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Assessment of nitrogen application form impacts on Saffron (Crocus sativus L.) productivity under salt stress

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ABSTRACT

Valuable locally adapted plants such as Saffron in the east of Iran need to be tested against abiotic stresses such as salinity to check the possibility of using saline water for their irrigation in harsh environments. The main aspire of this study was to weigh up the influence of various levels of salinity stress on yield and yield components of Saffron (Crocus sativus L.) under different nitrogen application forms in the semi-arid region east of Iran. Three years experiment (2006-2008) was performed using split-plot design using salinity of irrigation water as main-plot factor, and nitrogen application form as sub-plot factor in four replicates. Four levels of salt concentration included, irrigation water of 1.5 dSm−1 (as control), 3.5 dSm−1, 5.5 dSm−1 and 7.5 dSm−1 and sub-plot treatments consisted of three application forms of nitrogen encompass solid application, solid-foliar application, and foliar application were employed in this study. The results indicated that all study parameters were influenced by different salt stress concentrations. However, various application forms of nitrogen statistically affected saffron production only in 2006. There was strong correlation between corm dry weight and economic yield (R2=0.56). Highest economic yield under highest salt concentration were reached under solid application of nitrogen in 2006 (0.18 gr.m-2), 2007 (0.48 gr.m-2), and 2008 (0.29 gr.m-2). Foliar application of nitrogen showed positive effect on economic yield on lower salinity levels. Despite, foliar application showed highest biological yield under higher salinity stress levels. In conclusion, saline water up to 5.5 dSm−1 could be applied for saffron production in saline areas. Also, Foliar application of nitrogen in lower levels of salinity and solid application under higher salinity stress might be increasing saffron production in east of Iran.
KEYWORDS: Economic yield, Fertilizer, salt concentration, yield components

INTRODUCTION

Global population increasing and food demands will lead to use marginal lands and unconventional water resources for agricultural use [1]. This situation occurs in semi-arid zones that exposed to potential saline hazards[2]. Salinity has long been recognized as a major threat to agriculture worldwide including Iran, leading to policies aimed at improving irrigation and drainage practices and implementing more salt tolerant plants across these areas. In arid and semi-arid areas, where 25% of the irrigated land is currently affected by salts [3],wide range of processes such as seed germination, seedling growth and vigor, vegetative growth, flowering and fruit set are affected by high salt concentration in the soil, ultimately causing poor crop quality and diminished economic yield [4]. Moreover, the utilization of brackish water (either as drainage water or as groundwater) is thus increasing in importance [5].

The use of salt-tolerant crops is one of the solutions to problems associated with salt-affected soils or with the utilization of brackish water for irrigation[6]. However, irrigation with this low quality water during the whole growing season of the crops, even the tolerant ones, does not always produce high yield[7]. The favorable growing conditions of the semi arid regions of east of Iran contrast sharply with the scarcity of good quality water, which forces growers to use water with moderate or high saline concentrations. It is well known that salinity severely limits the ability of irrigated land to maintain high levels of productivity in east of Iran [8].

Saffron (*Crocus sativus* L.) is a sterile autumn flowering species, which propagates vegetative by means of a tuberous corm [9]. It is a perennial cash crop well adapted to arid and semi-arid lands which produce flower annually, and its stigmas separated from the flower as economical yield. It is long scarlet stigmas were highly valued for flavouring foods and for coloring them golden-yellow. The appreciation for saffron as a food additive continues today and it has become the world's highest priced spice [10]. Saffron has also been a component of

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the traditional medicine in many cultures, and this use may expand in the future as it has been demonstrated that some of its components have cytotoxic, anti-carcinogenic and anti-tumor properties [11].

Balanced fertilizer application plays a fundamental role to obtain high yield under saline conditions [12]. Nitrogen application can significantly increase the yield and improve the quality of saffron [13]. Nitrogen is an essential element for saffron growth to build up protoplasm and proteins, which induce cell division and meristematic activity, resulting consequently in more plant cells in number and size with an overall increase in bulb fresh weight and plant growth. Under sub-optimal supply of N, saffron can be severely stunted, with bulb size and marketable yields reduction. By contrast, too much nitrogen can result in excessive vegetative growth, delayed maturity, increased susceptibility to diseases, reduced dry matter contents and storability and, thus, result in reduced yield and quality of marketable flowers and bulbs. Saffron production response to nitrogen is very different in saline and non-saline conditions [14]. Owing to the fact that nitrogen absorption by saffron roots could interrupt under high salt concentration [12]. Therefore, using different forms such as liquid form may simplify nitrogen uptake by this plant.

Given the relative lack of investigation into various nitrogen application forms might influence the effects of salinity on production of saffron, this research was undertaken with the goal of studying different salinity concentration under diverse nitrogen application forms impacts on yield and yield components of saffron in east of Iran.

MATERIALS AND METHODS

1.Study location

The field experiment was carried out during three growing seasons (2006 to 2008) at the Research Farm of the College of Agriculture, Birjand University (latitude: 52°32' N, longitude: 59°12' Elevation: 1480 m) in the Southern Khorasan province of Iran. Climatic conditions of Southern Khorasan province varies between semi-dry and locally humid in the north to dry in the southern parts. Annual precipitation rate in Birjandis 169 mm. Rainfall during growth period was represented in Fig.1. The soil of the experimental field was silty loam with pH 7.9, contains total N (478 ppm), total P (13 ppm), and total K (386 ppm) with an EC of 14.3 dSm^{-1}.

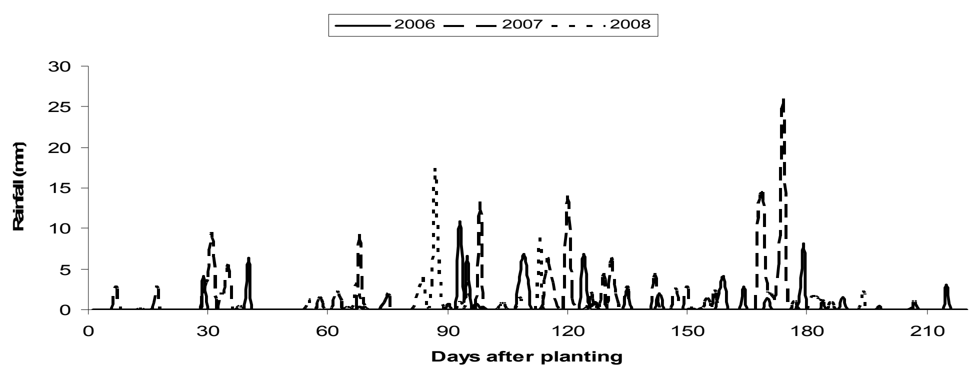


Fig 1. Daily values of rainfall (mm) of study years

2. Experimental design

The two-factor experiment was set up in a split-plot randomized complete block design with different concentration of salt in irrigated water as main-plot factor and method of nitrogen fertilizer application as sub-plot factor in four replicates for three years (2006-2008). Four levels of salt concentration included irrigated by 1.5 dSm^{-1} (as control) (S1 3.5 dSm^{-1} (S2), 5.5 dSm^{-1} (S3) and 7.5 dSm^{-1} (S4) and sub-plot treatments consisted of three methods of nitrogen application including encompass solid application (N1), solid-foliar application (N2), and liquid foliar application (n3) were employed in this study. The size of each plot was 3.0m × 2.3m.

3.Field conditions

All plots were fertilized uniformly with 20 ton/ha by rusty cow manner prior to experiment. Saffron corms were cultivated at 12th of October in 2006 and they were grown in all years of experiment. Plant harvesting was performed manually and divided to three stages, flower (economic yield) were harvesting at 7th Nov to 15th Nov, biological yield harvesting at 2nd May to 10th May and finally corm harvesting at 8th Jun to 18th Jun in all years of study. In addition, plants were irrigated 5 times by saline water during growing season as identified by evaporated pan at early October, December, January, February and March. Irrigation practice was brought the soil moisture back to field capacity. Weeds were controlled by hand when needed. We used the local ecotype of saffron which is cultivated in Birjand. Planting density was 50 plants.m^{-2} and sowing depth was 10 cm^{-1}. Fertilization treatments performed in one time at March of all study years by 50 kg/ha nitrogen which applied by irrigation water for solid application and solid-foliar treatments. Foliar application of nitrogen was done by 5000 ppm liquid nitrogen application.

4. Plant measurements

Plant measurements in this study was in different phonological and yield factors included biological and economic yield (gm^{-2}), flowering time (days after planting), flowering duration (day), corm number per m^{-2}, corm dry weight per m^{-2}, and leaf length (cm^{-1}). Biological and stigma (economic) yield were measured by collecting plants materials from 0.5 m^{-2} of each plot. Collected materials were weighted after drying in an oven at 75 °C for 72 h.

5.Statistical analysis

In order to compare the treatments impacts on study parameters, analysis of variance (ANOVA) was performed as standard procedure for split-plot randomized complete block design. The t-test was used to find significant differences among treatments. The significant differences between treatments were compared by Duncan's multiple range tests at 5% probability level.

RESULTS

1. Salt concentration

Different salt concentration in irrigated water imposed a significant impact (*P*> 0.05) on yield, yield components, flowering duration and leaf length of saffron across all years of the experiment (Table 1). Flowering duration and leaf length decreased by increasing in salt concentration across study years except 2007 (Table 1). Highest (15 day and 38 cm^{-1}) and lowest (12 day and 30 cm^{-1}) flowering duration and leaf length obtained in S2 (3.5 dSm^{-1}) and S4 (7.5 dSm^{-1}) salt concentrations (Table 1). Corm number and dry weight influenced negatively under various salt concentrations. Maximum concentration of salt showed lowest values of corm number (157 corm. m^{-2}) and corm dry weight (154 gr.m^{-2}) across all years of study (Table 1).

Table 1. Effects of different salinity concentration of irrigated water on flowering duration, corm number, and corm dry weight, and leaf length of saffron.

Salt concentration	flowering duration (day)			corm number per m^{-2}			corm dry weight per m^{-2}			leaf length (cm^{-1})		
	2006	2007	2008	2006	2007	2008	2006	2007	2008	2006	2007	2008
S1	15^{a}	12^{a}	14^{a}	213^{a}	367^{a}	391^{a}	314^{a}	534^{a}	322^{ab}	31^{ab}	37^{a}	31^{ab}
S2	15^{a}	12^{a}	13^{a}	196^{ab}	247^{ab}	392^{a}	265^{a}	412^{ab}	381^{a}	33^{a}	38^{a}	33^{a}
S3	13^{ab}	12^{a}	12^{ab}	169^{ab}	268^{ab}	269^{b}	203^{b}	352^{b}	255^{b}	29^{b}	38^{a}	29^{b}
S4	12^{b}	12^{a}	12^{ab}	157^{b}	190^{b}	244^{b}	154^{b}	334^{b}	242^{b}	30^{b}	37^{a}	30^{b}

Letters indicated different salinity concentration of irrigated water include 1.5 dSm^{-1} (as control) (S1), 3.5 dSm^{-1} (S2), 5.5 dSm^{-1} (S3) and 7.5 dSm^{-1} (S4).

There were no statistically differences among S1 (1.5 dSm^{-1}), S2 (3.5 dSm^{-1}), and S3 (5.5 dSm^{-1}) salt concentrations on corm number (Table 1). Economic and biological yield of saffron was affected by salt concentrations (Fig. 2). Utmost economic (0.76 gr.m^{-2}) and biological (164 gr.m^{-2}) yield under different salt stress intensities reached under S2 (3.5 dSm^{-1}) concentration in 2007 (Fig. 2). Economic and biological yield of saffron sharply declined by increasing salt concentration in irrigated water (Fig. 2). Generally, saffron plants produced higher economic and biological yield in 2007 in comparison with other study years.

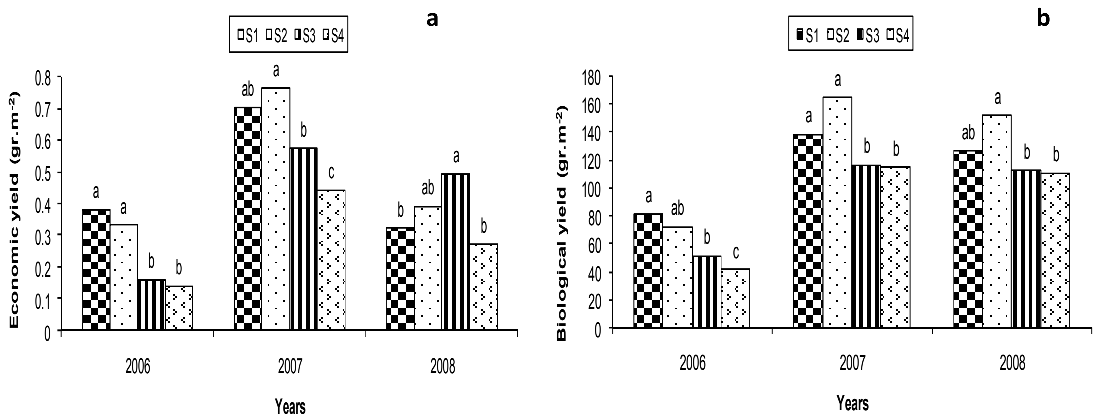


Fig2. Effect of different salt concentrations *on economic (*a) and biological (b) yield of saffron (Mean values with the same letter(s) are not statistically different (*P*=0.05)).

2.Nitrogen application method

Different nitrogen application forms did not showed significant impact on saffron yield and yield components between 2007 and 2008 (Table 2). However, nitrogen application forms indicated significant impacts (P< 0.05) on corm number, economic and biological yield in 2006. Our results illustrated highest corm number (198 corm. m^{-2}) was obtained at solid-foliar application in 2006 (Table 2). Despite, maximum values of economic and biological yield was reached under solid application of nitrogen in 2006 (Fig. 3). The lowest economic and biological yield of saffron was obtained in 2006 across all years of experiment (Fig. 2).

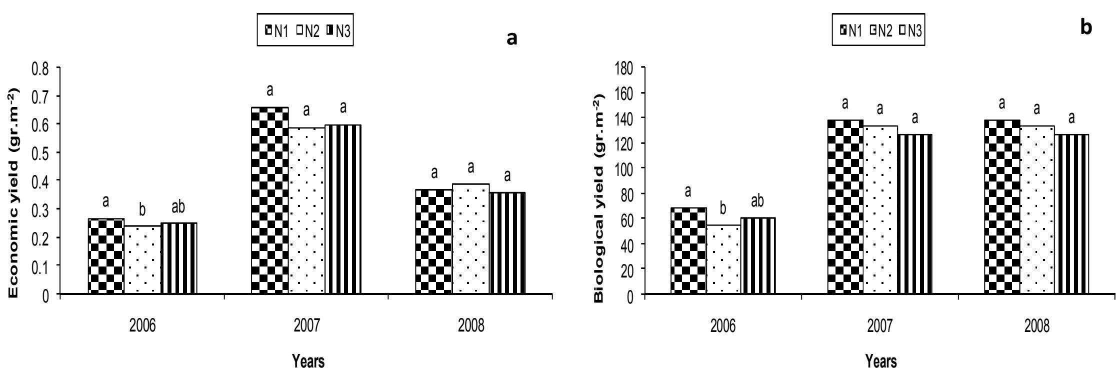


Fig 3. Effect of various nitrogen application forms on economic (a) and biological (b) yield of saffron (Mean values with the same letter(s) are not statistically different (*P*=0.05).

Table 2. Effects of various form of nitrogen application on flowering duration, corm number, corm dry weight, and leaf length of saffron

Nitrogen form	flowering duration (day)			corm number per m^{-2}			corm dry weight per m^{-2}			leaf length (cm^{-1})		
	2006	2007	2008	2006	2007	2008	2006	2007	2008	2006	2007	2008
N1	14^{a}	12^{a}	13^{a}	166^{b}	258^{a}	326^{a}	235^{a}	411^{a}	286^{a}	32^{a}	39^{a}	32^{a}
N2	14^{a}	12^{a}	13^{a}	198^{a}	282^{a}	310^{a}	238^{a}	402^{a}	302^{a}	30^{a}	38^{a}	30^{a}
N3	13^{a}	12^{a}	12^{a}	186^{ab}	263^{a}	335^{a}	229^{a}	412^{a}	313^{a}	30^{a}	36^{b}	30^{a}

Letters indicated various form of nitrogen application include solid application (N1), solid-foliar application (N2), and foliar application (N3)

3.Interactive effects of salt concentrations and nitrogen application forms

3.1. Corm number and dry weight

Saffron production is directly influenced by corms size at the time of sowing [15]. Production number and dry weight of daughter corms was also harshly declined by increasing of salt concentration under different forms of nitrogen application in all years of study (Table 3). Number of corm produced increased year by year from 2006 onward. Maximum corm number in highest salt concentration (S4) was obtained in foliar application of nitrogen (180 corm.m^{-2}) in 2006 and solid application in 2007 (237 corm.m^{-2}) and 2008 (273 corm.m^{-2}) (Table 3). In addition, changing the application of nitrogen form solid application to solid-foliar application showed the highest interaction of the two treatments on corm number at high salt concentrations (S3 and S4) (Table 3).

Table 3. Interactive effects of different salinity concentration of irrigation water and various form of nitrogen application on corm number and corm dry weight in 2006 to 2008

Salt concentration	corm number per m^{-2}			Ratio		corm dry weight per m^{-2}			Ratio	
	N1	N2	N3	N2/N1	N3/N1	N1	N2	N3	N2/N1	N3/N1
2006										
S1	174	249	216	1.4	1.2	309	344	299	1.1	0.9
S2	171	226	189	1.3	1.1	246	271	278	1.1	1.1
S3	159	150	162	0.94	1.0	209	170	230	0.8	1.1
S4	162	165	180	1.0	1.1	152	175	134	1.1	0.8
2007										
S1	423	279	399	0.6	0.9	536	485	582	0.9	1.0
S2	162	357	222	2.2	1.3	367	453	416	1.2	1.1
S3	210	306	288	1.4	1.3	334	300	423	0.8	1.2
S4	237	189	144	0.7	0.6	409	368	226	0.8	0.5
2008										
S1	450	273	450	0.6	1.0	343	239	383	0.6	1.1
S2	384	423	369	1.1	0.9	372	420	353	1.1	0.9
S3	246	273	288	1.1	1.1	243	258	265	1.0	1.0
S4	273	255	234	0.8	0.8	186	291	246	1.5	1.3

Letters indicated different salinity concentration of irrigated water include 1.5 dsm^{-1} (as control) (S1), 3.5 dsm^{-1} (S2), 5.5 dsm^{-1} (S3) and 7.5 dsm^{-1} (S4) and various form of nitrogen application include solid application (N1), solid-foliar application (N2), and foliar application (N3)

Different nitrogen application methods showed significant influenced corm dry weight especially under higher levels of salt stress (S3 and S4) (Table 3). Utmost corm dry weight in peak salt concentration (S4) was achieved in solid-foliar application of nitrogen in 2006 (175 gr.m^{-2}) and 2008 (291 gr.m^{-2}) solid application in 2007 (409 gr.m^{-2}) (Table 3).

3.2.Economic and biological yield

On the whole, economic and biological yield significantly reduced through growing of saffron under salt concentration in irrigated water and under various application form of nitrogen in this experiment (Table 4). Highest values of economic yield of saffron in highest salt concentration (S4) were gained under solid application of nitrogen in 2006 (0.18 gr.m^{-2}), 2007 (0.48 gr.m^{-2}), and 2008 (0.29 gr.m^{-2}) (Table 4). Furthermore, shifting the application of nitrogen form solid-foliar application to foliar application showed the uppermost interaction of the two treatments on economic yield in high salt concentrations (S3 and S4) (Table 4).

Biological yield of saffron was influenced sharply by various nitrogen applications under salt stress (Table 4). Maximum Biological yield of saffron in climax salt concentration (S4) was reached in foliar application of nitrogen in 2006 (47 gr.m^{-2}), 2007 (126 gr.m^{-2}) and 2008 (106 gr.m^{-2}) (Table 4). Highest increase in biological yield (30%) obtained by using solid-foliar application of nitrogen under 5.5 dSm^{-1} (S3) salt concentration in irrigated water in 2008 (Table 4).

Table 4. Interactive effects of different salinity concentration of irrigation water and various form of nitrogen application on economic and biological yield of saffron in 2006 to 2008

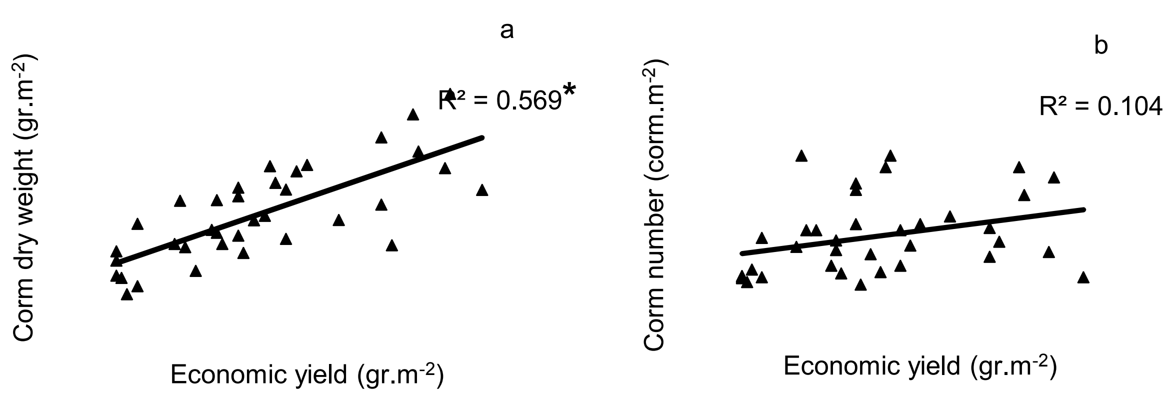
Salt concentration	Economic yield (gr.m^{-2})			Ratio		Biological yield (gr.m^{-2})			Ratio	
	N1	N2	N3	N2/N1	N3/N1	N1	N2	N3	N2/N1	N3/N1
2006										
S1	0.42	0.33	0.40	0.7	0.9	86	67	91	0.7	1.0
S2	0.34	0.33	0.32	0.9	0.9	87	73	57	0.8	0.6
S3	0.14	0.15	0.14	1.0	1.0	57	46	51	0.8	0.8
S4	0.18	0.14	0.16	0.7	0.8	45	32	47	0.7	1.0
2007										
S1	0.70	0.64	0.77	0.9	1.1	137	134	144	0.9	1.0
S2	0.83	0.71	0.76	0.8	0.9	179	163	151	0.9	0.8
S3	0.64	0.56	0.50	0.8	0.7	116	141	89	1.2	0.7
S4	0.48	0.46	0.38	0.9	0.7	118	99	126	0.8	1.0
2008										
S1	0.26	0.27	0.44	1.0	1.6	117	114	124	0.9	1.0
S2	0.37	0.43	0.37	1.1	1.0	159	143	131	0.9	0.8
S3	0.66	0.46	0.37	0.6	0.5	96	121	69	1.3	0.7
S4	0.29	0.18	0.25	0.6	0.8	98	79	106	0.8	1.0

Letters indicated different salinity concentration of irrigated water include 1.5 dSm^{-1} (as control) (S1), 3.5 dSm^{-1} (S2), 5.5 dSm^{-1} (S3) and 7.5 dSm^{-1} (S4) and various form of nitrogen application include solid application (N1), solid-foliar application (N2), and foliar application (N3)

DISCUSSION

Study results showed that altering the application form of nitrogen have potential to change and recover yield and yield components of saffron under different levels of salt stress. Saffron production response to applied treatments was different across study years. Highest and lowest yield of saffron was obtained in 2007 and 2006, respectively. Moreover, there was sharply difference between rainfall amounts in between study years (Fig. 1). It seems that, higher rainfall in 2007 (190 mm) in comparison with rainfall in 2006 (86 mm) was main reason of yield differences in study years (Fig. 1). The potential risk of salt stress significantly decline by increasing of rainfall during growth period [16]. Flowering duration of saffron was declined by increase in salt stress intensity (Table 1). However, decrease in flowering duration was not significant except 2006. [4]proved that total available water played vital role in determination of flowering duration of saffron under salt stress conditions. Another reason for lower yield in 2006 is because of establishing of saffron in the first year, in this year a month after sowing saffron plants started to flowering and there might not be enough assimilates for producing big flowers [14].

There was a significant correlation between corm dry weight and economic yield of saffron (Fig. 4a) but correlation between corm number and economic yield is obviously poor (Fig. 4b). Foliar application of nitrogen showed higher corm dry weight under lower salinity levels but maximum values of corm dry weight was obtained in solid nitrogen application under higher salt levels in irrigation water.



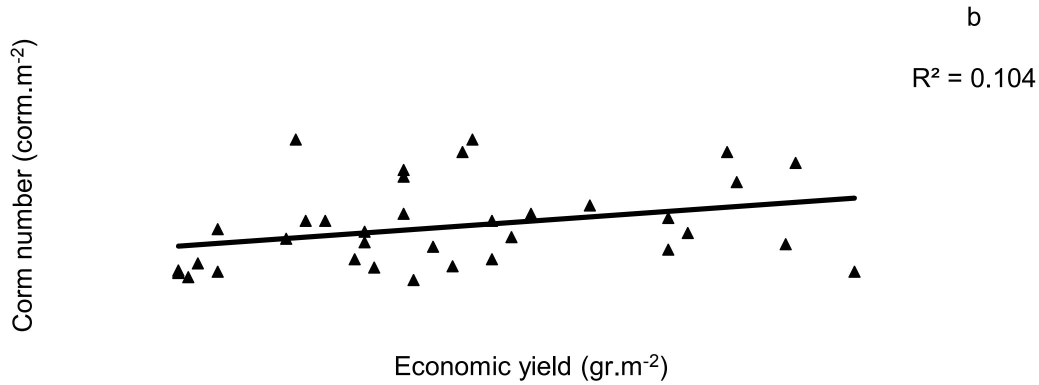


Fig 4. Relationship between economic yield and corm dry weight (a) and corm number (b).
(*Significant at 5% level).

Rising of salt concentration generally declined the economic and biological yield of saffron in all years of this experiment, but in saline areas with shortage of fresh water for irrigation, saline water up to 5.5 dSm^{-1} could be applied for saffron production if farmers apply efficient management system and accept some yield reduction [17]. Saffron economic yield response to application forms of nitrogen was depending to aboitic stress intensity[18, 17]. Foliar application of nitrogen showed positive impact on economic yield of saffron on lower salinity levels but higher economic yield values was obtained in solid nitrogen application under higher levels of salinity (Table 4). On the other hand, foliar application showed utmost biological yield unde2005r higher salinity stress levels. Increasing in salinity levels could decline carbon partitioning to vegetative parts of plant for faster accomplishment of growth period [19]. Therefore, lower vegetative growth might increase allocation of carbon to reproductive parts of plants [20]. In conclusion, according of this experiment results using by foliar application of nitrogen in lower levels of salinity and solid application under higher salinity stress might be increasing saffron yield in east of Iran.

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