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Performance of Seaweed Extracts on Yield and Quality of Black Cumin (*Nigella sativa* L.) with Organic Input Management

Mahendra Belagumpi [a*], Gorle Roja Ramani [a], Konathachira Sreeja [a], D.K. Ghosh (LKN) [a], N. Chattopadhyay [a] and A. Bandyopadhyay [a]

[a] *Department of Plantation, Spices, Medicinal and Aromatic Crops, Faculty of Horticulture, Bidhan Chandra Krishi Vishwavidyalaya, Mohanpur-741252, Nadia, West Bengal, India.*

Authors' contributions

This work was carried out in collaboration among all authors. All authors read and approved the final manuscript.

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ABSTRACT

A field experiment was conducted during the rabi season of the two consecutive years of 2020-21 and 2021-22 at the Horticultural Research Station, Mondouri, BCKV, Nadia, West Bengal to examine the effectiveness of seaweed extract on yield and quality of black cumin. The treatments were composed of 9 different doses of seaweed extract granule soil application, liquid foliar spray and control. Among the 10 treatments, T_5 (e.g., SWE granules @4kg ha^{-1}) recorded the highest average plant height of 29.80 cm, 59.45cm and 73.30 cm, at 60, 90 and 120 DAS and the highest

**Corresponding author: E-mail: mahendrahb1998@gmail.com;*

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number of primary branches (7,10) and secondary branches (24,10) plant^{-1} respectively at 120 DAS. Similarly, the highest seed yield of 536 kg ha^{-1} along with different yield attributing characters like the highest mean fresh pod weight (1.40g), dry pod weight (0.36 g) and pod diameter (0.91cm), seed yield plant^{-1} (2.76g) and 1000 seed weight (2.45 g) were recorded under the treatment T_5. The highest B: C ratio (1.97) and highest net return (Rs.52816 ha^{-1}) were also recorded under T_5 during the same period of experimentation. From the above experiment, it may be concluded that the soil application of Seaweed Extract in granular formulation @ 4kg ha^{-1} has a positive influence on growth, yield and quality of black cumin.

Keywords: B:C ratio; organic inputs; biostimulants; black cumin; farm yard manure; SWE; yield; quality.

1. INTRODUCTION

Black cumin, scientifically known as *Nigella sativa* L. is a revered flowering plant native to Southwest Asia, celebrated for its rich historical, cultural, and medicinal significance. Commonly referred to as black seed or kalonji, it boasts a Manny of therapeutic benefits deeply rooted in traditional medicine systems such as Ayurveda, Unani, and traditional Middle Eastern medicine. Its small, crescent-shaped seeds, with their distinct aroma and flavour, are not only prized as a spice in global cuisines but also esteemed for their potent medicinal properties.

Biostimulants are indispensable in organic farming as they provide a holistic solution to the challenges faced by growers striving for sustainable agricultural practices. These natural compounds, sourced from various organic materials like seaweed, microorganisms, and plant extracts, offer multifaceted benefits that extend from the roots of plants to the health of the soil. By improving nutrient uptake efficiency, biostimulants ensure that crops receive essential elements necessary for robust growth and development, ultimately leading to increased yields and improved crop quality. Moreover, they bolster plants' innate defence mechanisms, equipping them to withstand environmental stresses such as drought, extreme temperatures, and pest pressures. Seaweed extract falls under this category which holds significant importance in promoting plant growth and development due to its rich nutritional composition and bioactive compounds. Derived from various species of marine algae, seaweed extract is a natural source of macro and micronutrients, vitamins, amino acids, and growth-promoting hormones such as auxins, cytokinins, and gibberellins. These components play key roles in stimulating root development, enhancing nutrient uptake, and promoting overall plant vigour.

2. MATERIALS AND METHODS

A field experiment (*Rabi* seasons of 2020-21 and 2021-22) was carried out at the Horticultural Research Station, Mondouri and the laboratory of the Department of Plantation, Spices, Medicinal and Aromatic crops, Bidhan Chandra Krishi Viswavidyalaya, Mohanpur, Nadia, West Bengal (22.94551203753782, 88.53351785151352). The experimental material comprised of 9 different doses of seaweed extract (SWE) as foliar spray and soil application as granules given on black Cumin at 30, 60 and 90 days after showing (T_1-SWE foliar spray@1mll^{-1} , T_2-SWE foliar spray @2mll^{-1}, T_3-SWE foliar spray @3mll^{-1}, T_4- SWE granules @ 3kg ha^{-1}, T_5-SWE granules @4kg ha^{-1}, T_6 - SWE granules @ 5kgha^{-1}, T_7 - SWE foliar spray @1ml l^{-1}+ SWE granules @3kg ha^{-1} ,T_8- SWE foliar spray @2mll^{-1}+ SWE granules @ 4kgha^{-1}, T_9 - foliar spray @ 3mll^{-1} + SWE granules @ 5kgha^{-1} and T_{10} - control) following randomized block design with 3 replications.

The soil of the experiment at the field was Gangetic Alluvial sandy clay loam texture, well-drained, good water holding capacity with moderate soil fertility status (Sand- 54.25%, Silt-30.20%Clay-14.30%, pH-5.74, Organic carbon (%)- 0.85, N (kg/ha) – 207, P2O5(kg/ha)- 380.1, K2O (kg/ha)- 526.6, S (mg/ha) - 60.18, Zn (mg/ha)- 1.66, Ca (mg/ha)- 949.55, B (mg/ha)- 0.44). Well rotten Farm Yard Manure @ 10 t ha^{-1} was applied at the time of field preparation as basal application and mixed well with the soil, no chemical fertilizers were applied. The entire experimental area was leveled and then divided into 30 plots of 1.8m × 2.5 m in size with 1 m isolation distance between plots. Black Cumin variety Rajendra Shyama seeds were collected from Rajendra Agricultural University, Bihar and treated with *Trichoderma viride* @ 4g kg^{-1}. Each year the seeds were sown during the first week of November at a spacing of 30 cm x 10 cm @ 6kgha^{-1}. First irrigation was given immediately after sowing. Subsequent irrigations were given at an interval of 8-10 days depending upon the soil moisture. Necessary treatments were given as per schedule in the respective plots from time to time. Randomly selected five tagged plants from each plot were considered for recording the growth parameters like plant height(cm), number of primary and secondary branches and dry matter accumulation (g $plant^{-1}$). The following yield parameters like fresh and dry pod weight (g), pod diameter (cm), 1000 seed weight(g), plot yield(g) and projected yield (kg ha^{-1}) were also recorded. Harvesting was done during the first fortnight of March of each year based on the climatic conditions of that time. The quality parameters like essential oil content were done by hydro distillation using Clevenger apparatus. The prices of the inputs that prevailed at the time of their use were taken into consideration to work out the cost of cultivation. Gross income was calculated by multiplying by the prevailing market price of the seed. Fisher's method of the analysis of variance as given by Panse and Sukhatme [1] was applied for analysis and interpretation of data. The level of significance used in the 'F' was at P = 0.05 and critical difference (CD) values were worked out wherever the 'F' test was significant. Correlations were performed using Pearson's correlation coefficient (r).

Plate 1. General view of experimental plots (Experiment-I)

3. RESULTS AND DISCUSSION

Table 1. Performance of seaweed extract on plant height, number of primary, secondary branches and dry matter of black Cumin (Mean of 2 years)

Treatment	Plant height(cm) Days after sowing			Primary branch $plant^{-1}$	Secondary branch $plant^{-1}$	Dry matter $plant^{-1}$g
	30	60	120			
T_1	6.20	25.55	65.08	6.20	20.00	15.64
T_2	5.95	26.35	67.82	6.70	21.30	15.99
T_3	6.20	27.35	68.98	6.30	21.10	16.16
T_4	6.65	27.95	69.65	6.30	20.20	16.44
T_5	5.90	29.80	73.30	7.10	24.10	18.05
T_6	6.55	27.85	70.15	6.70	21.80	15.75
T_7	6.50	26.25	68.24	6.00	20.40	17.41
T_8	6.20	25.90	69.50	6.60	21.30	16.38
T_9	6.20	28.35	71.55	6.90	23.50	17.95
T_{10}	5.40	25.10	64.02	5.70	18.70	15.19
SEm(±)	0.19	0.72	0.89	0.12	0.41	0.41
LSD (0.05)	0.57	2.14	2.61	0.36	1.20	1.21

(SWE=Sea weed extract, Liquid=L, Granules=G. T_1- SWE(L) foliar spray @ 1ml/l, T_2 - SWE(L) foliar spray @ 2ml/l, T_3 - SWE (L) foliar spray @ 3ml/l, T_4- SWE (G) @ 3kg/ha, T_5 - SWE (G) @ 4kg/ha, T_6 - SWE (G) @ 5kg/ha, T_7- SWE(L) foliar spray @1ml/l+SWE (G) @ 3kg/ha, T_8 - SWE (L) foliar spray @2ml/l +SWE (G) @ 4kg/ha, T_9 - SWE (L) foliar spray @ 3ml/l +SWE (G) @ 5kg/ha and T_{10} – Control)

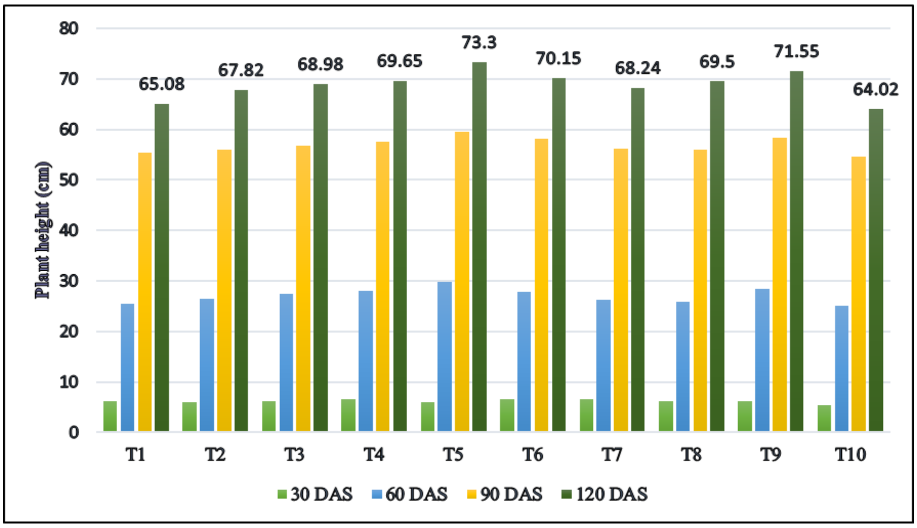

Fig. 1. Effect of seaweed extract on plant height of black cumin at different stages of growth

Table 2. Performance of seaweed extract on fresh, dry pod weight and diameter of black Cumin pods (Mean of 2 years)

Treatment	Fresh pod weight(g)	Dry pod weight(g)	Pod diameter(cm)
T_1	1.28	0.27	0.86
T_2	1.29	0.29	0.89
T_3	1.22	0.27	0.87
T_4	1.22	0.26	0.87
T_5	1.40	0.36	0.91
T_6	1.27	0.31	0.90
T_7	1.25	0.30	0.88
T_8	1.34	0.28	0.89
T_9	1.39	0.34	0.90
T_{10}	1.20	0.25	0.85
Sem (±)	0.02	0.02	0.02
LSD (0.05)	0.06	0.06	0.06

(SWE=Sea weed extract, Liquid=L, Granules=G. T_1- SWE(L) foliar spray @ 1ml/l, T_2 - SWE(L) foliar spray @ 2ml/l, T_3 - SWE (L) foliar spray @ 3ml/l, T_4- SWE (G) @ 3kg/ha, T_5 - SWE (G) @ 4kg/ha, T_6 - SWE (G) @ 5kg/ha, T_7- SWE(L) foliar spray @1ml/l+SWE (G) @ 3kg/ha, T_8 - SWE (L) foliar spray @2ml/l +SWE (G) @ 4kg/ha, T_9 - SWE (L) foliar spray @ 3ml/l +SWE (G) @ 5kg/ha and T_{10} – Control)

Table 3. Performance of seaweed extract on seed yield plant^{-1}, plot^{-1}, 1000 seed weight, projected yield ha^{-1}, increase in yield and essential oil content in black cumin (Mean of 2 years)

Treatment	Yield plant^{-1}(g)	Yield plot^{-1}(g)	1000seed weight(g)	Projected Yield (kgha^{-1})	Increase yield (%)	Essential Oil (%)
T_1	2.14	198.50	1.94	352.59	7.20	0.90
T_2	2.41	243.50	1.98	432.88	31.62	1.00
T_3	2.48	252.00	2.09	448.00	36.21	1.00
T_4	2.39	279.00	1.91	496.00	50.81	0.90
T_5	2.76	301.50	2.45	536.00	62.97	0.90
T_6	2.31	294.50	2.04	523.55	59.19	0.90
T_7	2.26	213.50	2.17	379.55	15.40	0.90
T_8	2.35	236.50	1.92	420.44	27.83	0.90
T_9	2.51	299.00	2.36	531.55	61.62	1.00
T_{10}	1.92	184.00	1.86	328.88	-	0.80
Sem (±)	0.18	13.44	0.08	23.96	-	0.07
LSD (0.05)	0.53	39.94	0.24	71.18	-	0.20

(SWE=Sea weed extract, Liquid=L, Granules=G. T_1- SWE(L) foliar spray @ 1ml/l, T_2 - SWE(L) foliar spray @ 2ml/l, T_3 - SWE (L) foliar spray @ 3ml/l, T_4- SWE (G) @ 3kg/ha, T_5 - SWE (G) @ 4kg/ha, T_6 - SWE (G) @ 5kg/ha, T_7- SWE(L) foliar spray @1ml/l+SWE (G) @ 3kg/ha, T_8 - SWE (L) foliar spray @2ml/l +SWE (G) @ 4kg/ha, T_9 - SWE (L) foliar spray @ 3ml/l +SWE (G) @ 5kg/ha and T_{10} – Control)

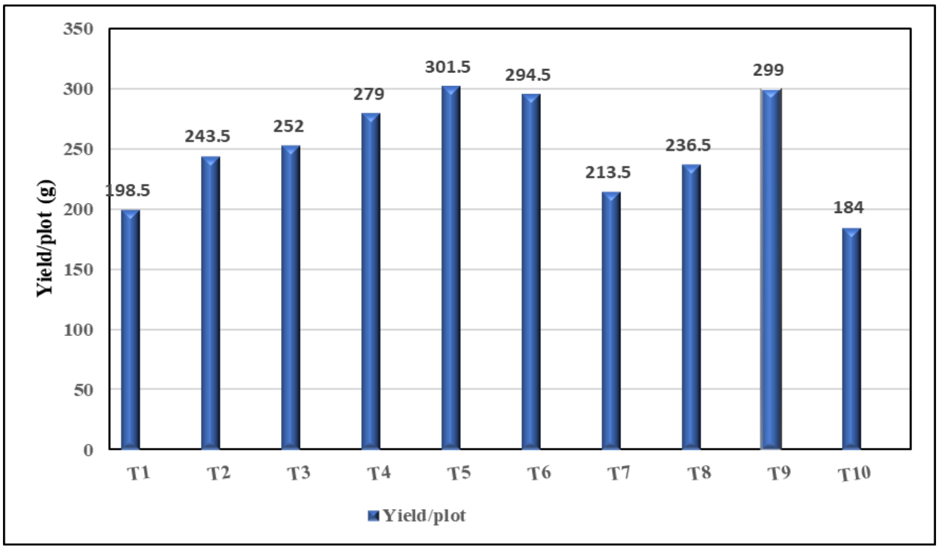

Fig. 2. Effect of seaweed extract on the seed yield/plot in black cumin

3.1 Growth Parameters

Data presented in Table 1 on plant height of black cumin as influenced by seaweed extract revealed that just before imposing treatments at 30 DAS maximum plant height of 6.65 cm was recorded in the plot to be treated with T_4 (SWE granules @ 3kg ha^{-1}) and the lowest plant height of 5.40 cm was recorded in the control plot (T_{10}). At 60 DAS, just before the application of the 2nd dose maximum plant height of 29.80 cm was recorded in the plot treated with T_5(SWE granules @4kgha^{-1}) followed by T_9 (SWE foliar spray @ 3ml l^{-1}+SWE granules @ 5kg ha^{-1}) which was 28.35 cm. At 120 DAS after imposing all the treatments as per schedule, the highest plant height of 73.30 cm was recorded in T_5 (SWE (G) @ 4kg ha^{-1}) followed by T_9 (71.55 cm) and least in control plots (64.02cm). The number of primary and secondary branches plant^{-1} at 120 DAS of black cumin varied significantly, the maximum number of primary branches plant^{-1} (7.10) was observed in the plots treated with T_5 and it was on par with T_9 (6.90) while a minimum of 5.70 was recorded under control. The maximum (24.10) number of secondary branches in plant^{-1} was recorded in T_5 followed by T_9 (23.50). Similarly, T_5 recorded highest dry matter accumulation of 18.05g plant^{-1} at 120 DAS and it was *on par* (17.95g) with T_9 whereas control (T_{10}) recorded a minimum of 15.19g dry matter plant^{-1}.

3.2 Yield Parameters

Perusal of data presented in Table 2 indicated that the highest fresh pod weight of 1.40g was recorded in the treatment T_5 followed by T_9 (1.39g) which are *at par* with each other and the minimum pod weight of 1.20g was recorded in control plot (T_{10}) only. The highest dry pod weight of 0.36 g was recorded in the treatment T_5 followed by T_9 (0.34 g) which are *at par* with each other and the least pod weight of 0.25 g was recorded in the control plot.

The effect of seaweed extract on seed yield plant^{-1} as presented in the Table 3 indicated that among the different treatments, T_5 recorded a significantly higher seed yield of 2.76 g plant^{-1} followed by T_9 (2.51 g plant^{-1}) and the lowest seed yield of 1.92 g plant^{-1} was recorded in T_{10}. Seed yield plot^{-1} indicated that among the different treatments, T_5 recorded a maximum seed yield of 301.50 g plot^{-1} followed by 299.00 g plot^{-1} was recorded in T_9 while lowest seed yield of 184.00 g plot^{-1} was recorded in the T_{10} and T_5 recorded a significantly highest seed weight of 2.45g (1000 seeds) followed by T_9 (2.36g) and lowest of 1.86g (1000 seeds) in the treatment T_{10}. Projected seed yield ha^{-1} indicated that the highest projected seed yield of 536 kg ha^{-1} was recorded in treatment T_5 followed by T_9 (531.55kgha^{-1}) while the lowest projected seed yield of 328.88 kg ha^{-1}was noted in treatment T_{10} and T_5 recorded the highest increase in yield of 62.97 % followed by T_9 (61.62 %). There were no significant differences in essential oil (%) content among treatments. Among treatments essential oil content ranges between 0.80-1.00 % out of which the highest essential oil content 1.00% was recorded in the treatments T_2, T_3 and T_9 whereas in all the other treatments it was recorded 0.90 % except T_{10} with 0.80%.

Table 4. Performance of seaweed extract on the economics of black cumin cultivation

Treatment	Cost of cultivation (Rs. ha^{-1})	Gross income (Rs. ha^{-1})	Net return (Rs. ha^{-1})	B:C ratio
T_1	57523	70518	12995	1.23
T_2	60372	86576	26204	1.43
T_3	63222	89600	26378	1.42
T_4	53994	99200	45206	1.84
T_5	54384	107200	52816	1.97
T_6	54804	104710	49906	1.91
T_7	62748	75910	13162	1.21
T_8	65988	84088	18100	1.27
T_9	69258	106310	37052	1.53
T_{10}	48768	65776	17008	1.35

(SWE=Sea weed extract, Liquid=L, Granules=G. T_1- SWE(L) foliar spray @ 1ml/l, T_2 - SWE(L) foliar spray @ 2ml/l, T_3 - SWE (L) foliar spray @ 3ml/l, T_4- SWE (G) @ 3kg/ha, T_5 - SWE (G) @ 4kg/ha, T_6 - SWE (G) @ 5kg/ha, T_7- SWE(L) foliar spray @1ml/l+SWE (G) @ 3kg/ha, T_8 - SWE (L) foliar spray @2ml/l +SWE (G) @ 4kg/ha, T_9 - SWE (L) foliar spray @ 3ml/l +SWE (G) @ 5kg/ha and T_{10} – Control)

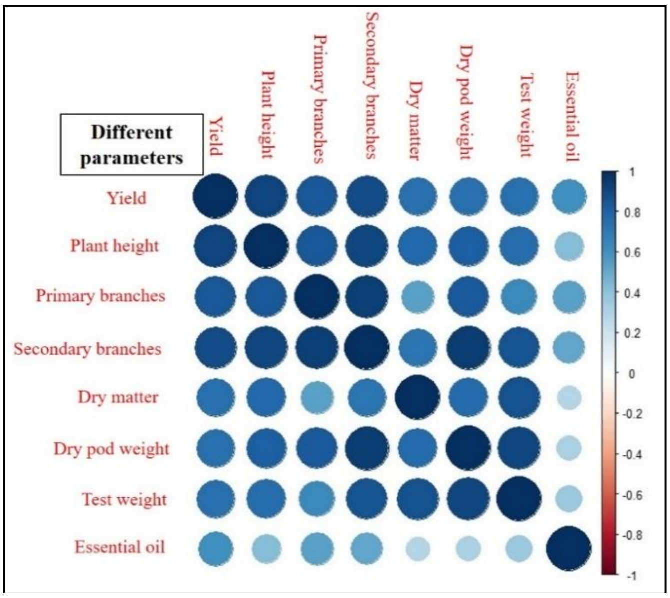

Fig. 3. Correlation coefficient between traits of black cumin

3.3 Economics

Economics is an important and ultimate factor that decides the beneficial effect of imposing different treatments on the ultimate economic returns of the farmers. The data presented in Table 4 on the economics of black cumin cultivation indicated that T_5 recorded the highest B: C ratio of 1.97 with the highest net return of Rs. 52816 ha^{-1} followed by T_6 (1.91 BCR and Rs. 49,906 ha^{-1}).

3.4 Correlation Analysis between Yield and Agronomic Traits

The correlation analysis was performed between seed yield, plant height, number of primary and secondary branches, dry matter accumulation, dry pod weight, seed weight (1000) and essential oil content. Yield showed a positive correlation with plant height and number of branches. It showed a negative correlation with essential oil content. All the growth parameters showed a negative correlation with essential oil content. Test weight had a negative correlation with yield.

3.5 Discussion

These results are in good agreement with previous studies in which the growth and seedling vigor of mungbean and maize were enhanced by SWE treatment [2,3]. The positive effect of SWE on cabbage may be due to the result of combined interactions between SWE and endogenous growth hormones (auxins and cytokinins) [4]. In another way we can say that organic molecules such as organic acids, methionine and even amino acids in SWE can increase nutrient absorption in plants by chelating the available nutrients, thereby increasing their absorbance [5]. Seaweed extracts can equilibrate growth as a result of auxin and gibberellin acid presence, which will increase the vitamins and hormones produced in the treated plants [6]. This increases macronutrients like nitrogen, potassium, and phosphorous are very essential for the growth and development of the plant [7]. It has been indicated that seaweed extract stimulates the mycorrhizal activities in the soil which plays a crucial role in the absorption of water and nutrients, alleviating any shock. The seaweed extracts which promoted root and plant growth through uptake of nutrients may be due to the presence of plant growth regulators at low concentrations such as cytokinins and auxins, polyamines such as putrescine and spermine which had synergistic action with other plant growth regulators especially auxin [8]. The observation of SWE-treated Arachis hypogea plants suggested that the growth and biochemical characteristics might be promoted by micro and macro elements and growth-promoting hormones present in the SWE [9]. Our findings coincide with those of earlier studies carried out on soybeans [10] where there was an increase in vegetative growth by the application of SWE. Similar results were also observed in *Cajanus cajan* (L.) *Mill* sp. [11], *Vigna sinensis* L. [12], and Abelmoschus esculentus [13]. Seaweed extracts contain cytokinins as well, which induce physiological activities and increase the total chlorophyll in the plant. Also, this will positively reflect on the activity of photosynthesis and the synthesized materials, which will show on shoot characteristics. The yield of a particular crop may be due to the function of a gene, environment (climate and soil) and management practices adopted. Further, the yield of the crop depends majorly on the accumulation of photoassimilates during the growth period and in what way they are partitioned between storage organs and vegetative parts of the plant. Photosynthetic ability, biomass accumulation, translocation efficiency and finally the economic yield and quality of the crops are highly influenced by organic matter, fertility and other soil characteristics which were improved by the seaweed extract. This superiority of yield attributes could have been because of improving the plant height, branches plant^{-1} and dry weight by induction of biochemicals that transport from the vegetative part to the reproductive organs of the plant which ultimately reflects on yield components of the plant. Regarding the biochemical traits application of SWE showed a significant effect on the content of plant essential oil compared to the control. This result is in good line with the findings of Golzadeh et al. [14] on *Matricarai recutita* and Rafiee et al. [15] on *Calendula officinalis* L. Ardebili et al. [16] indicated that foliar application of SWE as a source of amino acids, at suitable concentrations, had positive effects on the content of secondary metabolites, antioxidants, and antioxidant activity. Naboulsi et al. [17] indicated that secondary metabolites such as essential oils extracted from the plants, showed interesting biological activities against numerous harmful pests and microorganisms. In addition, some of the secondary metabolites have a beneficial effect as plant growth regulators which will help to increase growth and yield. Here the highest essential oil content (1.0%) was recorded in treatments T_2, T_3 and T_9 indicating that seaweed extract in different formulations either single or in combination may influence the essential oil content of black cumin by increasing the photosynthetic ability, biomass accumulation and translocation efficiency resulted in higher oil content. The increase in essential oil content due to the effect of SWE was also observed in sunflowers by Osman and Salem [18], [19-22].

4. CONCLUSION

It may be concluded that growth, yield and quality of black cumin can be enhanced by soil application of Seaweed Extract in granular formulation@ 4 kg ha^{-1}. Based on the results obtained from the present study, it is evident that there is a wide scope for future research on the following for increasing production and for improving the quality of black cumin. Intensive long-term studies of combined effect of other biostimulants, method, time of application, physiological and metrological interaction can be performed in future for continuation of this research.

DISCLAIMER (ARTIFICIAL INTELLIGENCE)

Author(s) hereby declare that NO generative AI technologies such as Large Language Models (ChatGPT, COPILOT, etc) and text-to-image generators have been used during writing or editing of manuscripts.

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COMPETING INTERESTS

Authors have declared that no competing interests exist.

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