10.63
pH in 1:5 solution	8.50
Cl^- (meq l^{-1}) in 1:5 solution	72.50
Na^+ (meq l^{-1}) in 1:5 solution	20.73
Ca^{2+} (meq l^{-1}) in 1:5 solution	21.50
Mg^{2+} (meq l^{-1}) in 1:5 solution	17.50
K^+(meq l^{-1}) in 1:5 solution	79.17
Total phosphorous (%)	0.80
Total nitrogen (%)	2.10