Effect of Nano-NPK Fertilizer and Alga600 Seaweed Extract on Vegetative Growth, Yield and Active compounds of Ginger (*Zingiber officinale*)

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Abstract

A field experiment was conducted on ginger plants in the shade of the Department of Horticulture and Landscape designing, College of Agriculture/University of Diyala, from May 2025 to February 2026, with a randomized complete block design (RBCD) with three replications, to study the effect of nano-NPK and the effect of seaweed Alga600 on the growth and yield of ginger plants and their content of active compounds. Different concentrations of nano-NPK (0, 1, 1.5 and 2 ml L^{-1}) were used with different concentrations of seaweed Alga600 (0, 2 and 4 g L^{-1}). The results showed that the 1 ml L^{-1} concentration had the highest average plant height and number of branches, reaching 19.11 cm and 15.52 branches per plant. The number of ginger cloves reached 81.33 cloves plant^{-1}. The 1.5 ml L^{-1} concentration of nano-NPK had the highest average number of leaves and leaf chlorophyll content, reaching 69.66 leaves plan^{-1}t and 1.081 mg g^{-1} respectively. The 2 ml L^{-1} concentration of nano-NPK had the highest average rhizome fresh weight and the highest average values of Gingerol, Shogaol and Zingerone, reaching 130.7 g, 687.4, 202.0 and 284.8 respectively. The 2 g L^{-1} concentration of seaweed resulted in the highest average number of lobes and rhizome fresh weight, reaching 8, 83.75 lobes plant^{-1}, and 127.0 g respectively. Seaweed at a concentration of 4 g L^{-1} gave the highest average values of Gingerol, Shogaol, and Zingerone, reaching 4.965, 681.5, 198.7, and 244.0 mcg ml^{-1} respectively. The interaction of 2 ml L^{-1} NPK nanoparticles with 2 g L^{-1} Seawead gave the highest average number of lobes, rhizome fresh weight, and root number of 103 lobes plant^{-1}, 171.1 g, and 28.00 roots plant^{-1}. The interaction of 1.5 ml L^{-1} NPK nanoparticles with 2 g L^{-1} Seawead gave the highest average root fresh weight of 27.00 g.

Keywords: Ginger, Nano NPK Fertilizer, Alga600, Active Compounds.

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***The research is taken from the first researcher's thesis.**

Introduction

Ginger *Zingiber officinale* Roscoe belongs to the ginger family Zingiberaceae. It is a perennial herbaceous plant that is cultivated in early spring. It belongs to the monocotyledonous plant order and includes about 80 species of medicinal and aromatic plants. It is considered a healthy food, whether used as a spice or juice [22]، The rhizome represents the active part of the ginger plant and is an important nutritional and medicinal source due to its content of active substances such as alkaloids, phenols, glycosides, resins and active oils, as well as vitamins, fiber, fats and minerals [16] . Gingrol, Shogaols and Zingerone are among the most important active compounds in the rhizome, to which the medicinal activity is attributed, and they are also responsible for the plant's hot and pungent taste [21]. Ginger is a shallow-rooted plant and a crop that requires many nutrients and needs an abundant supply of nitrogen, phosphorus and potassium. Adding them through nano-fertilizers allows them to be released slowly to the plant and absorbed with high efficiency, which enhances productivity and supports metabolic processes [19]. The indiscriminate use of chemical fertilizers has a harmful effect on the soil, and the thoughtful combination of organic fertilizers, represented by seaweed, and chemical fertilizers, represented by nano-NPK fertilizer, in ideal proportions is a good option for achieving sustainable ginger production [24]، Nano-fertilizers possess unique properties such as high .

adhesion to reduce nutrient loss while releasing them slowly, which not only promotes plant growth and increases yield but can also improve stress conditions [23]. Nano-fertilizers enhanced plant growth and increased productivity, as they accumulated in plant parts to increase mineral content. Mineral deficiencies in the plant were addressed, and its resistance to stress conditions was improved. However, the best approach is to use nano-fertilizers in conjunction with traditional fertilizers [6]. The work was on synthesizing inorganic nanomaterials to provide nutrients such as nitrogen, phosphorus, potassium and other elements to provide them to the plant in the form of nanocomposites or nanocarriers manufactured using porous nanomaterials. These nanomaterials act as effective nanocarriers as they are characterized by their ability to improve the loading of nutrients, prolong the release time and reduce the side effects resulting from environmental factors [17], In their study [13], the addition of NPK fertilizer (125:50:100) kg ha^{-1} to ginger plants caused a significant increase in yield, reaching 26.54 tons ha^{-1}, [20] In their study on turmeric plants to demonstrate the effect of NPK chemical fertilizer at three levels of 0, 125, and 250 kg ha^{-1}, the results showed the superiority of the NPK treatment at a rate of 250 kg ha^{-1} in terms of plant height, number of leaves, and yield.

Seaweed is a rich source of proteins, fats, vitamins, minerals, phenolic compounds and pigments, which contribute significantly to soil health and improved crop productivity, as it improves soil structure and nutrient availability [10]. It works to improve the absorption of nutrients and stimulate microorganisms in the soil, enhances antioxidant properties, and contains minerals, organic matter, plant hormones, and polysaccharides (laminarin, fucoidan, and alginate). It also acts as a chelating agent that improves the plant's ability to absorb minerals and nutrients and improves soil structure and aeration [1], Treating the soil with seaweed extract improves plant growth regulation and drought resistance compared to foliar spraying under drought conditions [9], A study was conducted by [11] to demonstrate the effect of stimulants on potato growth for two seasons, 2023 and 2024. Seaweed was used at a concentration of 2 g/L-1 sprayed on the foliage after 85 days of planting. The results showed that the seaweed was superior to the control treatment in terms of plant height, number of branches, nitrogen, phosphorus, potassium, and total chlorophyll.

In order to develop ginger cultivation in Iraq in general and Diyala Governorate in particular, and due to the scarcity of studies on the subject, this study aims to Cultivate tissue-cultured and acclimatized ginger plants in the field and acclimatize them to the environmental conditions of Diyala Governorate, and to demonstrate the role of adding nano-NPK fertilizer and the seaweed Alga 600 in the growth of ginger plants and the production of rhizomes from the acclimatized plants.

Materials and Methods: Acclimated seedlings were taken from tissue culture cultures of Chinese ginger, Planting took place on 1/5/2026, and Grown in pots and containing peat moss in a 1:1 ratio and planted in a 7 x 3.5 m^2 shaded area in the Horticulture Department, College of Agriculture, University of Diyala. The shaded area was covered with 50% shade netting to protect the plants from direct sunlight. The shaded area was equipped with a desert cooling system consisting of layers of

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cardboard cooling cells, a pump to raise water above the cooling cells, and a vacuum system to draw air from inside the shaded area and replace it with cool air.

The experiment was carried out with two factors: the first was the addition of Nano-NPK fertilizer and seaweed extract (Alga 600).

Agent 1: Nano-NPK at four concentrations: 0, 1, 1.5, and 2 ml L^{-1}.

Agent 2: Seaweed extract (Alga 600) at three concentrations: 0, 2, and 4 g L^{-1}, With three replicates and four plants per experimental unit, we have a total of 144 plants.

Agent 1 was added on June 10, 2025, and Agent 2 on June 11, 2025, once a month for five months, added to the soil of the pots. Soil analysis was performed before the experiment began, and some of its chemical and physical properties were determined, as shown in Table (1). The analysis was conducted at the Central Laboratory for Soil and Water Analysis, College of Agricultural Engineering Sciences, University of Baghdad.

Table 1: It shows the physical and chemical properties of the river soil used.

الصفة		القيمة	وحدة القياس
Available nitrogen		31.9	gm Kg^{-1}
Available phosphorus		11.87	
Available potassium		145.5	
Soil separators	Sand	80.4	%
	Silken clay	5.3	
	Clay	6.1	
Soil texture		Lomy sand	....
$CaCO_3$		78.05	gm Kg^{-1}
Ca^{+2}		12.25	m ml^{-1}
Mg^{+2}		9.21	
Bicarbonate		10.7	
Na		1.59	
Cl		8.7	
EC		1.5	Desi Siemens. $M.^{-1}$
Ph		5.81	....

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Studied Characteristics:

1: Vegetative Characteristics

- Number of leaves (leaf per branch): The number of leaves per branch was counted.

- Plant height (cm): Plant height was measured using a measuring tape.

-Number of branches (branch per plant): The number of branches formed per plant was counted.

- Estimation of total leaf chlorophyll content (mg/g fresh weight): Chlorophyll was estimated according to method [14].

2- Yield 2:Characteristics and Components

- Number of rhizome lobes: The number of rhizome lobes formed in each experimental unit was counted and divided by the number of plants in the experimental unit.

- Rhizome fresh weight (g): This characteristic was calculated using a digital rhizome scale.

3: Extraction of the compounds (Gingerol, Shogaol, and Zingerone) using HPLC: The analysis was conducted in the laboratories of the Scientific Research Authority/Department of Environment and Water to detect the compounds Gingerol, Shogaol, and Zingerone using high-performance liquid chromatography (HPLC) technology manufactured by the German company Sykam, according to the method presented by the scientist [7].

The field experiment was carried out using a Completely Randomized Block Design (RCBD) with 3 replicates and an average of 4 plants per experimental unit, and the results were analyzed using SAS software according to Duncan's multiple range test at a probability level of 0.05 [4].

Results and Discussion:

1- Effect of Adding Nano NPK and Seaweed on Vegetative Growth Characteristics

- Number of Leaves

Table 1 shows the effect of nano NPK on the number of leaves in ginger plants. A concentration of 1.5 ml L^{-1} resulted in the highest number of leaves (69.66 leaves per plant), while the control treatment resulted in the lowest number of leaves (55.00 leaves per plant). The same table shows no significant differences between the seaweed treatments in terms of leaf count.

Table (2) shows a significant interaction effect between nano NPK and seaweed. The interaction treatment (1.5 ml L^{-1} NPK + 2 g L^{-1} seaweed) resulted in the highest number of leaves (76.66 leaves per plant), while the control treatment (no addition) resulted in the lowest number of leaves (53.6 leaves per plant).

Table 2: Effect of adding nano-NPK and seaweed and their interaction on the average number of leaves of ginger plants growing under field conditions

Nano NPK concentrations $^{1-}$ml L	Seaweed concentrations g L^{-1} 0	2	4	Means Nano NPK
0	53.66 b	58.66 B	52.66 b	55.00 C
1	61.33 b	58.00 b	61.00 b	60.11 BC
1.5	65.00 ab	76.66 a	67.33 ab	69.66 A
2	61.33 b	66.00 ab	62.33 ab	63.22 AB
Means Seawead	60.33 A	64.83 A	60.83 A	

Transactions that share at least one letter are not significantly different from each other according to Duncan's polynomial test at a probability level of 0.05

Plant Height (cm)

The results in Table 3 indicate that adding 2 ml L^{-1} of nano-NPK to ginger plants resulted in an increase in plant height of 19.11 cm, compared to the control treatment, which yielded the lowest value of 16.63 cm. There were no significant differences in the height of the ginger plants due to the addition of seaweed.

The results of the interaction between adding nano-NPK and seaweed show that the treatment combining 1 ml L^{-1} with 4 g L^{-1} of seaweed resulted in the highest plant height of 20.91 cm, while the control treatment recorded the lowest value of 15.08 cm.

Table 3: Effect of adding nano-NPK and seaweed and their interaction on plant height (cm) of ginger grown under field conditions

Nano NPK concentrations $ml\ L^{-1}$	Seaweed concentrations g L^{-1} 0	2	4	Means Nano NPK
0	15.08 b	17.33 ab	17.50 ab	16.63 B
1	18.41 ab	18.00 ab	20.91 a	19.11 A
1.5	17.50 ab	20.91 a	17.25 ab	18.55 AB
2	18.91 ab	18.75 ab	17.58 ab	18.41 AB
Means Seawead	17.47 A	18.75 A	18.31 A	

Transactions that share at least one letter are not significantly different from each other according to Duncan's polynomial test at a probability level of 0.05

Number of Branches

Table 4 shows a significant increase in the number of branches with the addition of nano-NPK. The highest number of branches was recorded at a concentration of 1 ml L^{-1} (15.52 branches plant $^{-1}$), and this was not significantly different from the other concentrations. The number of branches was 15.0 branches plant^{-1} at a concentration of 1.5 ml L^{-1} and 15.33 branches plant^{-1} at a concentration of 2 ml L^{-1}. The

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control treatment produced the lowest number of branches, at 11.55 branches plant^{-1} . The same table shows no significant differences between the treatments for adding seaweed to ginger plants. The interaction between nano-NPK and seaweed in Table (4-8) shows that the interaction treatment of 1 ml L^{-1} NPK with zero seaweed treatment was superior, giving the highest number of branches, which reached 17.66 branches plant^{-1} , while the two treatments of not adding nano-NPK with the two concentrations of seaweed, 2 and 4 g L^{-1}, gave the lowest number of branches, which reached 11.25 branches plant^{-1} for both treatments.

Table 4: Effect of adding nano-NPK and seaweed and the interaction between them on the number of branches of a ginger plant growing under field conditions

Nano NPK concentrations $^{1-}$ml L	Seaweed concentrations g L^{-1} 0	2	4	Means Nano NPK
0	12.16 ab	11.25 b	11.25 b	11.55 B
1	17.66 a	15.16 ab	13.75 ab	15.52 A
1.5	14.25 ab	15.41 ab	15.50 ab	15.05 A
2	17.16 ab	12.91 ab	15.91 ab	15.33 A
Means Seawead	15.31 A	13.68 A	14.10 A	

Transactions that share at least one letter are not significantly different from each other according to Duncan's polynomial test at a probability level of 0.05

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- Total leaf chlorophyll content

Table 5 shows a significant increase in leaf chlorophyll content when adding nano-NPK to ginger. The treatment with 1.5 ml L^{-1} nano-NPK gave the highest leaf chlorophyll content of 1.081 mg g^{-1} wet weight, which was not significantly different from the 2 ml L-1 treatment, which gave a total chlorophyll content of 1.043 mg g-1. The control treatment gave the lowest chlorophyll content of 0.681 mg g-1 wet weight. There were no significant differences between the treatments of adding seaweed to ginger.

The results in the same table show the significant effect of the interaction between the two treatments under study. The interaction treatment of adding 2 ml L^{-1} nano-NPK with the addition of 2 g L^{-1} Seawead gave the highest chlorophyll content of the leaves, reaching 1.233 mg g^{-1} wet weight, while the comparison treatment of nano-NPK with the treatment of 4 mg L-1 marine algae gave the lowest chlorophyll content of the leaves, reaching 0.596 mg g^{-1} wet weight.

Table 5: Effect of adding nano-NPK and seaweed and their interaction on the total chlorophyll content of leaves of ginger plant grown under field conditions

Nano NPK concentrations $^{1-}$ml L	Seaweed concentrations g L^{-1}			Means
	0	2	4	Nano NPK
0	0.724	0.723	0.596	0.681
	ab	ab	b	B
1	0.922	0.890	0.936	0.916
	ab	ab	ab	AB
1.5	1.110	1.094	1.038	1.081
	ab	ab	ab	A
2	0.862	1.233	1.034	1.043
	ab	a	ab	A
Means	0.904	0.985	0.901	
Seawead	A	A	A	

Transactions that share at least one letter are not significantly different from each other according to Duncan's polynomial test at a probability level of 0.05

The increase in vegetative growth characteristics may be due to the addition of nano-NPK fertilizer, which leads to increased absorption rates along with increased growth rates. Nitrogen is involved in the formation of amino acids, thus increasing protein formation. Phosphorus also plays a pivotal role in plant growth and

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development, in addition to the role of potassium, which is involved in metabolic processes within the plant. These elements work to increase plant activity and thus increase growth through an increase in the number of leaves, plant height, and number of branches [5]. These results are consistent with [15].

Yield Characteristics and Components

- Number of Clusters

The results in Table 6 show that adding nano-NPK to ginger at a concentration of 2 ml L^{-1} resulted in the highest number of clusters, reaching 84.22 clusters per plant, while the control treatment resulted in the lowest number of clusters, at 61.33 clusters $plant^{-1}$. The same table shows the effect of seaweed on ginger, where a concentration of 2 g L^{-1} resulted in the highest number of clusters, reaching 83.75 clusters per plant, while the control treatment resulted in the lowest number of clusters, at 65.41 clusters $plant^{-1}$.

The results in Table 6 indicate a significant increase in the interaction treatment of 2 ml L^{-1} NPK nanoparticles with 2 mg L^{-1} Seawead, reaching 103.0 lobules $plant^{-1}$, while the comparison treatment of NPK nanoparticles with 4 mg L^{-1} Seawead gave the lowest number of lobules, reaching 53.33 lobules $plant^{-1}$.

Table 6: Effect of adding nano-NPK and seaweed and the interaction between them on the number of lobes of a ginger plant growing under field conditions.

Nano NPK concentrations $^{1-}$ml L	Seaweed concentrations g L^{-1}			Means
	0	2	4	Nano NPK
0	62.67	68.00	53.33	61.33
	c	bc	c	B
1	65.67	80.00	98.33	81.33
	bc	abc	ab	A
1.5	62.00	84.00	67.00	71.00
	c	abc	bc	AB
2	71.33	103.0	78.33	84.22
	abc	a	abc	A
Means	65.41	83.75	74.25	
Seawead	B	A	AB	

*Transactions that share at least one letter are not significantly different from each other according to Duncan's polynomial test at a probability level of 0.05.

Fresh weight of rhizome (g)

The results in Table 7 indicate a significant increase in the fresh weight of ginger rhizome when nano-NPK was added to the plants. The 2 ml L^{-1} treatment was characterized by giving the highest rhizome weight of 130.7 g, while the control treatment gave the lowest rhizome weight of 85.67 g.

The same table shows the effect of seaweed on rhizome fresh weight. The treatment with 2 g L^{-1} resulted in the highest rhizome fresh weight of 127.0 g, while the control treatment resulted in the lowest rhizome fresh weight of 97.36 g. The results in Table (2-6) illustrate the interaction between the treatments under study, with the treatment combining 2 ml L^{-1} NPK nanoparticles with 2 g L^{-1} seaweed yielding the highest rhizome weight of 171.1 g. In contrast, the control treatment combining NPK nanoparticles with 2 mg L^{-1} seaweed resulted in the lowest rhizome weight of 82.87 g.

Table 7: Effect of adding nano-NPK and seaweed and their interaction on the fresh weight (g) of ginger plants grown under field conditions

Nano NPK concentrations $^{1-}$ml L	Seaweed concentrations g L^{-1}			Means
	0	2	4	Nano NPK
0	88.90	82.87	85.27	85.67
	cde	e	de	C
1	82.43	125.9	115.6	108.0
	e	b	b	B
1.5	109.9	128.1	106.8	114.9
	bcd	b	b-e	B
2	108.2	171.1	112.8	130.7
	b-e	a	bc	A
Means	97.36	127.0	105.1	
Seawead	B	A	B	

*Transactions that share at least one letter are not significantly different from each other according to Duncan's polynomial test at a probability level of 0.05

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The results indicated a significant increase in rhizome weight and the number of rhizome lobes. This increase may be due to an increase in vegetative growth characteristics, which are indicators of plant growth. This positively impacts root system growth and increases photosynthesis rates, leading to the accumulation of nutrients formed in the rhizomes. The increase in N, P, and K in the leaves led to an increase in photosynthesis and an increase in the transfer of nutrients from their manufacturing sites to their storage sites in the rhizomes [12], [20] on turmeric plants, and [8] on ginger and turmeric plants.

The results obtained indicate that the improvement in yield characteristics may be due to the seaweed extract and its content of auxins and cytokinins, which work to increase yield characteristics by improving absorption efficiency and photosynthesis within the leaf by increasing the efficiency of the photosynthesis process and stimulating root growth [2].

3: Rhizomatous Content of Active Compounds

- Gingerol

Table 8 shows that the addition of nano-NPK and seaweed significantly increased the Gingerol content. Adding nano-NPK to ginger at a concentration of 2 ml L^{-1} resulted in a significant increase in Gingerol, reaching 687.4 mcg ml^{-1}, while the control treatment yielded the lowest Gingerol value at 641.8mcg ml^{-1} . The same table also shows that seaweed at a concentration of 4 g L^{-1} produced the highest Gingerol value at 681.5mcg ml^{-1} , while the control treatment yielded the lowest value at 653.3 mcg ml^{-1}. Table (8) indicates the binary interaction between nano-NPK and marine algae. The interaction treatment of 2 ml L^{-1} nano-NPK with 4 g L^{-1} seawead gave the highest values for the Gingerol compound, reaching 700.7 mcg ml^{-1}, while the comparison treatment gave the lowest values, reaching 631.9mcg ml^{-1}.

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Table 8: Effect of adding nano-NPK and seaweed and their interaction on the rhizome content of gingerol in ginger plants grown under field conditions

Nano NPK concentrations $^{1-}$ml L	Seaweed concentrations g L^{-1} 0	2	4	Means Nano NPK
0	631.9	639.9	653.6	641.8
	l	k	I	D
1	649.7	666.4	677.9	664.6
	j	g	e	C
1.5	659.7	682.4	693.9	678.6
	h	d	b	B
2	671.9	689.6	700.7	687.4
	f	c	a	A
Means	653.3	669.6	681.5	
Seawead	C	B	A	

*Transactions that share at least one letter are not significantly different from each other according to Duncan's polynomial test at a probability level of 0.05

-Shogaol:

Table 9 shows that the addition of nano-NPK and seaweed significantly increased shogaol levels. Adding nano-NPK to ginger at a concentration of 2 ml L^{-1} resulted in a significant increase in shogaol, reaching 202.0mcg ml^{-1}, while the control treatment yielded the lowest shogaol value at 171.0mcg ml^{-1} . The same table also shows that seaweed at a concentration of 4 g L^{-1} produced the highest shogaol value at 198.7mcg ml^{-1} , while the control treatment yielded the lowest value at 177.4mcg ml^{-1}.

Table 9 indicates the binary interaction between nano-NPK and marine algae. The interaction treatment of 2 ml L^{-1} nano-NPK with

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4 g L^{-1} seawead gave the highest values for the Shogaol compound, reaching 213.9 mcg ml^{-1}, while the control treatment gave the lowest values, reaching 165.2 mcg ml^{-1}.

Table 9: Effect of adding nano-NPK and seaweed and the interaction between them on the rhizome content of Shogaol of ginger plant grown under field conditions.

Nano NPK concentrations $ml\ L^{-1}$	Seaweed concentrations g L^{-1} 0	2	4	Means Nano NPK
0	165.2 I	169.9 k	178.0 i	171.0 D
1	174.0 j	185.1 g	193.9 e	184.3 C
1.5	180.9 h	198.4 d	208.9 b	196.0 B
2	189.7 f	202.4 c	213.9 a	202.0 A
Means Seawead	177.4 C	188.9 B	198.7 A	

*Transactions that share at least one letter are not significantly different from each other according to Duncan's polynomial test at a probability level of 0.05.

Zingerone

Table 10 shows that the addition of nano-NPK and seaweed significantly increased Zingerone levels. Adding nano-NPK to ginger at a concentration of 2 ml L^{-1} resulted in a significant increase in Zingerone, reaching 284.8, while the control treatment yielded the lowest Zingerone value at 211.3 mcg ml^{-1} . The same table also shows that seaweed at a concentration of 4 g L^{-1} produced the highest Zingerone value at 244.0 mcg ml^{-1}, while the control treatment yielded the lowest value at 219.5 mcg ml^{-1}.

Table 10 indicates the binary interaction between nano-NPK and marine algae. The interaction treatment of 2 ml L^{-1} nano-NPK with 4 g L^{-1} seawead gave the highest values for the Zingerone compound, reaching 261.0 mcg ml^{-1}, while the control treatment gave the lowest values, reaching 204.9 mcg ml^{-1}.

Table 10: Effect of adding nano-NPK and seaweed and the interaction between them on the rhizome content of Zingerone of a ginger plant growing in field conditions.

Nano NPK concentrations $^{1-}$ml L	Seaweed concentrations g L^{-1} 0	2	4	Means Nano NPK
0	204.9 I	209.9 k	219.3 i	211.3 D
1	214.8 j	227.9 g	239.0 e	227.2 C
1.5	223.6 h	244.7 d	256.6 b	241.6 B
2	234.6 f	250.8 c	261.0 a	284.8 A
Means Seawead	219.5 C	233.3 B	244.0 A	

*Transactions that share at least one letter are not significantly different from each other according to Duncan's polynomial test at a probability level of 0.05

The increase in the active ingredient content of ginger when using nano-NPK fertilizer can be attributed to its role in improving nutrient absorption and increasing nutrient availability within the plant. This leads to the activation of metabolic processes and enhances the efficiency of biosynthesis of secondary compounds. The essential nutrients (K, P, N) support enzyme formation and provide the energy necessary for biochemical reactions, which positively impacts the accumulation of active compounds. Studies have indicated that nano-fertilizers enhance metabolic activity and increase the production of secondary compounds in medicinal plants [18].

The increased content of the active ingredient in ginger when using seaweed extract can also be attributed to its content of biostimulants. These compounds stimulate metabolic processes within the plant and activate biological pathways associated with the production of secondary compounds, as well as improving nutrient absorption efficiency, which positively impacts the accumulation of the active ingredient. Studies have confirmed that seaweed extracts contribute to stimulating physiological and metabolic processes and enhancing plant productivity by regulating gene expression and defense pathways [3].

Conclusion:

According to the results obtained, adding Nano-NPK fertilizer to ginger plants caused a significant increase in plant height, number of branches and leaves, chlorophyll content of leaves, number of lobes, wet weight of ginger rhizomes, and content of active compounds. Spraying seaweed on ginger plants resulted in an increase in the number of cloves, the weight of the wet rhizome, and an increase in active compounds. The interaction between Nano-NPK fertilizer and seaweed resulted in a positive increase in most of the studied traits.

Refrence:

[1] **Abirami, S., Srisudha, S., and Gunasekaran, P. 2013.** Comparative study of chromium biosorption using brown, red and green macroalgae. Int J Biol Pharm Res, 4. 115-129.

[2] **Abu Zaid, Al-Shahat Nasr. 2000.** Plant Hormones and Agricultural Applications. Second Edition. Arab House for Publishing and Distribution. Arab Republic of Egypt.

[3] **Ali, O., Ramsubhag, A., and Jayaraman, J. 2021**. Biostimulant properties of seaweed extracts in plants: Implications towards

ISSN 2072-3857

sustainable crop production. Plants, 10(3).1-27.

[4] **Al-Sahouki, Medhat and Karima Muhammad Wahib. 1990**. Applications in thedesign and analysis of experiments. Ministry of Higher Education and Scientific Research, Iraq.

[5] **Al-Shahat, Muhammad Ramadan. 2007**. Biofertilizers and Organic Agriculture: Food and Clean Environment. Faculty of Agriculture, Ain Shams University. Dar Al-Fikr Al-Arabi, Cairo.

[6] **Bollyn, J., Castelein, L., and Smolders, E. 2019**. Fate and bioavailability of phosphorus loaded to iron oxyhydroxide nanoparticles added to weathered soils. Plant and Soil. 438(1): 297-311.

[7] **Cafino, E. J. V., Lirazan, M. B., and Marfori, E. C. 2016**. A simple HPLC method for the analysis of [6]-gingerol produced by multiple shoot culture of ginger (Zingiber officinale). Int. J. Pharmacogn. Phytochem. Res, 8(1), 38-42.

[8]Ekwugha, U. E., Obenade, M., Anyaegbu, P. O., and Jennifer, O. C. 2021.

Growth Performance of Ginger and Tumeric as Influenced by Cropping System and NPK Fertilizer 15: 15: 15. International Journal of Research and Scientific Innovation (JRSI). 5(2): 230-243.

[9] Elansary, H. O., Skalicka-Woźniak, K., and King, I. W. 2016. Enhancing stress growth traits as well as phytochemical and antioxidant contents of Spiraea and Pittosporum under seaweed extract treatments. Plant Physiology and Biochemistry. 105: 310-320.

[10] El-Beltagi, H. S., Mohamed, A. A., Mohamed, H. I., Ramadan, K. M., Barqawi, A. A., & Mansour, A. T. 2022. Phytochemical and potential properties of seaweeds and their recent applications: A review. Marine drugs, 20(6): 1-49.

[11] Hamaiel, A., Saif Eldeen, U., Abdelhady, M., and Elgabry, S. 2025. Enhancing Potato Growth, Yield, and Quality via Tuber Eye Numbers and Natural Stimulants under Egyptian Conditions. Damietta Journal of Agricultural Sciences, 4(3): 1-14.

[12] Hassan, Ahmed Abdel Moneim .2000. Onion and Garlic Production Series: Crops Production Technology and Agricultural Practices, Arab House for Publishing and Distribution – Egypt .

[13] Hatiskar, P. N., Thorat, S. B., Mali, P. C., Meshram, N. A., Saitwal, Y. S., Wakade, P. A., and Surve, S. S. 2025. Response of Ginger (Zingiber officinale Rosc.) cv. IISR Mahima to varying fertilizer doses for growth and yield parameters. International Journal of Research in Agronomy. 8(11): 422-424.

ISSN 2072-3857

[14] Howrtiz, W. 1975. Official methods of analysis. Association of Analytical Chemists, Washington, D.C. USA.

[15] Jalal, Vian Jabbar, Omar Hashim Musleh Al-Muhammadi and Khattab Abdullah Muhammad. 2022. The effect of using NPK nano-compound fertilizer technology on the growth characteristics and yield of two potato varieties (Solanum tuberosum L) grown in the autumn season. Kirkuk University Journal of Agricultural Sciences. 3 (13):1-10.

[16] Kim, Y. T., Shin, J. S., Ye, S. J., Kim, J. H., Eom, S. H., and Baik, M. Y. 2024. Conversion of gingerols to shogaols in ginger (Zingiber officinale roscoe) by puffing. Food Chemistry. 452(1): 13-25.

[17] Kopittke, P. M., Lombi, E., Wang, P., Schjoerring, J. K., and Husted, S. 2019. Nanomaterials as fertilizers for improving plant mineral nutrition and environmental outcomes. Environmental Science: Nano. 6(12): 3513-3524.

[18] Lala, S. 2021. Nanoparticles as elicitors and harvesters of economically important secondary metabolites in higher plants. IET Nanobiotechnology, 15(1), 28-57.

[19] Mahdi, A. N., Abdullah, K. M. and Almyali, A. A. H. 2023. Effect of spraying with amino acids (tryptophan and glycine) and nano-potassium on some vegetative growth characteristics of stevia plant (Stevi rebaudiana Bertoni). IOP conf. series Earth and Envionment science. 1158, 10200.

[20] Nasser, H. H. A., and Al-shammari, A. M. A. 2025. Effects of NPK Fertilizer and Antioxidant Foliar Sprays on Turmeric (Curcuma longa) Growth and Yield. Euphrates Journal of Agricultural Science. 17 (3):1533-1544.

[21] Parveen, S. A., Mir, U. A., Nayab, M. and Ansari, A. N. 2025. Beyond flavor: The role of ginger (Zingiber Officinale) in human health and disease prevention. European Journal of Medical Research. 12(2): 226-233.

[22] Xiang, S., Jian, Q., Chen, W., Xu, Q., Li, J.andZheng, C. 2024. Pharmacodynamic components and mechanisms of ginger (*Zingiber officinale*) in the prevention and treatment of colorectal cancer. Journal of Ethnopharmacology. 11(2):33-37.

[23] Yadav, M. 2025. Nanoparticle-facilitated targeted nutrient delivery in plants: Breakthroughs and mechanistic insights. Plant Nano Biology, 100156.

[24] Zhang, P., Liu, D., Ma, J., Sun, C., Wang, Z., Zhu, Y.and Liu, Y. 2024. Genome-wide analysis and expression pattern of the ZoPP2C gene family in Zingiber officinale Roscoe. BMC genomics. 25(1), 83-93.

ISSN 2072-3857