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Original Article

Relationship between nutrient concentration in saffron corms and saffron yield in perennial fields of South Khorasan province

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Abstract

Saffron (*Crocus sativus* L.) is one of the most important exports products in Iran that proper concentration of nutrients is particularly important in the development and production. Since saffron is reproduced by corm, so always been considered production of replacement corms through appropriate nutrition; and concentration of element in corm in specific stage of growth and development has high correlation with plant yield. Therefore, this study was conducted to determine nutrients concentration in corm of saffron in perennial fields of Qaen and Nehbandan in South Khorasan in 2015. The information of two regions (Qaen and Nehbandan) were collected from 3, 5 and 7 years-old fields. Then, three fields with at least 500 m^2 under cultivation selected for each age of 3, 5 and 7 years fields and 3 plots from each field and one corm sample from each plot were selected. The concentration of phosphorus (P), potassium (K), nitrogen (N) and iron in corm of saffron were analyzed based on standard laboratory methods. Results revealed that there were significant differences in N, P, K and iron concentrations of saffron corm ($P \leq 0.01$), but the effects were distinct for corm number in different weight groups. The present study showed that in saffron fields, N, P, K and iron concentration in corm were the most effective parameters for saffron yield increment, which regression correlations showed yield increment compeer to the change in these indices. Investigation of nutrients concentration of the corm on saffron yield shows the important role of such elements in yield. Therefore, nutrient concentration in saffron corms affect the plant nutrition, promoting growth and yield of crop. Generally, corm selection with optimum weight for sowing and proper use of nutrients, especially nitrogen, phosphorus, potassium and iron, as well as their correct balance in soil, can be effective in yield increment and stability of soil fertility.

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Introduction

Saffron (*Crocus sativus* L.) belongs to Iridaceae family, which is xerophyte, herbaceous and perennial (Husaini and Ashraf, 2010; Gresta et al., 2009). In Iran, saffron is being noteworthy in various aspects such as high water efficiency, creating jobs and non-oil export extension (Hosseini et al., 2004). Saffron is male sterile and its reproduction is performed through the corm (Kafi et al., 2002). Due to reproduction of saffron is only possible through corm propagation, it is necessary to increase the production of this plant in

order to expand its cultivation. Today, in addition to the production of flowers and dry matter yield of saffron, special attention is paid to the production of saffron corms. It has been proven in different studies that the use of big, healthy and strong corms can increase the saffron yield (Kafi et al., 2002; Hassanzadeh Aval et al., 2013). Therefore, most of the physical and nutritional characteristics of corms (such as size and nutrient concentration) are evaluated as a benchmark.
Plant nourishment with nitrogen is important in terms of both quantity and quality of the product (Shen et al., 1994). Nitrogen (N) plays a key role in crop productivity. Indeed, N is involved in the functioning of meristem tic tissues, in photosynthesis, and in the determination of the protein content of harvested organs (Bertheloot et al., 2008).
Because of phosphorus importance role in vegetative growth and flower induction in saffron (Chaji et al., 2013; Naghdi Badi et al., 2011), the more phosphorus that a plant takes up, the more stability will be achieved during saffron perennial life cycle. In general, it can be said that suitable nourishment of saffron in the first year produce daughter corms, richer in phosphorous and higher reservoirs, which will act as seeds for the next year. Corm reservoirs increment will have a positive effect on yield and vegetative organs in the following year, and the phosphorus-rich corms will probably increase assimilates and production of bigger daughter corms in next years (Chaji et al., 2013). Amir Ghasemi (2001) also stated that phosphorus is involved in the completion of saffron corm reservoirs.
Potassium is one of the most important nutrients after nitrogen, which in addition of important physiological functions, has a special place in improving the quality of agricultural products that made it known as quality element (Malakoti and Homai, 2004; Marschner, 1995). Sadeghi et al. (1989) studied the effect of NPK fertilizers and manure on leaf production and the average weight of saffron corm, and concluded that the highest effect was obtained from NPK, NP and manure, respectively.
Medicinal herbs require adequate amounts of micronutrients to grow and produce extract (Leilah, 1988; Sarmadnia and Koocheki, 1992), and among micronutrients, iron is the most necessary element (Kafi et al., 2008). It was reported that iron is one of the most important micronutrient elements for plants (Ksouri et al., 2007). Micronutrient elements are essential for plant growth and development, but their application rates are lower than macronutrients such as nitrogen, phosphorus and potassium (Nateghi et al., 2015). Baghai and Maleki Farahani (2014) reported that the application of iron fertilizer has affected flower fresh weight, so that the application of 5 and 10 kg of both two iron fertilizers types, increased flower fresh weight.
According to all mentioned above, the current study was aimed to determine nutrients concentration in corm of saffron and relationship between nutrient concentration in saffron corms and saffron yield in perennial fields of South Khorasan.

Material and Methods

The study was carried out in two Nehbandan and Qaen regions and their geographical locations are presented in Table 1. This research was carried out in a factorial arrangement based on completely randomized design, with three replications in Nehbandan and Qaen regions, in 2015 in 3, 5 and 7 years old fields. The first factor was the location and the second factor was field′s age. Firstly, based on the available information, received from Agriculture Jihad Organization of Nehbandan and Qaen Province and the opinion of relevant experts and considering area under saffron cultivation and awareness about farmers' ability, 3, 5 and 7 years old fields were identified. Then, three fields with at least 500 m^2 under cultivation selected for each age of 3, 5 and 7 years fields and 3 plots from each field and one corm sample from each plot were selected. 54 corm samples were collected from two regions about 10 day after the first irrigation. In order to determine nitrogen, phosphorus, potassium and iron concentrations in saffron corms, one corm sample was randomly harvested in each plot from 0-30 cm depth and 20×20 cm^2 dimensions with saffron shoot; then transferred to Soil Laboratory of Faculty of Agriculture in University of Birjand and the corms were separated from the soil. Soil physical and chemical characteristics of the studied regions are presented in Table 2. Phosphorus concentration was determined by spectrophotometer at 660 nm wavelength, and nitrogen was determined by Kjeldahl method in saffron corms (Soil and Plant Analysis Council, 1999). Potassium concentration of corms were performed by flame photometer (Thomas, 1982). Iron concentration was determined using acid digestion method and atomic absorption (Page et al., 1982). To estimate saffron yield in studied fields, it was stipulated that 3 plots in each field, to be harvested and weighed daily. The average yield of 10 days was collected and weighed, that totally was generalized to hectare. Due to the fact that farmers in these regions have been cultivating saffron using traditional and indigenous methods, thus there is an interact in terms of agronomic and nutritional management with each other, so all 3 selected fields from each age, have almost the same management. Accordingly, the basis for selection of the fields was the uniformity of field management in each two regions. At the end, the correlation coefficients of measured factors were investigated with saffron yield. Data analysis was performed using SAS software. Means comparison was performed by LSD test at a significant level of 5%.

Results and Discussion

The ANOVA of the effect of region and fields age on the nutrients concentration in saffron corms and saffron dry matter yield are shown in Table 3. As it is obvious, there was a significant difference between three age groups of 3, 5 and 7 years old fields in terms of nutrients concentration in saffron corms and saffron dry matter yield. There was a significant difference between Nehbandan and Qaen regions in terms of nutrients concentration in saffron corms and saffron dry matter yield. Among different nutrients concentrations, only nitrogen concentration was not affected by the interaction between region and field′s age (Table 3).

Relationship between corm nitrogen concentration and dry matter yield

The study on the relationship between corm nitrogen content and dry matter yield at Nehbandan and Qaen regions in three age groups of 3, 5 and 7 years old fields showed a significant relationship. Fitting the linear regression function between saffron yield and nitrogen content in 3, 5 and 7 years fields of two studied regions showed that increasing in nitrogen percentage caused an increase in yield, while the five years old field in Qaen had the highest yield (Fig. 1).

Correlation coefficients of fitted equations also showed a significant linear relationship between nitrogen percentage and the yield. However, the slope of the yield curve in comparison to the percentage of nitrogen was higher than the rest, in five years old field in Nehbandan. Higher organic matter in five years old field of Qaen has led to nitrogen uptake via corm, resulting higher yield. Nitrogen, which is one of the most important elements which causes yield increment of saffron flowers and corms (Chaji et al., 2013), is known as a mobile element in the plant (Bertheloot et al., 2008) and can be transport during plant growth, from vegetative organs to underground parts, especially at the end of each season (Ourry et al., 1988; Masclaux-Daubresse et al., 2010). The increasing process of yield compared to nitrogen concentration of corm in both Nehbandan and Qaen regions shows that the five year fields of these two regions illustrate better reaction to nitrogen concentration and would obtain higher yield by corm nitrogen increasing. The yield response to low nitrogen content in five years old fields of Nehbandan and Qaen was more than those of three and seven; therefore, these fields had higher yields at lower nitrogen concentrations. Nitrogen is an essential and fundamental element for crops. Thus, nitrogen compounds affect dry matter yield, which has a direct relationship with photosynthesis and nitrogen uptake, and increasing of these compounds will increase total nitrogen in plants. One of the important requirements in agronomic planning is the evaluation of various plant nutrition systems in order to achieve higher yield and desirable quality, especially in case of medicinal herbs (Rezaenejad and Afyuni, 2001; Balkcom and Monks, 2007). The organic matter presence in Nehbandan and Qaen regions which was available due to manure addition to the soils of these fields by farmers has led to nitrogen uptake via plant corm, resulting yield increase, which is consistent with the results of Brussard (1997). He reported that organic matter addition into the soil increases soil nutrient content including nitrogen and its absorbance ability by crop, increasing nitrogen balance and the efficiency of phosphorus uptake.

Relationship between corm phosphorus concentration and dry matter yield

The relationship between phosphorus percentage of saffron corms in Nehbandan and Qaen fields with dry matter yield in three age groups of 3, 5 and 7 years old indicates that increase in corm phosphorus percentage increased yield (Fig. 2). Correlation coefficients of explained equations for all years indicate a significant relationship between them. In the five years fields of Qaen, phosphorus concentration of corm was higher than other field′s ages, of course had the highest yield. This can be attributed to the geographical location and soil fertility of Qaen region, which higher elevation and colder climate has led to soil fertility. Also, the lowest soil pH was found in Qaen's five year fields, which increased phosphorus uptake and availability. In a study by Mohammady-Aria et al., (2010) in association with soil pH and phosphorus solubility in laboratory conditions, it was reported that soil pH changes had a negative and significant correlation with soluble phosphorus, that soil pH decreasing, will increases the amount of absorbable phosphorus in the soil and thus the plant will be able to absorb more phosphorus from the soil.

Coefficients of fitted equations for fields with different ages in Nehbandan and Qaen regions indicate that X coefficient of the equation (fitted line slope) in Qaen five year fields is greater than that of Nehbandan five year fields. In other ages of fields, the three year fields of Nehbandan have given the highest X coefficient. Among the nutrients, phosphorus plays a special role in reproductive phase of crops (White and Veneklaas, 2012) and in addition of saffron yield improvement, it can affect the growth of daughters' corms in saffron (Naghdi Badi et al., 2011). The balanced nutrients availability based on proper fertilizers management, is one of the most effective factors in sustainability of saffron production, especially in arid and semi-arid regions (Amiri, 2008; Koocheki et al., 2009), so that, up to 80% of flower yield changes in saffron are affected by variables that govern the soil especially, the amount of organic matter (Nehvi et al., 2010). The organic matter presence in Nehbandan and Qaen regions due to manure addition to the soils of these fields by farmers has led to phosphorus uptake by saffron corm, resulting yield increase, which is consistent with the results of Koocheki et al. (2014). They found that organic fertilizers application and mother corms sowing with more than 8 gr weighing could have play more effective role in yield improving and also phosphorus uptake of saffron per unit area. According to the results of this experiment, it seems that more phosphorus uptake by daughter corms is one of the reasons for higher production of saffron daughter corms as a result of organic fertilizers application.

Relationship between corm potassium concentration and dry matter yield

Studying the relationship between potassium of saffron corm and dry matter yield in 3, 5 and 7 year fields (Figure 3) shows a positive linear relationship between corm potassium content and yield. The explanation coefficients were significant for all years ($P\leq0.01$). The fitted correlation evaluation between corm potassium concentration and saffron yield indicates that corm potassium concentration is lower in three and seven year fields compared to five year fields. Considering the greater curve slope in the five year fields of Qaen, it is concluded that due to higher potassium concentrations in the five year fields of Qaen, dry matter yield of saffron was more than the rest. This is probably due to higher soluble potassium content of soil in Qaen's five year fields, which has resulted in more potassium uptake by saffron corm in the county. Potassium is one of the essential elements for plant growth, and if not be sufficient in the soil, plant growth will greatly decrease, resulting yield reduction. The results of this study are consistent with the findings of Zabihi and Feizi (2014). Considering the multiyear saffron cultivation of saffron, they examined the effect of one time potassium application at sowing in a 4 year period. The results showed that there is a little need for potassium in saffron cultivation, but providing such a low amount of potassium can have a considerable and significant effect on saffron yield and should not neglect potassium fertilizer application in the nutrition management of saffron. Organic matter presence in Nehbandan and Qaen regions which was available due to manure addition to the soils of these fields by farmers, has led to potassium uptake via plant corm, resulting yield increase. Some studies (Munshi, 1994; Shahande and Mousavi, 1988; Negbi, 1999) have shown that there is a positive and high correlation between soil organic matter and saffron yield. Increasing yield by organic matter application is probably caused by nutrients supply, especially phosphorus, potassium, nitrogen, and the improvement of soil physical properties. Improving soil structure or increasing cation exchange capacity of the soil reduces potassium, calcium and magnesium leaching, which has a positive effect on saffron yield.

Relationship between corm iron concentration and dry matter yield

The relationship between iron concentrations of saffron and dry matter yield of Nehbandan and Qaen regions in each groups of 3, 5 and 7 year fields, indicate that there is a positive linear relationship between corm's iron concentration and saffron yield (Fig. 4). The explanation coefficients of the equations for all years indicate a significant relationship between them. Since iron is one of the most important nutrient for plants, its deficiency leads to leaf yellowing, changing iron and other metal elements concentration in plant tissues, which are closely related to crops yield. It can be concluded that increasing of iron concentration in saffron corm resulted in dry matter yield increment. The importance of iron in plant nutrition has been emphasized considering the strategies that plants use to absorb this element under iron stress conditions (Baghai and Maleki Farahani, 2014). Micro elements are used in plants in small amounts. But they have important effects. In case of deficiency, these elements can sometimes act as a limiting factor for growth and uptake of other nutrients, and this issue makes it necessary to pay more attention to their application (Malakoti, 2000).

The relationship between yield and corm number

The ANOVA of the effect of region and fields age on saffron corms number are shown in Table 4. As it can be seen, the number of saffron corms was significantly affected by field's age. There is a significant difference between Nehbandan and Qaen regions in terms of corm number of 4-8 gr and 8-12 gr groups. Among the different groups of corm, only corm number of 8-12 gr was affected by the interaction between the region and fields age (Table 4).

The ANOVA showed that total corm number per m^2 was significantly affected by fields age (Table 4). Generally, the studied regions did not differ in total number corm number, but field's age increased total corm number per unit area. Total corm number was only significant in three year fields. The highest corm number observed in 7 and 5 year fields, respectively. Although there were no significant difference between 5 and 7 year fields, but total corm number in 7 year fields increased 2.95%. The lowest amount of corm number was allocated to three year fields, so that total corm number per m^2 decreased 60.20% compared to 5 year fields (Fig. 5). The total corm number of saffron corms in both Nehbandan and Qaen regions was not statistically significant (Table 4). Fields with 3 and 7 years age had more corm number in 2 gr and 2-4 gr groups. In these fields, corm number was high in terms of quantity, while these corms were not been recommended for cultivation (Sadeghi, 1996; Kafi et al., 2002). One of the reasons for low yielding in traditional Iranian fields is the use of small corms of old fields as seed corm (Hemmati-Kakhki and Hosseini, 2003). Comparison of the average corm number of saffron fields showed that increasing the age of the saffron fields increased the reproduction of corms and consequently the total number of corms per m^2 (Fig. 5). However, in the seventh year, the highestcorm number was produced, but small corms did not produce economical yield. Small corms due to intense competition with each other have less nutritional reserve and weak vegetative growth resulting yield reduction (Ramezani, 2000). Fields with a life span of five years because of higher number of large corm had better condition. According to other researches, corm size and density are two major factors for yield increment. In this study, saffron fields have the highest number of corms with 8-12 gr weight in fifth year, which has a significant effect on saffron yield, and practically farmers obtain highest yield in third to fifth years from their fields (Mollafilabi, 2012; Sadeghi, 2012). It is recommended that farmers choose their corms form young or three year fields for cultivation and gaining maximum yield.

Among the measured nutrients in saffron corm, dry matter yield had a significant correlation with nitrogen ($r = 0.311$), phosphorus ($r = 0.561$), potassium ($r = 0.545$) and iron ($r = 0.433$) concentrations (Table 5). It can be concluded that the increase in yield is associated with the increase in concentrations of nitrogen, phosphorus, potassium and iron in saffron corms. Proper use of nutrients especially nitrogen, phosphorus and potassium and its correct balance in the soil can be effective in yield increment and soil fertility stability (Sacco et al., 2003; Bassanino et al., 2011).

Among the different sizes of corms in this study, corms with 8-12 gr weight had a positive and significant correlation with nutrient concentrations of nitrogen, phosphorus, potassium and iron of saffron corm in both regions (Table 5). This correlation shows that the highest concentrations of nutrients are belong to 8-12 gr corms. Also, the number of corms with 8-12 gr weight, had a positive and significant correlation with saffron yield ($r = 0.690$) in both regions. Also corms with 4-8 gr weight, had a positive and significant correlation with saffron yield ($r = 0.533$). Regarding the correlation with the increase in corm number of 8-12 gr, it can be said that the increase in yield in five year fields is associated with the increase in corm number with 8-12 gr weight.

Table1: Geographical characteristics of Qaen and Nehbandan South Khorasan

Region	Longitude (E)		Latitude (N)		Altitude (m)	Total annual precipitation (mm)
	Degrees	Minutes	Degrees	Minutes		
Nehbandan	60	30	31	33	1196	128.6
	58	32	30	28		
Qaen	58	38	15	33	1440	180
	60	56	12	34		

Table 2- Physical and chemical properties of soil (0-30 cm depth)

	Field age	P (mg/kg soil)	K (mg/kg soil)	Na (meq/l)	EC_e (dS/m)	pH	SAR	O.M (%)	Sp (%)	Soil texture
Nehbandan	3	28.0	240.8	19.24	2.6	7.90	6.89	0.8	35	Sandy loam
	5	35.5	350.6	15.31	2.0	7.91	5.18	1.1	36.33	loam
	7	21.4	280.6	12.43	2.2	7.76	3.72	0.8	36.11	Sandy loam
Qaen	3	18.9	392.2	24.49	3.6	7.9	8.74	0.9	34.29	loam
	5	29.5	380.8	46.86	6.1	7.72	9.60	1.4	42.11	loam
	7	19.8	391.4	58.84	8.9	7.71	12.77	1.2	36	loam

Table 3- Variation analysis (Sum of square) of the effects of field age and region on the yield of dry matter saffron and some of nutrients concentration of saffron

Source of variation	Degree of freedom	Sum of square				
		Corm nitrogen concentration (%)	Corm phosphorus concentration (%)	Corm potassium concentration (%)	Corm iron concentration (mg Kg^{-1})	yield of dry matter saffron (Kg h^{-1})
Region	1	3.833^{**}	0.0029^{**}	0.267^{**}	382.71^{**}	11.926^{**}
Field age	2	1.290^{**}	0.0025^{**}	0.196^{**}	47.45^{**}	82.988^{**}
Region ×Field age	2	0.598^{ns}	0.0009^{*}	0.025^{*}	32.25^{**}	18.882^{**}
Error	48	0.251	0.0002	0.008	5.07	0.613
%(cv)	-	32.58	19.18	13.28	32.68	24.46

ns, * and ** are non significant, significant at 5 and 1% probability levels, respectively.

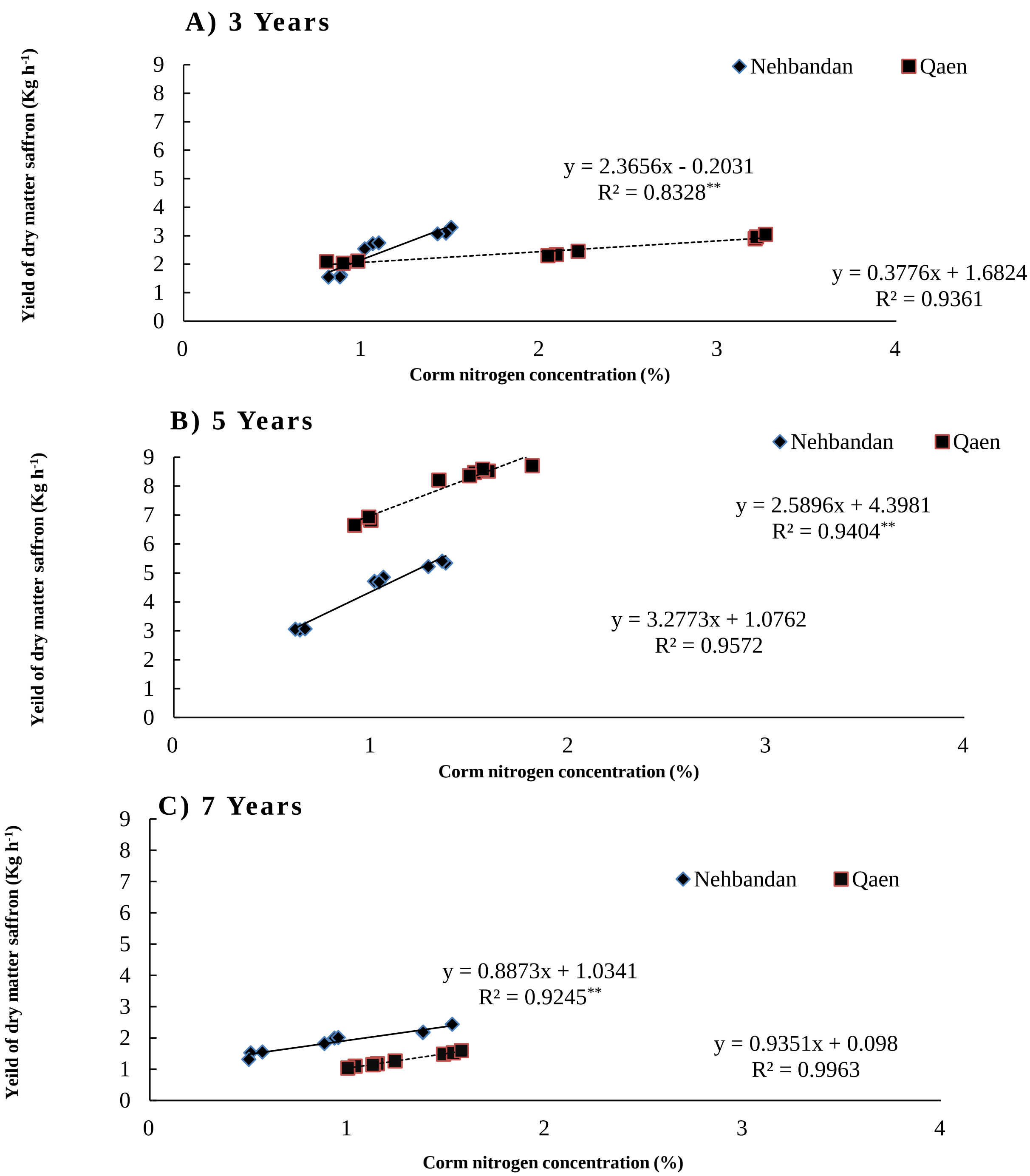

Figure 1: Relationship between nitrogen concentration of saffron corms in Nehbandan and Qaen fields with dry matter yield in three age groups of 1) Tree years, 2) Five years and 3) Seven years

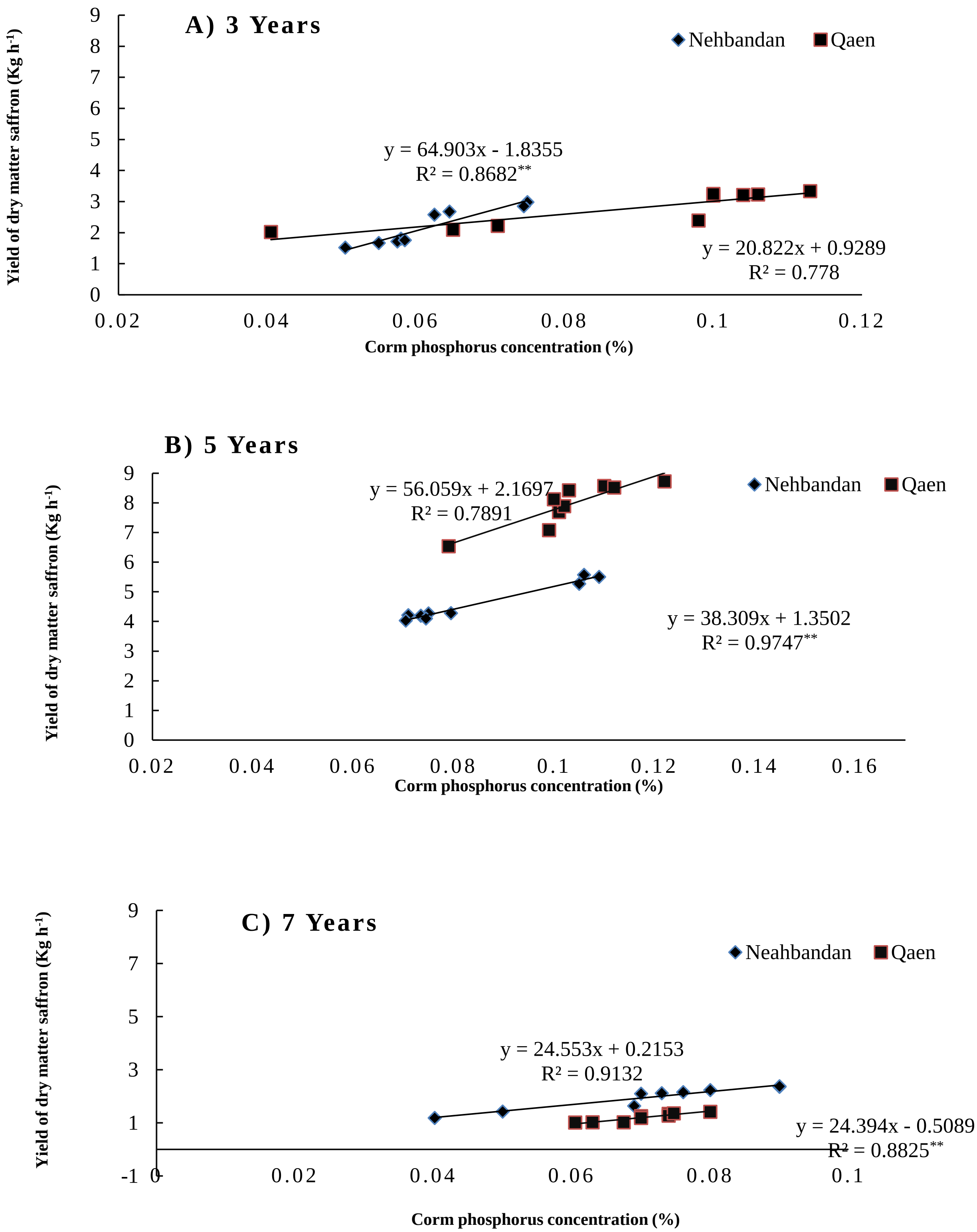

Figure 2: Relationship between phosphorus concentration of saffron corms in Nehbandan and Qaen fields with dry matter yield in three age groups of 1) Tree years, 2) Five years and 3) Seven years

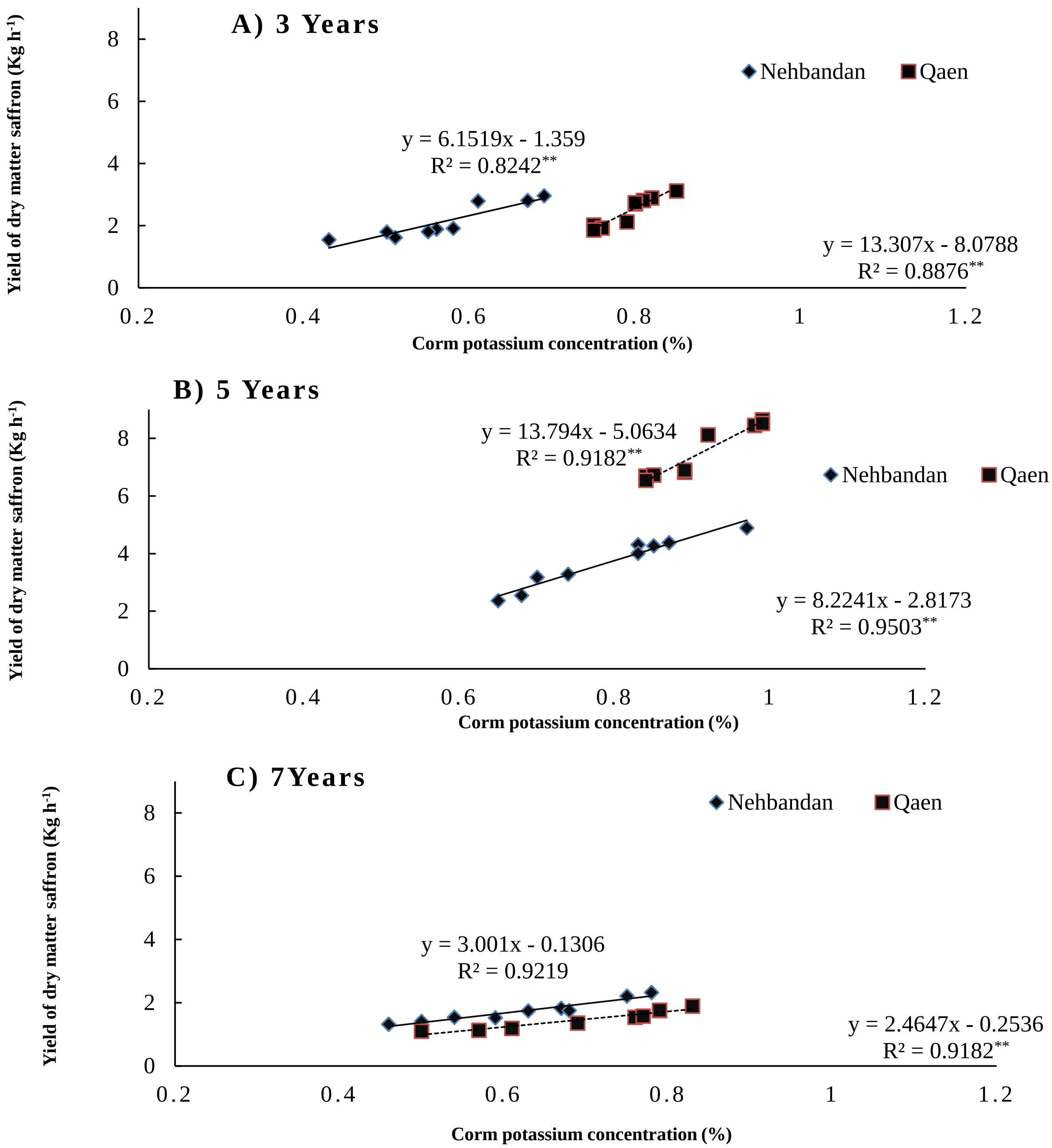

Figure 3: Relationship between potassium concentration of saffron corms in Nehbandan and Qaen fields with dry matter yield in three age groups of 1) Tree years, 2) Five years and 3) Seven years

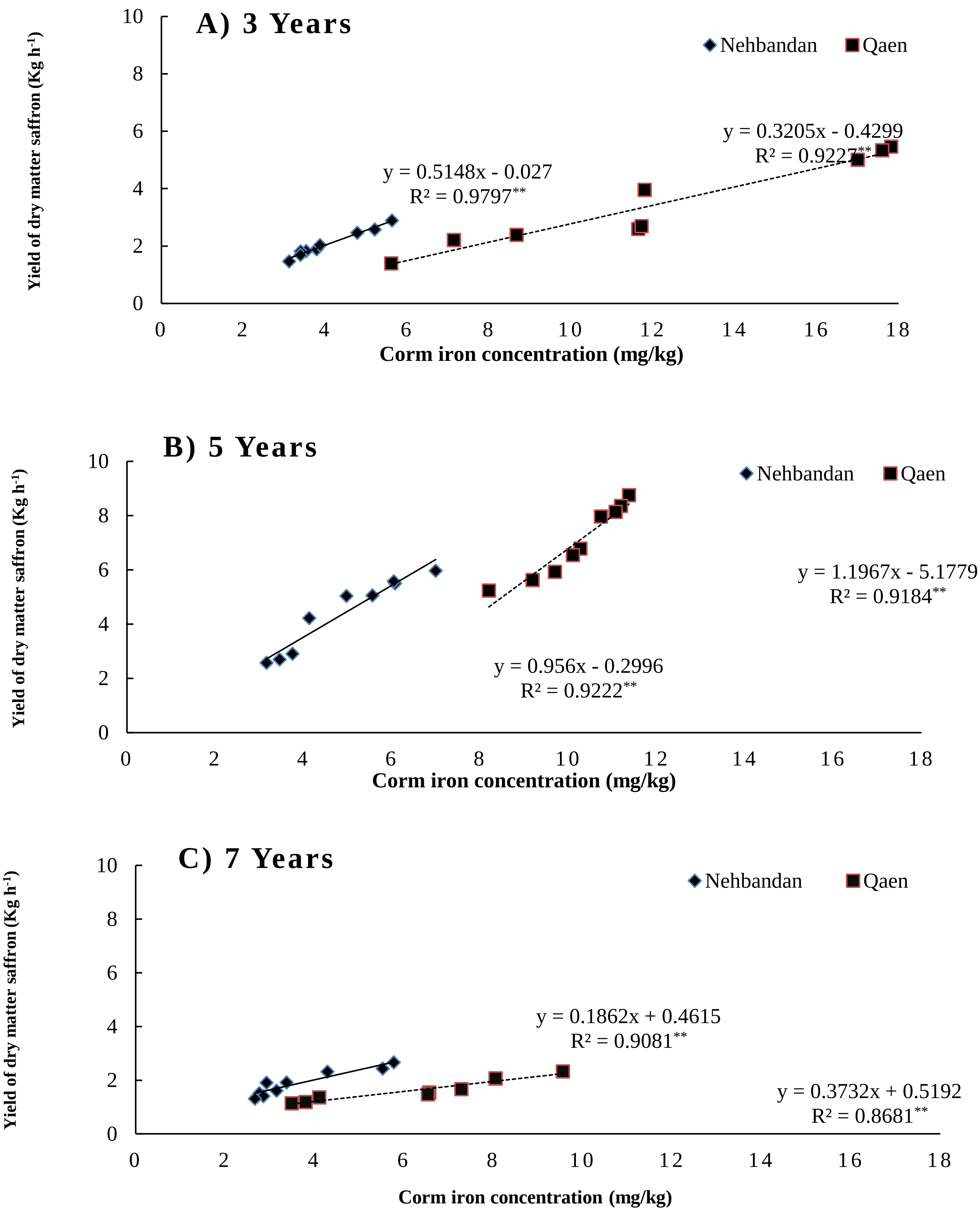

Figure 4: Relationship between iron concentration of saffron corms in Nehbandan and Qaen fields with dry matter yield in three age groups of 1) Tree years, 2) Five years and 3) Seven years

Table 4- Variation analysis (Sum of square) of the effects of field age and region on the number of saffron corms

Source of variation	Degree of freedom	The number of saffron corms				
		Under 2 g	2-4 g	4-8 g	8-12 g	Total
Region	1	12300.46^{ns}	6122.70^{ns}	16712.96*	1956.02*	244.91^{ns}
Field age	2	286072.69**	119867.13**	47604.17**	10983.80**	1030467.1**
Region ×Field age	2	15908.80^{ns}	9061.57^{ns}	8761.57^{ns}	1956.025**	74436.57^{ns}
Error	48	24041.09	15924.54	3075.81	384.84	58402.89

ns, * and ** are non significant, significant at 5 and 1% probability levels, respectively.

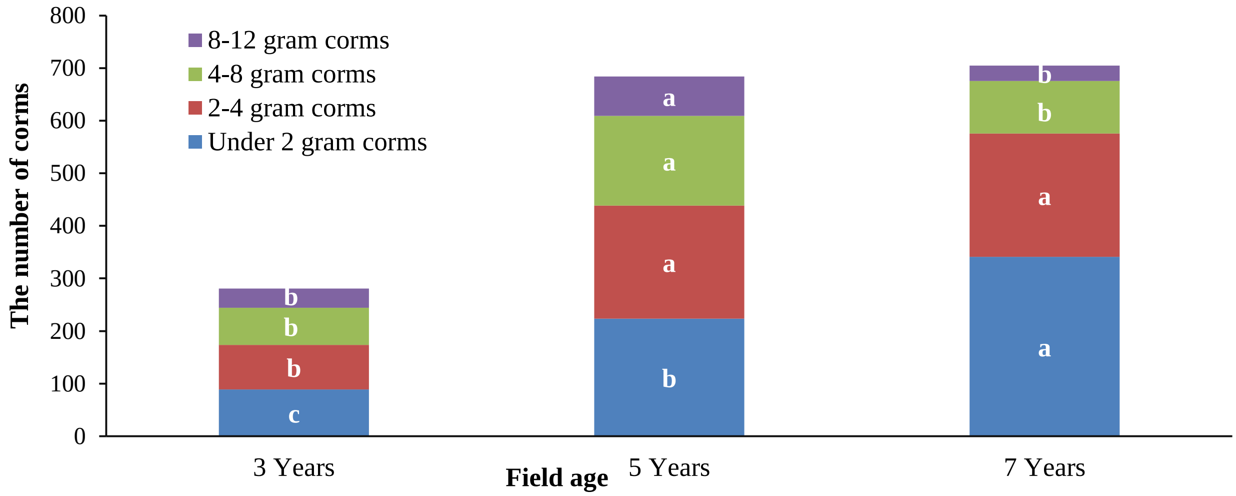

Figure 5: The effects of field age on the number of total saffron corms in perennial fields of Qaen and Nehbandan

Table 5: Pearson Correlation Coefficients of some nutrients concentration and number of saffron corms

	Corm nitrogen concentration (%)	Corm phosphorus concentration (%)	Corm potassium concentration (%)	Corm iron concentration (mg/Kg)	The number of saffron corms					yield of dry matter saffron (Kg h^{-1})
					Under 2 g	2-4 g	4-8 g	8-12 g	Total	
Corm nitrogen concentration (%)	1									
Corm phosphorus concentration (%)	0.227	1								
Corm potassium concentration (%)	0.284*	0.560**	1							
Corm iron concentration (mg/Kg)	0.642**	0.481**	0.461**	1						
The number of Under 2 g corms	-0.89	-0.164	-0.280*	-0.249	1					
The number of 2-4 g corms	0.60	0.006	0.133	-0.187	0.424**	1				
The number of 4-8 g corms	0.457**	0.416**	0.492**	0.316**	0.141	0.216	1			
The number of 8-12 g corms	0.443**	0.491**	0.579**	0.399**	0.082	0.139	0.507**	1		
yield of dry matter saffron (Kg h-1)	0.311**	0.561**	0.545**	0.433**	0.193	0.024	0.533**	0.690**	0.167	1

Conclusion

The results of this study showed that saffron yield was positively and significantly correlated with nutrient concentrations of nitrogen, phosphorus, potassium and iron in saffron corms. It can be said that increase in the yield is related to nutrients content increment in saffron corms, and can be attributed to animal manure application in these regions, which increased nitrogen, phosphorus and potassium uptake via saffron corm. The nutritional availability can increase yield due to the impact on crop growth processes. Its nature of perennial growth pattern in field conditions is effective in increasing nutrients absorption over time. In other words, with increasing life cycle of saffron, the number of daughter corms increases in the soil, which in proportion to this increase, the plant's ability to absorb nutrients such as nitrogen, phosphorus, potassium and iron also increase. Investigation of nutrients concentration of the corm on saffron yield shows the important role of such elements in yield. So that nitrogen, phosphorus, potassium and iron concentrations of the corm had a positive effect on saffron yield, among the investigated indices. Therefore, corm selection with optimum weight for sowing and proper use of nutrients, especially nitrogen, phosphorus, potassium and iron, as well as their correct balance in soil, can be effective in yield increment and stability of soil fertility. Generally it can be concluded that climatic condition, genotypic or management can stimulate plant growth and absorbing more elements from the soil.

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