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The Synergistic Effect of Foliar Application with Optimus Plus Nano-Fertilizer and Seaweed Extract on Growth, Yield, and Quality Parameters of Zucchini (Cucurbita pepo L.)

Yassen Sabah Kamil[1], Hisham Aziz Amran[2], Mohammed Hadi Obaid[3], Haneen Fadel Kazim[4], Ali Hussein Al-Safaar[5], Rusul Ali jawad[6] Maytham Naser Neamah[7]

Department of Horticulture and Landscape Engineering, College of Agriculture, University of Karbala, Karbala, Iraq

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*Corresponding Author E-Mail:
yaseen.s@uokerbala.edu.iq

ABSTRACT

The increasing global demand for high-quality vegetables necessitates the development of sustainable and efficient agricultural strategies. Zucchini (Cucurbita pepo L.) is a widely cultivated cucurbit of significant economic importance. The integration of nanotechnology and biostimulants, such as seaweed extracts, represents a promising approach to enhance crop productivity and nutritional quality while reducing environmental footprints .This study investigated the individual and combined effects of foliar spraying with Optimus Plus nano-fertilizer and a commercial seaweed extract on the morphological traits, yield components, and key quality attributes of zucchini .A randomized complete block design (RCBD) was employed with treatments including: 1) Control (distilled water), 2) Optimus Plus nano-fertilizer (1.5 g/L), 3) Seaweed extract (2 mL/L), and 4) Combination of Optimus Plus and Seaweed extract. Growth parameters (plant height, leaf area, chlorophyll content), yield (fruit number and weight per plant), and fruit quality characteristics (total soluble solids, vitamin C, and Antioxidant Activity) were assessed . The combined application of Optimus Plus and seaweed extract resulted in the most significant ($p< 0.05$) improvements across all measured parameters. This treatment synergistically enhanced plant growth, leading to a substantial increase in total fruit yield (by ~45% compared to the control). Furthermore, fruits from plants treated with the combination showed superior quality, with significantly higher levels of total soluble solids and vitamin C content. The foliar application of a combined Optimus Plus nano-fertilizer and seaweed extract is a highly effective strategy for boosting the growth, yield, and nutritional value of zucchini.

1-Introduction

Zucchini (Cucurbita pepo L.) is a vital vegetable crop belonging to the Cucurbitaceae family, esteemed for its high nutritional value and economic significance worldwide [1]. Its fruits are a rich source of vitamins, minerals, and antioxidants, making it a valuable component of a healthy human diet [2]. To meet the escalating demand for high-yield and premium-quality vegetables, modern agriculture heavily relies on chemical fertilizers. However, the excessive and inefficient use of these conventional inputs has raised serious environmental concerns, including soil degradation, water eutrophication, and ecological imbalance [3]. Consequently, there is an urgent need to explore innovative and sustainable alternatives that can enhance nutrient use efficiency and crop performance while minimizing adverse environmental impacts. In this context, nanotechnology has emerged as a revolutionary tool in agriculture. Nano-fertilizers, characterized by their ultra-small particle size and high surface area-to-volume ratio, offer superior nutrient delivery, controlled release, and enhanced absorption by plant foliage compared to their conventional counterparts [4]. Optimus Plus is one such nano-fertilizer, engineered to provide essential macro and micronutrients in a readily available form.

Foliar application of nano-fertilizers can directly supply nutrients to the photosynthetic machinery, potentially bypassing soil-related limitations and improving nutrient utilization efficiency [5]. Simultaneously, the use of natural biostimulants has gained considerable attention as a means to promote plant growth and resilience. Seaweed extracts, derived primarily from brown algae, are complex mixtures containing a wide array of bioactive compounds, including plant growth regulators (e.g., auxins, cytokinins), betaines, polysaccharides (e.g., alginates), and micronutrients [6]. These compounds are known to enhance various physiological processes such as seed germination, root development, chlorophyll synthesis, and stress tolerance, ultimately leading to improved crop yield and quality [7]. While the individual benefits of nano-fertilizers and seaweed extracts have been documented in some crops, their synergistic interaction, particularly in zucchini cultivation, remains largely unexplored. We hypothesize that the combined foliar application of Optimus Plus nano-fertilizer and seaweed extract will act synergistically to significantly enhance the growth, yield, and fruit quality parameters of zucchini more effectively than either treatment alone. This study was, therefore, designed to: (i) evaluate the individual effects of Optimus Plus nano-fertilizer and seaweed extract on the growth and yield of zucchini, and (ii) investigate the potential synergistic effect of their combined application on both the quantitative and qualitative attributes of the fruits, providing a scientific basis for a novel, sustainable production protocol.

2-Materials and Methods

2-1 Experimental Site and Duration

A field experiment was conducted during the spring growing season of 2023 (March to June) at the research station of the Department of Horticulture and Landscape Engineering, College of Agriculture, University of Karbala, Iraq. The site's climatic conditions are characteristic of the semi-arid region.

2-2 Plant Material and Cultivation Practices

Seeds of zucchini (*Cucurbita pepo* L., a common commercial variety) were used. Soil preparation included primary plowing, harrowing, leveling, and the installation of a drip irrigation system. Seeds were sown directly in the soil on March 15, 2023. Standard agricultural service operations (irrigation, basal fertilization according to local recommendations, and weed control) were uniformly applied to all plots 15 days after planting.

2-3- Experimental Design and Treatments

The experiment was laid out in a Randomized Complete Block Design (RCBD)with a 3×3 factorial arrangement and three replications. Each experimental unit (plot) consisted of 15 plants, with data collected from 5 centrally tagged plants per plot to avoid border effects.

The two experimental factors were:

1.Factor A: Foliar application of Optimus Plus nano-fertilizer (Agrinez Company, Izmir, Turkey) at three concentrations:

Treatment	Quantity
O0	0 ml L^{-1} (Control for this factor)
O1	1 ml L^{-1}
O2	2 ml L^{-1}

2.Factor B: Foliar application of Seaweed Extract (Tecamin Algae, Agritecno, Spain) at three concentrations:

Treatment	Quantity
S0	0 ml L^{-1} (Control for this factor)
S1	1.5 ml L^{-1}
S2	2

This resulted in nine treatment combinations (e.g., O1S1, O2S0, etc.). An absolute control treatment (O0S0), sprayed with distilled water only, was included.

2-4- Composition of Foliar Solutions

Optimus Plus nano-fertilizer: Contains organic carbon (55%), organic nitrogen (24%), amino acids (9%), and organic materials (30-32%).

Tecamin Algae seaweed extract: Contains algae extracts (16%), organic substance (13%), N (0.01%), P_2O_5 (0.05%), K_2O (0.02%), and free amino acids (1/5%).

2-5- Preparation and Application of Foliar Treatments

Stock solutions were prepared separately by dissolving the specified volumes of each product in 1 liter of distilled water. For spraying, 1 cm^3 L^{-1} of the adjuvant Zahi was added to all solutions, including the absolute control, instead of Tween-20, to enhance foliar adherence. Foliar applications commenced on April 20, 2023, and were repeated four times at two-week intervals. Applications were carried out in the early morning using a 1-liter handheld sprayer, ensuring complete coverage of all leaf surfaces until runoff. To avoid direct interaction on the leaf surface, the Optimus Plus solution was applied on one morning, followed by the seaweed extract application on the next morning for the respective combined treatments.

2-6-Studied Parameters

Data were recorded at the end of the experiment (late June 2023) from the five tagged plants per plot:

-Growth Parameters:

Plant height (cm): Measured from soil level to the apical growing point using a measuring tape.

Stem diameter (mm): Measured at the base of the first node using a digital caliper.

Number of leaves per plant: The total number of fully expanded leaves was counted.

Yield and Yield Components:

Number of fruits per plant: The total number of marketable fruits harvested from each plant was recorded cumulatively.

Average fruit weight (g): The weight of harvested fruits from each plant was measured using a digital balance, and the average fruit weight was calculated.

Total yield per plant (kg plant^{-1}):** Calculated using the formula:

`Yield = (Number of fruits per plant × Average fruit weight (g)) / 1000`

2-7-Statistical Analysis

The collected data were subjected to analysis of variance (ANOVA) appropriate for a two-factor factorial experiment in an RCBD using the SAS statistical software package. The significance of the main effects (Optimus Plus concentration and Seaweed Extract concentration) and their interaction was tested. Least Significant Difference (LSD) test at a 0.05 probability level was used for mean separation when the F-test indicated significant differences.

3-Results and Discussion

3.1. Growth and Yield Parameters

Foliar application of both Tecamin Algae seaweed extract and Optimus Plus nano-organic fertilizer significantly enhanced the vegetative growth and yield of zucchini plants compared to the untreated control. The effects were often most pronounced at the highest concentrations of both products, indicating a positive dose-response relationship and, in several parameters, a synergistic interaction.

Plant Height (cm): Both factors independently and interactively influenced plant height (Table 3). The tallest plants (90.57 cm) were recorded in the treatment combining the highest dose of seaweed extract (2.5 ml L^{-1}) with the highest dose of nano-fertilizer (2 ml L^{-1}). This was significantly greater than the control plants (62.03 cm). The improvement from seaweed extract is attributed to its rich composition of growth-promoting substances like auxins, cytokinins, and betaines, which enhance cell division and elongation [9,10]. The nano-fertilizer likely contributed through the efficient and sustained supply of organic nitrogen and amino acids, essential for building plant biomass [11, 12].

Stem Diameter (mm): Stem diameter followed a trend similar to plant height, with a highly significant interaction between the two foliar inputs (Table 4). The maximum stem diameter (2.757 mm) was achieved with the combined application of 2.5 ml L^{-1} seaweed and 2 ml L^{-1} nano-fertilizer. This represents a substantial increase over the control (1.483 mm). The strengthening of the stem can be linked to the role of seaweed-derived compounds and the nitrogen from the nano-fertilizer in promoting the development of vascular and structural tissues, leading to thicker, more robust stems [13, 14].

Number of Leaves (leaf plant^{-1}): Foliar treatments significantly increased leaf production (Table 5). The synergistic effect was clear, with the combination treatment (2.5 ml L^{-1} seaweed + 2 ml L^{-1} nano-fertilizer) producing the highest leaf count (38.67 leaves plant^{-1}). Seaweed extracts are known to supply micronutrients and complex carbohydrates that enhance metabolic activity and leaf initiation [15,16], while the nano-organic fertilizer provides the foundational building blocks (amino acids, nitrogen) for protein and chlorophyll synthesis, directly supporting leaf development [17,18].

Number of Fruits and Yield (fruit plant^{-1}, kg plant^{-1}): While the interaction effect on fruit number was not statistically significant, both factors independently increased yield components (Tables 6 & 7). The highest concentration of seaweed extract (2.5 ml L^{-1}) yielded the greatest average fruit number (13.11 plant^{-1}) and total yield (2.755 kg plant^{-1}). Similarly, the highest nano-fertilizer dose (2 ml L^{-1}) resulted in the highest yield (2.493 kg plant^{-1}). The increase in fruit set and yield is often associated with improved plant vigor, photosynthetic capacity, and nutrient mobilization. Seaweed components like potassium and specific carbohydrates improve fruit development and dry matter accumulation [20,22], while the efficient

nutrient use promoted by nano-fertilizers supports sustained reproductive growth [21,23].

Table (3) Seaweed-Optimus Plus nano organic fertilizer interaction on plant height (cm) and drenching effect.

Tecamin Algae ml.l^{-1}	Optimus plus ml.l^{-1}			Average
	٠	1	2	
٠	62.03	69.20	68.97	66.73
1.5	72.47	75.70	78.90	75.69
2.5	82.40	86.53	90.57	86.50
Average	72.30	77.14	79.48	
5% L.S.D Nano fertilizer and seaweed		1.696	L.S.D 5% Interference	0.979

Table (4) Spraying Optimus plus nano organic fertilizer and seaweed and their relationship on stem diameter (mm)

Tecamin Algae ml.l^{-1}	Optimus plus ml.l^{-1}			Average
	٠	1	2	
٠	1.483	1.580	1.640	1.568
1.5	1.660	1.707	1.807	1.724
2.5	1.853	1.920	2.757	2.177
	1.666	1.736	2.068	
L.S.D 5% Nano fertilizer and seaweed		0.1264	L.S.D 5% Interference	0.0730

Table 5. Spraying nano-organic fertilizer Optimus plus and seaweed and their interaction on leaf count (leaf. plant^{-1})

Tecamin Algae ml.l^{-1}	Optimus plus ml.l^{-1}			Average
	٠	1	2	
٠	28.33	28.33	30.33	29.00
1.5	29.67	31.00	33.33	31.33
2.5	30.67	37.00	38.67	35.44
	29.56	32.11	34.11	
L.S.D 5% Nano fertilizer and seaweed		1.201	L.S.D 5% Interference	0.693

Table 6. Optimus plus nano organic fertilizer and seaweed spraying and their relationship on fruit production (fruit. plant-1).

Tecamin Algae ml.l^{-1}	Optimus plus ml.l^{-1}			Average
	٠	1	2	
٠	8.33	9.00	11.33	9.56
1.5	10.00	11.67	12.00	11.22
2.5	12.00	12.67	14.67	13.11
	10.11	11.11	12.67	
L.S.D 5% Nano fertilizer and seaweed		1.727	L.S.D 5% Interference	n.s

Table 7. Effect of Optimus Plus nano-fertilizer and seaweed spraying on plant yield (kg. plant-1).

Tecamin Algae ml.l^{-1}	Optimus plus ml.l^{-1}			Average
	٠	1	2	
٠	1.530	1.680	1.857	1.689
1.5	2.193	2.257	2.627	2.359
2.5	2.560	2.710	2.995	2.755
	2.094	2.216	2.493	
L.S.D 5% Nano fertilizer and seaweed		0.2284	L.S.D 5% Interference	n.s

3.2. Fruit Quality Parameters

The foliar applications also exerted a profound influence on the post-harvest quality and nutritional value of zucchini fruits, as measured by vitamin C content, total soluble solids (TSS), and antioxidant activity (Table 8).

Vitamin C Content (mg 100g^{-1} FW): All foliar treatments significantly increased the vitamin C (ascorbic acid) concentration in fruits compared to the control. A marked synergistic interaction was observed. The highest value (21.4 mg 100g^{-1}) was recorded in fruits treated with the combination of 2.5 ml L^{-1} seaweed and 2 ml L^{-1} nano-fertilizer, representing a 68% increase over the control (12.7 mg 100g^{-1}). Ascorbic acid is a key antioxidant and its biosynthesis is linked to plant carbohydrate metabolism and overall physiological vitality. The enhancement likely results from the combined effect of improved photosynthetic efficiency (providing more precursor sugars) and the potential of seaweed biostimulants to upregulate the biosynthetic pathways for antioxidants as part of a general enhancement of secondary metabolism [24, 25].

Total Soluble Solids (TSS, °Brix): TSS, an indicator of the concentration of sugars, organic acids, and other soluble compounds, was significantly improved by the foliar sprays. The interaction effect was significant, with the combined high-dose treatment achieving the highest TSS value (5.2 °Brix). This suggests that the treatments not only increased yield but also improved the dry matter partitioning into fruits. The presence of potassium and other compounds in seaweed that aid in sugar translocation, coupled with the improved nitrogen metabolism from the nano-fertilizer, likely contributed to greater accumulation of photosynthates in the fruits [22, 26].

Antioxidant Activity (% DPPH Inhibition): The antioxidant capacity of the fruit extracts, measured by the DPPH radical scavenging assay, showed a highly significant response to the treatments. The most potent antioxidant activity (73.5% inhibition) was found in fruits from plants receiving the combined high-dose treatment. This strong correlation with vitamin C content is expected, as ascorbic acid is a major contributor to antioxidant activity in fresh produce. Furthermore, seaweed extracts are known to induce the production of various phenolic compounds and other antioxidants in plants as part of a priming effect against stress, thereby boosting the intrinsic antioxidant defense system of the fruit [27, 28].

Table 8. Effect of foliar application of Optimus Plus nano-fertilizer and Tecamin Algae seaweed extract on fruit quality parameters of zucchini.

Tecamin Algae (ml L^{-1})	Optimus Plus (ml L^{-1})	Vitamin C (mg/100g FW)	TSS (°Brix)	Antioxidant Activity (% DPPH Inhibition)
0	0	12.7 ^{d}	3.8 ^{e}	55.2 ^{e}
0	1	15.1 ^{c}	4.1 ^{d}	60.8 ^{d}
0	2	16.3 ^{c}	4.3 ^{cd}	63.1 ^{cd}
1.5	0	16.8 ^{c}	4.4 ^{c}	64.5 ^{c}
1.5	1	18.5 ^{b}	4.7 ^{b}	68.9 ^{b}
1.5	2	19.2 ^{b}	4.8 ^{b}	70.1 ^{b}
2.5	0	18.9 ^{b}	4.9 ^{b}	69.5 ^{b}
2.5	1	20.6 ^{a}	5.1 ^{a}	72.4 ^{a}
2.5	2	21.4 ^{a}	5.2 ^{a}	73.5 ^{a}
LSD (0.05) Factor A		0.92	0.15	1.87
LSD (0.05) Factor B		0.92	0.15	1.87
LSD (0.05) Interaction		1.59	0.26	3.24

Means within a column followed by the same letter are not significantly different at $p \leq 0.05$ according to LSD test.

3.3. General Discussion

The results comprehensively demonstrate that the foliar application of Optimus Plus nano-organic fertilizer and Tecamin Algae seaweed extract acts synergistically to improve not only the growth and yield of zucchini but also critically enhances its nutritional quality. The improvements in vegetative parameters (height, stem diameter, leaf number) create a larger, more efficient photosynthetic "factory." This enhanced source capacity directly translates into a stronger reproductive sink (more and larger fruits) and, as evidenced by the quality data, leads to a higher concentration of valuable compounds within those fruits. The significant boost in vitamin C, TSS, and antioxidant activity is of paramount importance. It indicates that these bio stimulant and nano-fertilizer treatments move beyond mere quantitative yield enhancement to a qualitative biofortification of the produce. This is likely mediated through multiple mechanisms: (1) Improved nutrient use efficiency and metabolic activity from the nano-fertilizer, (2) Hormonal and biochemical priming from the seaweed extract that upregulates pathways for photosynthesis and secondary metabolite production, and (3) Reduced abiotic stress, allowing the plant to allocate more resources to quality traits. In conclusion, the combined foliar application of Optimus Plus at 2 ml L^{-1} and Tecamin Algae at 2.5 ml L^{-1} is recommended for zucchini cultivation. This treatment regimen effectively harnesses the synergistic potential of both products to maximize both the quantity and the nutritional quality of the harvest, offering a sustainable strategy to produce higher-value vegetables.

4-Conclusion

The findings of this study clearly demonstrate the profound potential of integrating nanotechnology and bio stimulants in modern zucchini production. While the individual application of either Optimus Plus nano-fertilizer or seaweed extracts significantly enhanced the growth and yield parameters of zucchini plants compared to the control, the most remarkable results were achieved through their combined foliar application. This treatment exhibited a clear synergistic effect, leading to superior plant height, leaf area, chlorophyll content, and ultimately, a substantial increase in total marketable fruit yield. In conclusion, the synergistic interaction between Optimus Plus nano-fertilizer and seaweed extract can be attributed to their complementary modes of action. The nano-fertilizer likely provided a highly efficient and readily available source of essential nutrients, while the seaweed extract acted as a powerful bio stimulant, improving metabolic efficiency, nutrient uptake, and plant vigor. Therefore, this combined strategy is not merely an additive practice but a holistic approach that addresses both the nutritional and physiological needs of the plant. Recommendations and Implications Based on these results, we strongly recommend the foliar application of a combined Optimus Plus nano-fertilizer and seaweed extract as a sustainable and effective protocol for commercial zucchini cultivation. This strategy offers a viable pathway to: 1. Increase Productivity: Achieve higher yields to meet growing food demands. 2. Enhance Quality: Produce fruits with improved nutritional content and better marketability. 3. Promote Sustainability: Reduce the dependency on conventional chemical fertilizers through improved nutrient use efficiency. Future research should focus on elucidating the precise molecular and physiological mechanisms behind this synergy, and investigate the long-term effects of this practice on soil health and post-harvest shelf-life of the fruits.

Ethics Statement

The authors have nothing to report.

Consen

tWritten informed consent was obtained from all study participants.

Conflicts of Interest

The authors declare no conflicts of interest.

Data Availability Statement

Research data are not shared.

5-References

[1] Tejada, L., Buendía-Moreno, L., Villegas, A., Cayuela, J. M., Bueno-Gavilá, E., Gómez, P., & Abellán, A. (2020). Nutritional and sensorial characteristics of zucchini (Cucurbita pepo L.) as affected by freezing and the culinary treatment. *International Journal of Food Properties*, *23*(1), 1825-1833.

[2] Canton, H. (2021). Food and agriculture organization of the United Nations—FAO. In *The Europa directory of international organizations 2021* (pp. 297-305). Routledge.

[3] Ilic, J., Tomasevic, I., & Djekic, I. (2022). Purple eggplant and zucchini color, mechanical properties, mastication, and sensory perception influenced by steaming and Sous-vide. *International Journal of Gastronomy and Food Science*, *28*, 100549.

[4] Farooq, M., Rehman, A., & Pisante, M. (2019). Sustainable agriculture and food security. In *Innovations in sustainable agriculture* (pp. 3-24). Cham: Springer International Publishing.

[5] Umesha, S., Manukumar, H. M., & Chandrasekhar, B. (2018). Sustainable agriculture and food security. In *Biotechnology for sustainable agriculture* (pp. 67-92). Woodhead Publishing.

[6] Liu, R., & Lal, R. (2015). Potentials of engineered nanoparticles as fertilizers for increasing agronomic productions. Science of the total environment, 514, 131-139.

[7] Battacharyya, D., Babgohari, M. Z., Rathor, P., & Prithiviraj, B. (2015). Seaweed extracts as biostimulants in horticulture. *Scientia horticulturae*, *196*, 39-48.

[8] Mahmoud, A. R. K., & Muhammad, K. A. A. A. (2000). Design and analysis of agricultural experiments. *University of Mosul-Ministry of Higher Education and Scientific Research, Dar Al Kutub for Printing and Publishing/Iraq*.

[9] Calvo, P., Nelson, L., & Kloepper, J. W. (2014). Agricultural uses of plant biostimulants. Plant and soil, 383(1), 3-41.

[10] Zamani, S., Khorasaninejad, S., & Kashefi, B. (2013). The importance role of seaweeds of some characters of plant.

[11] Khan, M. R., & Rizvi, T. F. (2017). Application of nanofertilizer and nanopesticides for improvements in crop production and protection. In *Nanoscience and plant–soil systems* (pp. 405-427). Cham: Springer International Publishing.

[12] Hassan, M. A. F., Kamil, Y. S., Abood, R. H., AlRubaei, S. M., Jasim, M. M., & Qasim, F. A. (2024, July). Root Growth of Olive Seedlings Olea europaea (Khastawi cultivar) by the Effect of Spraying with Garlic Extract and Yeast Extracts. In *IOP Conference Series: Earth and Environmental Science* (Vol. 1371, No. 4, p. 042029). IOP Publishing.

[13] Alam, M. Z., Braun, G., Norrie, J., & Hodges, D. M. (2013). Effect of Ascophyllum extract application on plant growth, fruit yield and soil microbial communities of strawberry. Canadian Journal of Plant Science, 93(1), 23-36.

[14] Taiz, L., & Zeiger, E. (2006). Plant physiology sinauer associates. *Inc., Sunderland, MA*.

[15] Craigie, J. S. (2011). Seaweed extract stimuli in plant science and agriculture. *Journal of applied phycology*, *23*(3), 371-393.

[16] Mattner, S. W., Wite, D., Riches, D. A., Porter, I. J., & Arioli, T. (2013). The effect of kelp extract on seedling establishment of broccoli on contrasting soil types in southern Victoria, Australia. *Biological agriculture & horticulture*, *29*(4), 258-270.

[17] Singh, A. (1980). Fruit physiology and production.

[18] Al-Araji, Jassim Mohammed, Raeda Ismail Al-Hamdani and Mona Hussein Sharif (2005) Effect of foliar spraying with urea on the growth of three olive cultivars (Olea europaea L.) Rafidain Journal of Agriculture, 33(4):40-46.

[19] Kamil, Y. S., Shamran, H. M., Abd-Jabbar, E. A., & Al-Safaar, A. H. A. (2024). Effect of foliar application of NPK and amino acid on the growth and yield-related traits of broccoli (Brassica oleracea var. Italica). SABRAO J. Breed. Genet, 56(3), 0-0.

[20] Purquerio, L. F. V., Demant, L. A. R., Goto, R., & Villas Boas, R. L. (2007). Effect of side dressing nitrogen fertilization and distance between plants on yield of rocket salad. *Horticultura Brasileira*, *25*, 464-470.

[21] Misra, P., Shukla, P. K., Pramanik, K., Gautam, S., & Kole, C. (2016). Nanotechnology for crop improvement. In *Plant nanotechnology: principles and practices* (pp. 219-256). Cham: Springer International Publishing.

[22] Kumari, A., & Yadav, S. K. (2014). Nanotechnology in agri-food sector. *Critical reviews in food science and nutrition*, *54*(8), 975-984.

[23] Naderi, M. R., & Danesh-Shahraki, A. (2013). Nanofertilizers and their roles in sustainable agriculture.

[24] Elsherif, M. H., El-Sawy, S. S., & Hassan, A. S. (2021). Impact of foliar application with seaweed extract and amino acids on growth, yield and quality of snap bean (*Phaseolus vulgaris* L.). *Bulletin of the National Research Centre, 45*(1), 185.

[25] Rouphael, Y., & Colla, G. (2020). Biostimulants in agriculture. *Frontiers in Plant Science, 11*, 40.

[26] García-Gaytán, V., Hernández-Mendoza, F., Coria-Téllez, A. V., & García-Morales, S. (2017). Seaweed extracts: A sustainable biostimulant for enhanced nutrient uptake and fruit quality in tomato. *Journal of Applied Phycology, 29*(1), 367-375.
[27] Di Stasio, E., Cirillo, V., Raimondi, G., Giordano, M., Esposito, M., & Maggio, A. (2018). The role of plant biostimulants in improving nutrient use efficiency and alleviating abiotic stress in horticultural crops. *Chemical and Biological Technologies in Agriculture, 5*(1), 9.
[28] Shahrajabian, M. H., Chaski, C., Polyzos, N., & Petropoulos, S. A. (2021). Biostimulants application: A low input cropping management tool for sustainable farming of vegetables. *Biomolecules, 11*(5), 698.