Effects of 6-Benzylaminopurine (BAP) and Naphthaleneacetic Acid (NAA) on Selected Vegetative Growth Characteristics of Saffron *Crocus sativus L*

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ABSTRACT

Saffron *(Crocus sativus L.)* is a value medicinal and aromatic crop. However saffron production on a scale is slowed by the slow growth of saffron corms. This study looked at how 6-benzylaminopurine (BAP) and naphthaleneacetic acid (NAA) separately and together affect selected growth traits of saffron. The greenhouse experiment took place at Al-Musayyib Technical College, Al-Furat Al-Awsat Technical University, Iraq between December 2025 and April 2026. Treatments followed a 4 × 4 factorial design in a Randomized Design with three replicates. BAP was sprayed at concentrations of 0.0, 1.0 1.5 and 2.0 mg L^{-1} while NAA was sprayed at 0.0, 0.50 0.75 and 1.0 mg L^{-1}. All measured traits showed differences, between treatments and their interaction. The 0.0 mg L^{-1} BAP and 0.50 mg L^{-1} NAA treatment produced the corm diameter measuring 21.91 mm. The same treatment also produced the plants reaching 38.33 cm. The highest number of daughter corms 13.33, per plant was seen when 2.0 mg L^{-1} BAP and 1.0 mg L^{-1} NAA were used. The greatest fresh weight of daughter corms 3.31 g was recorded when 1.5 mg L^{-1} BAP and 0.75 mg L^{-1} NAA were applied. In general responses varied depending on the trait measured. This shows that the BAP–NAA mix depends on which growth characteristic is being considered in this experiment.

Key words: *Crocus sativus L.;* 6-benzylaminopurine; naphthaleneacetic acid; plant growth regulators; daughter corms; vegetative growth.

1. INTRODUCTION

Saffron (*Crocus sativus L.*) is a medicinal and aromatic crop used in food, pharmaceutical, cosmetic and nutraceutical products. The dried stigmas of saffron contain bioactive compounds, including crocin, crocetin, picrocrocin and safranal which have been associated with antioxidant, anti-inflammatory, antimicrobial and anticancer properties (4, 5).

Despite saffrons value saffron production is difficult to expand because C. Sativus is a sterile triploid plant and saffron is propagated mainly through daughter corms. The limited number of corms formed by each mother corm in a growing

season slows multiplication while disease pressure and unsuitable environmental conditions may further restrict propagation (3, 8).

Plant growth regulators can influence development and the formation of storage organs. Plant growth regulators such as the 6-benzylaminopurine (BAP) are linked to cell division and shoot development. Plant growth regulators such as the auxin acid (NAA) can affect root formation and other growth processes. Work on saffron and Plant growth regulators shows that responses depend on the regulator used and its concentration (1, 4, 7).

However the response of greenhouse-grown saffron to combined BAP and NAA treatments requires evaluation. I want to understand this. This study therefore assessed the interactive effects of selected concentrations of BAP and NAA on vegetative growth and daughter-corm characteristics with the aim of identifying treatment combinations that can lead to improved performance, under the experimental conditions.

2. MATERIALS AND METHODS

2.1Experimental Site and Plant Material

The experiment was carried out in a greenhouse at the Department of Plant Production Technologies, Al-Musayyib Technical College, Al-Furat Al-Awsat Technical University, Iraq from 19 December 2025, to 15 April 2026. Air temperature was kept between 15 and 20 degrees Celsius during the growth stage. When the plants started flowering the temperature was raised to between 20 and 25 degrees Celsius. The relative humidity was maintained at 60 to 70 percent. Shade was used when needed, with 30 to 50 percent shading applied as required. Uniform one-year-old saffron corms (Crocus sativus L.) were obtained from a certified supplier, in Babil Province, Iraq. These corms had been imported from Iran. Before planting the corms were stored at 7 ± 1 degrees Celsius for 21 days. This treatment helped break dormancy.

2.2Experimental Design and Treatments

A 4 × 4 factorial experiment was set up using a Randomized Design (CRD) with three replicates. The BAP treatments were 0.0, 1.0 1.5 and 2.0 mg L^{-1}. The NAA treatments were 0.0, 0.50 0.75 and 1.0 mg L^{-1}. Both regulators were applied as sprays. Each treatment had three replicates. Each replicate had four pots and each pot had four corms. So each treatment had 12 pots and 48 corms. Across all 16 treatment combinations there were 192 pots and 768 corms. Each pot was the unit. The average of the four plants in each pot was used for analysis. Corms were planted in pots that were 30 × 30 cm. The pots were filled with a 1:1 (v/v) mix of peat moss and sand. The pH of the mixture was, between 6.5 and 7.5.

2.3 Plant Growth Regulator Application

I followed the manufacturer's instructions to prepare BAP and NAA from CAISSON Laboratories. BAP was dissolved in a dilute NaOH solution. NAA was first dissolved in an amount of absolute ethanol and then diluted with distilled water. I

applied the treatments every fifteen days using a hand sprayer until each leaf was completely wet. I added a surfactant to every spray solution. The control plants received distilled water but the water had the same amount of surfactant

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2.4 Data Collection and Ststistical Analysis

At the end of the experiment these traits were measured: corm diameter, root number, root length, daughter-corm number, plant height, leaf number and fresh weight of daughter corms. The data were analyzed using analysis of variance (ANOVA) in GenStat. Treatment means were compared with the significant difference (LSD) test, at $P \leq 0.05$.

3. RESULTS AND DISCUSSION

3.1Effect of BAP and NAA on Corm Diameter

I examined Table 1. I found that corm diameter was significantly impacted by BAP, NAA and the interaction between BAP and NAA. The largest diameter, 21.91 mm was observed when BAP was 0.0 mg L^{-1} and NAA was 0.50 mg L^{-1}. When I considered the effects separately the highest mean diameter for BAP was 17.94 mm at 1.5 mg L^{-1} whereas the highest mean diameter for NAA was 17.34 mm at 0.50, mg L^{-1}. You might notice that changes in corm diameter show how cytokinin and auxin interact during corm development. BAP may help cell division while NAA may help root growth and how resources are taken in;. This experiment did not directly measure those physiological processes. Studies, on saffron growth and corm development give context for understanding these results [1, 4, 5].

Table 1. How 6-benzylaminopurine (BAP) acid (NAA) and their interaction effect the average corm diameter (mm) of *Crocus sativus L*.

NAA / BAP	0.0	0.50	0.75	1.0	Average of BAP
0.0	13.83	21.91	13.45	10.43	14.90
1.0	17.24	14.93	14.35	13.15	14.92
1.5	20.15	17.37	19.26	14.99	17.94
2.0	17.30	15.14	13.38	13.44	14.81
Average of NAA	17.13	17.34	15.11	13.00	
L.S.D. (0.05)	**BAP**		**NAA**		BAPxNAA
	2.579		**2.579**		5.157

3.2 Effect of BAP and NAA on the Number of Roots

reaching 21.33 roots, per plant. The results show that the outcome was influenced by how the regulators were mixed not just by one regulator by itself. BAP and NAA might have effects on how plants grow but the exact ways they work were not looked at in this study. This pattern can be talked about in connection with research, on saffron and plant growth regulators [1, 4, 5].

In Table 2 I see impacts of BAP, NAA and their interaction on root number. The top result was 24.33 roots per plant found in both the 1.5 mg L^{-1} BAP plus 1.0 mg L^{-1} NAA mix and the 2.0 mg L^{-1} BAP combined with 0.75 mg L^{-1} NAA mix. Looking at the BAP effect alone the 2.0 mg L^{-1} dose produced the highest count, which was 21.58 roots per plant. For NAA the 1.0 mg L^{-1} dose gave the best average

Table 2. Effect of 6-benzylaminopurine (BAP) acid (NAA) and their interaction on the average number of roots, per plant of *Crocus sativus L.*

NAA / BAP	0.0	0.50	0.75	1.0	Average of BAP
0.0	13.33	11.33	12.33	23.33	15.08
1.0	18.33	16.00	13.00	19.67	16.75
1.5	19.33	22.33	19.67	24.33	21.42
2.0	21.67	22.33	24.33	18.00	21.58
Average of NAA	18.17	18.00	17.33	21.33	
L.S.D. (0.05)	**BAP**		**NAA**		BAP×NAA
	2.024		**2.024**		4.048

3.3Effect of BAP and NAA on the Number of Small Corms

daughter corms per plant, at 0.75 mg L^{-1} NAA. I think the higher daughter-corm count observed with this treatment could be linked to changes in growth and to how assimilate allocation is carried out even though we did not directly measure those processes. This finding connects with earlier studies that looked at regulator effects and at corm development, in saffron [1, 5, 7].

Table 3 shows that the number of daughter corms changed significantly depending on BAP, NAA and how they worked together. The highest number of daughter corms 13.33 per plant was found when using 2.0 mg L^{-1} BAP with 1.0 mg L^{-1} NAA. Among the BAP treatments the highest average was 10.25 daughter corms per plant at 2.0 mg L^{-1} BAP. For the NAA treatments the highest average was 10.33

Table 3. Effect of (BAP) ,(NAA) and their interaction on the number of daughter corms, per plant of Crocus sativus L. Effect of BAP and NAA interaction is shown in Table 3.

NAA / BAP	0.0	0.50	0.75	1.0	Average of BAP
0.0	6.33	11.00	12.67	7.67	9.42
1.0	6.33	8.00	9.67	7.67	7.92
1.5	5.33	10.00	11.33	11.67	9.58
2.0	9.67	10.33	7.67	13.33	10.25
Average of NAA	6.92	9.83	10.33	10.08	
L.S.D. (0.05)	**BAP**		**NAA**		BAP×NAA
	1.987		**1.987**		3.974

3.4Effect of BAP and NAA on Root Length

variation in root length across treatments shows that root elongation responded to the regulator regime. Although changes in cell division, root elongation and resource uptake may explain the results these mechanisms were not tested directly in this study. The results can be compared with studies, on saffron growth and regulator treatments [1, 5, 7].

According to Table 4 BAP, NAA and their interaction significantly affected root length. The longest roots, measuring 20.67 cm were found when using 2.0 mg L^{-1} BAP with 0.75 mg L^{-1} NAA. The highest mean for BAP was 15.75 cm at a concentration of 2.0 mg L^{-1} while the highest mean for NAA alone was 15.08 cm, at a concentration of 0.75 mg L^{-1}. The

Table 4 shows the Effect of 6-benzylaminopurine (BAP) naphthaleneacetic acid (NAA) and their interaction, on the root length (cm) of Crocus sativus L.

NAA / BAP	0.0	0.50	0.75	1.0	Average of BAP
0.0	5.33	12.67	10.33	12.67	10.25
1.0	9.00	13.00	11.00	11.00	11.00
1.5	12.33	13.33	18.33	9.33	13.33
2.0	12.33	14.00	20.67	16.00	15.75
Average of NAA	9.75	13.25	15.08	12.25	
L.S.D. (0.05)	**BAP**		**NAA**		BAP×NAA
	3.579		**3.579**		7.158

3.5Effect of BAP and NAA on Plant Height

measured in this study. The way the plants grew shows that the 0.0 mg L^{-1} BAP plus 0.50 mg L^{-1} NAA mix worked best in this test. Looking at research on plant growth regulators, in saffron can help explain why this happened [4, 8].

Other studies have also looked at how greenhouse settings, plant growth regulators and saffron growth're connected [8].

These kinds of comparisons need to be thought about carefully because the environment and the steps used in each study might not be the same

Table 5 shows that plant height was greatly affected by BAP, NAA and how they work together. The tallest plant height was 38.33 cm when there was 0.0 mg L^{-1} BAP and 0.50 mg L^{-1} NAA. For the effects the tallest plant height, for BAP was 26.50 cm when there was 0.0 mg L^{-1} BAP. For NAA the tallest plant height was 29.08 cm when there was 0.50 mg L^{-1} NAA. One possible reason for the height response is that auxin-related processes can affect how cells stretch and tissues expand. At the time cytokinins help control cell division and the growth of shoots. These ideas should be seen as explanations because the actual physical processes, inside the plant weren't

.Table 5 shows how 6-benzylaminopurine (BAP) and naphthaleneacetic acid (NAA) both alone and together affect the plant height (cm) of Crocus sativus L. Plants.

NAA / BAP	0.0	0.50	0.75	1.0	Average of BAP
0.0	18.00	38.33	25.67	24.00	26.50
1.0	20.00	31.67	25.67	20.00	24.33
1.5	20.33	26.33	21.00	23.33	22.75
2.0	21.33	20.00	21.67	21.00	21.00
Average of NAA	19.92	29.08	23.50	22.08	
L.S.D. (0.05)	**BAP**		**NAA**		BAP×NAA
	4.950		**4.950**		9.901

3.6 Effect of BAP and NAA on the Number of Leaves

was 5.17 leaves per plant at 1.5 mg L^{-1}. For NAA the top average was 5.67 leaves per plant, at 1.0 mg L^{-1}. The answer could have to do with how plants grow and develop when different regulators are used

Table 6 shows that leaf number changed based on the BAP–NAA treatments. The most leaves seen was 6.33 leaves per plant when using 1.0 mg L^{-1} BAP plus 1.0 mg L^{-1} NAA. For BAP the highest average

even though the reasons behind these changes were not studied directly. Some past studies, about saffron help explain what is happening here [1, 5, 6].

Table 6. Effect (BAP), (NAA), and their interaction on the mean number of leaves per plant of Crocus sativus L.

NAA / BAP	0.0	0.50	0.75	1.0	Average of BAP
0.0	3.33	3.33	4.67	4.67	4.00
1.0	5.00	2.33	5.67	6.33	4.83
1.5	5.33	4.00	5.33	6.00	5.17
2.0	5.67	4.00	5.00	5.67	5.08
Average of NAA	4.83	3.42	5.17	5.67	
L.S.D. (0.05)	**BAP**		**NAA**		BAP×NAA
	0.823		**0.823**		1.646

3.7 Effect of BAP and NAA on Fresh Weight of Daughter Corms

combination may indicate that fresh weight has increased in daughter corms when the treatment was applied. BAP- and NAA-related effects on growth and resource acquisition could be important but the movement of assimilates and the physiological activity were not measured directly. The fresh weight result can be compared with published studies, on saffron corm development and plant growth regulators [1, 4, 8].

As shown in Table 7 the fresh weight of daughter corms varied depending on the BAP and NAA treatments and how they were combined. The highest fresh weight recorded was 3.31 grams, which happened when using 1.5 mg L^{-1} BAP with 0.75 mg L^{-1} NAA. The highest average fresh weight for BAP was 2.21 grams at 1.5 mg L^{-1}. For NAA the highest average fresh weight was 2.16 grams, at 0.75 mg L^{-1}. The higher fresh weight recorded for this

Table 7. Effect of (BAP), (NAA), and their interaction on the mean fresh weight of daughter corms (g) *of Crocus sativus L*

NAA / BAP	0.0	0.50	0.75	1.0	Average of BAP
0.0	1.33	1.43	1.61	0.83	1.30
1.0	1.57	2.83	2.38	1.43	2.05
1.5	2.07	1.83	3.31	1.63	2.21
2.0	2.23	0.80	1.33	1.73	1.53
Average of NAA	1.80	1.72	2.16	1.41	
L.S.D. (0.05)	**BAP**		**NAA**		BAP×NAA
	0.587		**0.587**		1.173



Figure 1. Developmental stages of saffron (Crocus sativus L.) plants during the experimental period.

1.Corm before dormancy breaking treatment.

2.Corm at the shoot emergence stage, 28 days after planting.

3.Vegetative growth 15 days after the first foliar application of plant growth regulators.

4.Well-developed foliage observed after the final foliar application

4. CONCLUSION

daughter-corm weight was recorded when the plants received 1.5 mg L^{-1} BAP with 0.75 mg L^{-1}

NAA. These findings show that fresh daughter-corm weight can be increased with a BAP–NAA ratio. The results also support study of trait-specific BAP–NAA combinations. Nevertheless any recommendations that go beyond the conditions used in this experiment must be confirmed by trials.

Under the greenhouse conditions I noticed that BAP and NAA treatments had an effect on vegetative growth and daughter-corm development and the best-performing combination varied, among traits. The combination of 0.0 mg L^{-1} BAP plus 0.50 mg L^{-1} NAA gave the corm diameter and the tallest plant while the combination of 2.0 mg L^{-1} BAP plus 1.0 mg L^{-1} NAA gave the greatest number of daughter-corms. The maximum fresh

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ISSN 2072-3857