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Comparative Effects of Four Plant Growth Regulators on Yield and Field Performance of *Crocus sativus* L.

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Abstract: The effects of four plant growth regulators on *Crocus sativus* L. (saffron) yield and performance were studied in two consecutive years under field conditions. Saffron corms were immersed in solutions of gibberellic acid (GA_3), salicylic acid (SA), paclobutrazol (PBZ), chlormequat chloride (CCC), distilled water (hydroprime), and dry corms as the control. Results showed that among the different treatments, plants primed with GA_3 500 µM had the highest flower fresh weight and stigma dry weight. In contrast, primed corms with 1000 µM CCC and 100 µM PBZ had the lowest flower dry weight. Furthermore, the plants primed with SA 1400 had the highest leaf numbers, leaf dry weight, and leaf area index (LAI). Plants treated with GA_3 induced narrow but the longest leaves, while those treated with SA showed the widest ones. It was also demonstrated that the application of CCC and PBZ can produce shorter leaves. Furthermore, the greatest numbers of daughter corms were obtained in 1400 µM SA. Both PBZ and CCC were reported to have no impacts on the corm numbers but produced larger and heavier daughter corms. The results revealed that the priming of saffron corms with GA_3 and then SA improved saffron growth and yield.

Keywords: chlormequat chloride; *Crocus sativus* L.; gibberellic acid; paclobutrazol; priming; salicylic acid; stigma yield

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1. Introduction

Crocus sativus L. (saffron) is an herbaceous perennial plant from the Iridaceae family. It is one of the most significant medicinal spice and aroma plants, which plays a remarkable role in world trade. Saffron is a plant native to Asia, and Iran is one of the leading countries in terms of cultivated area and rate of production [1]. Afghanistan, Greece, Morocco, India, Spain, and Italy are other producers of saffron, though their production levels are negligible [2]. Saffron is a complicated plant as it has reduced inflorescence and a very short stand under the ground [3]. Saffron sprouting and flowering are regulated by the interaction of phytohormones and sugar signals [4]. Different methods, such as planting larger and heavier corms, application of fertilizers, optimizing plant nutrition, and utilizing plant growth regulators (PGRs), have been proposed to increase saffron yield. Accordingly, Kothari and colleagues stated that the primary application of PGRs induces saffron growth and development by alternating the plant growth retardants ratio and/or enhancing growth promoters [5].

There are two main groups of PGRs, growth promoters and retardants [6–16]. Growth promoters mainly enhance cell division and enlargement; stimulate growth rate and height; and promote flowering, fruiting, and seed formation [11,12,17–20]. Among plant hormones, gibberellins (GA) interfere in many plant growth and developmental processes, such as seed germination, dormancy breaking, stem elongation, flowering, fruit ripening, and senescence [21]. As stated in the literature, GA application enhanced plant weight, height, root length, diameter [22], and leaf growth [21]. Asil and Ayanoglu reported the immersion

of saffron corms in GA_3 solution stimulated flowering and stigma dry weight [23]. Salicylic acid (SA) or ortho-hydroxy benzoic acid is an internal growth regulator from natural phenol compounds that plays a key role in the physiological processes of plants. Stimulation of flowering, growth, and synthesis of ethylene is the most important role of this hormone [24]. In different concentrations, SA had significant effects on flower numbers and date of flowering on *Petunia* plants. SA increased flower numbers in lower concentrations, but in higher concentrations, it increased flower numbers and accelerated flowering six days earlier than control plants [25].

Plant growth retardants are a group of PGRs, which are mainly able to inhibit or interfere with gibberellin biosynthesis and ultimately inhibit plant growth and development. Paclobutrazol (PBZ) is a plant growth retardant that belongs to the triazoles group. The PBZ molecule has a heterocyclic structure with three nitrogen atoms, including two enantiomers with regulatory and fungicidal activity. The improving effects of PBZ have been reported in plant functions [26]. For example, PBZ increased the female flower and fruit numbers per plant but reduced male flowers in pumpkin [27]. PBZ reduced shoot growth and increased roots formation, growth, and densityin cowpea. Moreover, PBZ increased the root/shoot ratio and root systems and induced darker leaves [27]. Chlormequat chloride (CCC) inhibits gibberellin biosynthesis in the phase of geranyl geranyl pyrophosphate changes to ent-kaurene [26] but enhances cytokinin concentration [28]. CCC reduces the rate of cell division and elongation in shoots, which results in shorter plants [26]. Zhao and colleagues examined the spraying of GA, BA, and CCC on Chinese pine [29]. Results showed that there are different effects on male and female strobili based on applied PGR and concentration. CCC of 500 mg/L increased female strobili, but 1000 mg/L enhanced the appearance of male strobili. Meanwhile, GA of 500 mg/L had significant effects on female strobili numbers compared to the control plants. It showed that PGRs in different concentrations had different impacts on the plants' physiological processes [29].

Saffron yield and productivity are low in the planting year; therefore, saffron producers do not earn enough money during the first growing season. Stimulating saffron plants with PGRs to increase flower numbers will lead to increased yield and economic income. According to our searches, there are not enough reports on the effects of growth retardants, such as PBZ and CCC, on saffron flowering or its response to these PGRs. On the other hand, the effects of growth stimulators or retardants on saffron are not evaluated as comparative. In this research, the corm priming with four PGRs at different concentrations besides hydropriming was examined to evaluate their effects on saffron yield and field performance.

2. Materials and Methods

2.1. Plant Growth Conditions

This research was carried out in a research station of Agriculture Faculty of Zanjan University, Zanjan, Iran. The station is located in the northern latitudes of 40° and 36′, the eastern length of 24° and 48′, and an altitude of 1610 m from sea level. The experiment was done in a completely randomized block design with three replications in two years of 2015–2016 and 2016–2017. Soil samples were taken from 0–30 cm depth in three replications before the experiment. Air-dried samples were measured in terms of some physical and chemical characteristics. The results of soil analysis are shown in Table 1. Average meteorological data of two years was shown in Table 2.

Table 1. Physical and chemical soil traits of Zanjan University's research station.

pH	Electrical Conductivity (mS/m)	K (ppm)	P (ppm)	Total Nitrogen (%)	Sand	Silt	Clay	Soil Texture	Bulk Density ($g \cdot cm^{-3}$)	Moisture Content (%)	Sample Depth (cm)
7.56	13.86	267	13.4	0.12	52	31	17	Sandy loom	1.564	1.56	0–30

Table 2. Average meteorological monthly data of Zanjan Agricultural Research Station in the two years of experiment on saffron response to four PGR applications in 2015/2016 and 2016/2017.

2015/2016	**April**	**May**	**June**	**July**	**August**	**September**	**October**	**November**	**December**	**January**	**February**	**March**
Precipitation	83.2	6.6	0.5	1.1	0.0	2.9	16.6	73.6	14.6	15.9	31.8	31.6
Mean Temp	10.8	16.7	22.3	26.6	25.9	21.5	17.3	9.5	2.5	2.4	2.3	8.8
Min Temp	4.2	8.4	12.9	18.5	16.1	12.7	9.1	4.6	−2.8	−2.8	−3.2	2.6
Max Temp	17.4	25.0	31.8	34.6	35.8	30.3	25.4	14.3	7.9	7.7	7.9	15.0
Mean Relative Humidity	56	46	44	41	36	50	52	66	65	64	63	56
2016/2017	**April**	**May**	**June**	**July**	**August**	**September**	**October**	**November**	**December**	**January**	**February**	**March**
Precipitation	62	28.1	15.9	1.6	0	0	0.1	22.6	21.9	9.7	27.2	42
Mean Temp	9.5	16.5	19.9	24.7	25.6	22.6	15.6	11.3	1.81	1.7	−0.5	4.3
Min Temp	3.7	8.6	11.1	16.5	16.3	12.8	6.1	4.3	−4.4	−4.5	−5.2	−2.4
Max Temp	15.3	24.4	28.6	32.9	34.8	32.5	25.1	18.2	8	7.8	4.1	11
Mean Relative Humidity	61	55	47	46	42	42	46	55	54	62	67	60

2.2. Treatments

Treatments included control treatment (non-primed corms); primed corms by distilled water (hydroprime, HP); GA_3 (Merck, Darmstadt, Germany) with 250, 500, and 750 µM; SA (Merck, Darmstadt, Germany) with 700, 1400, and 2100 µM; PBZ (Merck, Darmstadt, Germany) with 50, 100, and 150 µM and CCC (Merck, Darmstadt, Germany) with 500, 1000, and 1500 µM.

Corms were obtained in late June every two years from a farm in Torbat-e Jam, Iran and were transferred to the research station of the University of Zanjan. Uniform corms with two cm diameter and 8–10 g weight without wound or crush were selected. Saffron corms were soaked in the mentioned solutions for 24 h on 9 July and 7 July in the first and second years, respectively. Then, they were kept at room temperature for six days to reduce water content by airflow and return to the level before treatment. Corm disinfection was conducted with 5% copper sulfate. They were planted on 18 July every two years. The corms were planted in flat form with a density of 50 corms in each square meter in plots of 3×1.25 m^2 and 20 cm depth. Cultural practices, such as manual weed control and fertilizer application, were done through the growth seasons. Plots were not irrigated until October and then irrigated in mid-October. Saffron flowers appeared two weeks after irrigation. Flowers were harvested daily from all plots in both years in the early hours of the morning, and their fresh weights were measured. Following this stage, stigmas were separated from flowers. After drying, stigma dry weights were measured on a digital scale with 0.001 g balance. Twelve plants were taken out from each plot to evaluate the effect of the experimental treatments on daughter corms and leaf growth in early April. Daughter corm numbers and the numbers of leaves in each corm were recorded. After separating the leaves, individual leaf widths and lengths were measured by a ruler. Leaf area was recorded by leaf area meter (ΔM200, ADC.CO.UK), and leaf area index was calculated by dividing the leave area to ground area [30]. After drying the corms and leaves at 70 °C, the dry weights were measured using a 0.001g balance.

2.3. Statistical Analysis

MSTATC 5.4 and Excel software were used to analyze data and draw the figures. Moreover, Duncan's multiple range test was employed to compare the means of each trait at 5% probability. Before combined analysis, homogeneity of variance of experimental errors was tested using Bartlett's test.

3. Results

The growth regulators at various levels had a significant effect on the dry weight of the flower and stigma, leaf area, leaf number, width and length of leaves, dry leaf weight, number of daughter corms, and fresh and dry weight of daughter corms in both years.

3.1. Leaf Size, Number and Dry Weight

The application of PGRs changed the width and length of the leaf compared to the control plants. The primed plants with GA_3 had leaves with narrow widths and longer lengths. The longest leaf was observed in GA 250 in the first year and GA 250 and 500 treatments in the second year (Table 3).

Table 3. Meancomparison of saffron vegetative traits primed with distilled water and different plant growth regulators.

Year	Treatment		Leaf Length (cm)	Leaf Width (mm)	LAI	Leaf Number	Leaf Dry Weight (mg)	Number of Daughter Corms	Corm Fresh Weight (g·m^{-2})	Corm Dry Weight (g·m^{-2})
2015–2016	Control		31 e	3 e	1.1 g	6.3 de	65 l	2 e	4.36 g	1.99 g
	HP		30 f	3.2 d	1.43 de	7.3 cd	97 k	3.33 b	14.3 b	4.7 c
	GA_3	250	38 a	2.1 h	1.23 f	8.3 bc	125 h	3 c	10.87 d	3.61 d
		500	37 b	2.3 g	1.59 c	9.7 b	165 f	3.33 b	9.73 e	3.05 e
		750	33 d	2.4 f	1.48 e	8.7 c	196 b	2.33 d	4.49 i	3.71 d
	SA	700	32 cd	3.4 c	1.56 d	7.7 d	143 g	3 c	16.06 a	6.11 a
		1400	35 c	4 a	2.73 a	10.3 a	217 a	5.5 a	15.55 b	5.03 b
		2100	31 e	4.1 a	2.37 b	8.7 c	175 e	3 c	6.85 g	2.42 f
	CCC	500	30 f	3.1 cd	1.11 g	5.7 f	108 hi	2.33 d	10.14 d	3 e
		1000	24 i	3 e	1.2 f	6.7 e	113 i	2 e	7.1 f	3.18 e
		1500	20 l	3.7 b	0.93 gh	5.3 g	122 gh	1.63 f	6.05 g	2.16 f
	PBZ	50	28 g	3.2 d	0.84 hi	4.7 h	191 c	1.66 f	12.18 c	3.67 d
		100	26 h	3.3 bc	1.07 h	5.7 f	216 a	2.33 d	7.66 f	3.01 e
		150	22 k	3.6 ab	0.97 i	5.7 f	186 d	2.33 d	6.82 g	2.3 f
2016–2017	Control		27 e	3 e	0.96 f	6.1 cd	57 m	1.9 e	4.25 h	1.89 f
	HP		29 cd	3.2 d	1.23 bc	7.3 d	84 kl	3.91 b	14.21 b	4.71 ab
	GA_3	250	35 a	2 g	1.17 e	8.3 c	114 i	2.87 c	10.76 d	3.52 c
		500	35 a	2.4 f	1.51 c	9.1 b	157 f	3.01 b	9.62 e	3.04 d
		750	29 cd	2.4 f	1.13 d	8.1 c	178 c	2.32 d	6.38 g	3.61 c
	SA	700	30 d	3.2 d	1.22 bc	7.3 d	135 g	3.93 b	16.05 a	6.1 a
		1400	34 b	3.7 b	2.76 a	10.7 a	211 a	5.3 a	14.43 b	4.02 ab
		2100	29 cd	4 a	2.32 b	9.3 b	169 d	2.78 c	6.74 g	2.31 e
	CCC	500	31 c	3 e	1 de	5.7 e	971	2.22 d	10.03 d	3.01
		1000	22 g	3 e	0.87 g	6.3 cd	109 k	1.94 e	7.12 f	3.16 d
		1500	19 i	3.4 c	0.82 h	5.3 e	124 h	1.64 f	6.04 g	2.17 e
	PBZ	50	28 e	3.1 cd	0.81 h	4.7 f	183 b	1.59 f	12.07 c	5.55 b
		100	24 f	3.2 d	0.86 g	5.3 e	210 a	2.1 d	7.57 f	3.02 d
		150	19 i	3.4 c	0.83 h	5.3 e	162 e	2.1 d	4.71 h	2.21 e

Means sharing the same letter for a parameter in a growing season do not differ significantly at $p \leq 0.05$ (Duncan multiple range test).

The second rank was observed in SA 1400 treatment in both years. Furthermore, the application of SA in all concentrations produced wider leaves. CCC and PBZ reduced leaf length. This reduction happened due to the increased concentrations. The smallest leaf was observed in CCC 1500 and PBZ 150 treatments in both years. The leaf length reduction followed by the application of the growth retardants' compounds was accomplished with leaf width increase (Table 3). The leaf numbers in each corm treated with GA_3 and SA increased in both years compared to the control plants, but in the plants treated with CCC and PBZ, the leaf numbers reduced significantly. Also, in HP treatment, the leaf numbers did not show a significant difference with control plants (Table 3). The lowest leaf numbers were observed in CCC 1500 and PBZ 100 and 150 in both years. The increase in leaf numbers and leaf area in HP, GA, and SA treatments led to the increased leaf area index (Table 3). Among the PGRs treatments, SA had the greatest effect on leaf area index (LAI). SA 1400 treated plants had the highest LAI compared to the control group during the two years. The applications of CCC and PBZ reduced LAI compared to control plants.

All primed plants showed significant higher values in leaf dry weight than the control plants (Table 3). The highest dry weights of the leaf were obtained under SA 1400 and PBZ 100 treatments in both years.

3.2. Flower and Stigma Number, Fresh Weight, and Dry Weight

Growth retardants had no positive effects on the flower number. The application of these compounds along with HP treatment either reduced the flower number/m^2 or was equal with the control treatment (Figure 1). In fact, except for HP and PBZ 50 which had no significant differences with control treatment, other CCC and PBZ treatments reduced the produced flowers/m^2. Corm priming with GA_3 and SA increased the flower numbers/m^2 (Figure 1).

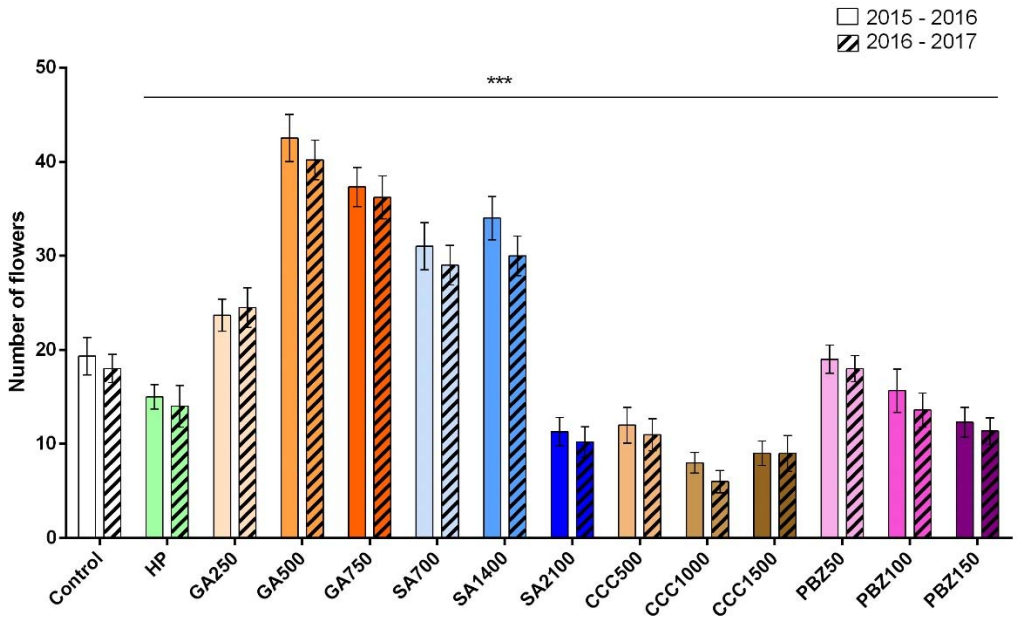

Figure 1. Effects of saffron corm priming with distilled water and four different growth regulators on flower numbers per m^2 grown under field condition. HP, hydropriming; GA, gibberellic acid; SA, salicylic acid; CCC, chlormequat chloride; PBZ, paclobutrazol. Data are shown as mean ± standard deviation; *** $p < 0.001$ vs. control group. The empty white and colored columns correspond to the data for the years 2015–2016. The white and colored columns with oblique lines correspond to the years 2016–2017.

The highest flower fresh and dry weights were observed in GA 500 and GA 750 treatments in both years (Figures 2 and 3). Like flower number, the lowest flower fresh weights were observed in CCC treated corms in both years. Additionally, the applications of PBZ 100 and 150 showed lower flower fresh and dry weights than PBZ 50 in both years. After GA_3 treatment, SA increased flower fresh and dry weights. Among the treatments, CCC 1000 had the lowest flower dry weight.

In both years, GA 500 following GA 750 produced the highest stigma fresh weight. The least stigma fresh weights were for CCC 1500 and PBZ 100 (Figure 4).

Priming corms with distilled water (HP) had no significant effect on stigma fresh weight. However, except for CCC 500, growth retardants had lower stigma fresh weights than the control. In general, CCC and PBZ not only did not show any priority to the control plants in both years, but further showed lower stigma dry weights than the control (Figure 5).

The highest stigma dry weight belonged to the GA 500 treatment in both years. After the GA_3 group, priming corms with SA showed higher stigma dry weights than the control plants. Priming corms with distilled water, HP, showed values near the control (Figure 5).

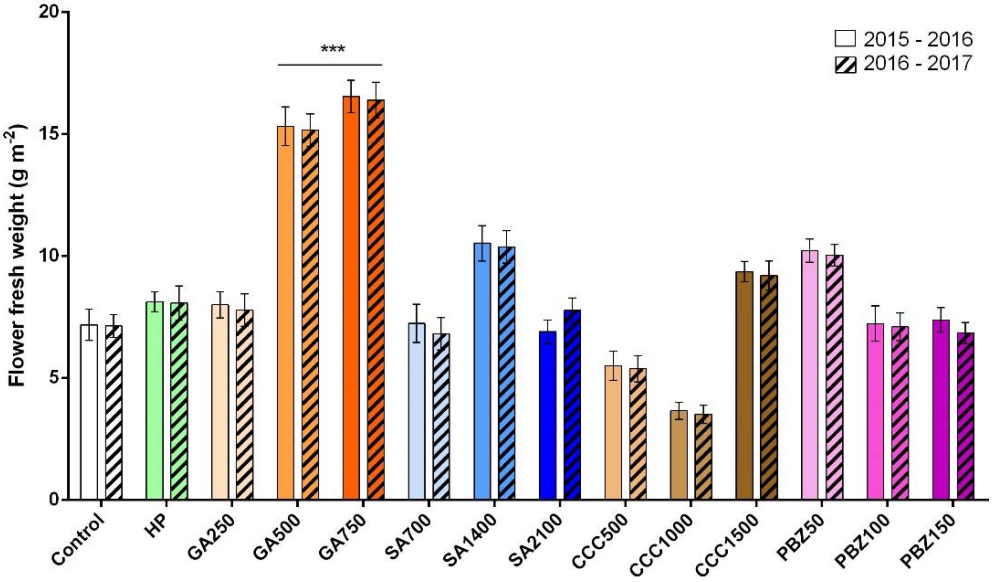

Figure 2. Effects of saffron corm priming with distilled water and four different growth regulators on flower fresh weight grown under field condition. HP, hydropriming; GA, gibberellic acid; SA, salicylic acid; CCC, chlormequat chloride; PBZ, paclobutrazol. Data are shown as mean ± standard deviation; *** $p < 0.001$ vs. control group. The empty white and colored columns correspond to the data for the years 2015–2016. The white and colored columns with oblique lines correspond to the years 2016–2017.

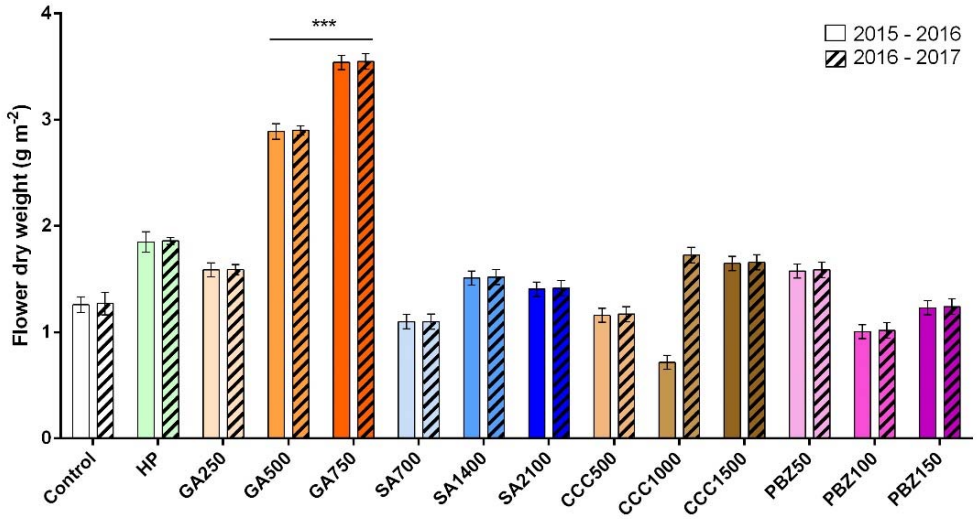

Figure 3. Effects of corm priming with distilled water and four different growth regulators on flower dry weight of saffron plants grown under field condition. HP, hydropriming; GA, gibberellic acid; SA, salicylic acid; CCC, chlormequat chloride; PBZ, paclobutrazol. Data are shown as mean ± standard deviation; *** $p < 0.001$ vs. control group. The empty white and colored columns correspond to the data for the years 2015–2016. The white and colored columns with oblique lines correspond to the years 2016–2017.

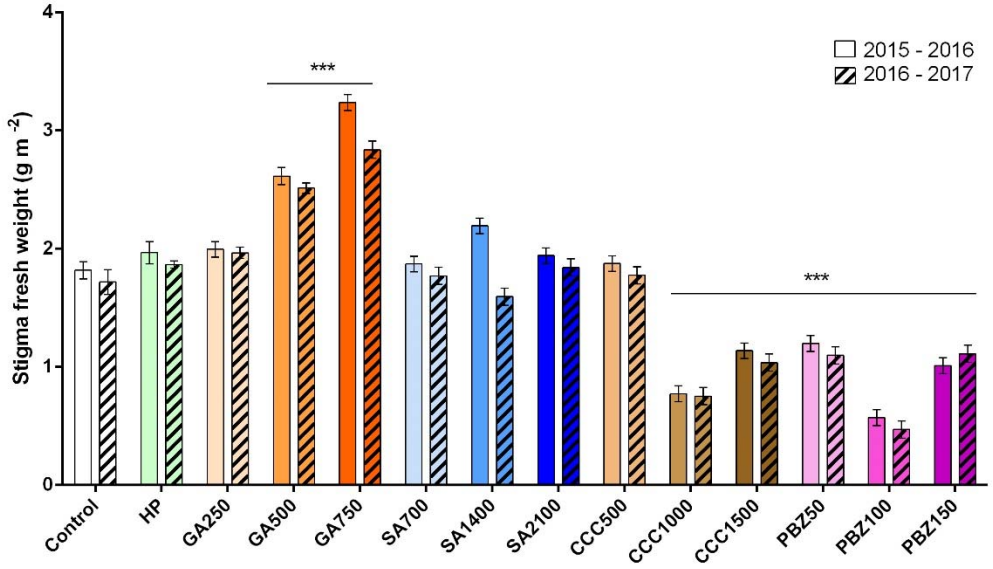

Figure 4. Effects of corm priming with distilled water and four different growth regulators on stigma fresh weight of saffron plants grown under field condition. HP, hydropriming; GA, gibberellic acid; SA, salicylic acid; CCC, chlormequat chloride; PBZ, paclobutrazol. Data are shown as mean ± standard deviation; *** $p < 0.001$ vs. control group. The empty white and colored columns correspond to the data for the years 2015–2016. The white and colored columns with oblique lines correspond to the years 2016–2017.

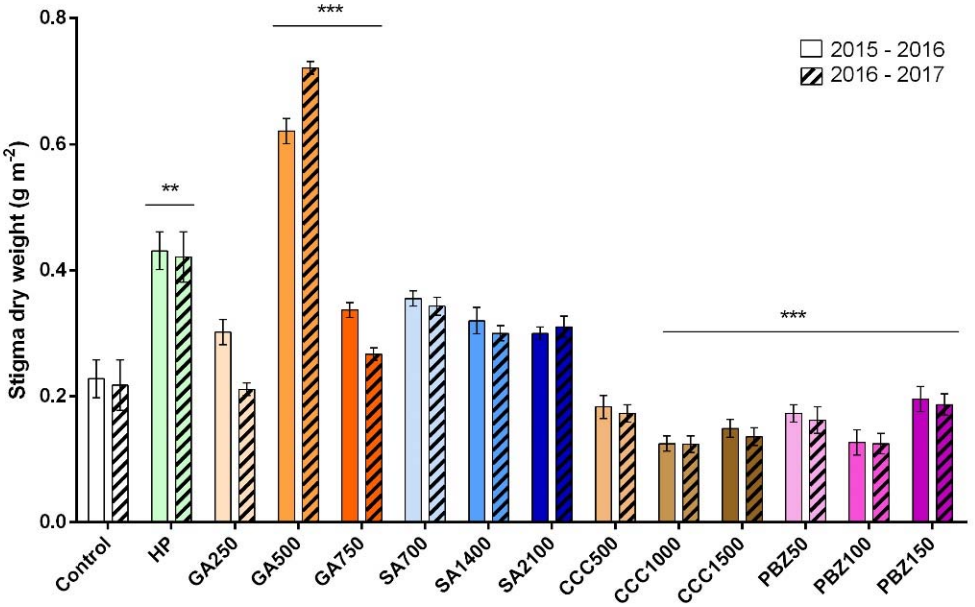

Figure 5. Effects of corm priming with distilled water and four different growth regulators on stigma dry weight of saffron plants grown under field condition. HP, hydropriming; GA, gibberellic acid; SA, salicylic acid; CCC, chlormequat chloride; PBZ, paclobutrazol. Data are shown as mean ± standard deviation; *** $p < 0.001$ vs. control group; ** $p < 0.005$ vs. control group. The empty white and colored columns correspond to the data for the years 2015–2016. The white and colored columns with oblique lines correspond to the years 2016–2017.

3.3. Daughter Corm Number and Weight

Priming with distilled water, SA and GA_3 increased the daughter corm numbers compared to the control treatment (Table 3). Among the treatments, the highest daughter corm numbers were found in SA applications. SA 1400 produced the highest daughter corm num-

bers (over five daughter corms for each corm) in both years. HP treatment as an inexpensive method could produce daughter corms more than 50% compared to the control. The comparison of GA_3 and SA in the daughter corm numbers showed that GA_3 did not play the same role as SA in producing daughter corms. Produced daughter corms in CCC and PBZ treatments neither showed any difference with the control group nor resulted in fewer daughter corms (Table 3). The lowest daughter corm numbers were observed in two CCC 1500 and PBZ 50 treatments. The daughter corm weights increased in all priming methods compared to the control group. The highest daughter corm dry weights were observed in SA 700 and then in SA 1400. Like the daughter corm numbers, SA had higher effects on the daughter corms' fresh and dry weights than GA_3. The lowest corm weight was observed in the control group and the PBZ 150 and CCC 1500 treatments. As mentioned above, the applications of CCC and PBZ reduced the corm numbers. However, this reduction was accomplished by increasing corm weight compared to the control group (Table 3).

4. Discussion

In this study, priming with HP and PGRs changed the leaf traits. GA_3 and SA increased leaf length and leaf numbers significantly in both years compared to the control plants. The highest leaf length was found in the treatment with GA_3 and the widest leaf in treatment with SA. It seems that corm treatment with GA_3 was more effective on leaf length than leaf width. HP did not show a significant effect on leaf width. On the other hand, the applications of CCC and PBZ reduced leaf length and width compared to the control in both years. Similar to the leaf number, the LAI in HP, GA_3, and SA increased, but the application of CCC and PBZ decreased LAI compared to the control. It appears that LAI reduction was the result of the reduction in the leaf number in each corm and the simultaneous reduction in the individual leaf size. As a result, the covered ground area was reduced in treatment by CCC and PBZ.

The leaf dry weights increased in all priming treatments compared to the control group treatment. The increment in leaf dry weights could be due to the increase in leaf thickness or the increase in the number of mesophyll layers. Additionally, the leaf dry weight increase could be due to the increase of the minerals in leaf tissue, which could uptake more elements from the soil. Comparing the two growth retardants, PBZ had a more significant effect on increasing leaf dry weight than CCC. On the other hand, in comparison to priming of corms with HP, SA, and GA_3, SA proved to be more effective on leaf dry weight.

Leaf initiation is a trait that can be affected by various environmental factors, including temperature and plant internal factors [31]. Leaves start their lives by regular primordium that appears on the sides of the apical meristem. The controlling factors have not been clearly indicated in the appearance of these primordia. However, they may be controlled by plant growth regulators. It was reported that among plant hormones, auxin and gibberellin are effective on phyllotaxis and leaf production [32,33]. Since the environmental conditions were similar for the examined plants, the differences in leaf traits were mostly related to the effects of applied PGRs on physiological and biochemical reactions of the corms. One reason for the increasing leaf numbers can be due to prevention from leaf primordia abortion, proper nutrition of them, and/or increasing hormones levels, such as auxin and cytokine, by the application of SA and GA_3. Ibrahim and colleagues reported that the application of SA and Zn increased the leaf numbers, leaf area, and leaf dry weight in sweet pepper [34]. SA spraying increased auxin, cytokine, and GA concentrations in the pepper plants. On the other hand, the concentrations of mineral elements, such as N, P, K, and Zn, increased, which could lead to better nutrition of the plant. The application of exogenous GA increases plant cell lengths [21]. In addition, it is reported that the spraying of GA on tobacco [35] and lettuce [36] increased leaf numbers, dry weight, and area, as well as stem and root length.

Since both used retardants, CCC and PBZ disturbed the GA biosynthesis pathway and reduced the GA concentration in the plant; the reduction in leaf numbers, size, and the area may be related to GA reduction in the plant. It is stated that GA is responsible

for expanding and lengthening plant meristem [26]. In contrast, some reports showed the use of CCC or PBZ may have positive effects on leaf traits. For instance, Pourmohammad and colleagues reported that the application of CCC in rapeseed increased leaf area and dry weight [37]. Miranzadeh and collaborators mentioned that the application of CCC on four wheat cultivars produced plants with higher LAI than non-used CCC plants [38]. In contrast, Pinto and colleagues showed that leaf number was not influenced by CCC and PBZ in *Zinnia elegans* [39]. It seems that if retardants could not reduce apical meristem dominance, they would not affect leaf initiation and appearance. Therefore, this was a reason for the difference between the findings of the current research and similar works.

Tsegaw and colleagues reported that the application of PBZ in potatoes significantly reduced leaf area. Additionally, it caused thicker and darker leaves [40]. The leaf thickness increased due to the increase in the thickness and length of the palisade and spongy mesophyll cells and their epidermal cells. Carvalho-Zanao and colleagues stated paclobutrazol changed leaf tissue proportions by increasing the thickness of leaf blade, mesophyll, palisade parenchyma, and spongy parenchyma but did not influence the thickness of leaf epidermis [41]. In a similar report, Yeshitela and collaborators stated in mango plants, leaf area is reduced by PBZ treatment [42]. Similarly, there was a linear relationship between the increase in PBZ concentration and leaf area reduction in treated rose plants [41].

Among all treatments, GA_3 showed significant priority for flower numbers, flower fresh and dry weight, as well as stigma dry weight. None of the treatments could present an amount close to what was gained from the GA_3 treatment. Based on the data obtained in this experiment, priming saffron corms showed better reactions to GA_3 during both years. Following GA_3, SA showed the highest effect on flower and stigma production. According to Farooq and Koul, the concentration of GA compounds demonstrated significant changes during saffron dormancy and sprouting [43]. In May and June, these compounds were reduced, which is in agreement with saffron activity reduction while these compounds reached their highest level in September. It seemed that corms immersed in GA_3 solution increased corm internal GA concentration and improved flower production and dry weight. Reports showed that exogenous GA increased flower production in plants. Farooq and Chrungoo treated and planted the large corms of saffron in concentrations of 100 to 500 ppm from GA and observed that treatment by GA accelerated flowering [44]. Moreover, it increased the flower numbers and weight in each corm and accelerated flowering time. Sajid and colleagues showed that the application of GA increased the plant height, flowering branches, and flower numbers but reduced days to flowering in *Chrysanthemum morifolium* [45]. In the present study, the highest flower production was found in 500 µM GA.

As illustrated in Figure 1, besides GA_3, only SA had improving effects on saffron flower numbers. The stimulation effects of SA on flower induction on the short day, long day, and insensitiveness to photoperiod plants were recognized previously [46]. In addition, an increase up to 2–5 fold in the levels of endogenous SA was reported in some plants in flowering or transition to flowering [47]. It was reported that the role of SA in flowering is most obvious in flower initiation and not flower development [48]. Abbas and colleagues stated that spraying SA on marigold plants led to an increase in inflorescences/plant, fresh and dry weight of inflorescences, and total flavonoid content in flowers [49]. Biareh and colleagues declared that spraying SA on *Cucurbita pepo* plants increased the quantity and quality of treated plants [18]. Although, there were some reports about accelerating effects of CCC [50] or PBZ [3] on the time of flowering or flower numbers in some plants, other studies claimed that CCC or PBZ had no effects on flower buds and flower numbers [51]. In the current experiment, CCC or PBZ had no positive effect on flower numbers but reduced flower numbers. These different results may be due to PGRs application time or applied concentrations, especially on experimented plants.

SA treatments had the highest effect on the corm numbers and weight among all treatments. In addition to SA, HP and GA treatments could produce more corms compared to the control treatment. PBZ and CCC treatments had equal or near to equal daughter corm numbers compared to the control setting. All treatments (HP and PGRs) showed higher

corm weights than the control group condition. It seems that the plants' photosynthesis rates increased by treating corms (data is not shown in this article). Consequently, the accumulated dry weight increased during the corm-filling periods. Moreover, by referring to the LAI trait (Table 3), it is observed that the highest LAI in all treatments was related to the pretreatments of corms by SA. Since dry weight production is directly related to leaf area development and photosynthesis rate, each factor increasing leaf area may effectively increase photoassimilate production and the accumulation of dry weight in storage parts [31].

The findings reveal that SA significantly affects photosynthesis, leaf structure, chloroplast, rubisco, and carbonic anhydrate enzymes activity [46]. Shaki and colleagues reported that the application of SA increased the photosynthesis rate, photosynthesis efficiency and, stomatal conductance in safflower [52]. Additionally, chlorophyll content and RWC increased by increasing SA concentration. The incremental effect of SA on plant biomass was reported by other authors [47,52]. Although the incremental effects of PBZ [53] and CCC [54] have been reported on photosynthesis, Venugopalan and colleagues reported that among three growth regulators, CCC showed the least effect on the cotton photosynthesis rate [55]. Comparing two growth retardants in the mentioned experiment, PBZ showed a greater effect on cotton plant weight than CCC. Increasing photosynthesis by PBZ was reported in wheat cultivars. This increase was accomplished with the maximal quantum yield of PSII application of PBZ [53].

5. Conclusions

Stigma yield and the number of daughter corms in the saffron plant are significantly important. Among the treatments, GA 500 and 750 μM produced the highest flower numbers and stigma dry weight. Besides GA_3, SA showed effectiveness on flower and stigma weight. According to the obtained data, SA had great effects on daughter corm numbers and weight, and the 1400 μM SA treatment also produced the highest number of daughter corms. The lowest flower yield was related to 1000 μM CCC and 100 μM PBZ. Since the highest LAI was observed in SA treatment in both years, it is reasonably incremented in corm weight and number in SA treatments. In general, SA and GA_3 produced more leaves and LAI compared to the control treatment and other priming methods. According to this experiment, GA_3 and SA may increase flower traits, but CCC and PBZ increased only corm weight. As a result, the application of GA_3 and SA can have a positive role in the sustainable production of saffron in planting years.

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