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Effect of urea spraying and seaweed extract on growth indicators, yield, and content of medicinally active compounds of anise (*Pimpinella anisum* L.)

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Abstract

A protected pot experiment was conducted in a wire shelter of the Department of Plant Production Techniques at Al-Mussaib Technical College, located at coordinates 32º47′ N latitude and 44º26′ E longitude, to investigate the effects of foliar urea application and seaweed extract application on growth, yield, and quality traits of *Pimpinella anisum* L. (Anise). The experiment was conducted in plastic pots and arranged in a completely randomized design (CRD) with three replications, with pots randomly distributed within each replication. Data were statistically analyzed, and mean differences were tested using the least significant difference (LSD) at the 5% significance level. Results showed that foliar application of urea at 15 g L^{-1} produced the highest averages for plant height (42.90 cm), number of branches per plant (7.63), number of leaves per plant (32.75), leaf area per plant (160.83 cm^2), number of umbels per plant (26.43), seed yield per plant (5.13 g), seed oil content (5.03%), carbohydrate content (53.27%), protein content (17.15%), fiber content (17.55%), flavonoids (16.15 mg g^{-1}), and relative limonene abundance (22.73%). Meanwhile, foliar spray of seaweed extract at 6 mL L^{-1} resulted in the highest averages for the same traits, reaching 44.28 cm, 8.40 branches per plant, 34.80 leaves per plant, 172.68 cm^2 leaf area, 29.88 umbels per plant, 5.80 g seed yield, 5.40% oil, 55.53% carbohydrates, 17.98% protein, 19.05% fiber, 17.38 mg g^{-1} flavonoids, and 24.10% relative limonene abundance, respectively.

Key words: *Pimpinella anisum* L., anise, foliar urea, seaweed extract, growth traits, seed yield, essential oil, limonene, flavonoids

Introduction

Anise (*Pimpinella anisum* L.) is an annual herbaceous plant of the Apiaceae family, generally 40-50 cm tall, with a slender, ribbed stem, branched form, round serrated leaves, and small white flowers that turn into brown fruits (Orav *et al.,* 2008). The seeds are rich in essential oil, mainly anethole, but also estragole, anisaldehyde, caffeic acid, fixed oils, carbohydrates, proteins and flavonoids (Orav *et al.*, 2008). Anise is traditionally used in drinks and valued for its appetite-stimulating, calming, diuretic, antispasmodic and cold-relieving properties.

Foliar nutrition is regarded as an important factor for plant growth and development especially in the early stages (Kocoń, 2010; Vishwanatha *et al.*, 2025). The soil contains major and minor elements but the amounts available to plants for uptake are often not sufficient for optimum growth. Some nutrients, particularly micronutrients, may be leached, fixed or adsorbed in some soils, which limits their availability to the plant roots and results in deficiency symptoms in the seedling. These limitations can be overcome by foliar application of nutrients and can enhance seedling growth (Abu Dahi and Al-Younis, 1988; Ajeel *et al.*, 2025). The physiological and biochemical process in plant cells are affected by fertilisers, which have much effect on the growth and yield of the plants (Ajeel and Al-Hakeim, 2024). Foliar fertilisation affects physiological processes which in turn affect the vegetative growth and yield components (Al-Tayeb, 2012). Nitrogen is an essential element for chlorophyll formation, protein synthesis, nucleic acid synthesis, plant hormones and energy compounds and its availability improves production and quality (Mengel and Kirkby, 1987). Foliar application of urea is a widely used technique for a variety of crops and systems of cultivation, since most of the plants can absorb urea solutions applied on the leaves (Nicoulaud and Bloom, 1996). Foliar urea fertilisation is done for the supply of additional nutrients to enhance optimum growth and yield (Wahle and Masiunas, 2003). Nitrogen activates many enzymes involved in the synthesis of ATP, which is essential for photosynthesis and nutrient translocation, thus having a positive effect on protein content in plants and seeds (Daur *et al.*, 2008). Foliar application techniques increase the uptake of nutrients and improve seedling quality to withstand field stress conditions (Rouphael and Colla, 2020).

In recent years, seaweed extracts have been extensively used as a source of macro- and micronutrients and growth regulators (Taha *et al.*, 2025). Seaweed extracts contain bioactive compounds including cytokinins, auxins, and gibberellins that may influence cell division, nutrient uptake, and plant growth. They contain micronutrients such as Co, B, Mo, Zn and Cu, auxins, gibberellins and cytokinins which improve root growth, nutrient uptake, stem thickness, leaf area and overall vegetative and root growth leading to higher yields (Jensen, 2004). Foliar application of seaweed extracts significantly enhanced vegetative growth, yield and leaf chlorophyll content in studies on rosemary and legumes (Temple and Bomke, 1989).

Although nitrogen fertilization and biostimulants have been studied in several horticultural and medicinal crops, limited information is available on the combined factorial effect of foliar urea and seaweed extract on vegetative growth, seed yield, proximate seed composition, flavonoids, and GC–MS-derived volatile constituents of Pimpinella anisum under protected pot conditions.

This study aims to evaluate the response of growth, yield, and quality traits of local anise plants to foliar urea application and different levels of seaweed extract under controlled growth conditions.

Material and methods

At the Department of Plant Production Technique, Al-Mussaib Technical College, the coordinates 32º 47′ N and 44º 26′ E a protected pot experiment was conducted in plastic pots which had a capacity of 10 kg, filled with soil: peatmoss ratio (1:2). The physical and chemical properties of the original field soil (prior to mixing) were determined in the lab according to the Black (1965) and Page *et al.* (1982) methods presented in Table 1.

The aim of the study was to assess the four levels of foliar urea application (0, 5, 10, 15 g L^{-1}) and four seaweed extract application (0, 2, 4, 6 mL L^{-1}) on growth, yield and quality traits of anise (*Pimpinella anisum L.*). Treatments were arranged in a 4 × 4 factorial completely randomized design (CRD) with three replicates, giving 16 treatment combinations and 48 experimental pots. The pot was considered the experimental unit. Five seeds were sown per pot and later thinned to three plants. Data were recorded from the three plants per pot and the mean value per pot was used for statistical analysis. The experimental design was suitable for CRD because the pots were randomly arranged and re-randomized periodically to minimise positional effects. Before the experiment, microclimatic measurements were made in the wire-netted shelter. Measurements of temperature, light intensity and relative humidity did not show any significant spatial variation within the experimental area and thus confirmed the uniformity of the environment.

Sowing was done on 25th November, 2024 with five seeds per pot and after germination the plants were thinned to three. Phenological observations were performed during the whole growing season. Plants were harvested at full seed development (ca. 100 days after sowing), according to the normal maturity period of *Pimpinella anisum* L. During soil preparation, phosphate fertiliser (triple superphosphate, 21% P_2O_5) was added at 120 kg ha^{-1} and potassium fertiliser (potassium sulphate, 41.5% K_2O) was added at 100 kg ha^{-1} two weeks after germination, directly into the growth medium (Matloub *et al.*, 1989). Fertiliser application rates were converted to equivalent values per pot based on the surface area of pots (20 cm diameter; 0.0314 m^2) and expressed on a hectare basis (kg ha^{-1}). The conversion was done using the equation: g pot^{-1} = kg ha^{-1} × 1000 × (0.0314/10000). According to this calculation, the respective amounts applied were 0.38 g of triple superphosphate (120 kg ha^{-1}) and 0.31 g of potassium sulphate (100 kg ha^{-1}). These quantities were thoroughly mixed with the soil during the initial preparation of the growth medium before sowing.

Foliar urea was applied in two stages: the first 20 days after germination and the second 20 days after the first application. Each plant received foliar spray until full leaf wetting (approximately 50 mL per pot). Spraying was carried out in the early morning between 08:00–09:00 to reduce evaporation losses. No tank mixing was performed, and seaweed extract was applied separately from urea. Seaweed extract was applied as a foliar spray at 0,2,4 and 6 mL L^{-1} using a commercial liquid biostimulant (Alga 300, manufactured by Qingdao Leili Biostimulant Co., Ltd., China). This liquid extract is derived from the marine brown alga (Ascophyllum nodosum) and contains organic matter (≥ 300 g L^{-1}), alginic acid (≥ 30 g L^{-1}), total N-P_2O_5-K_2O (≥ 100 g L^{-1}), along with trace micronutrients and natural plant growth regulators including cytokinins, auxins, and gibberellins. The seaweed extract was applied separately from urea following the same application schedule (two sprays during the growing period). All treatments were applied using a hand-held sprayer without a wetting agent. Weeding and irrigation were done as needed. Vegetative growth traits (plant height, number of branches, number of leaves, and leaf area) and yield parameters (number of umbels per plant and seed yield) were recorded. Seed quality traits were evaluated using standard analytical protocols. Crude fixed oil content was determined using the Soxhlet extraction method with petroleum ether as a solvent (AOAC Method 920.39). Total nitrogen was determined using the Micro-Kjeldahl method, and crude protein content was calculated by multiplying the nitrogen percentage by a conversion factor of 6.25 (AOAC Method 960.52). Crude fiber was determined using the standard acid-base digestion method (AOAC Method 962.09). Total carbohydrate content was estimated spectrophotometrically (Herbert *et al.*, 1971). For flavonoid content, seed samples were extracted with methanol, and quantification was performed using the aluminum chloride colorimetric method (AOAC, 2000). Quercetin was used as the calibration standard, and absorbance was measured at 415 nm. Results were expressed as mg of quercetin equivalent per g of dry weight (mg QE g DW^{-1}). To determine the relative limonene abundance, essential oil was first extracted from the seeds via hydrodistillation for 3 hours using a Clevenger-type apparatus. The extracted essential oil was dried over anhydrous sodium sulfate and stored at 4 °C until analysis. The essential oil components, including limonene, were then analyzed by gas chromatography–mass spectrometry (GC–MS) using an Agilent 7890B gas chromatograph linked to an Agilent 5977A mass selective detector. The separation was done in an HP-5MS capillary column (30 m × 0.25 mm internal diameter × 0.25 µm film thickness). Although anethole is the primary constituent of anise essential oil, limonene was selected as the targeted marker compound in this study. This selection was made to specifically evaluate the influence of foliar urea and biostimulants on the monoterpene biosynthesis pathway (MEP pathway). Unlike anethole (a phenylpropanoid synthesized via the shikimate pathway), monoterpenes such as limonene are highly responsive to environmental elicitors and external biostimulant applications, making limonene an excellent indicator for assessing treatment efficacy. Helium (99.999% purity) was used as the carrier gas at a constant flow rate of 1.0 mL min^{-1}. The pressure of the on-line

Table 1. Soil properties of the experimental medium before planting.

Characterstics	Unit	Value
pH	–	7.8
Electrical conductivity (ECe)	dS m^{-1}	2.1
Calcium carbonate ($CaCO_3$)	%	19.5
Calcium sulfate ($CaSO_4$)	%	0.54
Organic matter	%	0.83
Sand fraction	%	40.5
Silt fraction	%	39.4
Clay fraction	%	20.1
Texture	–	Silt Loam
Cation exchange capacity (CEC)	cmol kg^{-1} soil	19.3
Available nitrogen (N)	mg kg^{-1} soil	28.4
Available phosphorus (P)	mg kg^{-1} soil	10.6
Available potassium (K)	mg kg^{-1} soil	143.7
Bulk density	g cm^{-3}	1.52

integration system for the injector was 10 bars with split ratio of 1: 20 and injection volume of 1µl. The oven temperature was programmed as follows: oven temperature was initially set to 60 °C for 2 min, then ramped to 200 °C and set to 5 °C min^{-1}, finally increased to 280 °C with a ramping rate of 10 °C min^{-1} and then kept for 5 min. Operation with electron ionization of the mass spectrometer was done in 70 eV and the ion source and quadrupole temperatures were set at 230 °C and 150 °C, respectively, and mass spectra were collected covering the mass range of 40 to 500 m/z. Identification was done by comparing with mass spectra from the NIST library and expressed as a relative percentage of the total identified essential oil components by GC–MS peak area. Absolute quantification was not performed using external standards.

The data were statistically analyzed with two-way factorial analysis of variance (ANOVA) in completely randomized design (CRD) laid out in a 4 × 4 factorial experiment design. The model included urea concentration, seaweed extract concentration, and their interaction as fixed effects. The pot was considered the experimental unit, and plant measurements within each pot were averaged before analysis. Means were compared using the least significant difference (LSD) test at $P \leq 0.05$ only when the corresponding F-test was significant. Statistical analysis was performed using GenStat (Al-Rawi and Khalaf Allah, 2000).

Results

Plant height and number of branches: Plant height and number of branches per plant were significantly affected by foliar urea and seaweed extract treatments (Table 2). Urea at 15 g L^{-1} increased plant height to 42.90 cm and branches to 7.63, while seaweed extract at 6 mL L^{-1} produced 44.28 cm and 8.40 branches. The combined treatment of 15 g L^{-1} urea + 6 mL L^{-1} seaweed extract recorded the highest plant height and branch number, reaching 47.20 cm and 9.70 branches per plant, respectively, compared to the control (0 g L^{-1} urea + 0 mL L^{-1} extract), which recorded the lowest values of 32.60 cm and 4.30 branches.

Table 2. Effect of foliar application of urea and seaweed extract on plant height and number of branches of *Pimpinella anisum* L.

Seaweed extract (mL L^{-1})	Plant height (cm)				Mean	Branches per plant				Mean
	Urea (g L^{-1})					Urea (g L^{-1})				
	0	5	10	15		0	5	10	15	
0	32.6d	33.2c	35.7b	38.4b	34.98d	4.3d	4.6d	4.8d	5.7c	4.85d
2	34.1d	36.8b	39.5b	41.3b	37.93c	4.8b	5.2c	5.9c	6.7b	5.65c
4	37.4c	40.5b	42.2a	44.7a	41.20b	5.7c	6.8b	7.9b	8.4ab	7.20b
6	41.2b	43.1a	45.6a	47.2a	44.28a	7.2b	8.1ab	8.6ab	9.7a	8.40a
Mean	36.33d	38.40c	40.75b	42.90a		5.50d	6.18c	6.80b	7.63a	

Means followed by different letters within each trait differ significantly at $P \leq 0.05$ according to LSD.

Number of leaves and leaf area: Foliar application of urea and seaweed extract significantly increased the number of leaves per plant and leaf area (Table 3). Urea at 15 g L^{-1} produced 32.75 leaves and 160.83 cm² leaf area, while seaweed extract at 6 mL L^{-1} gave 34.80 leaves and 172.68 cm². The combination of urea (15 g L^{-1}) and seaweed extract (6 mL L^{-1}) recorded the highest values of 38.70 leaves per plant and 185.40 cm² leaf area, compared to the combined control (0 g L^{-1} urea + 0 mL L^{-1} extract), which recorded the lowest values of 21.50 leaves and 131.10 cm².

Table 3. Effect of foliar spraying with urea and seaweed extract on the number of leaves and leaf area per plant

Seaweed extract (mL L^{-1})	Number of leaves per plant				Mean	Leaf area per plant (cm²)				Mean
	Urea (g L^{-1})					Urea (g L^{-1})				
	0	5	10	15		0	5	10	15	
0	21.5 d	22.5 d	24.6 c	27.1 c	23.93d	131.1 d	135.4 d	137.5 c	140.3 c	136.08d
2	23.8 c	25.6 c	28.9 b	30.6 b	27.23c	137.8 c	141.1 c	145.7 b	150.4 b	143.75c
4	27.3 c	30.2 b	32.1 b	34.6 a	31.05b	145.9c	152.3 b	158.6 b	167.2 a	156.00b
6	31.7 b	33.2 ab	35.6a	38.7a	34.80a	160.5 b	168.6 ab	176.2 a	185.4 a	172.68a
Mean	26.08d	27.88c	30.30b	32.75a		143.83d	149.35c	154.50b	160.83a	

Means followed by different letters within each trait differ significantly at $P \leq 0.05$ according to LSD.

Number of umbels and seed yield per plant: Foliar application of urea and seaweed extract significantly improved the number of umbels per, plant and seed yield (Table 4). Urea at 15 g L^{-1} produced 26.43 umbels and 5.13 g seed yield per plant, while seaweed extract at 6 mL L^{-1} gave 29.88 umbels and 5.80 g. The combined treatment (15 g L^{-1} urea + 6 mL L^{-1} seaweed extract) recorded the highest values of 35.10 umbels per plant and 6.80 g seed yield, compared with the untreated control (0 g L^{-1} urea + 0 mL L^{-1} extract), which recorded the lowest values of 12.50 umbels and 2.60 g. The interaction effect on seed yield is presented in Fig. 1.

Oil and carbohydrate content in seeds: Foliar application of urea and seaweed extract significantly affected seed oil and carbohydrate, content (Table 5). Urea at 15 g L^{-1} increased oil and carbohydrate content to 5.03% and 53.25%, while seaweed extract at 6 mL L^{-1} raised them to 5.40% and 55.53%. The combined treatment (15 g L^{-1} urea + 6 mL L^{-1} extract) had a synergistic effect, recorded the highest values of 6.30% oil and 58.30% carbohydrate, whereas the untreated control (0 g L^{-1} urea + 0 mL L^{-1} extract) recorded the lowest, 3.20% oil and 43.10% carbohydrate.

Protein and fiber content in seeds: Foliar application of urea and seaweed extract significantly influenced seed protein and fiber content (Table 6). Urea at 15 g L^{-1} increased protein and fiber to 17.15% and 17.55%, while seaweed extract at 6 mL L^{-1} raised them to 17.98% and 19.05%. The combined treatment (15 g L^{-1} urea + 6 mL L^{-1} extract) recorded the highest protein (19.50%) and fiber (21.70%) levels. In contrast, the untreated control (0 g L^{-1} urea + 0 mL L^{-1} extract) recorded the lowest protein (13.50%) and fiber (12.60%).

Flavonoids and limonene in seeds: Foliar application of urea and seaweed extract significantly affected seed flavonoid and relative limonene abundance (Table 7). Urea at 15 g L^{-1} increased flavonoids to 16.15 mg g^{-1} and limonene to 22.73% of total identified essential oil components, while seaweed extract at 6 mL L^{-1} raised them to 17.38 mg g^{-1} and 24.10%, respectively. The combined treatment (15 g L^{-1} urea + 6 mL L^{-1} extract) recorded the highest values of 18.50 mg g^{-1} flavonoids and 26.60% limonene. In contrast, the untreated control recorded the lowest values of 12.30 mg g^{-1} flavonoids and 17.40% limonene

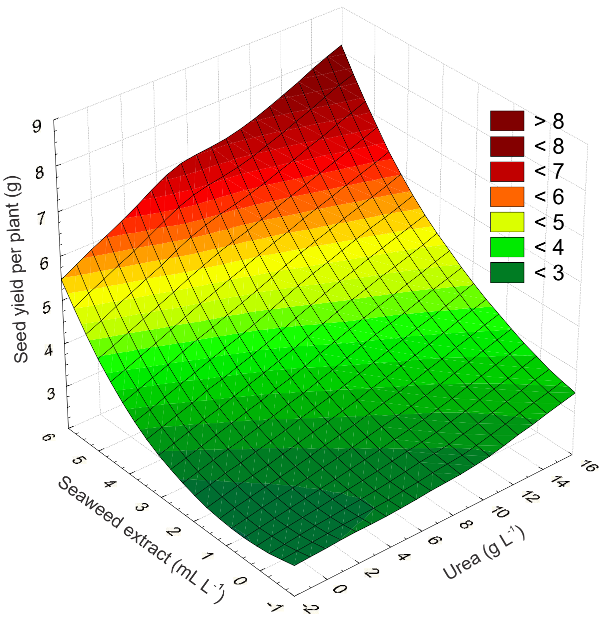

Fig. 1. Interaction effect of urea and seaweed extract on seed yield per plant illustrated as a 3D response surface.

Discussion

The results indicate a significant superiority of foliar urea spraying at 15 g L^{-1} across the studied vegetative growth and yield traits. This effect may be attributed to the influence of nitrogen in urea, which enhances gibberellin activity within plant tissues, promoting cell division and positively affecting vegetative traits such as plant height, number of branches, leaf number and area, and dry weight, all of which contribute to improved yield and quality (De Lucas *et al.*, 2008). Nitrogen availability may enhance processes associated with production of plant hormones, such as auxins and cytokinins, which promote cell division and leaf primordia formation, leading to increased nucleic acid and protein synthesis necessary for growth. Yin *et al.* (2011) reported that the positive effect of nitrogen spraying on leaf chlorophyll is due to its role in forming porphyrins, essential for chlorophyll and cytochrome synthesis, supporting photosynthesis and respiration. Nitrogen also prolongs the grain-filling period by keeping leaves active longer, increasing assimilate production and transport to seeds (Kocoń, 2010). The increase in seed protein content is attributed to nitrogen-enhanced amino acid synthesis and to enzymatic cofactors that promote protein synthesis (Taub and Wang, 2008). These results align with Kamal *et al.* (2016), who observed similar effects of organic fertilization combined with nitrogen on pea plants.

The better response of anise plants to foliar urea application can be attributed to the calcareous nature of the experimental soil and the high $CaCO_3$ level (19.5) and alkaline pH (7.8) of the experimental soil. Precipitation and fixation reactions usually decrease nutrient availability, particularly the nitrogen, phosphorus, and micronutrient, in such soils (Aswad *et al.*, 2026). Foliar fertilization delivers nutrients by bypassing soil-related chemical constraints, and the nutrients are used more effectively (Ajeel, 2026) thus vegetative growth and yield are greatly enhanced when using urea spraying.

The effect of the foliar application of seaweed extracts on the observed growth and yield traits was also significant to the point that the tables show that the approach would have a positive impact, the positive impact of seaweed extract can be explained by the fact that the extract is a biostimulant especially in the alkaline and moderately salty conditions of the experimental medium (pH 7.8 and ECe 2.1 dS m^{-1}). Bioactive compounds found in seaweed extracts are associated with increased root activity, nutrient uptake, and

Table 4. Effect of foliar spraying with urea and seaweed extract on the number of umbels and seed yield per plant

Seaweed extract (mL L^{-1})	Number of umbels per plant				Mean	Seed yield per plant (g)				Mean
	Urea (g L^{-1})					Urea (g L^{-1})				
	0	5	10	15			5	10	15	
0	12.5d	13.7d	15.4c	17.8c	14.85d	2.6d	2.8d	3.1c	3.6c	3.03d
2	14.5c	17.6c	19.7b	23.4b	18.80c	2.9c	3.4c	3.9b	4.5b	3.68c
4	18.3c	22.1b	26.3b	29.4a	24.03b	3.6c	4.2b	5.1b	5.6a	4.63b
6	24.2b	28.3ab	31.9a	35.1a	29.88a	4.7b	5.6ab	6.1a	6.8a	5.80a
Mean	17.38d	20.43c	23.33b	26.43a		3.45d	4.00c	4.55b	5.13a	

Means followed by different letters within each trait differ significantly at $P \leq 0.05$ according to LSD.

Table 5. Effect of foliar spraying with urea and seaweed extract on seed oil and carbohydrate content

Seaweed extract (mL L^{-1})	Seed oil content %				Mean	Seed carbohydrate content %				Mean
	Urea (g L^{-1})					Urea (g L^{-1})				
	0	5	10	15		0	5	10	15	
0	3.2d	3.3d	3.4c	3.8c	3.43d	43.1d	44.7d	46.8c	47.5c	45.53d
2	3.4c	3.6c	4.2b	4.7b	3.98c	46.7c	48.2c	49.5b	52.4b	49.20c
4	3.7c	4.3b	4.9b	5.3a	4.55b	49.4c	52.6b	53.7b	54.8a	52.63b
6	4.5b	5.2ab	5.6a	6.3a	5.40a	52.9b	54.7ab	56.2a	58.3a	55.53a
Mean	3.70d	4.10c	4.53b	5.03a		48.03d	50.05c	51.55b	53.25a	

Means followed by different letters within each trait differ significantly at $P \leq 0.05$ according to LSD.

Table 6. Effect of foliar spraying with urea and seaweed extract on seed protein and fiber content

Seaweed extract (mL L^{-1})	Seed protein content (%)				Mean	Seed fiber content (%)				Mean
	Urea (g L^{-1})					Urea (g L^{-1})				
	0	5	10	15		0	5	10	15	
0	13.5d	13.8d	14.6c	15.1c	14.25d	12.6d	13.1d	13.8c	14.5c	13.50d
2	14.5c	15.2c	15.9b	16.7b	15.58c	13.5c	14.3c	14.9b	15.9b	14.65c
4	15.8c	16.2b	16.7b	17.3a	16.50b	14.9c	15.6b	17.2b	18.1a	16.45b
6	16.7b	17.4ab	18.3a	19.5a	17.98a	16.4b	18.5ab	19.6a	21.7a	19.05a
Mean	15.13d	15.65c	16.38b	17.15a		14.35d	15.38c	16.38b	17.55a	

Table 7. Effect of foliar application of urea and seaweed extract on seed flavonoid content (mg g^{-1}) and relative limonene abundance (% of total identified essential oil components)

Seaweed extract (mL L^{-1})	Flavonoids (mg g^{-1})				Mean	Relative limonene abundance (% of total identified GC–MS peak area)				Mean
	Urea (g L^{-1})					Urea (g L^{-1})				
	0	5	10	15		0	5	10	15	
0	12.3d	12.5d	12.9c	13.6c	12.83d	17.4d	17.8d	18.5c	18.9c	18.15d
2	12.8c	14.1c	14.7b	15.3b	14.23c	18.2c	18.8c	19.9b	21.3b	19.55c
4	14.5c	15.6b	16.3b	17.2a	15.90b	19.4c	21.2b	22.6b	24.1a	21.83b
6	16.1b	17.2ab	17.7a	18.5a	17.38a	21.7b	23.3ab	24.8a	26.6a	24.10a
Mean	13.93d	14.85c	15.40b	16.15a		19.18d	20.28c	21.45b	22.73a	

photosynthetic efficiency (Rouphael and Colla, 2020; Rasouli *et al.*, 2023). These compounds additionally enhance plant tolerance to abiotic stress through the enhancement of antioxidant activity, osmotic adjustment, and membrane stability (Ali *et al.*, 2021). In calcareous and salty environments, the chelation of nutrients through seaweed extracts can alleviate the adverse impacts of elevated concentration of $CaCO_3$ and salinity on the growth of plants and their yield (Craigie, 2011; Rasouli *et al.*, 2023).

Foliar application of urea at 15 g L^{-1} significantly improved growth, yield, and seed quality traits of Pimpinella anisum L. under the conditions of this study . Seaweed extract at 6 mL L^{-1} also enhanced all measured parameters compared with untreated plants. These levels may be recommended for anise under similar protected pot conditions. Field validation is required before wider application, and further studies are needed to evaluate their effects on other crops within the Apiaceae family under different environmental conditions.

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References

Abu Dahi, Y.M. and M.A. Al-Younis, 1988. Plant nutrition guide. Directorate of Printing and Publishing, University of Mosul, Ministry of Higher Education and Scientific Research, Iraq.

Ajeel, M.R. and M.S. Al-Hakeim, 2024. The influence of biological and organic fertilization and boron spraying in some soil characteristics. *IOP Conf. Ser.: Earth Environ. Sci.,* 1371(8): 082022. https://doi.org/10.1088/1755-1315/1371/8/082022

Ajeel, M. R., Hamid, M. M. H., Al-Shahbani, I. R. (2025). The impact of biofertilizers, organic fertilizers, and foliar application of boron on yield characteristics of maize (Zea mays L.). *Basrah J. Agric. Sci.,* 38(1), 312–323. https://doi.org/10.37077/25200860.2024.38.1.24

Aswad, A.H., M.M. Hamid, M.T.A. Almeekh and M.R. Ajeel, 2026. Phosphorus adsorption and release dynamics in calcareous soil as affected by humic and fulvic acids. *J. Degraded Mining Lands Manage.,* 13(1): 9463-9472.

Ajeel, M.R., 2026. Agricultural consideration of the effects of biofertilizers and boron on desertified soils: A sustainable strategy for enhancing soil chemical properties. *Jordan J. Earth Environ. Sci.,* 17(1): 106. https://jjees.hu.edu.jo/Vol17.htm

Ali, O., A. Ramsubhag and J. Jayaraman, 2021. Biostimulant properties of seaweed extracts in plants: Implications towards sustainable crop production. *Plants,* 10(3): 531. https://doi.org/10.3390/plants10030531

Al-Rawi, K.M. and A.M. Khalaf Allah, 2000. Design and analysis of agricultural experiments. University of Mosul Press, Iraq.

Al-Tayeb, F.A.S., 2012. Evaluation of the effect of some biotic factors on growth and productivity of spinach (*Spinacea oleracea* L.) and its content of calcium oxalate crystals. Ph.D. Diss., College of Agriculture, University of Kufa, Iraq.

AOAC, 2000. Official methods of analysis of the Association of Official Analytical Chemists, 17th ed. Washington, D.C., USA.

Black, C.A. (Ed.), 1965. Methods of soil analysis, part 2: chemical and microbiological properties. Amer. Soc. Agron., Madison, Wisconsin, USA.

Craigie, J.S., 2011. Seaweed extract stimuli in plant science and agriculture. *J. Appl. Phycol.*, 23: 371–393. https://doi.org/10.1007/s10811-010-9560-4

Daur, I., H. Sepetoglu, K.B. Marwarth, G. Hassan and I. Khan, 2008. Effect of different levels of nitrogen on dry matter and grain yield of green gram. *Pak. J. Bot.*, 40(6): 2453–2459.

De Lucas, M., J.M. Daviere, M. Rodríguez-Falcón, M. Pontin, J.M., Iglesias-Pedraz, S. Lorrain and S. Prat, 2008. A molecular framework for light and gibberellin control of cell elongation. *Nature*, 451(7177): 480-484.

Herbert, D., P. J. Phipps, and R.E. Strange, 1971. Determination of total carbohydrates. *Methods in microbiology*, 5(8), 290-344.

Jensen, E. 2004. Seaweed; fact or fancy. *Organic Broadcaster*, *12*(3), 164-170.

Kamal, J.A.K., B.A.A. Ghalib and S.S. Farqan, 2016. Effect of organic fertilizer and urea addition on growth and yield of pea plants. *Univ. Babylon J. Pure Appl. Sci.*, 24(4): 991–1002.

Kocoń, A., 2010. The effect of foliar or soil top-dressing of urea on some physiological processes and seed yield of faba bean. *Pol. J. Agron.*, 3: 15–19.

Matloub, A.N., A.M. Sultan and K.S. Abdul Kareem, 1989. Vegetable production, part one. Directorate of Printing and Publishing, University of Mosul, Iraq.

Mengel, K. and E.A. Kirkby, 1987. Principles of plant nutrition, 4th ed. Int. Potash Inst., Basel, Switzerland.

Nicoulaud, B.A.L. and A.J. Bloom, 1996. Absorption and assimilation of foliar-applied urea in tomato. *J. Am. Soc. Hortic. Sci.*, 121: 1117–1121.

Orav, A., A. Raal and E. Arak, 2008. Essential oil composition of *Pimpinella anisum L.* fruits from various European countries. *Nat. Prod. Res.*, 22(3): 227–232.

Page, A.L., R.H. Miller and D.R. Keeney (Eds.), 1982. Methods of soil analysis, part 2, 2nd ed. Madison, Wisconsin, USA.

Rasouli, F., Nasiri, Y., Hassanpouraghdam, M. B., Asadi, M., Qaderi, T., Trifa, A., Szczepanek, M. (2023). Seaweed extract and arbuscular mycorrhiza co-application affect the growth responses and essential oil composition of *Foeniculum vulgare* L. *Sci. Rep.*, 13(1), 11902. https://doi.org/10.1038/s41598-023-39194-3

Rouphael, Y., Colla, G. (2020). Biostimulants in agriculture: A review of their action mechanisms and applications. *Front. Plant Sci.*, 11, 40. https://doi.org/10.3389/fpls.2020.00040

Taha S.S., A. Abdel-Wahab, A.M.M. Gabr and A.M.A. Abd Elgayd, 2025. Enhancing productivity of foundation potato seeds produced *in vitro* using organic and mineral fertilizers. *J. Appl. Hortic.,* 27(3): 501-507. https://doi.org/10.37855/jah.2025.v27i03.91

Taub, D.R. and X.Z. Wang, 2008. Why are nitrogen concentrations in plant tissues lower under elevated CO_2? A critical examination of the hypotheses. *J. Integr. Plant Biol.*, 50: 1365–1374.

Temple, W. D., Bomke, A. A. (1989). Effects of kelp (Macrocystis integrifolia and Ecklonia maxima) foliar applications on bean crop growth. *Plant and Soil*, *117*(1), 85-92.

Wahle, E.A. and J.B. Masiunas, 2003. Population density and nitrogen fertility effects on tomato growth and yield. *HortScience*, 38(3): 367–372.

Vishwanatha V.E., Chitranjan Kumar, KD Lamani,Girish Kumar Killada, H.R. Bhanuprakash, H.P. Rajathand B.S. Vidyashree, 2025. Evaluating the effects of nano-formulated nitrogen and potassium on physiological response, yield and nutrient uptake in potato (*Solanum tuberosum* L.). *J. Appl. Hortic.,* 27(4): 709-714.

Yin, L., T. Hu, C. Xie, Y. Feng, Z. Yan, Y. Li and Y. Wang, 2011. Effect of nitrogen application rate on growth and leaf photosynthetic characteristics of *Jatropha curcas* L. seedlings. *Acta Ecol. Sin.*, 31: 4977–4984. https://doi.org/10.1016/j.chnaes.2011.08.001

Zeng, Z., S. Zhang, H. Wang and X. Piao, 2015. Essential oil and aromatic plants as feed additives in non-ruminant nutrition: A review. *J. Anim. Sci. Biotechnol.*, 6(1): 7–18.

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