



Impact of different humic acid levels and seaweed extract rates on productivity and economical value of khella (*Ammi visnaga*) plant

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Keywords:

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ABSTRACT

To enhance khella plant growth, yield components, chromone content, and economic value, a field experiment was conducted at the Farm of the Faculty of Agriculture, Al-Azhar University, Assiut, Egypt, over the two successive seasons of 2022/2023 and 2023/2024. The different humic acid levels (0.0, 5.0, 10.0, and 15.0 kg/ha), different seaweed extract rates (0.0, 1.0, 3.0, and 6.0 ml/L), and their combination treatments were studied. The obtained results were pointed out that utilizing humic acid (HA) at 15 kg level per hectare significantly increased khella growth (plant height, branches number and herb fresh and dry weights/ plant), fruit yield per plant and hectare and khellin, visnagin and total chromone percentages compared to control and the other levels under study. The highest values of growth traits, yield components, and chromone percentages were noticed when khella plants were sprayed with seaweed extract (SE) at 3 ml/l compared to the control. Generally, the best combination treatment between humic acid levels and seaweed extract rates regarding khella yield components was 15 kg/ha of HA + 6 ml/l of SE, compared to the other combination treatments under study in both seasons.

وقيمته الاقتصادية (*Ammi visnaga*) تأثير مستويات مختلفة من حمض الهيوميك ومعدلات مستخلص الأعشاب البحرية على إنتاجية نبات الخلة

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الكلمات المفتاحية

نبات الخلة
حمض الهيوميك
الأعشاب البحرية
الخللين والفسناجين

الملخص

لتحسين نمو نباتات الخلة وزيادة مكونات المحصول ومحتوى المكونات الفعالة وكذا القيمة الاقتصادية، أُجريت تجربة حقلية في مزرعة كلية الزراعة بجامعة الأزهر بأسيوط، مصر، خلال موسمي 2022/2023 و 2023/2024. دُرست مستويات مختلفة من حمض الهيوميك (0.0، 5.0، 10.0، 15.0 كجم/هكتار)، وتركيزات مختلفة من مستخلص الأعشاب البحرية (0.0، 1.0، 3.0، و 6.0 مل/لتر)، وكذا المعاملات المركبة المتداخلة بين هذين العاملين. أشارت النتائج إلى أن استخدام حمض الهيوميك (HA) بمعدل 15 كجم/هكتار أدى إلى زيادة معنوية في نمو نباتات الخلة (ارتفاع النبات، وعدد الأفرع، ووزن النباتات الطازج والجاف)، وإنتاجية الثمار للنبات (جم) والهكتار (كجم)، والنسبة المؤية لمادتي الخلين والفيسنجين والكرومون الكلي، مقارنةً بالمجموعة الضابطة والمعاملات الأخرى قيد الدراسة. سُجّلت أعلى قيم لصفات النمو، ومكونات المحصول، ونسب الخلين والفيسنجين والكرومون الكلي عند رش نباتات الخلة بمستخلص الأعشاب البحرية (SE) بتركيز 3 مل/لتر مقارنةً

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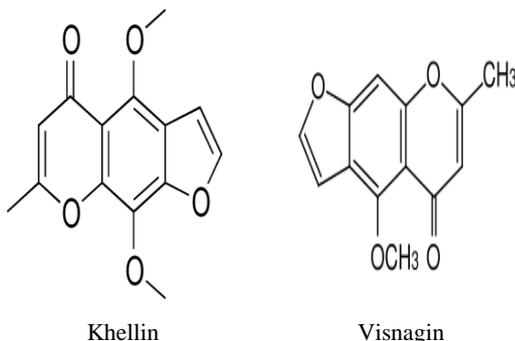
بالشاهد. وبشكل عام، كانت أفضل معاملة مركبة بين مستويات حمض الهيوميك وتركيزات مستخلص الأعشاب البحرية فيما يتعلق بمكونات محصول الخلة هي 15 كجم/هكتار من حمض الهيوميك + 6 مل/لتر من مستخلص الأعشاب البحرية، مقارنة بالمعاملات المركبة الأخرى قيد الدراسة في كلا الموسمين

Introduction

The plant known as khella (*Ammi visnaga* L.) is native to North Africa, West Asia, and a large portion of the European Mediterranean [1]. It is frequently used to treat kidney stones, uncomfortable menstruation, stomach cramps and colic [2]. The best environmental conditions for *Ammi visnaga*, L. growing and production are found in Egypt [3]. Many medications used as diuretics and antispasmodics for urethral stones contain khellin and visnagin as active components. Khellin, a powerful coronary vasodilator that is currently marketed in tablets and injection form, is a long-standing medication used in Egypt that is made from dried ripe fruits. Kidney calculi might pass more easily when a decoction is administered [4]. Khella seeds that contain visnagin are typically found in Middle Eastern nations like Egypt and Turkey, as well as Northern African nations like Morocco. Khella seeds can be used directly to extract visnagin [5]. Additionally, it is utilized to treat gall bladder and liver problems [6]. *A. visnaga* has been reported to be effective when administered topically for the treatment of wound healing, vitiligo, psoriasis, toxic bites and inflammatory disorders [7].

Humic acid is a component of humus compounds, which enhance the soil chemical, biological and physical characteristics and are crucial for maintaining plant nutrition balance. According to [8], humic acid has a large molecular weight and a great capacity to improve complexation. According to [9], humic material affects the physical, chemical, and biological characteristics of soil as well as the physiological and biochemical processes in plants in two ways. Raising the rates of humic acid increased the quality and qualitative yield of Italian basil plants [10]. In addition, HA at 3 kg/ hectare had a substantial effect on leaf parameters, flower weight, flower quantity, stigma weight, the amount of saffron bioactive compounds and macronutrient uptake of saffron (*Crocus sativus*), as shown by [11].

Growth and development of plants are positively impacted by seaweed extracts that are regarded as biostimulants [12]. Seaweeds are utilized to enhance plant development, improve the chemical makeup of secondary metabolites, and increase yield and quality [13]. Natural organic goods that are good for the environment, like seaweed fertilizers, are becoming more and more popular for use in agriculture [14]. Seaweed liquid extracts have recently been applied to several plants as foliar nutrients [15]. It was asserted that the application of seaweed extracts in agriculture improved germination, root development, leaf size, the ability to withstand soil nutrient uptake and adverse soil conditions [16] and [17]. Applying seaweed foliar nutrients to plant leaves helps accelerate cell division and growth. These fertilizers can also be sprayed on the soil surface as a liquid.



Thus, the purpose of this study is to examine the impacts of humic acid as a soil drench, seaweed extract as a foliar spray and as well as their combinations, on khella plants' vegetative growth, yield and yield components, active ingredients and the economically valuable.

Materials and methods:

This experiment was conducted at the Farm of Faculty of Agriculture, Al-Azhar University, Assiut Governorate, Egypt,

throughout the two consecutive seasons of 2022/2023 and 2023/2024 in order to improve the growth and production of the khella plant. The experiment included two factors: humic acid (HA 0.0, 5, 10 and 15 kg/hectare) as the main plot and seaweed extract (SE 0.0, 1, 3 and 6 ml/l) as the sub plot and their combinations between them.

Experimental Design

Using a randomized complete blocks design (RCBD), the study's experimental design was a split-plot with three replicates. The main plot was occupied by humic acid (four levels), while the sub-plots were made up of seaweed extract (four rates). There were sixteen treatments from the encounter.

Material and Culture of Plants

Khella fruits were acquired from the Department of Medicinal and Aromatic Plants' Agricultural Research Center in Dokky, Giza, Egypt. These fruits were immediately planted in the 3 × 3 m plot that comprised the experimental unit area on November 5th of each of the two seasons. There were five 3 m long rows in each experimental unit, with ridges spaced 60 cm apart and hills spaced 30 cm apart. There were roughly five to seven fruits on each hill, which were later thinned to two plants per hill. 72 plants were thus included in the experimental unit. Table 1 lists the physical and chemical characteristics of the test soil as indicated by [18].

Sampling and Data Collection

Three plants were randomly selected from each experimental plot 110 days after planting khella seeds to study the following traits: plant height (cm), number of branches/plant, and weight of fresh and dry herb, g/plant. When harvesting in the third week of April for both seasons, the following data were recorded: umbels number /plant, fruit productivity (g/plant), (kg/ha) and % of khellin, visnagin and total chromones in the khella fruits. The percentages of khellin and visnagin in khella fruits were assessed using the [19] with Memphis adjustment; also, the sum of the percentages of khellin and visnagin was used to get the percentage of total chromones.

Table 1. Chemical and physical characteristics of the soil used in this study during 1st and 2nd seasons

Soil texture	Physical analysis									
	Sand (%)	Silt (%)	Clay (%)	Time						
Silty loam	19.98	57.44	22.58	1st season						
	19.11	58.14	22.75	2nd season						
Chemical analysis										
Soluble anions (meq./l)	Soluble cations (meq./l)			CaCO ₃ (%)	Organic Matter (%)	E.C. dSm-1	pH			
S04 ⁻ Cl ⁻ HCO ₃ ⁻	K ⁺	Na ⁺	Mg ⁺⁺	Ca ⁺⁺						
6.7	2.3	3.3	3.48	21.82	2.2	3.7	2.61	0.55	2.19	7.7
6.6	2.2	3.3	3.41	19.33	2.4	3.5	2.52	0.59	2.11	7.4

Economic evaluation:

Two factors that may be used in economic appraisal are the project's economic profitability, while the value is positive and the net return farm, which is the difference between the expenses and benefits. These standards align with economic reasoning and the conditions of the field trial. Second, the project's profitability is gauged by the cost-benefit analysis, which is the ratio of benefits to expenses. The different crops are grouped according to economic commerce and profitability, if the proportion is high.

Statistical analysis:

Both seasons of collected data were analyzed by analysis of variance, and treatment means were compared at P≤0.05 with the least significant difference (LSD) test. The statistical calculations were performed with Statistix software version 9 [20].

Results and discussion:

Plant growth:

From the data in Table 2, it is clear that any humic acid level significantly increased plant height compared to control in both seasons. The more branches per khella plant was noticed with 15 kg of humic acid per hectare compared to the other levels under study (Table 3). In general, increasing humic acid levels from 5 to 15 kg/hectare gave a gradual improvement improve of herb fresh weight per plant during the 1st and 2nd seasons (Table 4). The heaviest herb dry weight of the khella plant was obtained when humic acid was added to the soil as a drench at 15 kg hectare compared to the lowest levels under study (Table 5). The increases in herb dry weight were about 23.57 and 27.21 % as well as 12.70 and 11.04 % for 15 and 10 kg of humic acid/hectare, respectively, compared with the control in the 1st and 2nd seasons.

These outcomes might be the result of commercial humic acid's abundance of nitrogen and other vital elements that promote plant growth [21]. Additionally, when humic acid is put in the field, it is transformed into easily accessible humic compounds that either directly or indirectly promote plant development [22]. Likewise, [23] pointed out that the utilization of any humic acid level gave a significant enhancement in vegetative growth traits of black cumin (plant height and number of branches/plant as well as fresh and dry weight of herb/plant) compared with the control group.

Table 2. Impact of humic acid level (A), seaweed extract rate (B) and their combination (A×B) treatments on plant height (cm) of *Ammi visnaga* during both seasons

Humic acid level (kg/hectare)	Seaweed extract (ml/l)				Means (A)
	Control	1	3	6	
First season					
Control	92.00	93.33	96.33	98.00	94.92
5	101.67	105.33	108.33	111.33	106.67
10	106.00	108.33	112.00	116.00	110.58
15	108.00	111.67	116.00	119.33	113.75
Means (B)	101.92	104.67	108.17	111.17	
L.S.D. at 5 %	For A= 0.86		For B= 0.81		For AB= 1.64
Second season					
Control	97.33	101.00	104.33	107.67	102.58
5	109.00	111.67	114.00	116.33	112.75
10	112.00	114.33	117.67	122.67	116.67
15	113.67	116.33	122.33	126.00	119.58
Means (B)	108.00	110.83	114.58	118.17	
L.S.D. at 5 %	For A= 0.64		For B= 0.57		For AB= 1.17

Table 3. Impact of humic acid level (A), seaweed extract rate (B) and their combination (A×B) treatments on number of branches per plant of *Ammi visnaga* during both seasons

Humic acid level (kg/hectare)	Seaweed extract (ml/l)				Means (A)
	Control	1	3	6	
First season					
Control	5.00	5.50	6.17	6.67	5.83
5	5.67	6.50	7.33	7.67	6.79
10	6.00	7.00	7.50	8.25	7.19
15	6.92	8.08	8.50	9.42	8.23
Means (B)	5.90	6.77	7.38	8.00	
L.S.D. at 5 %	For A= 0.43		For B= 0.16		For AB= 0.51
Second season					
Control	6.00	6.83	7.33	7.67	6.96
5	6.08	7.00	7.50	7.42	7.25
10	6.92	7.92	8.33	9.25	8.10
15	7.92	9.00	9.50	10.83	9.31
Means (B)	6.73	6.69	8.17	9.04	
L.S.D. at 5 %	For A= 0.21		For B= 0.17		For AB= 0.35

Table 4. Impact of humic acid level (A), seaweed extract rate (B) and their combination (A×B) treatments on herb fresh weight per plant (g) of *Ammi visnaga* during both seasons

Humic acid level (kg/hectare)	Seaweed extract (ml/l)				Means (A)
	Control	1	3	6	
First season					

Control	150.67	154.67	157.33	162.00	156.17
	5	161.00	164.00	167.33	171.00
10	171.33	179.00	185.00	191.00	181.58
15	175.67	185.00	191.67	200.00	188.08
Means (B)	164.67	170.67	175.33	181.00	
L.S.D. at 5 %	For A= 1.27		For B= 0.75		For AB= 1.81
Second season					
Control	155.00	157.33	162.67	167.67	161.17
5	168.00	170.33	173.00	177.67	172.25
10	181.67	185.67	193.00	199.67	190.00
15	183.67	195.00	197.33	209.33	196.33
Means (B)	172.08	177.58	181.50	188.57	
L.S.D. at 5 %	For A= 2.90		For B= 0.65		For AB= 3.11

Table 5. Impact of humic acid level (A), seaweed extract rate (B) and their combination (A×B) treatments on herb dry weight per plant (g) of *Ammi visnaga* during both seasons

Humic acid level (kg/hectare)	Seaweed extract (ml/l)				Means (A)
	Control	1	3	6	
First season					
Control	32.50	33.17	33.67	35.25	33.65
5	33.33	34.25	34.92	36.00	34.63
10	36.00	36.67	37.83	38.67	37.92
15	38.17	40.17	43.00	45.00	41.58
Means (B)	35.00	36.06	37.35	38.73	
L.S.D. at 5 %	For A= 0.84		For B= 0.22		For AB= 0.92
Second season					
Control	33.83	34.80	35.17	37.17	35.24
5	35.08	35.08	36.17	38.00	36.08
10	37.25	38.25	39.67	41.33	39.13
15	41.67	43.67	46.00	48.00	44.83
Means (B)	36.96	37.95	39.25	41.13	
L.S.D. at 5 %	For A= 1.12		For B= 0.30		For AB= 1.23

As for the extract of seaweed effect, the plant height of khella was increased gradually as humic acid levels increased, in comparison with unsprayed plants (Table 2). The highest rate of seaweed extract (6 ml/l) as foliar spray recorded the maximum values of branch number, fresh weight and dry weight per plant compared to 1 and 3 ml/l levels in both seasons (Tables 3, 4 and 5). In addition, seaweed extract improves and controls the physiological functions of the crops because it is a fantastic source of many primary nutrients like potassium and phosphorus and secondary nutrients like calcium and magnesium, as well as trace elements like manganese, iron, copper, and zinc [24] and [25]. Likewise, *Allium wakegi*'s fresh weight, dried weight, tuber width, and total yield were all significantly impacted by the use of seaweed extract, according to [26].

Results presented in Tables 2, 3, 4 and 5 reveal that the best combination treatment between humic acid levels and seaweed extract rates regarding khella growth traits was 15 kg/hectare of HA + 6 ml/l of SE, compared to the other combination treatments under study in both seasons. Under and rate of seaweed extract, khella height, number of its branches, herb fresh and dry weights, gradually increased by increasing humic acid levels from 5, 10 to 15 kg/ hectare in both seasons. All combinations between humic acid and seaweed extract significantly enhanced plant growth traits compared to the control (without humic and/or seaweed extract application) during the two

consecutive seasons. In addition, [23] showed that there was a substantial interaction effect on the black cumin plant's height, number of branches per plant, and fresh and dry weight per plant; the majority of the combined treatments considerably enhanced all of the parameters that were studied. Generally speaking, the most successful treatment was a foliar application of 6 ml/L of seaweed extract combined with 15 kg/ha of humic acid.

Yield components:

From data tabulated in Tables 6, 7 and 8, it is clear that raising humic acid levels from 5, 10 to 15 kg/ hectare gradually increased umbel number per plant, the fruit yield per plant and per hectare in both seasons. The highest yield component parameters [number of umbels per khella plant (14.33 and 17.33 umbels/ plant), fruit yield per plant (29.00 and 32.00 g/ plant) and fruit yield per hectare (2320 and 2560 kg/ hectare)] were obtained with 15 kg humic acid/ hectare in comparison with control. All humic acid levels significantly increased the yield components of the khella plant. A natural stimulant, humic acid (HA) is a rich source of macronutrients like sulfur, phosphorus, and nitrogen that can improve soil fertility, promote plant development, and boost root initiation [27]. These results are in line with those reported by [28] on garden thyme.

Table 6. Impact of humic acid level (A), seaweed extract rate (B) and their combination (A×B) treatments on number of umbels per plant of *Ammi visnaga* during both seasons

Humic acid level (kg/hectare)	Seaweed extract (ml/l)				Means (A)
	Control	1	3	6	
First season					
Control	7.33	8.00	8.83	9.33	8.38
5	9.33	10.00	10.83	12.00	10.54
10	10.83	12.00	13.00	15.33	12.79
15	11.67	14.00	15.00	16.67	14.33
Means (B)	9.79	11.00	11.92	13.33	
L.S.D. at 5 %	For A=0.94	For B= 0.27			For AB= 1.05
Second season					
Control	8.83	9.50	10.33	11.17	9.96
5	11.33	12.33	13.17	14.33	12.79
10	13.17	15.00	16.00	18.67	15.71
15	14.67	16.67	18.00	20.00	17.33
Means (B)	12.00	13.38	14.38	16.04	
L.S.D. at 5 %	For A= 0.66	For B= 0.28			For AB= 0.81

Table 7. Impact of humic acid level (A), seaweed extract rate (B) and their combination (A×B) treatments on fruit yield per plant (g) of *Ammi visnaga* during both seasons

Humic acid level (kg/hectare)	Seaweed extract (ml/l)				Means (A)
	Control	1	3	6	
First season					
Control	20.67	21.67	23.00	24.00	22.33
5	21.67	22.67	23.67	24.67	23.17
10	24.00	25.00	26.33	29.00	26.08
15	26.00	28.00	29.33	32.67	29.00
Means (B)	23.08	24.33	25.58	27.58	
L.S.D. at 5 %	For A= 0.53	For B= 0.36			For AB= 0.82
Second season					
Control	23.00	24.00	25.33	26.33	24.67
5	23.67	24.67	25.67	26.67	25.17
10	26.33	28.33	29.33	32.67	29.17

15	28.00	31.33	33.00	35.67	32.00
Means (B)	25.25	27.08	28.33	30.33	
L.S.D. at 5 %	For A= 1.07	For B= 0.32			For AB= 1.20

Table 8. Impact of humic acid level (A), seaweed extract rate (B) and their combination (A×B) treatments on fruit yield per hectare (kg) of *Ammi visnaga* during both seasons

Humic acid level (kg/hectare)	Seaweed extract (ml/l)				Means (A)
	Control	1	3	6	
First season					
Control	1653.3	1733.33	1840.0	1920.0	1786.7
5	1733.3	1813.3	1893.3	1973.3	1853.3
10	1920.0	2000.0	2106.7	2320.0	2086.7
15	2080.0	2240.0	2346.7	2613.3	2320.0
Means (B)	1846.7	1946.7	2046.7	2206.7	
L.S.D. at 5 %	For A= 42.6	For B= 29.2			For AB= 65.9
Second season					
Control	1840.0	1920.0	2026.7	2106.7	1973.3
5	1893.3	1973.3	2053.3	2133.3	2013.3
10	2106.7	2266.7	2346.7	2613.3	2333.3
15	2240.0	2053.3	2640.0	2853.3	2560.0
Means (B)	2020.0	2166.7	2266.7	2426.7	
L.S.D. at 5 %	For A= 85.5	For B= 25.7			For AB= 96.2

Data listed in Table 6 show that sprayed khella plants with seaweed extract significantly increased umbel number per plant compared to the control. Using SE at 6 ml/l gave the highest values of fruit yield per plant (g) and per hectare (kg) compared to the other rates under study (Tables 7 and 8). The increases in fruit yield per hectare were about 19.49 and 10.63 % as well as 20.13 and 12.21 % for 6 and 3 ml seaweed extract/l, respectively, compared with the control in the 1st and 2nd seasons. There was a strong correlation between the herb and oil yield of geranium when varying amounts of seaweed extract were administered at different stages of the crop [29]. Also, [30] reported that the foliar application with seaweed extract at 7.5 ml/l is recommended for optimizing holy basil biomass yield.

Concerning the combination effect, data in Tables 6, 7 and 8 demonstrate that increasing seaweed extract rates under any humic acid level gradually increased the number of fruits per plant and fruit yield per plant and hectare. The highest values in this connection were achieved with the combination treatment was 15 kg HA/ hectare and 6ml SE/l, compared to the other combinations under study during the two seasons. In general, as mentioned just before, both humic acid and different seaweed extracts (each alone) increased the number of umbels per plant, fruit yield per plant and per hectare of khella plant; in turn, they together might maximize their effects, leading enhancement of yield components.

Active ingredients:

Data recorded in Tables 9, 10 and 11 suggest that khellin, visnagin and total chromone percentages were significantly enhanced by utilizing humic acid at 15 kg/ hectare compared to the control during both seasons. There was a gradual increase in khellin% %, visnagin% % and total chromone% % was noticed with increasing humic acid levels during the two seasons. The increases in total chromone were about 5.92 and 6.50 % as well as 3.24 and 3.33 % for 15 and 10 kg of humic acid/hectare, respectively, compared with the control in the 1st and 2nd seasons. Through the activation of carbon and nitrogen metabolism, humic acid may improve plant development. Humic acid stimulated the enzymes glutamine synthetase, glutamate dehydrogenase, and nitrate reductase, which are linked to N assimilation pathways [31] and [32]. Furthermore, [33]. reported that the planting medium containing 8 g kg-1 of humic acid increased the activity and content of the medicinal plant valerian antioxidants.

Seaweed extract rate treatments significantly increased khellin %, visnagin % and total chromone % of khella fruits compared to control in both seasons (Tables 9, 10 and 11). Active ingredients of khella fruits increased gradually with every increased rates of SE from 1, 3 to 6 ml/l. The increases in total chromone were about 0.054 and 0.047 % for 6 ml/l of seaweed extract rate compared to control in the 1st and 2nd seasons, respectively.[34] found that seaweed-based liquid fertilizers yielded more organic matter, macro and micronutrients, fatty acids, and vitamins, as well as growth regulators, than chemical fertilizers.[35] noticed that spraying *Hyoscyamus niger* plants with seaweed extract at 3 ml/l significantly increased total alkaloids content compared to control.

The data listed in Tables 9, 10 and 11 reveal that the combination influencing gave the great effect of humic acid combined with seaweed extract on khellin% %, visnagin% % and total chromone% % of Ammi visnaga during both seasons. Furthermore, utilizing 3 as well as 6 ml/l biomagic combined 15 kg/hectare level of humic acid significantly increased active ingredients as compared to seaweed extract rates alone. Generally, as mentioned just before, both humic acid and different seaweed extracts (each alone) increased khellin % %, visnagin % % and total chromone % % of khella plant; in turn, they together might maximize their effects, leading highest active ingredients percentages. Moreover,[36] reported that application of SE combined with HA treatment increased the amount of 2,2- DiPhenyl-1-Picrylhydrazyl (DPPH) radical scavenging activity, flavonoid and total phenolic contents in fenugreek in comparison to the control.

Table 9. Impact of humic acid level (A), seaweed extract rate (B) and their combination (A×B) treatments on khellin (%) of Ammi visnaga during both seasons

Humic acid level (kg/hectare)	Seaweed extract (ml/l)				Means (A)
	Control	1	3	6	
First season					
Control	1.788	1.800	1.809	1.820	1.804
5	1.800	1.818	1.823	1.829	1.817
10	1.843	1.840	1.849	1.855	1.847
15	1.875	1.887	1.897	1.913	1.893
Means (B)	1.827	1.836	1.844	1.854	
L.S.D. at 5 %	A=0.029		B=0.008		AB=0.032
Second season					
Control	1.819	1.836	1.846	1.853	1.838
5	1.841	1.830	1.839	1.847	1.839
10	1.867	1.877	1.885	1.907	1.884
15	1.915	1.930	1.945	1.977	1.942
Means (B)	1.860	1.868	1.879	1.896	
L.S.D. at 5 %	A=0.017		B=0.004		AB=0.019

Table 10. Impact of humic acid level (A), seaweed extract rate (B) and their combination (A×B) treatments on visnagin (%) of Ammi visnaga during both seasons

Humic acid level (kg/hectare)	Seaweed extract (ml/l)				Means (A)
	Control	1	3	6	
First season					
Control	0.719	0.725	0.732	0.740	0.729
5	0.734	0.742	0.752	0.758	0.746
10	0.753	0.763	0.773	0.783	0.768
15	0.775	0.785	0.795	0.805	0.790
Means (B)	0.745	0.754	0.763	0.772	
L.S.D. at 5 %	A=0.005		B=0.002		AB=0.006
Second season					
Control	0.750	0.738	0.748	0.755	0.748
5	0.752	0.763	0.772	0.782	0.767
10	0.772	0.780	0.791	0.803	0.786
15	0.795	0.807	0.820	0.827	0.812
Means (B)	0.767	0.772	0.783	0.792	
L.S.D. at 5 %	A=0.009		B=0.006		AB=0.014

Table 11. Impact of humic acid level (A), seaweed extract rate (B) and their combination (A×B) treatments on total chromone (%) of Ammi visnaga during both seasons

Humic acid level (kg/hectare)	Seaweed extract (ml/l)				Means
	Control	1	3	6	

(A)					
First season					
Control	2.507	2.525	2.541	2.560	2.533
5	2.534	2.560	2.574	2.587	2.564
10	2.597	2.603	2.622	2.638	2.615
15	2.650	2.672	2.692	2.718	2.683
Means (B)	2.572	2.590	2.607	2.626	
L.S.D. at 5 %	A=0.028		B=0.008		AB=0.032
Second season					
Control	2.569	2.575	2.594	2.608	2.586
5	2.592	2.593	2.611	2.628	2.606
10	2.639	2.657	2.676	2.710	2.670
15	2.710	2.737	2.765	2.803	2.754
Means (B)	2.627	2.640	2.661	2.687	
L.S.D. at 5 %	A=0.023		B=0.007		AB=0.026

Economic evaluation:

The investment and operating costs, total costs, revenue and profit cost ratio (P/C) of the Khella crop field experiment are displayed in Table 12. According to the obtained analysis, the highest profit/cost ratio (2.345) was obtained by applying the soil with 15 kg/hectare of humic acid compared to the other levels under study. Furthermore, the highest profit/cost ratio (2.389) was obtained under the seaweed extract treatment at 6 ml/l as compared to the control treatment. The best combination treatment was 15 kg/hectare of humic acid combined with 6 ml/l seaweed extract, which gave 2.713 ratios compared to the other combination treatments under study. In general, it could be said that the highest net return and value for khella plants was obtained by applying humic acid in combination with seaweed extract. These results are following those found by [37] and [38] on medicinal plants.

Table 12. Economic evaluation of khella production under influences of humic acid level, seaweed extract rate and their combination (average of both seasons)

Treatments	Input			Output		
	Investment costs	Operating costs	Total costs cultivation (L.E./fed.)	Revenue	profit /cost ratio	Order
Effect of humic acid level (kg / hectare)						
0.0	24000	31210	55210	112800	2.043	3
5	24000	32860	56860	116000	2.040	4
10	24000	34460	58460	132600	2.268	2
15	24000	36127	60127	146400	2.435	1
L.S.D. at 5 %	-	196.16	669.19	359.2	0.055	-
Effect of seaweed extract rate (ml / l)						
0	24000	33323	57315	116000	2.021	4
1	24000	33545	57545	123400	2.140	3
3	24000	33775	57775	129400	2.235	2
6	24000	34005	58022	139000	2.389	1
L.S.D. at 5 %	-	88.10	530.96	1191.6	0.020	-
Effect of humic acid level × seaweed extract rate						
0.0	24000	30865	54865	104000	1.910	16
1	24000	31095	55095	109000	1.989	14
		31325	553116	116209	2.097	10
3	24000	31555	555120	120217	2.174	7
		32515	565108	125085	1.925	15
5	24000	32745	567113	123002	2.002	13
		32975	569118	125078	2.078	12
6	24000	33205	572123	125054	2.154	9
				2004		

	0	24000	34115	581	120	2.07	11
				15	800	9	
10	1	24000	34345	583	128	2.19	6
				45	000	4	
	3	24000	34575	585	133	2.28	5
				75	600	1	
15	6	24000	34805	588	148	2.51	2
				05	000	7	
	0	24000	35832	597	129	2.16	8
				65	600	9	
15	1	24000	35995	599	142	2.37	4
				95	400	4	
	3	24000	36225	602	149	2.48	3
				25	600	4	
6	6	24000	36455	605	164	2.71	1
				22	000	3	
L.S.D. at 5 %		-	247.65	1133.80	4134.3	0.065	-

Conclusion:

Based on the aforementioned findings, it can be said that applying humic acid to the soil and applying seaweed extract foliar application are both practical and environmentally beneficial methods for producing crops in sustainable agriculture. Whereas, with treatments of soil-drenched application of humic acid at 15 kg/hectare combined with seaweed extract foliar spraying at 6 ml/l, the optimal values of vegetative development, total yield, and active components of khella (*Ammi visnaga*) plants were achieved.

There are also some suggestions to adopt the organic farming method by using safe alternatives to improve the productivity of plants in general and medicinal and aromatic plants in particular, and to determine the best concentrations and levels of these alternatives.

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