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Original Article

Nutrients can be Effectively Absorbed by Saffron (*Crocus sativus* L.) Leaves and Affect Positively the Vegetative Growth and Flowering

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ABSTRACT

Foliar application of nutrients (FAN) during the end of the saffron growing season, when the root absorption capacity is slightly reduced, can probably improve plant growth and yield. This study investigates the impact of various foliar nutrition treatments, including zinc, boron, copper, potassium phosphate, amino acids, and pure seaweed extract, alongside a control treatment of tap water (pH = 7 and EC = 0.7 dS m^{-1}), on the nutrient absorption capacity of saffron leaves, as well as its vegetative and reproductive growth. All FAN treatments, especially amino acids, significantly increased leaf length and leaf width compared to the control treatment. Amino acid consumption delayed leaf senescence. Foliar application of all nutrients reduced the number of small replacement (daughter) corms (RC) in the weight group of 1-8 g (339.9 *vs*. 486 corms per m^2, for FAN and control, respectively) while increasing their number in the group weight of 8-16 (205.5 *vs*. 146.0 corms per m^2) and more than 16 g (17.2 *vs*. 6.6 corms per m^2). The potassium phosphate treatment demonstrated the highest yield of RC, surpassing the non-foliar nutrient application (control) by 15.5%. FAN treatments increased the mean weight and diameter of RC by 16.2% and 23.8%, respectively, compared to the control treatment. Amino acid spraying increased leaf (5.55 vs. 2.42%) and corm nitrogen content (2.25 vs. 1.4%) compared to the control treatment. Potassium phosphate has a significant effect on increasing the content of phosphorus and potassium in leaves and corms. The application of seaweed extract and boron increased the leaf boron content from 27.8 ppm in the control treatment to 44 and 76.5 ppm, respectively, and the corm boron content from 18 to 40.9 and 69.2 ppm, respectively. Foliar application of copper and zinc had a significant effect on increasing the concentration of these elements in saffron leaves and corms. All FAN treatments significantly increased the number of flowers, flower yield (120.0 and 61.9 g m^{-2}, for FAN and control, respectively), mean flower weight, and flower length compared to the control. Stigma yield with the application of amino acids, zinc, copper, potassium phosphate, boron, and seaweed extract was 158.5, 141.4, 47.1, 180.0, 78.5, and 165.7% more than the control treatment, respectively. The quality of the saffron stigma was not significantly affected by FAN treatments. In general, FAN, with the development of leaves as photosynthetic organs of the plant and increasing the content of nutrients in saffron leaves and corms, caused a significant increase in its flowering.

Keywords: Amino acid, Boron, Corm, Micronutrients, Stigma, Flowering, Zinc

INTRODUCTION

Saffron (*Crocus sativus* L.), a member of the Iridaceae family, has many applications in the pharmaceutical, cosmetic, health, and food industries [1]. The cultivation of this crop is primarily concentrated in West Asia, particularly in countries such as Iran, India, and Afghanistan, as well as in Southern Europe, with Greece, Spain, and Italy being significant contributors. Additionally, North Africa, especially Morocco, plays an important role in its cultivation. In recent years, there has been an expansion of its cultivation to other regions, including parts of America [2, 3]. Crocin (Responsible for the color and constitutes 6-16% of saffron dry matter), picrocrocin (Responsible for the taste and constitutes 1-13% of saffron dry matter), and safranal (Responsible for the aroma and the most important compound among more than 160 volatile components and represents 30-70% of essential oil and 0.001–0.006% of saffron dry matter) are three main components in saffron stigma [2-4].

In saffron production, the priority is to provide the nutritional requirements through soil application of fertilizers, particularly organic ones. However, at the end of the growing season, when the root system becomes weak, FAN can also be considered as supplement nutrition [2, 5]. Since the middle of March, the potential of the saffron root system to absorb nutrients has decreased, and it is relatively difficult to provide all the nutrient requirements from the soil. Therefore, foliar application is an appropriate strategy to overcome nutrient deficiency [6-8].

Emami *et al.* [9] found that FAN (humic acid, amino acid, complete chemical fertilizer) is an effective approach for improving saffron flowering. The results of Monemizadeh *et al.* [10] also showed that foliar nutrition is effective in increasing corm growth characteristics in saffron. In another research, it was concluded that nitrogen and protein contents of RC increased by FAN, and the total nitrogen content of biomass increased from 104 kg ha^{-1} (in control) to 130 kg ha^{-1} [5]. The results of Gerdakaneh *et al*. [11] also revealed that foliar application of humic acid improved the content of leaf nutrients, flowering, and corm growth of saffron. Similar results were obtained by Khorramdel *et al.* [12] when Dalfard fertilizer (containing different micro and macro elements) was sprayed, Rostami *et al,* [13] by zinc application, Tabatabaeian *et al.* [14] when potassium and zinc were applied, Maleki *et al.* [15] when a mixture of microelements was used and by Kermani and Amirmoradi [16] when silica was sprayed on saffron leaves. Recent studies indicate that saffron leaves, primarily due to their physical structure and thick cuticle, demonstrate limited effectiveness in nutrient absorption. As a result, foliar spraying may not significantly enhance growth and yield [17]. Khorasani *et al.* [18] also reported that due to the unique pattern of leaf and low nutrient demand of saffron, FAN in different levels, times, and frequencies cannot increase the vegetative growth and nutritional properties of saffron corms. This conflict in results between previous studies necessitates the implementation of new research in which the nutrient content in leaves and corms is measured after foliar spraying.

Due to the contradictions in the foliar absorption ability of nutrients by saffron leaves, it is necessary to track and compare the content of nutrients in leaves and corms before and after foliar application in comprehensive research. Therefore, the present study aimed to evaluate these hypotheses: 1- Different foliar nutrition treatments may increase the content of nitrogen, phosphorus, potassium, zinc, copper, and boron in saffron corms and leaves 2- Nutrient spraying may increase the leaf area and leaf durability by delaying leaf senescence, 3- foliar nutrition is probably effective on increasing the corm growth and thereby flowering capacity, and 4- stigma quality may be affected by FAN. Accordingly, the main innovation of this research was to determine the foliar absorption capacity of nutrients by the saffron leaves by using several new nutritional resources and evaluate its effect on plant growth, yield, and quality.

MATERIAL AND METHODS

Research Area

This research was carried out from October 2020 to the end of the saffron flowering phase in December 2021 in a four-year-old saffron field (established in 2016) located in Soumea, a village in Neyshaboor county, Razavi Khorasan province (36 ºN, 58 ºE with an altitude of 1520 m). Before initiating the experiment, a soil sample was collected and analyzed to assess its key characteristics (Table 1). The current experimental field was in a region that could be climatically representative of many saffron fields in Iran. However, conducting similar experiments in more diverse climatic conditions could reveal the effect of ecological factors on the extent of foliar nutrient uptake by saffron leaves.

Table 1 The main chemical and physical soil properties in research field of saffron located in Soumea, Neyshaboor, during 2020 growing season.

Soil texture	Clay	Silt	Sand	Lime	Organic matter	K^+	Available P	EC (dS m^{-1})	pH	Ca (Meq L^{-1})
	%					ppm (mg.kg^{-1})				
Silt Loam	15	56	29	15	0.47	510	6.11	1.35	7.42	3
Available Boron	Cu	Mn	Zn	Fe	N	SAR	Cl^-	Na	Bicarbonate	Mg
ppm (mg.kg^{-1})					%		Meq L^{-1}			
0.5	1.86	30	1.0	10.8	0.04	7.1	9	10	8	1

Field Background and Management

The field where the research was carried out was established in September 2016, using mother corms with the same weight (~12 g or ~ 3.3 cm in diameter). Planting density was 110 corms per m^2, the distance between planting lines was 20 cm, between corms on rows 4.5 cm, and the planting depth was 18-20 cm. During the four years before exerting the experimental treatments, four irrigations were done during each saffron growing season (before flowering, after flowering, the corm propagation stage in early February, and the corm filling stage in late April). Moreover, in the first year of planting, 100 kg ha^{-1} urea was used after flowering due to the low content of nitrogen in the soil (Table 1), and regarding the appropriate soil nitrogen content in soil of saffron fields recommended by Fallahi *et al.* [19]. Weed controlling was done once in the second year after planting (2018), during the corm propagation stage (mid-February), using Super Galant (Haloxyfop-R-methyl) herbicide at a dose of 1 l ha^{-1}. The super gallant herbicide was provided by Partov-Nar Company, Iran, which was sprayed when the air was calm.

Treatments and Experimental Design

In this study, we assessed the impact of foliar application of nutrients (FAN) on saffron in a four-year-old field. Before the initiation of the research, the only fertilization applied was 100 kg ha^{-1} of urea during the first growing season, with no additional fertilizers utilized afterward. The experiment was structured using a randomized complete block design, consisting of seven treatments and three replications (plots). The treatments included the control (tap water: pH: 7 and EC: 0.7 dS m^{-1}), zinc element (Zn), boron (B), copper (Cu), potassium phosphate, amino acid, and pure seaweed extract. The reason for using water as a control treatment was to determine the pure effect of the fertilizer treatments because a part of the effect of the fertilizer treatments could be due to the impact of water and not the nutrients. The effect of water spraying, for example, could be explained as the removal of dust on the leaves and increased light absorption. The applied rates of nutritional treatments were based on the doses recommended by the producer companies and based on the dissolution of the recommended rates in 750 liters of water per hectare for leaf spraying.

Powdery boron with the general name of SpeedFull, produced by the SQM Company, has 17% chelated boron and was used at the rate of 1 kg ha^{-1}. The zinc was in liquid form and made by Coda Company, Spain. It has 10.4% chelated zinc with lignosulfonate and was used with a dosage of 2 l ha^{-1}. The copper used in the experiment was produced by IFTC Company (general name of Koksil-91) and was in powder form. This fertilizer has 29% total copper (91% copper carboxyl), and its recommended dosage is 1 kg ha^{-1}. The applied potassium phosphate is produced by IFTC Company, with the general name of Win Phos, in liquid form. This fertilizer contains 40% phosphorus in the form of phosphate and 30% potassium. Its recommended dose is 2 l ha^{-1}. The pure extract of seaweed (*Ascophyllum nodosum*) made by E-Dalgin Company, Spain, is in liquid form. This fertilizer contains N, P, K, Ca, Mg, and S macronutrients, micronutrients (Fe, Mn, Zn, Cu, B, Mo), plant growth hormones (auxin, gibberellin, and cytokinin), carbohydrates (Mannitol, laminarin, alginic acid) and free amino acids. The recommended rate of its application is 2 l ha^{-1}. The consumed amino acid (common name of PN-14) was made in Italy (SICIT 2000 Company), and was in powder form. This fertilizer has 87.5% total amino acid, 6% free amino acid, 15% total nitrogen, 40% organic carbon, and 1% ammonia. Its application dose is 1 kg ha^{-1}.

Nutrients Foliar Application and Agronomic Management

The experimental plots (4×1.5 m) were established in the autumn of 2020. Spraying of nutrients in each plot was done in two stages (March 2 and 16, 2021), which were chosen according to the plant status by the continuous monitoring of the aerial and underground parts of the plant. In this research, when the root system of the plant started to dwindle and the first symptoms of deficiency, aging, and drying were observed in the leaves of the plant, the first phase of foliar spraying was done. Spraying was carried out using a 20-liter sprayer with a certain amount of water (based on 750 l ha^{-1} per spraying time) and fertilizer, along with the use of soap liquid as a surfactant, to increase the nutrient absorption capacity by the leaves. Each fertilizer was sprayed separately. When each fertilizer was sprayed, the sprayer was rinsed to remove the previous fertilizer residue, and then the new fertilizer was sprayed. The foliar spraying was done around 11 p.m. when the weather was sunny and calm, to maximize the absorption. During the winter, the early morning and evening are cold, which has a negative effect on the opening of the stomata and the possibility of nutrient absorption by the leaves. To prevent the movement of nutrient solution from one plot to the adjacent one, spraying was done when there was no wind, and to increase the assurance, the adjacent plots were covered by plastic. After spraying, there was no rain for at least four days. During the experiment, no organic or chemical fertilizers and no herbicides were used. Four times flood irrigation (700 m^3 ha^{-1}, in each round) was applied, similar to the previous years and based on the recommended amount of water requirement of saffron [20].

Measured Traits

Nutrients Content in Leaf and Corm

To evaluate the foliar absorption capacity of saffron leaves, ten days after the second foliar application (March 26), the content of nitrogen (in the plots of amino acids, seaweed, and control), phosphorus (in the plots of potassium phosphate, seaweed, and control), potassium (in the plots of potassium phosphate, seaweed and control), zinc (in zinc, seaweed, and control plots), boron (in boron, seaweed, and control plots) and copper (in the plots of copper, seaweed and control) were measured in both leaves and replacement corms. The methods of determination are available in Ahmadi [21].

Leaves Growth

From March 9, 2021, seven days before the second stage of foliar spraying, the leaf length (green part of the leaf) was measured seven times at weekly intervals (in 30 leaves from 10 fixed plants in each plot). The end of the saffron growing season (yellowing of the leaves) was also determined in different experimental plots, to determine the effect of foliar nutrition on leaf area duration, because an increase in the greenness duration of leaves can lead to an increase in the weight of the replacement corms (RC). In early May 2021, a systematic harvest of leaves was conducted from a continuous row measuring 0.5 meters. The subsequent analysis focused on various traits associated with the growth of the aerial parts, including the quantification of leaf count, the average length and width of the leaves, as well as the percentage of dry matter content in the leaves. Leaf length and width were measured across a sample of 30 leaves, and the results were subsequently averaged for evaluation. To assess the percentage of dry matter in both leaves and corms, 100 grams of each sample was accurately weighed and subsequently dried in an oven at 105 °C for 24 hours. Following this process, Equations 1 and 2 were employed for calculation.

Moisture percentage of corms or leaves = (Fresh weight-dry weight) / dry weight ×100 Equation 1

Dry matter of corms or leaves=100-Moisture percentage Equation 2

Replacement Corms Growth

At the end of the growing season on May 12, 2021, the saffron leaves were harvested and dried. Subsequently, all replacement corms (RC) were removed from 0.5 meters of a central planting row in each plot. We then assessed several corm growth parameters, including the number of replacement corms, the total weight of these corms, as well as their mean weight and diameter. In saffron cultivation, the development of larger replacement corms is of significant importance; thus, the number of corms was categorized based on weight into three groups: 1-8 grams, 8-16 grams, and greater than 16 grams. To evaluate the dry matter percentage of the replacement corms, we employed equations 1 and 2.

Flowering Parameters

In the autumn of 2021, flowers were harvested daily, in the early morning, from 5th to November 26th. During the flowering stage, the reproductive indices include the number of flowers per m^2 (sum of all flowers collected from each plot during the flowering period), the average weight of each flower, means flower length, mean stigma length, mean style length, fresh flower yield, dry stigma yield and dry petal yield were determined. Every day, the number of flowers in each plot was counted and weighed, and at the end of the experiment, the mean fresh weight of flowers was determined by dividing the flower yield by the number of flowers. Stigma, petals, and styles obtained from the flowers of each plot were dried at ambient temperature (25-27°C) and shaded, under laboratory conditions. The dried stigma samples were kept in the dark place at room temperature (25°C, although the lower temperature is more proper) [2], for quality assessment in February 2022.

Stigma Quality

Stigma quality parameters, including crocin, picrocrocin, and safranal content, were determined using a spectrophotometric method based on the ISO procedure [22]. For this purpose, 500 mg of dried stigma (from the total stigma belonging to each plot collected during 21 days of flowering) was weighed, milled, and poured into a 1000 ml balloon, covered with aluminum foil to prevent light penetration. After adding 900 ml of distilled water, the balloon was placed on a magnetic stirrer for one hour and then was brought to a volume of 1000 ml by adding new 100 ml of distilled water. Then, 20 ml of the obtained solution was added into a new balloon and reached the volume of 200 ml with distilled water. The solution was filtered using a vacuum pump and silicate filter paper (cellulose acetate with a diameter of 45 micrometers). Then, the optical absorption of the solution was measured using a spectrophotometer (model WPA, S2000 UV/Vis) at wavelengths of 257, 330, and 440 nm for picrocrocin, safranal, and crocin, respectively. Finally, equation 3 was used to determine the content of three apocarotenoids based on direct readings of the absorbance of 1% aqueous solution of dried stigma at the related wavelengths.

$A^{\%1}_{1cm}(ymax)=(D×10000)/ m×(100 - W_{mv})$ Equation 3

D = the amount of absorption at 257, 330, and 440 nm, M = mass of the sample (in grams), W_{mv} = the moisture content of the sample.

To calculate the Wmv stigma, samples were initially weighed and then placed in an oven maintained at 103±2 °C for 16 hours. Following this procedure, the percentages of moisture and volatile matter were determined [3].

Data Analysis

A randomized complete block design was used for the analysis of the data. Statistical evaluations were conducted utilizing SAS software, version 9.4. Comparisons were performed through the Least Significant Difference (LSD) test at a significance level of 5%. The resulting figures were created using Excel software.

RESULTS AND DISCUSSION

Nutrients Content in Leaf and Corm

Nitrogen Content

Foliar application of some fertilizers which contained nitrogen, had a significant effect on both leaf and RC nitrogen content (Table 2). Leaf nitrogen content increased by 2.2 times when amino acid was sprayed. Both amino acid and seaweed extract significantly enhanced corm nitrogen content compared with the control treatment, where the nitrogen percentage of corms was 2.25, 1.95 and 1.4% for amino acid, seaweed extract, and control, respectively (Fig. 1). In a similar study, Fallahi and Mahmoodi [5], reported that foliar application of a fertilizer containing nitrogen increased the nitrogen content of RC from 0.76 to 0.87%. Moreover, it increased the leaves and roots' durability, thereby nutrient absorption through the root system increased. In another study, the application of nutrients on saffron leaves increased the amount of nitrogen absorbed by the plant from 5.0 to 5.8 g m^{-2} [23]. Hosseini *et al.* [24] also found that nitrogen spraying is a helpful strategy in saffron cultivation. Therefore, it can be concluded that against the results of Asadi *et al*. [17], and Khorasani *et al.* [18], nutrients can be absorbed effectively by the aerial parts of saffron. A possible reason for the significant uptake of nutrients by saffron leaves in the current experiment is the use of soap liquid as a surfactant, which can increase the nutrient absorption capacity of the leaves.

Table 2 Mean square for the effect of foliar application of seaweed extract and amino acid on leaf and corm nitrogen content of saffron

S.O.V	Df	Leaf nitrogen percentage	Corm nitrogen percentage
Treatment	2	8.27 *	0.56 *
Replication	2	0.01 ns	0.26 ns
Error	4	0.67	0.05
C.V. (%)	-	22.31	12.41

** and *: significant at 1 and 5% level of probability, respectively. ns: no-significant

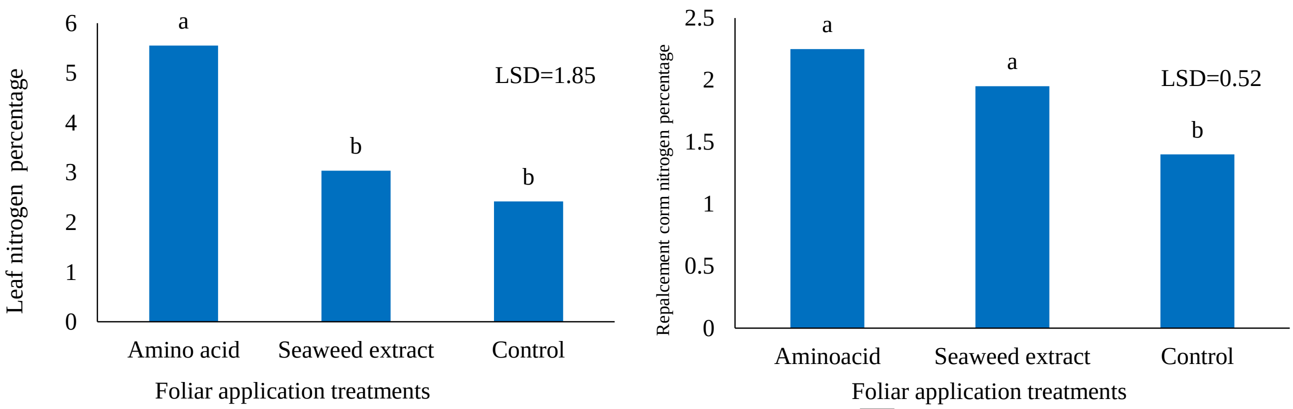

Fig. 1 Mean comparison for the effect of foliar application of seaweed extract and amino acid on leaf (left) and corm (right) nitrogen content of saffron

Phosphorous Content

The effect of foliar application of fertilizers containing phosphorous was significant on the content of this element in both leaf and corm (Table 3). The content of leaf phosphorous in the control and potassium phosphate treatments was 0.11 and 0.36%, respectively. Similarly, the content of this element in RC, was respectively, 2.13 and 1.84 times more than control (no foliar nutrition) and seaweed extract, when potassium phosphate was used (Fig 2). Gerdakaneh *et al.* [11] found that foliar application of a mixed fertilizer containing humic and fulvic acid, K, and Fe, increased phosphorous content in saffron leaves. The phosphorus content of the soil at the experimental site (Table 1) was lower than the recommended level for saffron (about 20 ppm) [19]. Therefore, the FAN eliminated its deficiency. Jahanian *et al*. [25], also positively reported the role of phosphate application in improving the phosphorus and potassium content in the plant. The positive role of seaweed extract in increasing the content of nutrients in saffron is probably due to the presence of a wide range of macro and micro-nutrients in this fertilizer [26, 27].

Table 3 Mean square for the effect of foliar application of seaweed extract and potassium phosphate on leaf and corm phosphorous and potassium contents of saffron

S.O.V	df	Leaf phosphorous percentage	Corm phosphorous percentage	Leaf potassium percentage	Corm potassium percentage
Treatment	2	0.047 *	0.0235 **	0.025 ns	0.077 *
Replication	2	0.001 ns	0.0022 ns	0.012 ns	0.005 ns
Error	4	0.003	0.0005	0.005	0.010
C.V. (%)	-	25.54	11.48	4.88	14.69

** and *: significant at 1 and 5% level of probability, respectively. ns: no-significant

Potassium Content

RC potassium content was significantly affected by the foliar application of some fertilizers containing potassium (Table 3). There was no significant difference between seaweed extract and control in terms of corm potassium percentage, but potassium phosphate spraying significantly increased the content of this macronutrient in the corms (Fig 2). In the study of Khorasani *et al.* [18], on saffron, foliar application of a fertilizer containing 5% potassium increased the leaves' K content by 3.2% which had no significant difference with the control treatment, probably due to no application of surfactant. In the study of Maktabdaran *et al.* [28] there was a positive correlation between potassium content in corms and saffron flowering capacity, which is consistent with the results of the present experiment because the application of potassium phosphate increased the content of K in corms and produced the highest flower and stigma yield (Table 12).

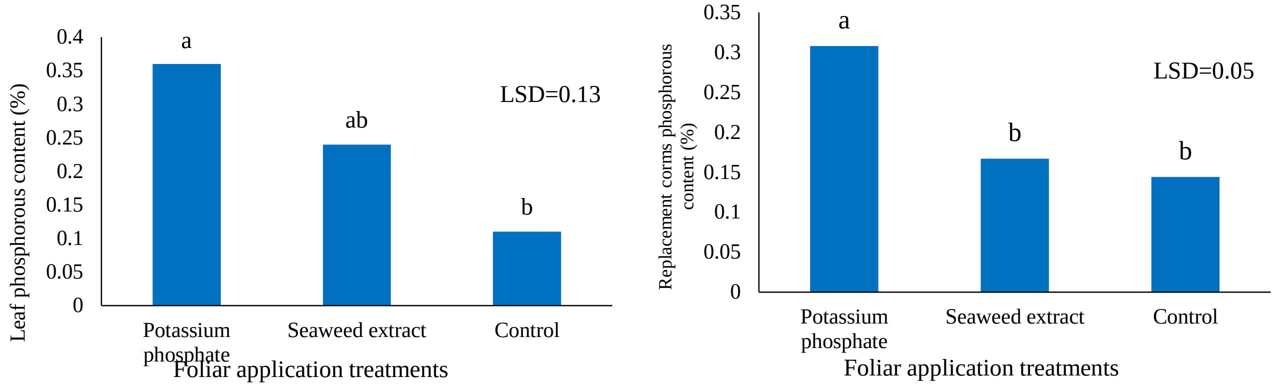

Fig. 2 Mean comparison for the effect of foliar application of seaweed extract and potassium phosphate on leaf (left) and corm (right) phosphorous content of saffron

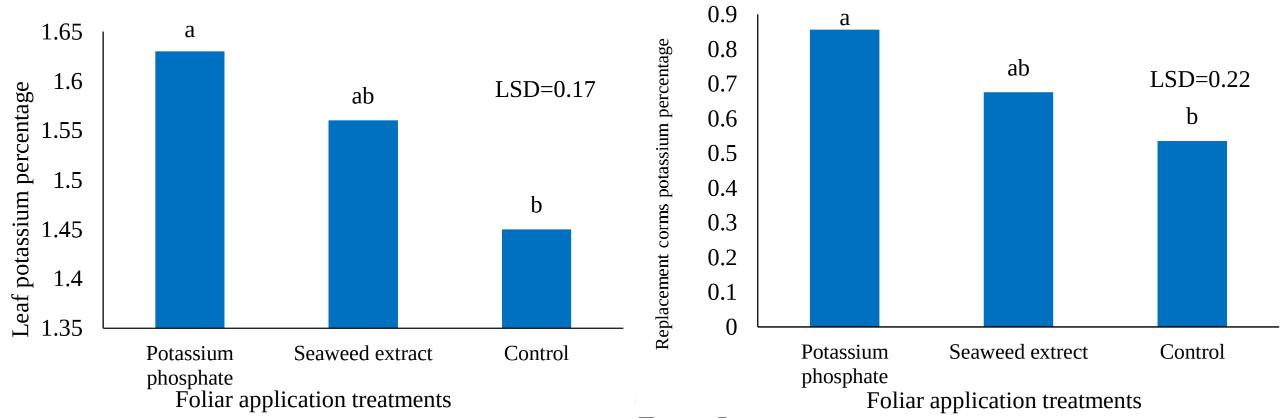

Fig. 3 Mean comparison for the effect of foliar application of seaweed extract and potassium phosphate on leaf (left) and corm (right) potassium content in saffron

Boron Content

Boron content in leaves and RC of saffron was significantly affected by the foliar application of seaweed extract and boron (Table 4). The content of boron in leaves was 58.3 and 175.3% higher than in control when seaweed extract and boron were respectively applied to the aerial parts of saffron. Similarly, the RC boron content was increased by 126.6 and 283.5% as the results of the foliar application of seaweed extract and boron, respectively (Fig. 4). Based on the soil analysis results (Table 1), it seems that soil boron content was lower than the optimal level; accordingly, FAN has probably solved this deficiency. Boron as a micronutrient is one of the essential elements with potential toxicity its excessive concentration in the plant can lead to an inhibitory effect on growth [21]. Usually, if boron concentration in plant dry matter is less than 25 mg kg^{-1}, deficiency symptoms and if its concentration becomes more than 200 mg kg^{-1}, the toxicity symptoms will occur in most plants [29]. However, the optimal level of boron has not been exclusively determined for saffron. Regards to the boron level recorded in Fig 4, led to an increase in the growth and flowering of saffron (Table 12), therefore, it seems that these levels are required, although more studies are needed.

Table 4 Mean square for the effect of foliar application of seaweed extract and boron on leaf and corm boron content in saffron

S.O.V	df	Leaf boron content	Corm boron content
Treatment	2	1850.06 **	1973.55 **
Replication	2	300.40 *	111.76 ns
Error	4	17.25	98.94
C.V. (%)	-	8.39	23.26

** and *: significant at 1 and 5% level of probability, respectively. ns: no-significant

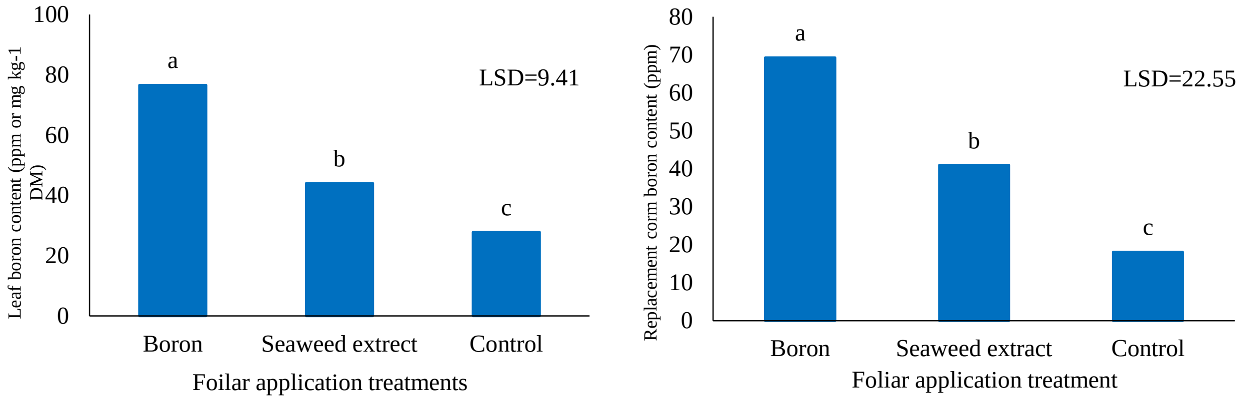

Fig 4. Mean comparison for the effect of foliar application of seaweed extract and boron on leaf (left) and corm (right) boron content of saffron

Copper Content

The effect of foliar nutrition of saffron by seaweed extract and copper was significant on the content of copper in both leaves and RC (Table 5). Although, there was no significant difference between seaweed extract and control in terms of copper percentage in leaves and corms, copper spraying on aerial parts of saffron significantly enhanced the content of this element in both underground and leaves of saffron (Fig 5). Rostami *et al.* [30] reported that copper carbonate had a significant effect on the physiological indices of saffron. Rezvani *et al.* [31], found that the use of copper in saffron under hydroponic conditions increased the content of this element in both leaves and corms, although its accumulation in corms was much higher than in leaves. In calcareous soils like the soil in the present study (Table 1), due to the presence of large amounts of calcium carbonate and high pH, the possibility of copper deficiency is high. Therefore, its foliar application can be useful [21]. High levels (toxicity) of both necessary and unnecessary heavy metals, can cause damage to the cell membrane, enzymes, cell functions, and the DNA structure [30]. However, the use of copper in the present experiment improved the growth (Table 8, 10) and flowering of saffron (Table 12), which can indicate its appropriate levels in the plant tissues (Fig. 5). Still its optimum concentration must be carefully determined in the future studies. The content of copper in leaves of saffron was higher than replacement corms (Fig 5), which was similar to those gained for nitrogen (Fig 1), phosphorous (Fig. 2), potassium (Fig. 3), and boron (Fig 4). The measurement of nutrients in both leaves and corms was done ten days after the second foliar application (March, 26). It seems that at this stage of growth, nutrients have not yet been transferred from the leaves to the replacement corms, and if the content of nutrients is measured at the end of the growing season, the accumulation of nutrients in the replacement corms will probably be higher.

Table 5 Mean square for the effect of foliar application of seaweed extract and copper on leaf and corm copper content of saffron

S.O.V	df	Leaf copper content	Corm copper content
Treatment	2	321.194 **	37.19 **
Replication	2	7.444 *	0.86 ns
Error	4	0.777	0.69
C.V. (%)	-	10.51	23.07

** and *: significant at 1 and 5% level of probability, respectively. ns: no-significant

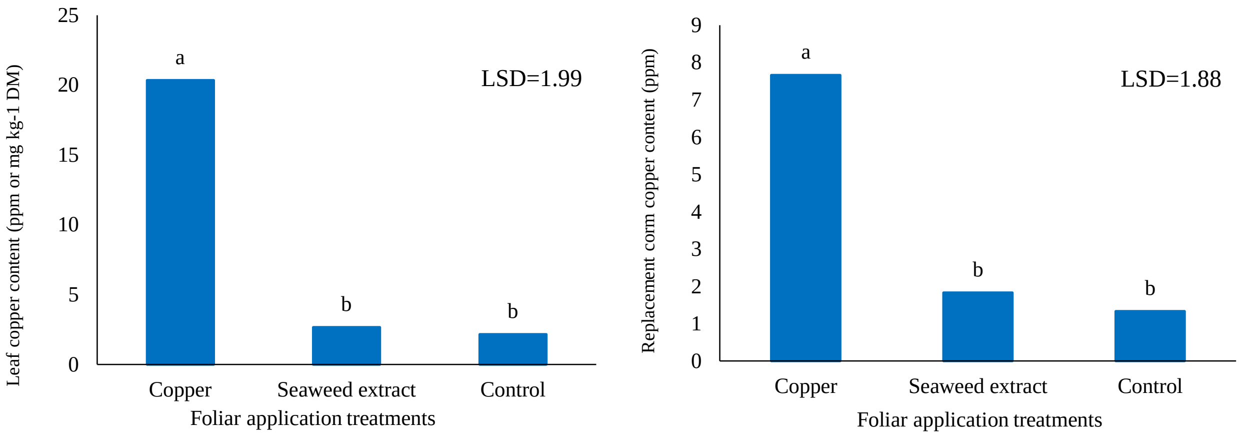

Fig. 5 Mean comparison for the effect of foliar application of seaweed extract and copper on leaf (left) and corm (right) copper content in saffron

Zinc Content

Leaf zinc content was significantly affected by the foliar application of seaweed extract and zinc (Table 6). There was no significant difference between seaweed extract (17.6 ppm) and control (14.3 ppm) treatments, in terms of leaf zinc content, but spraying of zinc on saffron above-ground parts increased the content of this element in leaves by 58.0% compared with the control (Fig 6). The results of Koocheki *et al.*, [32], also indicate the positive effect of zinc application on saffron corm growth. In many soils in dry regions, for several reasons such as the soil calcareousness, high pH, high bicarbonate in the irrigation water, the excessive consumption of phosphate fertilizers, and low application of zinc-containing fertilizers, the deficiency of zinc in the plant is common [21]. Therefore, foliar application of zinc, as observed in this experiment, can increase the zinc content in saffron leaves and corms by eliminating the above-mentioned inhibiting factors that are common when zinc is used in the soil. It must also be noted that the zinc content of the soil in the experimental site seems to be some lower than the optimum levels (Table 1).

Table 6 Mean square for the effect of foliar application of seaweed extract and zinc on leaf and corm zinc content of saffron

S.O.V	df	Leaf zinc content	Corm zinc content
Treatment	2	52.77 **	12.11 ns
Replication	2	3.44 ns	3.11 ns
Error	4	4.77	1.77
C.V. (%)	-	11.99	7.94

** and *: significant at 1 and 5% level of probability, respectively. ns: no-significant

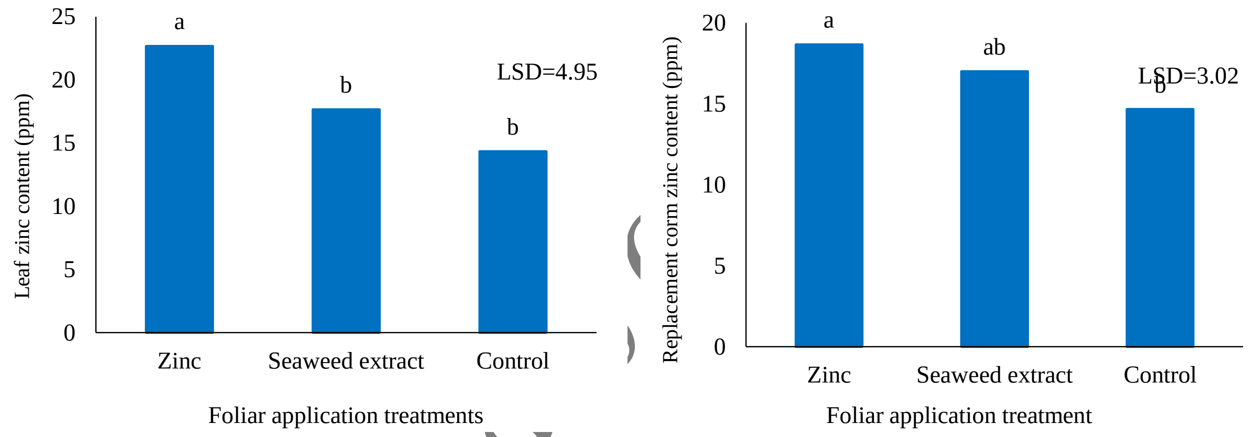

Fig. 6 Mean comparison for the effect of foliar application of seaweed extract and zinc on leaf (left) and corm (right) zinc content in saffron

Leaves Growth

The effect of FAN on the length of green parts of saffron leaves was significant in all seven stages of sampling during the growing season (Table 7). In all the sampling stages, the highest and the lowest leaf lengths were obtained in the foliar application of amino acid and foliar spraying with water (control treatment), respectively. The difference between these two treatments in the first to sixth sampling dates was 12.9, 22.6, 25.4, 37.5, 36.7, and 84.7% respectively. In the last stage of leaf sampling, even though the leaf length in the amino acid treatment was 6.6 cm, in the control treatment, there was no green part, and all the leaves were dried. The other foliar spraying treatments also caused an increase in leaf length compared to the control treatment, although, foliar applications of zinc and copper elements had more positive effects (Table 8).

In a similar experiment, Aminifard *et al.* [27], attributed the increase in saffron leaf growth due to the application of seaweed extract to the richness of this fertilizer in terms of nutrients and phytohormones particularly cytokinin. Jabbari *et al.* [33] also found that saffron foliar spraying with a concentration of 1000 mg l^{-1} of potassium nitrate was effective in increasing the leaf length. During the six stages of sampling, the six treatments of nutrient consumption, on average increased the leaf length by 6.0, 8.5, 9.7, 18.9, 14.8, and 35.7%, respectively, compared to the control treatment (Table 8). This shows that towards the end of the growing season, the FAN has a more influential role in the greenness of saffron leaves.

In saffron, until early March, the root system has enough capacity to absorb nutrients from the soil, but towards the end of the growing season, the length of the roots gradually decreases. Therefore, the FAN can exert a compensatory effect. It causes a delay in the aging and early necrosis of the leaves. The outcome of this process is to increase the duration of the RC filling period; thereby an increase will be observed in their flowering capacity in the next growing season [2, 6]. In a research, it was reported the dry weight of saffron root had an increasing trend until about 90 days after the first autumn irrigation, i.e., until the end of January, and then it reduced [5]. Renau-Morata *et al.* [34] also found that the maximum root weight of saffron is achieved in the middle of January and then decreases. In a similar study on saffron, it was observed that the root weight increased in the first four months of the growing season and then decreased until the middle of the spring [35]. These results indicate the importance of FAN at the end of the saffron growing season, when the root system becomes weak, to help the greenness of the leaves.

The results showed that in all the experimental treatments, the length of the green part of the leaves increased until the second sampling stage (March 20) and then it began a decreasing trend and finally reached zero (except for amino acid) in the last sampling stage (May 12) (Table 8). The results of Fallahi and Mahmoodi [5] also showed that at the end of the saffron growing season, the area and weight of leaves gradually decreased and the nutritional elements in the leaves were transferred to the replacement corms, which enhanced the mean corm weight.

The effect of experimental treatments on saffron leaf width was significant (Table 7). The highest and lowest values of this index were obtained in the amino acid and control (no-FAN), respectively. Regarding the leaf width, all the experimental treatments showed a significant superiority compared to the control treatment. The value of this index in the foliar spraying with amino acid, zinc, copper, potassium phosphate, boron, and seaweed was 24.4, 8.5, 21.1, 13.8, 7.7 and 18.7% more than the control, respectively (Table 8). FAN, especially with amino acids, also significantly improved the dry matter percentage of saffron leaves (Table 8), which indicates the improvement of the photosynthetic capacity of the leaves due to the foliar consumption of nutrients [21].

In general, FAN increased the length and width of saffron leaves, which resulted in an increase in the leaf area as the photosynthetic organ of the plant. Considering that in saffron, the last 45 days of the growing season are vital for increasing the weight of RC [2, 24], it is expected that the increase in the green area of the plant will have a positive effect on the production of larger RC [5] that was confirmed by the corm growth parameters (Tables 9 & 10).

Table 7 Mean square for the effect of foliar application of nutrients on leaf growth of saffron

S.O.V	df	Leaf length in 1 to 7 sampling dates							Lead width	Number of leaf per m^2	Percentage of leaf dry matter
		1	2	3	4	5	6	7			
Treatment	6	4.27 **	16.01**	13.39 **	14.77 **	11.33 **	14.47 **	18.66 **	0.13 **	93849.2 ns	15.96 *
Replication	2	0.72 ns	4.06 *	2.06 ns	0.45 ns	0.44 ns	2.06 ns	0.01 ns	0.01 ns	446071.4 ns	2.16 ns
Error	12	0.73	0.83	0.67	0.72	0.58	1.44	0.01	0.01	186349.2	3.39
C.V (%)	-	3.01	3.02	2.98	3.64	4.19	11.19	14.45	4.06	11.96	5.41

** and *: significant at 1 and 5% level of probability. ns: no-significant

Table 8 Mean comparison for the effect of foliar application of nutrients on leaf growth of saffron

Treatment	Leaf length in 1 to 7 sampling dates (cm)							Lead width (mm)	Number of leaf per m^2	Percentage of leaf dry matter
	1	2	3	4	5	6	7			
Amino acid	30.46 a	34.46 a	31.90 a	27.73 a	22.10 a	15.20 a	6.60 a	3.06 a	3716.67 a	37.96 a
Zinc	29.00 ab	31.03 b	27.73 b	23.20 b	19.20 b	11.10 b	0 b	2.67 c	3483.33 a	32.76 bc
Cupper	28.73 b	31.53 b	27.20 c	23.20 b	17.46 cd	10.90 b	0 b	2.98 ab	3633.33 a	33.93 bc
Potassium phosphate	28.33 bc	28.93 c	27.70 b	23.60 b	18.06 bc	10.63 b	0 b	2.80 bc	3650.00 a	34.26 b
Boron	27.91 bc	28.50 c	25.80 cd	23.01 b	17.40 cd	9.63 bc	0 b	2.65 cd	3283.33 a	35.73 ab
Seaweed extract	27.16 c	28.63 c	27.16 bc	23.16 b	17.13 cd	9.56 bc	0 b	2.92 ab	3833.33 a	32.66 bc
Control	26.96 c	28.10 c	25.43 d	20.16 c	16.16 d	8.23 c	0 b	2.46 d	3650.00 a	30.86 c
LSD	1.52	1.62	1.46	1.51	1.35	2.14	0.24	0.20	767.96	3.27

In each column, means with at least one similar letter are not significantly different based on LSD test.

Replacement Corms Growth

FAN had a significant effect on the number of saffron RC in weight categories of 1-8, 8-16, and more than 16 g, as well as on the total number of RC (Table 9). The nutrient spraying on leaves reduced the total number of RC (Table 10). It is possible that the saffron plant, when faced with low nutrient availability stress (control treatment), focuses on reproduction to ensure its survival. Therefore, it even produces new corms at the end of the growing season, when the rate of reproduction decreases compared to the period after flowering [21]. The highest total number of RC was obtained in the control and the lowest number was gained in the boron and copper treatments, which showed a 23% difference (Table 10).

Application of seaweed extract, potassium phosphate, and control were in the same statistical group in terms of the total number of RC. However, the other experimental treatments significantly reduced this index (Table 10). It must be noted that in saffron, what is more important than the increase in the number of RC is the increase in large corms and the mean weight of corms [36]. The results showed that FAN caused a decrease in the number of small RC (1-8 g) and an increase in the number of large corms (>8g), which resulted in an increase in the average weight and diameter of RC. The number of small corms in the control treatment was 42.9% more than the average value of the six foliar spraying treatments, while the number of corms weighing 8-16 and more than 16 g in the non-FAN (control) were respectively 40.7 and 158.5% lower than the average value of all foliar spraying treatments (Table 10).
The use of potassium phosphate was the best treatment in terms of increasing the number of 8-16 g RC, and the treatments of boron and potassium phosphate were the best treatments in terms of increasing the number of RC weighing more than 16 g (Table 10). According to the results of soil analysis (Table 1) the amount of phosphorus in the soil is less than the optimal level for saffron [19], improving the growth of the corms by potassium phosphate application is acceptable.
Fallahi and Mahmoodi [5] in a similar experiment, found that the total number of saffron RC almost did not change due to FAN, but it caused a decrease in the number of small corms and an increase in the number of large corms. A similar result was obtained by Koocheki *et al*. [32] when Fe and Zn were sprayed on saffron. Jabbari *et al.* [33] also, reported that the foliar application of potassium nitrate in saffron increased the photosynthetic capacity of the plant by increasing the content of chlorophyll a and b, and the final result was an improvement in the weight of RC. Rezvani *et al.* [31] also under hydroponic conditions, found that the appropriate concentration of copper in the nutrient solution could improve saffron corm growth.
All FAN treatments were in the same statistical group in terms of average weight and diameter of RC, while compared to the control treatment, all of them significantly increased both weight (16.3%) and diameter (23.8%) (Table 10). Jabbari *et al*. [33] also found that potassium nitrate spraying (1000 mg l^{-1}) increased the weight of saffron RC. In the study of Fallahi and Mahmoodi [5], the average weight of saffron RC increased by 22% by FAN. In saffron, the last two months of growing season are very vital in terms of increasing the weight of the corms [24]. An appropriate supply of nutrients in this period causes an increase in the leaf area, leaf durability, and the rate of photosynthesis. It ultimately leads to an increase in the weight of the corms [2]. In the present study, the FAN also increased the length and width of the leaves (leaf green area), and the durability of the leaf area (Table 8), which provided more time for filling of RC (Table 10).
The mean weight of replacement corms was between 7.31 and 8.81 g, in different treatments (Table 10), which is lower than the mean weight of planted mother corms (12 g). The experiment was done in a four-year-old saffron field (established in 2016) with an initial density of 110 corms per m^2. However, due to the annual multiplication of corms into the soil, the number of replacement corms in the year of the experiment in different treatments varied between 520-640 corms per m^2 (Table 10). Increased competition between corms due to their successive annual multiplication is one of the important reasons for the decrease in the weight of replacement corms compared to the mean weight of the initial mother corms [2].
The use of amino acids significantly increased the dry matter percentage of the RC by about 24% compared to the control treatment (Table 10). Amino acids, as a source of nitrogen, are essential compounds in producing chlorophyll and improving photosynthesis. Considering that nitrogen plays a role in the structure of photosynthetic pigments, the use of amino acids as a source of organic nitrogen can increase the content of chlorophyll, photosynthesis, and finally the growth and flowering of saffron [37].
Mollafilabi [6] and Koocheki *et al.* [32], showed that FAN can improve the RC growth and flowering of saffron. However, the results of Asadi *et al.* [17] and Khorasani *et al.* [18] revealed that foliar spraying had no significant effect on the growth and yield of saffron. These differences could be caused by the difference in the nutrient solution concentration, number of spraying times, environmental conditions during and after spraying, the content of nutrients in the soil, the type and the quality of the used fertilizer, the use or non-use of surfactant, etc. [21]. What most researchers agree on is that the root system of saffron gradually declines from around early February ahead and plays a lower role in the absorption of nutrients. The growth of RC that takes place from this time onwards, is mainly dependent on the photosynthesis of the leaves, and for this reason, the FAN at this time when the capacity of absorbing nutrients from the soil decreases, has been recommended [2, 6].

Table 9 Mean square for the effect of foliar application of nutrients on replacement corms growth of saffron

S.O.V	df	Number of replacement corms in different weight groups			Total weight of replacement corms	Mean weight of replacement corms	Mean diameter of replacement corms		Percentage of corms dry matter
		1-8 g	8-16 g	>16 g	Total				
Treatment	6	14696.82 *	3426.98 **	585.71 **	6638.09 **	382107.09 **	0.77 **	0.12 **	89.24 **
Replication	2	11004.76 ns	171.42 ns	132.14 ns	461.90 ns	123948.90 ns	0.29 ns	0.03 ns	8.25 ns
Error	12	3749.20	526.98	73.80	1211.90	61985.57	0.13	0.02	9.29
C.V (%)	-	16.96	11.64	54.67	6.06	5.22	4.47	6.06	7.55

** and *: significant at 1 and 5% level of probability, respectively. ns: no-significant

Table 10 Mean comparison for the effect of foliar application of nutrients on replacement corms growth of saffron

Treatment	Number of replacement corms in different weight groups				Total weight of replacement corms (g m^2)	Mean weight of replacement corms (g)	Mean diameter of replacement corms (cm)	Percentage of corms dry matter
	1-8 g	8-16 g	>16 g	Total				
Amino acid	366.67 bc	196.67 bc	13.33 b	576.67 bcd	4952.67 b	8.59 a	2.73 a	50.66 a
Zinc	323.33 bc	223.33ab	0b	546.67 cd	4565.00 bc	8.35 a	2.70 a	32.56 c
Cupper	303.33 c	203.33 bc	13.33 b	520.00 d	4298.67 c	8.26 a	2.60 a	39.43 b
Potassium phosphate	333.33 bc	250.00 a	33.33 a	616.67 ab	5411.00 a	8.77 a	2.76 a	41.86 b
Boron	293.33 c	190.00 bc	36.66 a	520.00 a	4583.00 bc	8.81 a	2.80 a	37.73 bc
Seaweed extract	420.00 ab	170.00 cd	6.66 b	596.67 abc	4885.67 b	8.23 a	2.76 a	39.20 b
Control	486.67 a	146.67d	6.66 b	640.00 a	4683.67 bc	7.31 b	2.20 b	40.76 b
LSD	108.93	40.83	15.28	61.93	442.91	0.66	0.28	5.42

In each column, means with at least one similar letter are not significantly different based on LSD test.

Flowering Parameters

FAN significantly affected all traits related to saffron reproductive growth, including number of flowers, flower yield, mean flower weight, flower length, style length, stigma length, stigma yield, style yield, and petal yield (Table 11). All FAN treatments improved the number of flowers compared to the control treatment (No-FAN). The highest and the lowest number of flowers (379.6 and 239.6 No m^{-2}, respectively) were obtained in the amino acid foliar spraying and control, respectively, which shows a difference of 58.4%. Amino acid, potassium phosphate, and seaweed extract treatments were in the same statistical group regarding this trait and increased saffron flowering more than other FAN treatments (Table 12). The flower yield also showed a significant increase because of foliar spraying of all nutrients compared to the control treatment. The highest flowering (151.6 kg ha^{-1}) was obtained by foliar application of amino acid, while the lowest flower yield (61.9 kg ha^{-1}) was gained in control, which represents a difference of 144.6%. On average, the six treatments of FAN caused the flowering of saffron to increase by more than 93% compared to the control treatment (Table 12). These results are according to Kianimanesh *et al.* [38], who found that saffron flowering significantly increased by foliar nutrition. In another study, it was concluded that an increase in the saffron flower number is possible but, when spraying of nutrients is done at an appropriate concentration [39]. The mean weight of the flower also showed similar results, so all the spraying treatments improved the value of this trait significantly compared to the control treatment. Again, amino acid spraying was the best treatment with a superiority of 60% compared to the control treatment (Table 12).

The use of amino acids, which are rich in organic nitrogen, provides some minerals and nutrients for the plant and enhances the chlorophyll content. The amino acid positively affects the growth, flowering, and quality of flowers by increasing the content of nutrients and stimulating metabolism [37]. Similarly, Emami *et al.* [9] showed that using amino acids increased the number of flowers and flower yield in saffron. The positive effect of amino acids on plant growth is due to the increase of mRNA transcription by up to 2.5 times, phytohormones activation, carbohydrate production, and an increase in the absorption and transfer of nutrients [21, 40]. The benefit of fertilizers containing free amino acids is that the energy required for the biosynthesis of amino acids is stored and used for plant growth improvement [9].

All the FAN treatments increased the length of the flower, stigma, and style compared to the control treatment. The highest amount of flower length was obtained in the amino acid and potassium phosphate treatments, which showed an increase of 19.1% and 18.4%, respectively, compared to the control treatment. The amino acid spraying showed the highest stigma length, which was 22.2% superior compared to the control treatment. In terms of style length, the use of boron, amino acid, and zinc had the highest effect and increased it by 26.4, 22.4, and 21.2%, respectively, compared to the control (Table 12). The positive role of FAN in increasing saffron flowering traits has been previously confirmed by Fallahi *et al.* [41]. They found that the production of large replacement corms through the FAN is the main reason for increasing flower length and weight, which is confirmed by the results of the present study (Table 10).

Stigma yield showed a significant increase due to leaf consumption of all nutrients. The use of amino acid, zinc, copper, potassium phosphate, boron, and seaweed extract increased stigma yield by 158.5, 141.4, 47.1, 180.0, 78.5, and 165.7%, respectively, compared to the control treatment. Style yield also responded positively to foliar application of all nutritional treatments, except copper. The highest and the lowest amounts of this trait were observed in the amino acid application and control, respectively, which had a 165.5% difference. FAN also had a positive effect on increasing petal yield. On average, the value of this index in the FAN treatments was 54.2% higher than the no-FAN treatment (Table 12).

Kianimanesh *et al.* [38] stated that the production of auxin-like substances by FAN, particularly zinc, can increase saffron yield because zinc is present in the structure of tryptophan amino acid as the precursor of indole acetic acid. In the experiment of Aminifard *et al.* [27], similar to the results of the present experiment, application of seaweed extract improved saffron flowering. They stated that probably the presence of auxin, indole acetic acid, indole butyric acid, betaine, and betaine-like substances, as well as macronutrients such as phosphorus and potassium, along with various micronutrients and vitamins in seaweed extract could increase the flowering capacity. It must be noted that the flowering capacity of saffron is strongly influenced by the state of vegetative growth of the plant in the previous growing season. If in the previous growing season, the development of the aerial parts and thereby the production of large replacement corms are done, then the flowering parameters will improve during the flowering season [2, 36]. In the current experiment, FAN enhanced the leaf growth (Table 8), the weight of replacement corms (Table 10), and the content of nutrients in leaves and corms (Fig. 1-6), which resulted in a significant increase in the flowering parameters particularly flower and stigma yields (Table 12).

Table 11 Mean square for the effect of foliar application of nutrients on flowering of saffron

S.O.V	df	Number of flowers	Flower yield	Mean flower weight	Flower length	Stigma length	Style length	Dry stigma yield	Dry style yield	Dry petal yield
Treatment	6	7081.07 **	3135.80 **	0.00951 **	0.48 *	0.06 *	0.41 **	0.700 **	0.108 **	50.01 **
Replication	2	137.19 ns	17.37 ns	0.00001 ns	0.08 ns	0.01 ns	0.01 ns	0.004 ns	0.004 ns	2.79 ns
Error	12	577.57	202.15	0.00093	0.11	0.02	0.04	0.057	0.012	6.57
C.V. (%)	-	7.14	12.71	9.34	6.68	6.90	7.29	16.24	20.40	12.27

** and *: significant at 1 and 5% level of probability, respectively. ns: no-significant

Table 12 Mean comparison for the effect of foliar application of nutrients on flowering of saffron

Treatment	Number of flowers per m^2	Flower yield (g m^2)	Mean flower weight (g)	Flower length (cm)	Stigma length (cm)	Style length (cm)	Dry stigma yield (g m^2)	Dry style yield (g m^2)	Dry petal yield (g m^2)
Amino acid	379.67 a	151.66 a	0.40 a	5.43 a	2.36 a	3.06 a	1.81 a	0.77 a	20.18 bc
Zinc	350.00 ab	119.11 bc	0.34 b	5.00 ab	2.06 bc	3.03 a	1.69 a	0.66 ab	21.51 bc
Cupper	308.33 b	84.21 de	0.27 c	4.36 c	1.96 bc	2.13 d	1.03 bc	0.30 c	17.46 cd
Potassium phosphate	373.33 a	141.70 ab	0.38 ab	5.40 a	2.20 ab	2.93 ab	1.96 a	0.71 ab	26.73 a
Boron	342.67 ab	96.23 cd	0.28 c	5.13 ab	2.13 abc	3.16 a	1.25 b	0.54 b	23.28 ab
Seaweed extract	360.00 a	127.65 ab	0.35 ab	4.86 abc	2.20 ab	2.63 bc	1.86 a	0.58 ab	22.78 ab
Control	239.67 c	61.99 e	0.25 c	4.56 bc	1.93 c	2.50 c	0.70 c	0.29 c	14.26 d
LSD	42.75	25.29	0.05	0.59	0.26	0.36	0.42	0.2	4.56

In each column, means with at least one similar letter are not significantly different based on LSD test.

Stigma Quality

FAN had no significant effect on the content of crocin, picrocrocin, and safranal in saffron stigma (Table 13). However, the amount of crocin was higher than the control treatment in all experimental treatments, especially with amino acid and zinc spraying. The highest amount of picrocrocin was also obtained in amino acid foliar application (Table 14). The non-significant effect of FAN on stigma quality may be related to the presence of specific thresholds for nutrient concentrations that might influence the quality. However, this hypothesis should be tested in future studies. The effect of some factors such as FAN on the quality of stigma is not well known, and it is probably more influenced by genetic factors, environmental stresses, and climatic conditions [21, 42]. Fallahi *et al.* [43], found that FAN improved the crocin content of the stigma, but had no effect on picrocrocin and safranal. In the study of Khandan Deh-Arbab *et al.* [26], contrary to the results of the present experiment, seaweed extract improved the quality of saffron stigma, which may be due to the difference in the amount and the method of seaweed application which was used 15-10 l ha^{-1} as fertigation. In another study, Aminifard *et al.* [44] found that application of 2-4 l ha^{-1} amino acid as fertigation, was effective on increasing the quality of stigma. However, in another study it was concluded that split foliar fertilization increased saffron yield and crocin; while decreasing the safranal and picrocrocin content in stigma [7]. Based on Iranian [45] and ISO [46] standards, the stigma obtained from all experimental treatments were classified as excellent and Category I, respectively, in terms of the content of crocin, picrocrocin, and safranal, which is similar to those reported by Fallahi *et al.* [47] shows the high quality of Iranian saffron.

Table 13 Mean square for the effect of foliar application of nutrients on stigma apocarotenoids content of saffron

S.O.V	Df	Stigma crocin content	Stigma content	picrocrocin	Stigma safranal content

Treatment	6	17.65 ns	1.74 ns	0.65 ns
Replication	2	237.76 *	37.76 **	32.33 **
Error	12	37.65	4.48	1.05
C.V. (%)	-	2.28	2.11	2.89

** and *: significant at 1 and 5% level of probability, respectively. ns: no-significant

Table 14 Mean comparison for the effect of foliar application of nutrients on stigma apocarotenoids content of saffron

Treatment	Stigma crocin content (absorbance of 1% aqueous extract at 440 nm)	Stigma picrocrocin content (absorbance of 1% aqueous extract at 257 nm)	Stigma safranal content (absorbance of 1% aqueous saffron extract at 330 nm)
Amino acid	271.00 a	101.33 a	35.33 a
Zinc	272.00 a	100.67 a	36.33 a
Cupper	268.33 a	100.67 a	35.66 a
Potassium phosphate	268.00 a	100.33 a	35.33 a
Boron	269.00 a	100.00 a	35.66 a
Seaweed extract	266.00 a	99.66 a	35.00 a
Control	265.33 a	99.00 a	35.00 a
LSD	10.91	3.76	1.82

In each column, means with at least one similar letter are not significantly different based on LSD test.

CONCLUSION

The results of this research showed that different foliar nutrition treatments increased the aerial and belowground growth of saffron. In addition, the content of macro and micronutrients in leaves and corms of saffron increased by FAN, which indicates that despite their specific morphological characteristics, saffron leaves can effectively absorb nutrients. Due to the significant increase in saffron yield as a result of FAN and due to the high price of stigma, FAN is economically justified in saffron fields. It must be noted that the application of any fertilizer should be according to the results of soil analysis and only when a deficiency of one or more nutrients is observed in the soil, the FAN especially in the late growing season, can lead to the elimination of the deficiency and improvement of plant growth and yield. We did not consider assessing the long-term effects of FAN treatments on subsequent growing seasons. Therefore, it is advised to evaluate the impact of repeated applications of FAN on plant growth, soil health, and nutrient dynamics over time, in future studies. In addition, exploring different combinations or timings of nutrient applications might yield further insights.

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