Middle East Journal of Agriculture Research
Volume: 14 | Issue: 02| April – June| 2025

EISSN: 2706-7955 ISSN: 2077-4605
DOI: 10.36632/mejar/2025.14.2.20
Journal homepage: www.curresweb.com
Pages: 354-364

Response of Almond Seedlings to Foliar Spray with Indole-3-butyric acid (IBA), Benzyl amino purine (BAP) and Seaweed Extract (SE) under Nubaria Region Conditions

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Received: 10 May 2025 **Accepted:** 15 June 2025 **Published:** 25 June 2025

ABSTRACT

The experiment was carried out on one-year-old almond seedlings (*Prunus amygdalus* L.) cv. Nonpareil budded on Nemagaurd peach rootstock during experimental seasons 2023 and 2024 at a private orchard in Nubaria, El Behera governorate, Egypt. To examine the effects of foliar spray with different doses of indole-3-butyric acid (IBA), benzyl amino purine (BAP), and seaweed extract (SE) on growth and leaf nutrient status of seedlings. Under a randomized complete block design, there were ten treatments: T1-Control (water only), T2-IBA 5 ppm, T3-IBA 10 ppm, T4-IBA 15 ppm, T5-BAP 20 ppm, T6-BAP 40 ppm, T7-BAP 60 ppm, T8-SE 10 ml/L, T9-SE 15 ml/L, and T10-SE 20 ml/L each replicate consisted of five seedlings. The results reveal that all treatments significantly increased the parameters of vegetative growth; seedling height, stem diameter, number of leaves/seedlings, leaf area, fresh and dry weight of leaves, and total chlorophyll content of almond seedlings compared to untreated seedlings (control). This enhancing effect was further enhanced at lower doses of IBA and at higher doses of BAP and SE. This effect was positively reflected on total leaf carbohydrates as well as both macro- and micronutrients. Therefore, it can be concluded from the experimental results that foliar spraying with 5 ppm of indole-3-butyric acid, 60 ppm of benzyl amino purine, and 20 ml/L of seaweed extract is an effective method for enhancing vegetative growth and mineral content in almond seedling leaves.

Keywords: Almond, IBA, BAP, seaweed extract, leaf nutrient, carbohydrates, seedlings.

1. Introduction

Numerous processes of plant growth and development are regulated by plant hormones, a broad class of stimulants of vegetative and reproductive growth (Hasan and Jumaa, 2013). One of the hormones in plants, auxin controls a variety of morphogenesis and developmental processes, including apical dominance, cell enlargements, environmental response, phototropism and geotropism, and root primordial initiation (Woodward and Bartel, 2005; Camolesi *et al.,* 2007; Singh and Khan, 2009). A synthetic auxin called indole-3-butyric acid (IBA) is applied to rooted cuttings (Blythe *et al.,* 2003). In plants, cytokinin-induced root apical dominance is broken by IBA, the primary hormone that promotes root development (Cline, 2000). IBA is used extensively because it encourages root growth in many plant species and is non-toxic to the majority of plants (Hartmann *et al.,* 1990). According to recent research on IBA biosynthesis, plant hormones and different stressors can control the amount of this compound in plants (Ludwig-Müller *et al.,* 1995 and 2000). Additionally, all treatments for IBA were successful in increasing the quantity, length, and fresh weight of adventitious root cuttings in comparison to control cuttings (El-Abd, 1997).

According to certain studies, it can be applied topically to the vegetative parts of ornamental crops to root stem cuttings. This method produced results that were comparable to or less effective than

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submerging the stem cuttings' bases in IBA (Li *et al.,* 2011). According to other research, foliar application of IBA enhanced the growth of naval orange seedlings (Hasan *et al.,* 2020) and Jatropha curcas seedlings (Ahmed *et al.,* 2018).

One of the most important plant hormones, cytokinins can greatly enhance plant growth and may also promote improved environmental adaptation, as evidenced by improved vegetative growth traits, fruit crop productivity, and nutritional status (Mahmoud *et al.,* 2015). According to Shudok (1994), two classes of adenine and urea cytokinins with comparable physiological effects were found by the chemical structure of the cytokinins' active constituents. It has a significant impact on cotyledon growth and expansion, increasing the amount of photosynthetic pigments, proteins, and carbohydrates in leaves, promoting leaf expansion, and delaying senescence and other processes like cell division, differentiation, and organ formation in developing plants (Sakine *et al.,* 2011; Abou Aziz *et al.,* 2011; Abou Rayya *et al.,* 2015). N6-benzyladenine, also referred to as Benzyl amino purine (BAP), is a synthetic cytokinin that controls plant development. According to Rehman *et al.* (2023), it is essential for cell development, differentiation, and division. It can engage with plant cytokinin receptors and initiate growth-promoting reactions because of its chemical structure, which is similar to that of naturally occurring cytokinins, especially adenine. By encouraging the synthesis of proteins and nucleic acids, the growth of shoots and root tissue, the expansion of leaves, and plant vigor, BAP promotes cell division and proliferation. Additionally, it is employed in tissue culture methods for micropropagation or shoot proliferation (Selim *et al.,* 2023).

Seaweed is a known source of plant growth regulators such as cytokinins, auxins and auxin-like compounds; organic matter and fertilizer nutrients; amino acids; and vitamins, which are important roles in the metabolism and productivity of plants (Khan *et al.,* 2009). Seaweed extracts are applied as a foliar spray, increasing uptake of plant nutrients and promoting growth (Thanaa *et al.,* 2016; Merwad *et al.,* 2019; Eisa *et al.,* 2023), moreover giving resistance to frost, fungal diseases and stress conditions (Zodape, 2001). The Nemagaurd peach seedlings growth and leaf chemical composition, including stem diameter, stem length, leaves/seedling number, branches/seedling number, chlorophyll, leaf fresh weight, leaf area, and leaf dry weight, were enhanced when seaweed extract was applied as a foliar spray. It also considerably raised the leaves mineral and total carbohydrate content (Rakha *et al.,* 2024; Abou Rayya *et al.,* 2024 and 2025). In this study, we have examined and contrasted the foliar spray with extracts from seaweed and several plant hormones. Determining the effects of varying concentrations of seaweed extract (SE), benzyl amino purine (BAP), and indole-3-butyric acid (IBA) on the vegetative growth, element, and carbohydrate contents of almond seedling leaves was the purpose of this study.

2. Materials and Method

The experiment was carried out on one-year-old almond seedlings (*Prunus amygdalus L.*) cv. Nonpareil budded on Nemagaurd peach rootstock during two consecutive seasons in 2023 and 2024 at a private orchard in Nubaria, El Behera governorate, Egypt. The almond seedlings were planted in sandy soil with a drip irrigation system, spaced 3 by 4 meters apart (350 trees/fed). Table 1 displays the physical and chemical characteristics of the experimental soil prior to treatments, averaged across the two seasons. The same recommended cultural practices were applied to the trees, which were selected as healthy and uniform in vigor. These practices included chemical fertilization as 150 kg of ammonium sulfate (20.6% N), 100 kg of potassium sulfate (48-52% K_2O), 50 kg of magnesium sulfate, 20 liters of phosphorus acid, and three tons of compost (analysis is shown in Table 2). Ten treatments were designed and treatments were arranged in randomized complete block design with three replicates for each treatment and each replicate was represented by five seedlings. The following procedures were used:

T1	Control (Water only).	**T6**	BAP at 40 ppm
T2	IBA at 5 ppm	**T7**	BAP at 60 ppm
T3	IBA at 10 ppm	**T8**	SE at 10 ml/L
T4	IBA at 15 ppm	**T9**	SE at 15 ml/L
T5	BAP at 20 ppm	**T10**	SE at 20 ml/L

Middle East J. Agric. Res., 14(2): 354-364, 2025
EISSN: 2706-7955 ISSN: 2077-4605 *DOI: 10.36632/mejar/2025.14.2.20*

The "Hummer Hand" seaweed extract is composed of 80% algae and seaweed from the *Ascophylum nodosum* and *Laminaria*. In each season, the treatments were sprayed three times: in the middle of February, March, and April. Leaf fresh and dry weights (g), leaf numbers/seedling, stem length and diameter (cm) at the end of September.

Table 1: Physical and chemical properties of the experimental soil

Particle size distribution	Depths (cm)			Particle size distribution	Depths (cm)		
	0-30	30-60	60-90		0-30	30-60	60-90
Sand (%)	8.88	86.8	87.8	**EC (1:5) dSm^{-1}**	0.17	0.18	0.15
Silt (%)	4	4	3	**pH (1:2.5)**	8.15	7.9	7.91
Clay (%)	7.2	9.2	7.2	**OM (%)**	0.34	0.51	0.68
Texture grade		Sandy		**$CaCO_3$ (%)**	1.6	1.65	1.7

	Macro-elements (%)					Micro-elements (ppm)					Anions (meq/L)		
Depths (cm)	**N**	**P**	**K**	**Ca**	**Mg**	**Na**	**Fe**	**Mn**	**Cu**	**Zn**	**CO_3^-**	**HCO_3^-**	**Cl^-**
0-30	0.15	0.85	0.30	0.42	35.1	0.28	3.32	1.15	1.10	19.87	traces	2.4	3.5
30-60	0.20	1	0.34	0.49	39.4	0.36	4.62	2.13	1.59	21.54	traces	2.9	4.2
60-90	0.25	1.1	0.39	0.50	42.5	0.42	6.54	4.72	2.02	28.42	traces	3.7	4.8

Table 2: Physical and chemical properties of compost.

Moisture content (%)	pH	EC (dS/m)	Organic matter (%)	Organic carbon (%)	C/N ratio
25-30	7.5	1.5	57	50	18:01
Macro element (%)			**Micro element (ppm)**		
N	**P**	**K**	**Fe**	**Zn**	**Mn**
1.4	2.82	3	26	378.8	30

A Minolta chlorophyll meter SPAD-502 was used to measure the total leaf chlorophyll content (SPAD unit) in the field. In accordance with Dubois *et al.* (1956), the total carbohydrate content of the leaves (%) was calculated. To determine the elements, leaf samples were selected from each treatment, cleaned, and dried at 70°C until they reached a consistent weight. The content of N, P, K, and Mg (%) in leaves was calculated using the methods of Pregl (1945); Chapman and Pratt (1961); and Brown and Lilleland (1946), respectively. Leaf microelements content; Fe, Mn, Cu and Zn (ppm), was determined according to Jackson (1973).

2.1. Statistical analysis

The obtained data in both seasons were analyzed by ANOVA according to Snedecor and Cochran (1982). Means were separated by Duncan's (1955) multiple range test using a significance level of $P<0.05$.

3. Results

3.1. Vegetative growth

The effects of foliar application of seaweed extract (SE), benzyl amino purine (BAP), and indole-3-butyric acid (IBA) on vegetative growth measurements of Nonpareil almond seedlings are displayed in Tables 3 and 4. The findings showed that, in both experimental 2023 and 2024 seasons, the various treatments under investigation had an impact on every facet of vegetative development.

3.2. Stem length (cm)

In the 2023 and 2024 seasons, respectively, 5 ppm IBA records the highest value (209 and 224.3 cm). In terms of BAP treatment, the maximum values in both seasons (218.3 and 258 cm) are recorded at 60 ppm. In the first and second seasons, respectively, the highest values (246.3 and 296.3 cm) were obtained with the spraying of SE at a rate of 20 ml/L.

3.3. Stem diameter (cm)

In comparison to the control (spray with water alone), Table 3 showed that all treatments enhanced the stem diameter of Nonpareil cv. In the case of IBA treatment, 5 ppm produced the maximum value (2.43 and 2.68 cm) during the 2023 and 2024 seasons, respectively. In terms of BAP treatment, the maximum values (2.7 and 3 cm) were obtained at 60 ppm in both seasons. In the first and second seasons, the highest values (3.4 and 3.9 cm) were obtained with the application of SE at 20 ml/L.

3.4. Number of leaves/ seedling

The data obtained in Table 3 demonstrated that, in both the 2023 and 2024 seasons, seaweed extract at a concentration of 20 ml/L produced the most significant number of leaves per seedling when compared to other treatments (65 and 70 leaves/seedling, respectively). The maximum number of leaves for a seedling under IBA treatment was 5 ppm in the first and second seasons, respectively (36.67 and 27 leaves/seedling). In terms of BAP treatment, the maximum values were obtained in both seasons at 60 ppm (56.67 and 46.67 leaves/seedling, respectively).

3.5. Leaf area (cm^2)

In comparison to other treatments (2.57 and 2.24 cm²) in both the 2023 and 2024 seasons, seaweed extract at 20 ml/L produced the biggest significant leaf area per seedling, according to the results in Table 3. In the first and second seasons, respectively, 5 ppm IBA produced the greatest value (2.15 and 1.95 cm²). In terms of BAP treatment, the highest values (2.31 and 2.14 cm²) were obtained at 60 ppm in both seasons.

Table 3: Effect of foliar spray with IBA, BAP and SE on stem length, stem diameter, number of leaves/ seedling and leaf area of Nonpareil almond seedlings during 2023 and 2024 seasons.

Parameters Treatments	Stem length (cm)		Stem diameter (cm)		No. of leaves/ seedling		Leaf area (cm^2)	
	1st Season	2nd Season	1st Season	2nd Season	1st Season	2nd Season	1st Season	2nd Season
Control (Water only)	148.0F	158.0H	1.93G	2.03F	20.00I	20.33F	1.88E	1.75E
IBA at 5 ppm	209.0D	224.3F	2.43EF	2.68E	36.67F	27.00FG	2.15C	1.95C
IBA at 10 ppm	191.0E	206.0G	2.40F	2.60E	30.00G	26.67FG	2.04D	1.86D
IBA at 15 ppm	190.0E	206.0G	1.95G	2.06F	23.33H	23.67G	1.99E	1.83D
BAP 20 ppm	211.0D	246.7E	2.60DE	2.90A	43.33E	33.33E	2.21C	1.96C
BAP 40 ppm	216.7C	253.3D	2.60DE	2.95D	47.00D	35.00E	2.30B	2.08B
BAP 60 ppm	218.3C	258.0D	2.70CD	3.00CD	56.67C	46.67D	2.31B	2.14B
SE at 10 ml/L	239.3B	279.3C	2.83C	3.18C	60.00B	50.00C	2.31B	2.22A
SE at 15 ml/L	242.3AB	287.3B	3.03B	3.48B	60.00B	63.33B	2.32B	2.23A
SE at 20 ml/L	246.3A	296.3A	3.40A	3.90A	65.00A	70.00A	2.57A	2.24A

Mean values in the same column followed by the same letter are not significantly different at $p < 0.05$

3.6. Leaf fresh weight (LFW)

In the 2023 and 2024 seasons, 5 ppm produced the greatest value (19 and 20.5 g, respectively) for IBA treatment. The highest value (24 and 27.36 g) for BAP treatment was obtained at 60 ppm in both seasons. In the first and second seasons, the greatest increase in leaf fresh weight (28 and 31.5 g, respectively) was achieved by applying seaweed extract at a rate of 20 ml/L (Table 4).

3.7. Leaf dry weight (LDW)

In the 2023 and 2024 seasons, the maximum leaf dry weight values were obtained with 5 ppm IBA treatment (8.55 and 11.5g, respectively). In terms of BAP treatment, the greatest increase in leaf dry weight (9.14 and 13.3 g) was observed in the first and second seasons at 60 ppm. The maximum leaf dry weight values (11.32 and 16.24g) in the first and second seasons, respectively, were obtained with the application of seaweed extract at a rate of 20 ml/L (Table 4).

3.8. Total chlorophyll content

Table 4 shows that, in both the 2023 and 2024 seasons, the application of seaweed extract at a rate of 20 milliliters per liter produced the highest value (37.97 and 36.5 SPAD units) when compared to other treatments. Regarding IBA treatment, the results indicated that in the first and second seasons, the leaf with the lowest concentration had the maximum total chlorophyll content (23.53 and 24.3 SPAD units, respectively). Similarly, the maximum increase in leaf total chlorophyll content (28.73 and 27.2 SPAD units, respectively) in the first and second seasons after BAP treatment was achieved at 60 ppm.

3.9. Total carbohydrates

According to Table 4 results, foliar application of IBA, BAP, and SE at varying doses raised the amount of carbohydrates in almond seedling leaves when compared to the control treatment. In the 2023 and 2024 seasons, respectively, 5 ppm produced the greatest value (3.23 and 5.69%) for IBA treatment. In terms of benzyl amino purine (BAP) treatment, the highest values (4.14 and 7.64%) were obtained at 60 ppm in both seasons. The greatest increase in leaf total carbohydrates (4.4 and 9.2% in the first and second seasons, respectively) was obtained with the application of seaweed extract at a rate of 20 ml/L.

Table 4: Effect of foliar spray with IBA, BAP and SE on leaf fresh weight, leaf dry weight, leaf total chlorophyll and total carbohydrates content of Nonpareil almond seedlings during 2023 and 2024 seasons

Parameters	Leaf Fresh Weight (g)		Leaf Dry Weight (g)		Total chlorophyll (SPAD unit)		Total carbohydrates (%)	
Treatments	1st Season	2nd Season	1st Season	2nd Season	1st Season	2nd Season	1st Season	2nd Season
Control (Water only)	17.0I	18.00H	7.45F	8.47G	19.60H	2.20F	2.64G	3.14J
IBA at 5 ppm	21.0G	21.59E	8.55E	11.50E	23.53F	24.30G	3.23E	5.69D
IBA at 10 ppm	19.0H	20.50F	8.51E	10.52F	22.50G	23.90G	3.21E	4.33B
IBA at 15 ppm	17.5I	19.03G	8.30DE	10.28F	21.93B	22.13H	2.76F	3.80I
BAP 20 ppm	22.0F	24.25D	8.92D	11.64E	26.43E	25.27EF	3.60D	6.10F
BAP 40 ppm	23.0E	24.74D	9.12D	12.35D	27.23D	26.40E	3.98C	6.98E
BAP 60 ppm	24.0D	27.36C	9.14D	13.30C	28.73C	27.20D	4.14B	7.64D
SE at 10 ml/L	26.0C	27.50C	10.20C	14.20B	33.57B	33.23C	4.18B	8.12C
SE at 15 ml/L	27.0B	30.00B	10.85B	14.47B	37.30A	34.23C	4.25B	8.75B
SE at 20 ml/L	28.0A	31.50A	11.32A	16.24A	37.97A	36.50A	4.40A	9.20A

Mean values in the same column followed by the same letter are not significantly different at $p < 0.05$

3.10. Nutrition status

The impact of foliar spraying with IBA, BAP, and SE on the nutritional status of seedlings of the almond variety Nonpareil in the 2023 and 2024 seasons is displayed in Tables 5 and 6. The results obtained clearly show that, in comparison to the control treatment, the nutrition status was enhanced by all concentrations utilized in these applications.

3.11. Leaf macro-elements

3.11.1. Leaf nitrogen content (%)

In the 2023 and 2024 seasons, respectively, the greatest values of leaf nitrogen content (1.27 and 1.3%) were obtained with IBA treatment at 5 ppm. During the two research seasons, however, the values for the other concentrations 10 and 15 ppm were identical. In terms of BAP treatment, the greatest values (1.33 and 1.37%) were obtained at 60 ppm in both seasons. The maximum increase in leaf nitrogen content (1.45 and 1.5% in the first and second seasons, respectively) was obtained with the application of seaweed extract at a rate (20 ml/L).

3.11.2. Leaf phosphorus content (%)

In terms of IBA treatment, the maximum leaf phosphorus content values (0.13 and 0.43%) were obtained at 5 ppm in both seasons. Regarding BAP treatment, the first season showed no change between the three concentrations, but the second season saw the largest increase in leaf P content (0.52%) at the high concentration of 60 ppm. In the first and second seasons, respectively, 20 ml/L of seaweed extract treatment resulted in the largest increase in leaf phosphorus content (0.23 and 0.68%).

3.11.3. Leaf potassium content (%)

In terms of IBA treatment, the highest values of leaf potassium content (1.12 and 1.16 %) were obtained in the first and second seasons, respectively, from the foliar application of Nonpareil almond seedlings at low concentrations. In terms of BAP treatment, the administration of a high dose of 60 ppm in the first and second seasons, respectively, produced the greatest values of leaf potassium content (1.33 and 1.37%). In the first and second seasons, respectively, the maximum values of leaf potassium content were obtained with 20 ml/L of seaweed extract treatment (1.40 and 1.43%).

3.11.4. Leaf magnesium content (%)

Concerning IBA treatment, the results in Table 4 found that the low-dose scores the highest value of leaf magnesium content (0.33 and 0.37%) in the first and second seasons, respectively. With reference to BAP treatment, the highest values of leaf magnesium concentration (0.39 and 0.43%) were obtained by application with a high dose (60 ppm) in the first and second seasons, respectively. Similarly, in the first and second seasons, the greatest values for leaf magnesium concentration (0.45 and 0.47%, respectively) were obtained from treatment with a high dose of seaweed extract (20 ml/L).

Table 5: Effect of foliar spray with IBA, BAP and SE on leaf macro-elements of Nonpareil almond seedlings during 2023 and 2024 seasons

Parameters	**Nitrogen (%)**		**Phosphorus (%)**		**Potassium (%)**		**Magnesium (%)**	
Treatments	**1st season**	**2nd season**	**1st season**	**2nd season**	**1st season**	**2nd season**	**1st season**	**2nd season**
Control (Water only)	1.13H	1.15H	0.08F	0.11H	0.63G	0.65G	0.27H	0.31H
IBA at 5 ppm	1.27G	1.30F	0.13D	0.43F	1.12D	1.16D	0.33E	0.37EF
IBA at 10 ppm	1.20G	1.22G	0.12DE	0.42F	0.98E	1.01E	0.31F	0.36F
IBA at 15 ppm	1.20G	1.22G	0.11E	0.40G	0.84F	0.87F	0.29G	0.33G
BAP 20 ppm	1.30E	1.32E	0.19C	0.44EF	1.19D	1.23D	0.35D	0.38E
BAP 40 ppm	1.31E	1.34E	0.19C	0.45E	1.19D	1.23D	0.37C	0.41D
BAP 60 ppm	1.33D	1.37D	0.19C	0.52D	1.33C	1.37C	0.39B	0.43C
SE at 10 ml/L	1.35C	1.39C	0.20BC	0.54C	1.33C	1.37C	0.40B	0.45B
SE at 15 ml/L	1.40B	1.45B	0.21B	0.64B	1.37B	1.42B	0.42A	0.47A
SE at 20 ml/L	1.45A	1.50A	0.23A	0.68A	1.40A	1.43A	0.45A	0.47A

Mean values in the same column followed by the same letter are not significantly different at $p < 0.05$

3.12. Leaf micro-elements

3.12.1. Leaf copper content (ppm)

In the first and second seasons, 5 ppm IBA produced the highest value (12.8 and 13 ppm). According to the data, the greatest value (14.7 and 15.05 ppm) for BAP treatment was reached at 60 ppm in the first and second seasons, respectively. The biggest increase in leaf copper content (17.1 and 17.6 ppm) was seen in the first and second seasons, respectively, when seaweed extract was applied at a rate of 20 ml/L (Table 6).

3.12.2. Leaf iron content (ppm)

The greatest value for IBA treatment for the 2023 and 2024 seasons, respectively, is 5 ppm (142.1 and 137.2 ppm). In terms of BAP treatment, the biggest increase in leaf iron content (151.3 and 149 ppm) was seen in the first and second seasons at 60 ppm. Regarding the seaweed extract treatment, in the first and second seasons, 20 ml/L had the highest leaf iron content values (180 and 151.6 ppm, respectively) (Table 6).

3.12.3. Leaf zinc content (ppm)

In the 2023 and 2024 seasons, respectively, 5 ppm produced the highest value (10.9 and 11.1 ppm) for IBA treatment (Table 6). In terms of BAP treatment, the greatest increase in leaf zinc concentration occurred at 60 ppm in the first and second seasons (11.7 and 12.05 ppm, respectively). In the first and second seasons, respectively, 20 ml/L of seaweed extract produced the highest value (18 and 18.5 ppm).

3.12.4. Leaf manganese content (ppm)

About the treatment of IBA in the first and second seasons, 5 ppm displayed the highest values (49.8 and 50 ppm, respectively). In the first and second seasons, respectively, the high dose of BAP treatment had the highest leaf manganese content values (55.5 and 55.85 ppm). During the 2023 and 2024 seasons, respectively, the maximum value of leaf manganese concentration (65.1 and 65.6 ppm) was obtained with 20 ml/L of seaweed extract treatment.

Table 6: Effect of foliar spray with IBA, BAP and SE on leaf micro-elements of Nonpareil almond seedlings during 2023 and 2024 seasons

Parameters	Copper (ppm)		Iron (ppm)		Zinc (ppm)		Manganese (ppm)	
Treatments	1st Season	2nd Season	1st Season	2nd Season	1st Season	2nd Season	1st Season	2nd Season
Control (Water only)	8.9J	8.95I	129.6I	128.8I	7.9I	7.95I	41.9J	41.95J
IBA at 5 ppm	12.8G	13.00F	142.1	137.2F	10.9F	11.10F	49.8G	50.00G
IBA at 10 ppm	11.4H	11.55G	138.0G	131.0G	9.7G	9.50G	47.8	47.95H
IBA at 15 ppm	9.8I	9.90H	135.9H	129.9H	8.0H	8.90H	44.3I	44.40I
BAP 20 ppm	13.7F	14.00E	149.7E	138.3E	11.0E	11.25F	52.1F	52.35F
BAP 40 ppm	14.0E	14.25E	151.2D	140.1D	11.2E	11.50E	53.3E	53.60E
BAP 60 ppm	14.7D	15.05D	151.3D	149.0C	11.7D	12.05D	55.5D	55.85D
SE at 10 ml/L	15.6C	16.00C	156.7C	150.1B	12.0C	12.40C	58.8C	59.20C
SE at 15 ml/L	16.6B	17.05B	162.7B	151.2A	16.8B	17.25B	60.0B	60.45B
SE at 20 ml/L	17.1A	17.60A	180.0A	151.6A	18.0A	18.50A	65.1A	65.60A

Mean values in the same column followed by the same letter are not significantly different at $p < 0.05$

4. Discussion

The findings about the impact of foliar spraying benzyl amino purine (BAP) and indole-3-butyric acid (IBA) on Nonpareil almond seedlings are consistent with those of Mok (1994) and Al-Taey *et al.,* (2018), who reported their findings regarding key plant hormones. It also significantly improved plant growth and leaf enlargements. Additionally, the findings of this study are in line with other research that demonstrated that foliar application of IBA increased the growth and yield of cotton plants (Felixloh and Nina, 2000), significantly increased vegetative growth, yield and its components, and the chemical components of maize grains (Amin *et al.*, 2006), as well as the growth of pine seedlings (Xu *et al.,* 2012; Abd El Gayed, 2013). Additionally, foliar application of IBA significantly increased the height of the seedlings, stem height and diameter, number of leaves/seedlings, leaf area, fresh and dry leaf weight, chlorophyll pigment content, and minerals in Jatropha seedlings, especially when applied at low doses (Ahmed *et al*., 2018).

When IBA and BAP were sprayed on the leaves of almond seedlings, the amount of carbohydrates and macro- and micronutrients in the leaves increased. These outcomes were consistent with those of Hasan *et al*., (2020), who found that the primary function of foliar spraying plant growth promoters (IBA and CPPU) may be because of their impact on cell division and elongation, which in turn encouraged the leaves to absorb more nutrients. Additionally, it is proposed that the elevated chlorophyll concentration in leaves might be explained by the action of cytokinins, which are crucial for chlorophyll synthesis (Mahmoud *et al.,* 2015; Rehman *et al.,* 2023; Selim *et al.,* 2023).

EISSN: 2706-7955 ISSN: 2077-4605 *DOI: 10.36632/mejar/2025.14.2.20*

Additionally, as the amount of chlorophyll in leaves increased, so did the rates of photosynthesis and respiration, which control different aspects of plant growth. Al-Abedy and Al-Abbasi (2020), Kareem *et al.* (2022), Rakha *et al.* (2024), and Abou Rayya *et al.* (2024 and 2025) found that foliar application of seaweed extract was incrementally beneficial for all the plant growth parameters that were investigated, including plant height, lateral shoot number, leaf number, stem diameter, leaf area, and total leaf chlorophyll content. These findings are consistent with the stimulative effect of seaweed extract (SE) on the growth and nutrient concentrations of almond seedlings. In comparison to the control, it also raised the percentage of dry weight, dry matter, and carbs in the leaves.

The benefits of using seaweed extract to promote the production of organic materials, particularly carbohydrates, may be responsible for the improvement in all aspects of vegetative development. According to Jensen (2004), this is because the seaweed extract has a high concentration of organic matter, microelements, vitamins, fatty acids, and growth regulators such auxins, cytokinins, and gibberellins. The findings of Thanaa *et al*. (2016), and Mosa *et al.* (2023) showing seaweed extract includes critical minerals and amino acids, resulting in higher absorption and favorable seedling growth, are consistent with this discovery. Because seaweed extract contains vital macro- and microelements, plant hormones, and vitamins, it increases the dry matter percentage in leaves. As a result, the leaf area, photosynthesis products, and dry weight all rise. Furthermore, the proteins, oligosaccharides, enzymes, and various secondary metabolites found in seaweeds assist plants fend off illness by regulating their physiological, biochemical, and molecular functions (Agarwal *et al*., 2021; Elhan and Ahmad, 2022). According to studies, applying seaweed extract has been associated with improved cytological attributes, physiological traits, and plant molecular analyses, all of which point to a comprehensively beneficial effect on plant production and health (Hamouda *et al*., 2022).

5. Conclusion

Under Nubaria conditions, it could be concluded that using 5 ppm indole-3-butyric acid (IBA), 60 ppm benzyl amino purine (IBA) and 20 ml/L seaweed extract (SE) three times at mid-February, mid-March and mid-April as a foliar application for improving the growth and nutritional status of Nonpareil almond seedlings.

6. Acknowledgements

The authors acknowledge the National Research Centre (NRC) in Egypt for its financial support and outstanding cooperation with the project "Technology of establishing ideal almond orchard under Sandy Soil Conditions of Nubaria."

7. Funding

This research was made possible by funding from the National Research Centre through the project title: "Technology of establishing ideal almond orchard under Sandy Soil Conditions of Nubaria" Project ID: 13050131, during 2022/2025.

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