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The Effect of Foliar Fertilizer and Different Growth Regulators on Quantitative and Qualitative Yields of Saffron (*Crocus sativus* L.) in Farooj

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ABSTRACT

Both Foliar nutrients and phytohormones application have crucial roles in enhancing the yield of plants and meeting the increasing demand for food. To evaluate the effects of a foliar fertilizer and growth regulators on quality and quantity yields of saffron (*Crocus sativus* L.), a complete block randomized experiment was conducted on the experimental farm in Farooj in 2020-2021. This study consisted of seven treatments: 1-Control, 2- Gibberellin (200 ppm), 3-Auxin (200 ppm), 4- foliar spraying of Fruit Set (specific fertilizer containing 8.75% N as NO_3^-, 4.37% Zn, and 10% B, 6%K, and 6% sea weed extract at a rate of 0.5 L/ha + gibberellin (200ppm), 5-Fruit Set foliar fertilizer (0.5 L/ha), 6- N-phenyl-phthalamic acid (200 mg/L as irrigation), and 7-N-phenyl-phthalamic acid (spraying with 200 mg/L). It was found that the Fruit Set treatment resulted in the highest flower height (10.33 cm) and the auxin treatment resulted in 46 % increase in leaf height over the control treatment. In the Fruit Set + gibberellin treatment, the highest flower weight (2790g) was achieved, and the highest number of mother corms (15 pieces) was obtained in the auxin and gibberellin treatment. It also was observed that the mother corm weight (44 grams) and diameter (14 cm) were highest in gibberellin treatment (47%), and auxin treatment produced the largest number of daughter corms (32 pieces). Fruit Set + gibberellin, Fruit Set, auxin, and gibberellin significantly increased flower weight by 93%, 67%, 78%, and 77%. The Fruit Set treatment was found to be most effective in terms of crocin levels. Overall, the results of this research showed positive effects of gibberellin on quantitative yield and auxin on the number of daughter corms. In addition, the application of the Fruit Set improved the flowering and quality characteristics of saffron.

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1. Introduction

Saffron (*Crocus sativus* L.) is one of the most important medicinal and aromatic plants belonging to the Iridaceae family. Saffron contains more than 150 volatile and aroma-yielding compounds, and is a rich source of phenolic compounds with antioxidant activity (Ghanbari and Khajoei-Nejad, 2021). It also contains various apocarotenoids i.e., crocin, picrocrocin, and safranal which are responsible for the dark red color, bitter taste, and aroma of the saffron which have many applications in the production of food, pharmaceutical and chemical products (Kareem *et al*., 2019). Almost 94% of the total world's Saffron production (298 t) and 95% of total Iran's Saffron production (280 t) originates from the Khorasan province (Rezvani Moghaddam *et al*., 2016). Based on data from the Ministry of Agricultural Jahad, Khorasan area of the Khorasan province in 2019 amounted to about 91,000 hectares. Furthermore, saffron has an important role in providing livelihoods for about 70% of its benefactors and about 38% of them gained more than 50% of their income from the Saffron trade (Ramezani *et al*., 2022). Saffron is extensively cultivated in arid and semi-arid agricultural lands due to its low water and nutrient

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requirements as well as its high ecological and environmental adaptability and its unique economic characteristics (Shajari *et al*., 2022).

Applying foliar fertilizers and phytohormones amendments have been considered a potential way for the improvement of nutrient status and nutrient use efficiency of the plants as a result of direct absorption through the leaves (Ayub *et al*., 2021; Salas *et al*., 2020).

The higher use efficacy of foliar fertilizers compared to soil-applied fertilizers is well demonstrated (Ferrari *et al*., 2021; Shahrajabian *et al*., 2022). Results of several studies have shown that foliar application of nutrients (both macro and micro levels) has many benefits, including enhancing crop yield and quality parameters, increased resistance to insects, pests, and diseases, drought tolerance, soil salinity tolerance, and resistance to physiological stresses. (Niu *et al*., 2021; Shahrajabian *et al*., 2022).

Phytohormones (such as jasmonates, gibberellins, abscisic acid, brassinosteroids, nitric oxide, salicylic acid, etc.) have evolved to control vital functions in regulating various plant physiological and developmental processes (Sadiq *et al*., 2020). It revealed that gibberellic acid (GA) considered as major phytohormone which is regulated flower differentiation and development (Sheng *et al*., 2022). Furthermore, it plays an important role in cell division, plant height, dry matter accumulation, net assimilation rate, leaf expansion, elongation, photosynthesis, and transpiration rate (Javid *et al*., 2022; Sheng *et al*., 2022). Most of the studies into the hormonal control of flowering have been performed on the effects of GA, However, the involvement of other growth regulators, including auxins (IAA) has also been considered (Renau-Morata *et al*., 2021). indole-3-acetic acid (IAA) is an important phytohormone, which is associated with almost all stages of the plant's life cycle and stimulates cell division and elongation, lateral root (LR) initiation, apical dominance, tropic responses, and vascular tissue differentiation (Mishra *et al*., 2022). N-phenyl-phthalamic acid (PPA) is known as an auxin synergist growth regulator which is indeed a sort of flowering activator in plants. PPA contributes to enhancing the ovule longevity and receptivity of the stigma and supports better pollination processes, which results in a higher yield (Khadivi-Khub and Nosrati, 2013). The positive effect of PPA has been reported on flower formation, fruit set, and yield of different crops (Zahiri Barsari *et al*., 2018).

A few studies have been conducted on the effects of plant growth regulators and foliar fertilizers on saffron. It was investigated that GA and 6-benzylaminopurine had improved saffron flower quality and quantity by increasing the availability of carbohydrates. Furthermore, the length of stigma in corms treated with GA differed significantly from untreated corms (Javid *et al*., 2022). Based on the results of Ameri et al. (2019) the highest and lowest fresh and dry weight of harvested flowers in saffron were observed in 150 ppm GA3 (24.24 and 3.11 g plot^{-1}) and NAA (1.53 and 0.46 g plot^{-1}), respectively.

Fertilizer spraying during winter months also increased the number of flowers in saffron (Hosseini *et al*., 2003). Golzari Jahan Abadi et al. (2017) investigated the effects of different fertilizer sources on saffron (*Crocus sativus* L.). Their results indicate that foliar treatments increased leaf number, fresh weight, and dry weight of leaves, as well as the number of daughter corms. Khorramdel et al. (2015) also report that different levels of foliar fertilizer significantly influenced saffron yield components and growth characteristics. They found that Dalfard 15® foliar spraying at a rate of 15% (containing N, P, K, iron chelate, zinc, magnesium, and copper) was the most effective treatment.

Because the trend of planting saffron in Iran is increasing, particularly in the Faruj regions, and the remarkable demand for the nutraceutical and medicinal properties of this plant, finding solutions to increase the quality and production of this medicinal plant per unit area is essential. Given the role of phytohormones and foliar fertilizers on saffron, this study aims to evaluate the quality and quality of the saffron plants in Farooj by applying Fruit Set as foliar fertilizer and GA, IAA, and PPA as phytohormones.

2. Materials and methods

2.1. Experimental site and design

A randomized complete block design with three replications was conducted at the Experimental Farm in Farooj (37°13′52″N 58°13′08″E), located in the north of Khorasan, Iran, in 2020-2021.

Seven treatments were included in this study: 1-Control, 2- Gibberellin (200 ppm), 3-Auxin (200 ppm), 4- foliar spraying of Fruit Set (specific fertilizer

containing 8.75% N as NO_3^-, 4.37% Zn, and 10% B, 6%K, and 6% sea weed extract (contains both GA = 44ppm,) at a rate of 0.5 L/ha + gibberellin (200ppm), 5-Fruit Set foliar fertilizer (0.5 L/ha), 6- N-phenyl-phthalamic acid (200 mg/L as irrigation), and 7-N-phenyl-phthalamic acid (spraying with 200 mg/L).

2.2. Agronomic Practices and treatments application methods

In the experimental area, soil samples were collected at depths between 0 and 40 cm before basal fertilizer was applied. The soil test results are presented in Table 1. Bed preparation for saffron planting was done by plowing at a 25-30 cm depth in mid-April when spring rains were over. In Iran cow manure with rates of 10–80-ton ha−1 based on the type of soil and farmers habits is applied to the saffron fields due to low soil organic matter (Kafi *et al*., 2018). composted manure was spread at rate of 10 tons per hectare and thoroughly mixed into the soil before the last tillage operation. However, in addition to the application of farm manure, chemical fertilizers composed of granular sulfur (200 kg ha−1), triple super phosphate (50 kg ha−1) and potassium sulfate (70 kg ha−1) were applied considering to plant requirements rate and soil result to restore and sustain soil fertility (Kafi *et al*., 2018). finally, saffron corms were planted in August 2018. The experiment consists of 21 plots with a length of 20 meters and a width of 4 meters, separated by 50 cm. The experimental fields were kept free of weeds by hand weeding. For cultivation, healthy and high-quality corms with a dry weight of about 20 grams were used. Carbendazim as a fungicide and Omite (Propargite 57% EC) as miticide (Acaricide) were applied before planting and corms were cultivated by a spacing of 17 cm between rows, with 17 cm within row. The field was irrigated after planting, followed by second irrigation two weeks later. all treatment was applied before the flowering stage and Phenyl – Phthalamic acid (Nevirol 60 WP doses: Barafshan commercial name) was used for PPA treatment, and in the control treatment, foliar spraying with distilled water was also done at the same time as hormonal and foliar application treatments.

2.3. Sampling and measurements

two stages of sampling were performed: at the end of the growing season, and at the flowering time. The weight of produced corms in each plot was measured at the end of the growing season, by harvesting one-third of the cultivated corms. At the flowering time of plants growing in the remaining part of each plot, the flowers were harvested daily and the number and weight of flowers per plot were recorded. Then Stigma was separated from the flowers by hand and kept for 48 h at a room temperature of 25 °C (Ameri *et al*., 2019). For determining saffron quality characteristics including crocin, picrocrocin, and safranal, ISO/TS 3632- 2:2003 standard was considered. For quantifying the most important saffron components; crocins (color), picrocrocin (taste), and safranal (odor), have been identified and quantified using a UV spectroscopy determination (Varian-Cary 300 spectrophotometer; Agilent, Santa Clara, CA, USA) of the absorbance at 257, 330 and 440 nm, respectively (Rahaiee *et al*., 2015).

2.4. Statistical analysis

Data analysis was performed using statistical analysis variance (SAS 9.4) (SAS Institute, Cary, USA), and the means of the treatments were compared using the least significant difference (LSD) test ($P < 0.05$).

Table 1. Analysis table of some physical and chemical properties of farm soil

Soil texture	EC (dS/m)	nitrogen %	pH	Organic matter (%)	Phosphorus (%)	Potassium (ppm)
Loam clay	1.54	0.055	7.76	0.085	2.3	380

Table 2. Analysis table of some chemical properties of cow manure

	EC (dS/m)	nitrogen %	pH	Organic matter (%)	Phosphorus (%)	Potassium (ppm)
Cow manure	4.1	0.8	9.3	45	0.5	3200

3. Results and discussion

According to the variance analysis (Tables 3 and 4), all experimental significantly influenced flower height, leaf height, flower weight, number of mother corms, and the weight of mother corms, number of daughter corms, diameters of mother corms and diameters of daughter corms, as well as picrocrocin and crocin. In contrast, no treatment affected safranal.

Table 3. Variance analysis table of studied traits

S.O.V	df	The height of the flowers from the soil	flower weight	Number of mother corm	weight of mother corm	Number of daughters
Replication	2	0.8919^{ns}	3027604.7^{ns}	6.619*	1.476*	0.904^{ns}
Treatment	6	2.76*	720752.3*	20.22**	159.41**	60.42**
Error	12	0.71	536004.7	6.563	20.698	15.293
C.V%	-	9.55	32.9	21.01	15.81	17.07

Table 4. Variance analysis table of studied traits

S.O.V	df	Diameter of mother corm	Diameter of daughter	crocin	Picrocrocin	safranal
Replication	2	0.176^{ns}	0.0933*	16.0997*	36.01*	3.058^{ns}
Treatment	6	5.22**	3.22**	2322.78**	430.14**	17.942^{ns}
Error	12	1.407	0.281	25.6703	50.012	10.316
C.V%	-	10.36	6.68	2.03	8.12	8.95

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

3.1. The height of the flowers from the soil

According to the result (Table 3), the treatments significantly affected the height of the flowers from the soil (P≤0.05). the height of the flowers from the soil of 10.33 cm was observed in the Fruit Set treatment, which was 31 percent higher than the control treatment (7.83 cm), while PPA treatments (irrigation or foliar spraying) were not significantly differed (Fig. 1). An increase in the height of the flowers from the soil occurred in Fruit Set might due to the presence of zinc, iron, and particularly nitrogen in Fruit Set compared to other treatments.

Nitrogen and micro-nutrients such as zinc, which are the precursors of the synthesis of S-amino levulinic acid, which is also the precursor for the synthesis of chlorophyll and photosynthesis in the plant (Azizi *et al*., 2020). In addition, considering the Fruit set included seaweed, the growth stimulants in seaweed prevent the destruction of chlorophyll, and as a result increase photosynthesis (Azizi *et al*., 2020). It also is important to note that the Fruit Set contains zinc and boron, both of which play a crucial role in protecting saffron from stress and enhancing its quality. Akrami et al. (2015) also reported that the consumption of 25 kg ha^{-1} zinc sulfate increased by 65% number of flowers, 84% weight of flowers, 73% fresh weight stigma and %150 dry weight of stigma to control. Our results confirmed the results of Rostami et al. (2019). Who reported that Z improved all flower indices in saffron. Considering the fact that saffron production is labor-intensive and the close gap between the flower and soil is an important limitation of saffron harvesting time, Increasing the height of flowers positively decreases the time of picking saffron flowers by labor, consequently applying Fruit Set can be assumed that it will also decrease the labor cost (Saeidirad, 2020). In this regard, Azizi et al. (2020) concluded both micronutrient and sea weed increased all flower indices via more photosynthesis and partitioning to reproductive growth.

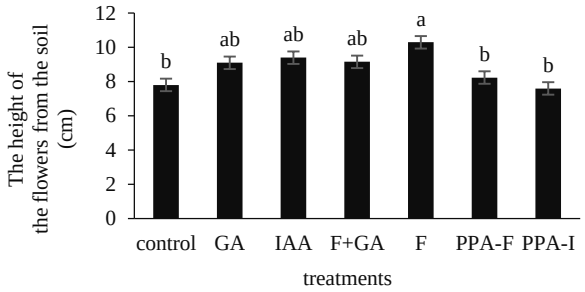

Figure 1. The effect of different treatments on the height of the flowers from the soil. (Gibberellin (GA), 3-Auxin (IAA), 4- Fruit Set + gibberellin (F+GA), 5-Fruit Set (F), 6- foliar application of N-phenyl-phthalamic acid (PPA-F), and irrigation application of 7-N-phenyl-phthalamic acid (PPA-I)

3.2. Flower weight

According to the results, flower weight was significantly affected by different treatments (P≤0.05) (Table 3). Among the treatments, the control treatment had the lowest flower weight (1446.67 g). In the N-phenyl-phthalamic acid irrigation treatment, flower weight increased by 23%, while in the foliar spraying treatment, flower weight increased by 29%. Moreover, Fruit Set + gibberellin (2790 g), Fruit Set (2423 g), auxin (2570 g), and gibberellin (2555 g) significantly differed from the control treatment, with an increase of 93, 67, 78, and 77%, respectively, in comparison to the control treatment (Fig. 2). Reports showed that exogenous GA increased flower production in plants (Heidari *et al*., 2022; Javid *et al*., 2022). Javid et al. (2022) concluded that the weight of flowers increases in response to plant regulators application. According to their results both GA3 and Cytokinin (BAP) affect on the metabolism of stored compounds. It is observed that GA_3 showed significant priority for flower numbers, flower fresh and dry weight, as well as stigma dry weight. It seemed that corms immersed in GA_3

solution increased corm internal GA concentration and improved flower production and dry weight (Heidari *et al*., 2022). GA also increased invertase activity in target tissues which accelerated the development of physiological processes and flower production by the accumulation of carbohydrates and more starch conversions into sugar, (Javid *et al*., 2022). which leads to the enhancement of cell division and cell elongation and improved flower yield (Shakeri *et al*., 2018). has been reported by researchers that the capacity of saffron to flower is determined by corm weight (Koocheki *et al*., 2019). A direct relationship between the weight of the corm and the yield of saffron flowers has been reported by researchers (Shakeri *et al*., 2021). The results of correlations also showed that these traits had a positive correlation (R=0.53*).

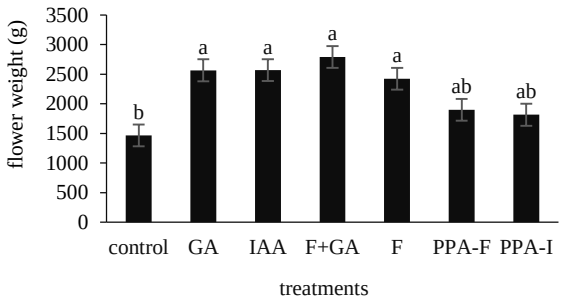

Figure 2. The effect of different treatments on flower weight. (Gibberellin (GA), 3-Auxin (IAA), 4- Fruit Set + gibberellin (F+GA), 5-Fruit Set (F), 6- foliar application of N-phenyl-phthalamic acid (PPA-F), and irrigation application of 7-N-phenyl-phthalamic acid (PPA-I)

3.3. The weight of the mother corm

Based on the results of the analysis of variance, different treatments in saffron had a significant impact on the weight of the mother corm ($P \leq 0.01$) (Table 3). Compared to the control treatment, gibberellin treatment increased the mother corm weight by 47%. The weight of the mother corm was not affected by other treatments (Fig. 3). Ameri et al. (2019) found that each saffron corm can produce 1 to 12 flowers, depending on its initial size and corm weight. According to their results application of 150 ppm, GA3 increased the weight of corms by 16.25 %. The weight of the mother corm is one of the important factors that determine the formation of daughter corms which will be considered as mother corms in the second year. It also affected the capacity of saffron for flowering. Increasing the weight of the mother corm caused more absorption and storage of moisture and the amount of nutrients in the corms, and as a result, it provides more assimilates transfer to leaf cells and photosynthesis and flowering (Shakeri *et al*., 2021).

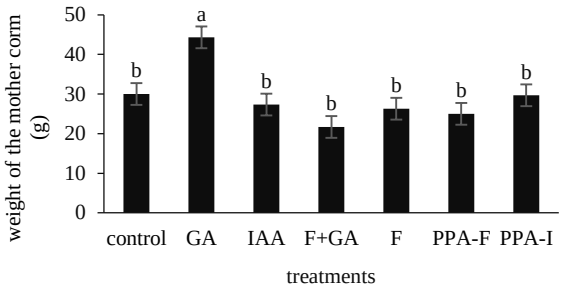

Figure 3. The effect of different treatments on the weight of mother corm. (Gibberellin (GA), 3-Auxin (IAA), 4- Fruit Set + gibberellin (F+GA), 5-Fruit Set (F), 6- foliar application of N-phenyl-phthalamic acid (PPA-F), and irrigation application of 7-N-phenyl-phthalamic acid (PPA-I)

3.4. The Diameter of mother corm

Different treatments significantly affected the diameter of the mother corm (Table 3). In the gibberellin treatment, the diameter of the mother corm increased from 10.16 cm to 14 cm compared with the control treatment (37%). The lowest diameter of the mother corm was also observed in the control treatment, which was not significantly different from the other treatments (Fig. 4). The increase in weight, size and volume of the corm with the application of GA3 can be attributed to increasing in the number of leaves per plant and leaf thickness which increased the photosynthetic assimilates. These assimilate are transported to the resulting daughter corms, thereby, increasing their weight, size and volume. Similar findings have also been reported by Roy et al. (2017). They have been reported maximum average diameter of daughter and mother corms was recorded for GA3 at 200 ppm.

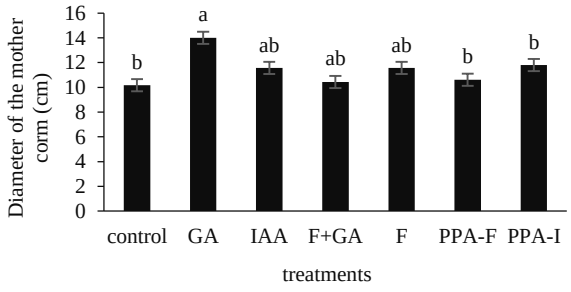

Figure 4. The effect of different treatments on the Diameter of mother corm. (Gibberellin (GA), 3-Auxin (IAA), 4- Fruit Set + gibberellin (F+GA), 5-Fruit Set (F), 6- foliar application of N-phenyl-phthalamic acid (PPA-F), and irrigation application of 7-N-phenyl-phthalamic acid (PPA-I)

3.5. The Number of daughter corm

Different treatments significantly affected the number of daughter corms ($P \leq 0.01$) (Table 3). Auxin treatment (32.33) produced the highest number of daughter corms over the control treatment (13.33). Based on the mean comparison results, other treatments except for Fruit Set treatments (21.33) and N-phenyl-phthalamic acid irrigation (13.66) significantly differed from the control treatment. Compared to the control treatment, gibberellin, N-phenyl-phthalamic acid foliar spray and Fruit Set + gibberellin produced 1.2, 1 and 0.8 times more daughter corms (Fig. 5). It was indicated that foliar spraying of phenylphthalmate on fruit vegetables such as tomato, cucumber and eggplant and cabbage had a positive effect on yield and yield components. It might be the role of PPA in the reduction of the terminal dominance and more appropriate distribution of carbohydrates and nitrogen in the whole plants (Javanpour *et al.*, 2014). Furthermore, several studies have revealed that growth regulators can enhance cell division, The increased growth and division of cells will result in greater assimilation and improved performance (Behdani *et al.*, 2020). According to Behdani et al. (2020), applying Acadian seaweed to plants increased the number of daughter corms.

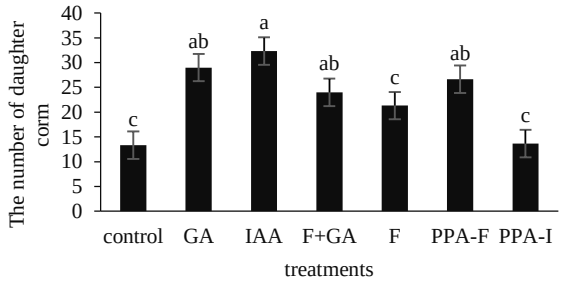

Figure 5. The effect of different treatments on the Number of daughter corm. (Gibberellin (GA), 3-Auxin (IAA), 4- Fruit Set + gibberellin (F+GA), 5-Fruit Set (F), 6- foliar application of N-phenyl-phthalamic acid (PPA-F), and irrigation application of 7-N-phenyl-phthalamic acid (PPA-I)

3.6. Diameter of daughter corm

According to Table 4, different treatments significantly influenced the diameter of the daughter corms ($P \leq 0.01$). The diameter of daughter corms was greatest in gibberellin (9.1 cm), Fruit Set (8.8 cm), and auxin (8.6 cm) treatments, which increased by 37, 33, and 31%, respectively, over the control treatment (6.6 cm). A significant increase of 25% was also observed as a result of N-phenyl-phthalamic acid foliar spraying in addition to the effects of the mentioned treatments on the diameter of the daughters' corms (Fig. 6). The mature and bigger mother corms in the previous studies have shown more flowers and daughter corms (Bayat *et al.*, 2016). The result of correlation in this study also showed a positive relation between mother corm size (diameter and weight) and the diameter of the daughters' corms (Appendix table) By increasing leaves, nutrient absorption from the soil is enhanced because of increased root secretions, which stimulate the beneficial microbe population in the root environment. Therefore, more elements, vitamins, and other useful substances are available for the plant, resulting in more underground organs (Behdani *et al.*, 2020).

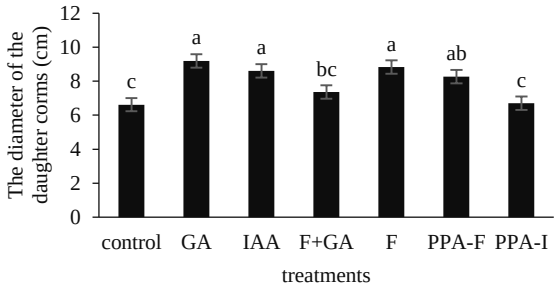

Figure 6. The effect of different treatments on the Diameter of daughter corm. (Gibberellin (GA), 3-Auxin (IAA), 4- Fruit Set + gibberellin (F+GA), 5-Fruit Set (F), 6- foliar application of N-phenyl-phthalamic acid (PPA-F), and irrigation application of 7-N-phenyl-phthalamic acid (PPA-I)

3.7. Crocin

There was a significant difference between treatments for crocin ($P \leq 0.01$) (Table 4). The highest units of crocin were obtained by Fruit Set (292 units at 440 nm), while the lowest units were obtained by control (217 units at 440 nm) and N-phenyl-phthalamic acid irrigation (221 units at 440 nm). Moreover, N-phenyl-phthalamic acid sprayed (242 units at 440 nm wavelength), auxin (258 units at 440 nm wavelength), and Fruit Set + gibberellin (276 units at 440 nm wavelength) gibberellin (236 units at 440 nm wavelength) increased crocin by 26, 18, 11 and 8% respectively, in comparison to the control treatment. (Fig. 7). Using all treatments resulted in an increase in crocin in saffron, showing that by providing timely and complementary nutrition, the amount of crocin, can be increased significantly. A similar result was observed in the study of the quality and quantity of the active

constituents by applying different fertilizers (agrimel, multipurplex and prolix) on saffron in Kashmar. their results showed that higher amounts of picrocrocin and safranal in multi purplex group (fertilizer contains nitrogen, micronutrient and amino acid and hormones), in comparison with prolix (fertilizer contains nitrogen, micronutrient and amino acid) and agrimel (fertilizer contains nitrogen, micronutrient and amino acid), could be due to the presence of hormones and carbon in this fertilizer (Rabani-Foroutagheh *et al*., 2014).

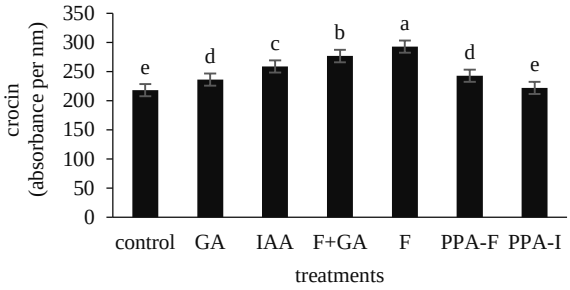

Figure 7. The effect of different treatments on crocin. (Gibberellin (GA), 3-Auxin (IAA), 4- Fruit Set + gibberellin (F+GA), 5-Fruit Set (F), 6- foliar application of N-phenyl-phthalamic acid (PPA-F), and irrigation application of 7-N-phenyl-phthalamic acid (PPA-I)

3.8. Picrocrocin

Picrocrocin was significantly affected ($P \leq 0.01$) by different treatments (Table 4). The Fruit Set treatment revealed the highest amount of picrocrocin at 257 nm (105 units), an increase of about 37% over the control treatment. The other treatments had a significant and increasing effect on picrocrocin levels, with the exception of N-phenyl-phthalamic acid spray (79 units at a wavelength of 257 nm). As a result of the application of Fruit set +gibberellin, auxin, gibberellin, and p N-phenyl-phthalamic acid irrigation, picrocrocin levels were increased by 25, 23, 14 and 12%, respectively (Fig. 8).This result, in agreement to what reported in the study of applying growth promoting fertilizer containing seaweed extract on qualitative parameters in petals and stigmas of saffron which study showed that the highest amounts of safranal (42.43), crocin (198.78) and picrocrocin (74.57) were obtained when fertilizer was used (Khandan Deh-Arbab *et al*., 2020). Increasing nutrient availability of elements status also was found to improve the biosynthesis of secondary metabolites in saffron, because it could favor the crocin and picrocrocin biosynthesis and its accumulation in stigmas (Cardone *et al*., 2020). Rabani-Foroutagheh et al. (2014) indicated that foliar fertilization with 'Agrimel', enhanced the saffron quality showing a positive effect on crocin and picrocrocin content but a negative effect on safranal. It also is important to note that the Fruit Set besides sea weed (contains hormones), contains different elements such as nitrogen, zinc and boron, which provides more nutrient availability for the plant.

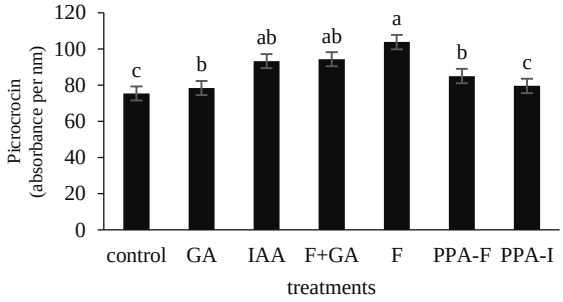

Figure 8. The effect of different treatments on picrocrocin. (Gibberellin (GA), 3-Auxin (IAA), 4- Fruit Set + gibberellin (F+GA), 5-Fruit Set (F), 6- foliar application of N-phenyl-phthalamic acid (PPA-F), and irrigation application of 7-N-phenyl-phthalamic acid (PPA-I)

3.9. Safranal

According to the results of the analysis of variance (Table 4), different treatments did not affect the amount of safranal.

4. Conclusion

The gibberellin growth regulator and Fruit Set nutrient solution affected the most important characteristics of the saffron plant, including flower weight, diameter, number of mother and daughter corms, and crocin and picrocrocin. As a result, the Gibberellin growth regulator is an important factor in plant nutrition, and should therefore be considered when developing a nutritional program for plants. Moreover, by utilizing Fruit Set as a food solution that contains essential elements for the flowering and fertility of the plant, an acceptable performance was achieved. However, the combination of these two treatments (gibberellin + fruit set) did not produce satisfactory quantitative and qualitative yields in saffron. As well as gibberellin and fruit set, auxin treatment demonstrated acceptable results. This treatment was the most effective in terms of economic performance (increasing daughter corm diameters and numbers) and improved vegetation indices for the next years. Overall, it can be concluded from the results that all treatments except N-phenyl-phthalamic acid had positive effects on saffron yield. Based on the

cultivation and the annual fertilizer consumption, certain amounts of these treatments (especially Fruit Set and gibberellin) may be considered in order to enhance the productivity of the saffron fields.

Appendix. Correlation of measured traits

	1	2	3	4	5	6	7	8	9	10
The height of the flowers	1									
Weight of mother corm	-0.028	1								
Number of mother corm	0.455*	0.391*	1							
Number of daughter corm	0.377*	0.288	0.597**	1						
Diameter of mother corm	0.155	0.800**	0.522**	0.337	1					
Diameter of daughter corm	0.429*	0.412*	0.422*	0.656**	0.394*	1				
Crocin	0.669**	-0.286	0.323	0.404*	-0.016	0.464*	1			
Picrocrocin	0.658**	-0.149	0.464*	0.465*	0.109	0.607**	0.956**	1		
Safranal	0.518**	-0.009	0.244	-0.129	0.098	0.221	0.386*	0.465*	1	
Flower weight	0.40*	0.53*	0.290	0.325	0.263	0.358	0.347	0.375*	0.420*	1

*. significant at the 0.05 level
**. significant at the 0.01 level

Conflict of Interests

All authors declare no conflict of interest.

Ethics approval and consent to participate

No human or animals were used in the present research.

Consent for publications

All authors read and approved the final manuscript for publication.

Availability of data and material

All the data are embedded in the manuscript.

Authors' contributions

Ghorban Ali Rassam has made substantial contributions to conception and design, writing—original draft preparation and supervision; Hadis Khoshkoo contributed analysis and interpretation of data. Mahdi Babaeian and Samaneh Rahban have been involved in verifying the analytical method and revising the manuscript critically for important intellectual content. Zahra Taghizadeh Tabari was involved in editing.

Informed Consent

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