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EFFECT OF MINERAL FERTILIZER COMBINATION AND FOLIAR APPLICATION OF SEAWEED EXTRACT ON THE GROWTH AND YIELD TRAITS OF MAIZE

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SUMMARY

A field experiment transpired during the autumn of 2022 to study the effects of mineral fertilizer combinations and seaweed extract on maize growth and yield traits in Al-Hussainiya, Kerbala, Iraq. The research had a randomized completely block design (RCBD) arranged in split plots with three replications, where the main plots included seaweed extract (Algazone Mx30) with two concentrations (2 and 4 ml L^{-1}). The subplots included mineral fertilizer formulations of nitrogen (0, 150, and 300 kg ha^{-1}) and phosphorus fertilizers (0, 50, and 100 kg ha^{-1}). The maize cultivar 'Maha' was the sample used for the experiment. The results showed excellence in treatments, which represents seaweed extract with a concentration of 4 ml L^{-1} combined with 150 N + 50 P giving better performance in plant height (188.82 cm), leaves $plant^{-1}$ (15.65), leaf area $plant^{-1}$ (5548.3 cm^2), rows per ear (16.46), grains row^{-1} (39.41), grain yield (10.74 t ha^{-1}), and protein concentration (13.81%) in grains. With the interaction of two study factors, the mineral fertilizer use had a 50% reduction because there was no significant difference between the two doses of NP, i.e., 150 N + 50 P and 300 N + 100 P kg ha^{-1}, and the seaweed extract (4 ml L^{-1}).

Keywords: Maize (*Zea mays* L.), seaweed extract, fertilizer combination, growth and yield-related traits, quality attributes

Key findings: A significant improvement in growth, yield, and quality traits of maize was evident due to the combined use of nitrogen and phosphorus fertilizers with the foliar application of seaweed extract (4 ml L^{-1}).

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INTRODUCTION

Maize (*Zea mays* L.) belongs to the grass family Poaceae and is one of the crucial cereal crops widely grown worldwide. Maize occupies the third position after wheat and rice crops in terms of cultivated area and global production, and countries like Russia, China, India, and South Africa are the leading producing countries (Kandil *et al*., 2020; Abdul Mohsin and Farhood, 2023). Increased maize productivity has become one of the main goals in plant breeding worldwide because of its predominant use as food by humans and animals alike.

In various developing countries, maize is a prime food, with its flour used in making bread after mixing with wheat flour. The maize oil also serves as a healthy food and medicine, which is very easy to digest and often an alternative for patients with high cholesterol in the blood. Maize grains are rich in vitamin E. It also benefits many industries and areas of energy production and biofuels. Its grains contain carbohydrates, calories, vitamins, amino acids, and dietary fibers, promoting digestive health and preventing fitness problems. Maize grains are ingredients in poultry and livestock feeds due to their carotene content, which requires good crop management to achieve high productivity per unit area.

Maize planting happens on a large scale in Iraq, and despite that, the production is still low compared with global production. For the best vegetative growth and highest grain yield with good quality, maize requires available high-fertility soil due to its higher absorption capacity of nutrients at various growth stages, especially nitrogen, phosphorus, and potassium, obtained by plants by adding fertilizers at proper times and quantities (Ort and Long, 2014; Desa, 2017). Studies also showed that nitrogen, phosphorus, and potassium nutrients limit the production of most field crops, especially maize, if not applied at the appropriate dose and time (Ali *et al*., 2014; Alsharifi *et al*., 2022). These major nutrients have a better impact through their entry into the physiological processes within the plant, which directly reflect the plant’s growth and productivity. Therefore, an appropriate type of fertilizer associated with the soil and crop types needs selection with the method of fertilization, significantly affecting crop plants and reducing environmental risks.

Balanced mineral fertilizer use can enhance crop production because the insufficient addition of fertilizer delays maturity and affects grain yield and quality. The excess and unbalanced quantities also lower grain yield and quality, and high soil fertilizers cause pollution and degradation. Irrational manure usage in irrigated agriculture is uneconomical and considerably harms the environment (Nanganoa *et al*., 2020; Yahaya *et al*., 2023). Therefore, the chief task is not to ban mineral fertilizers in agriculture, but to improve agricultural practices, especially for balanced and environmentally correct fertilization.

Mineral fertilizers are essential in crop plants; however, they require supplementation with other sources that provide the necessary nutrients at appropriate times. For high productivity with good quality, successful techniques reduce mineral fertilizer consumption and its environmental effect (Al-Yasari and Al-Hilli, 2019; Aljoubory and Al-Yasari, 2023). Seaweed extracts, which contain more than 30 natural compounds, macro and micronutrients, and growth-promoting substances like auxins, gibberellins, cytokinins, vitamins, amino and organic acids, and polysaccharides, increase the plant resistance to salinity and drought and enhance the chlorophyll content in plant leaves. These extracts also accelerate carbon metabolism and plant development by decomposing chlorophyll and acting as a bio-stimulant to help the plant absorb, transport, and transfer nutrients (Panda *et al*., 2012; Abbas, 2017). With the growing demand for high-quality food, the presented study aimed to determine the best soil fertilizer combination of nitrogen and phosphorus, along with using seaweed extract, and their interaction effects on maize growth, yield, and quality-related traits.

MATERIALS AND METHODS

The presented maize experiment commenced in the 2022 fall crop season at the District Al-Hussainiya, Kerbala, Iraq. The experiment in a randomized complete block design (RCBD) had a split-plot arrangement and three replications. The primary plots included seaweed extract (Algazone Mx30) with two concentrations (2 and 4 ml L^{-1}), and the subplots included mineral fertilizer combinations consisting of nitrogen (0, 150, and 300 kg ha^{-1}) and phosphorus (0, 50, and 100 kg ha^{-1}). The maize cultivar 'Maha' became the planted sample for the said experiment on clay loam soil. Before maize planting, the chemical and physical properties of the used soil underwent analysis at a depth of 0–30 cm, as provided in Table 1.

Fertilization transpired with mono-superphosphate fertilizer (P_2O_5 19%) as a source of phosphorus, applied in one batch before planting for all the treatments. The urea fertilizer (N 46%) and potassium sulfate (K_2O 50%) were the sources of nitrogen and potassium. The potassium sulfate application also occurred in one batch during planting for all the treatments. The first factor included fertilizer combinations of nitrogen and phosphorus. Three nitrogen levels (0, 150, and 300 kg N ha^{-1}) received symbols, i.e., N_0, N_1, and N_2, respectively. Three phosphorus levels (0, 50, and 100 kg P ha^{-1}) attained labels as P_0, P_1, and P_2, respectively, adding the urea fertilizer (N 46%) as a nitrogen source in the two batches. As a source of phosphorus, the mono-superphosphate fertilizer ($P_2O_5$19%) one-time use happened at planting. For nitrogen (Urea), the first batch application was seven to 10 days after germination, with the second dose added at the beginning of the formation of silk threads.

In the maize experiment, the second factor was seaweed extract (Algazone Mx30) added as a foliar spray on the plants with two concentrations (2 and 4 ml L^{-1}). The foliar application also ensued in two stages, i.e., the first spray was at the 6-8 true-leaves stage of the maize plants, and the second application was at the appearance of male inflorescences. The manual sprayer with a dorsal capacity of 16 liters served the foliar application of seaweed extract. The spraying process continued during the early morning with complete wetness of the plants to avoid high temperatures. The control treatment (with water only) and using a diffuser (bright cleaning solution) spraying helped reduce the surface tension of the water and ensure the complete wetness of the leaves to increase the efficiency of the spray solution.

Data recorded

For data recording, 10 randomly selected plants from each experimental unit served as samples. Measurement for plant height started from the soil surface to the lower node of the male inflorescence. Calculations for the number of leaves per plant, leaf area (cm^2 $plant^{-1}$), rows per ear, grains per row, and grain yield (t ha^{-1}) used the method according to Al-Mohammadi (1990). Measuring protein percentage in the grains followed the process according to AOAC (1980).

Table 1. Chemical and physical properties of the study soil at a depth of 0–30 cm before maize planting.

Properties		Values
pH		7.2
EC (1:1)		2.18 ds m^{-1}
OM		1.21 g kg^{-1}
N available		28.34 mg kg^{-1}
P available		10.8 mg kg^{-1}
K available		65.27mg kg^{-1}
Soil separators	Sand	250 G kg^{-1}
	Silt	360 G kg^{-1}
	Clay	390 G kg^{-1}
Texture		Clay loam

Statistical analysis

The analysis for all recorded data was according to the analysis of variance (ANOVA) as per randomized complete block design with a split-plot arrangement (Gomez and Gomez, 1984). Employment of the least significant difference ($LSD_{0.05}$) test compared and separated the mean differences for all the parameters. The study used the statistics software GenStat12 for the analysis.

RESULTS

According to the analysis of variance, fertilizer combinations, seaweed extract concentrations, and fertilizer combinations by seaweed extract interactions revealed significant ($P \leq 0.05$) differences for most of the traits (Table 2). The trait-related results are as follows:

Plant height

The results revealed the fertilizer combination of nitrogen and phosphorus (N_2P_2) showed the highest plant height (183.79 cm) (Table 3). The said treatment was significantly superior to all other fertilizer combinations, except for fertilizer combination N_2P_1, which did not differ significantly with an average plant height of 182.34 cm and an increase of 25.63% compared with the control combination (N_0P_0), which showed the lowest plant height (145.13 cm). Two other fertilizer combinations (N_1P_2 and N_1P_1) indicated significant superiority over the rest of the combinations, with an average of 180.98 and 180.36 cm, respectively, and an increase of 24.70% and 24.27%, respectively, compared with the control fertilizer combination (N_0P_0). The foliar application of seaweed extract also showed significant differences in the plant height. The seaweed concentration (4 ml L^{-1}) was substantially superior by giving the maximum average for plant height (172.59 cm), with an increase of 6.20% compared with the seaweed concentration (2 ml L^{-1}), which was 162.51 cm.

In the interaction of two factors, the results indicated significant differences, and the coefficients, $F_2N_2P_2$, $F_2N_2P_1$, $F_2N_1P_1$ and $F_2N_1P_2$, which did not have a relevant difference, achieved the highest plant height, with an average of 189.39, 189.23, 188.82, and 187.17 cm, sequentially. These interactions were significantly superior to the rest of the coefficients, with an increase of 31.86%, 31.75%, 31.47%, and 30.32%, respectively, compared with the control treatment ($F_1N_0P_0$), showing the lowest plant height (143.62 cm).

Leaves per plant

The fertilizer combinations, N_2P_2, N_2P_1, N_1P_1, and N_1P_2, achieved the most number of leaves (15.31, 15.29, 15.23, and 15.21 leaf $plant^{-1}$) with nonsignificant differences (Table 4). They were significantly superior to the rest of the fertilizer combinations, with an increased rate of 44.70%, 44.51%, 43.95%, and 43.76%, respectively, compared with the control combination recording the lowest leaves per plant (10.58 leaf $plant^{-1}$). The two foliar applications of seaweed extract also gave significant differences for the average number of leaves per plant, and seaweed concentration of 4 ml L^{-1} was significantly higher by producing the maximum average number of leaves per plant (14.37 leaves $plant^{-1}$) and the 6.12% increase, compared with the seaweed concentration (2 ml L^{-1}) (13.54 leaves $plant^{-1}$). The interaction treatment of the two factors also indicated significant differences for the leaves per plant. The interaction treatments, $F_2N_1P_1$, $F_2N_2P_2$, $F_2N_2P_1$, and $F_2N_1P_2$, showed the highest and at a par number of leaves (15.65, 15.64, 15.62, and 15.57 leaves $plant^{-1}$, respectively). These combinations notably outperformed the rest of the treatments, with an increase of 53.13%, 53.03%, 52.83%, and 52.34%, respectively, compared with the control treatment (10.22 leaf $plant^{-1}$).

Leaf area

The fertilizer combination N_2P_2 showed superiority by attaining the maximum leaf area (5210.80 cm^2 $plant^{-1}$), with an increase rate of 16.99% compared with the control combination (4454.00 cm^2 $plant^{-1}$) (Table 5). The promising treatment had the fertilizer

Table 2. Analysis of variance with two factors (seaweed extract [Algazone Mx30] and combination of nitrogen and phosphorus fertilizers), and their interaction for various traits in maize.

Source of variation	d.f.	Plant height (cm)	Leaves plant^{-1}	Leaf area (cm^2 plant^{-1})	Rows ear^{-1}	Grains row^{-1}	Grain yield (t ha^{-1})	Grains protein (%)
Replications	2	2649.138	32.7893	212554	38.40837	49.8477	2.19762	5.76765
Seaweed extract	1	1371.485*	9.3417*	2707264*	3.64001*	90.6889*	23.57858*	5.59057*
Error A	2	2.352	0.1562	2060	0.13701	0.3950	0.000878	0.08883
Fertilizer combination	8	1337.567 *	14.9458*	603736*	13.59859*	29.3016*	13.29771*	11.69050*
Seaweed extract × fertilizer combination	8	43.697*	0.1640 ^{NS}	80554*	0.08063 ^{NS}	0.4300*	0.89936*	0.20092*
Error B	32	5.00	0.1659	1181	0.05074	0.1708	0.01063	0.01857

Table 3. Effect of spraying with seaweed extract (Algazone Mx30) and combination of nitrogen and phosphorus fertilizers on the plant height.

Fertilizer combination	Seaweed extract		Means (cm)
	2 ml L^{-1}	4 ml L^{-1}	
N_0P_0	143.62	146.65	145.13
N_0P_1	150.81	154.77	152.79
N_0P_2	153.06	157.91	155.48
N_1P_0	154.28	162.01	158.14
N_1P_1	171.91	188.82	180.36
N_1P_2	174.79	187.17	180.98
N_2P_0	160.44	177.33	168.89
N_2P_1	175.46	189.23	182.34
N_2P_2	178.19	189.39	183.79
Means (cm)	162.51	172.59	

$LSD_{0.05}$ Fertilizer combination = 2.63, Seaweed extract concentration = 1.79, Fc × Se Interactions = 3.60

Table 4. Effect of spraying with seaweed extract (Algazone Mx30) and combination of nitrogen and phosphorus fertilizers on the number of leaves of plant.

Fertilizer combinations	Seaweed extract		Means (leaves plant^{-1})
	2 ml L^{-1}	4 ml L^{-1}	
N_0P_0	10.22	10.93	10.58
N_0P_1	12.58	13.03	12.81
N_0P_2	12.65	14.19	13.42
N_1P_0	13.12	14.31	13.71
N_1P_1	14.82	15.65	15.23
N_1P_2	14.86	15.57	15.21
N_2P_0	13.65	14.39	14.02
N_2P_1	14.96	15.62	15.29
N_2P_2	14.99	15.64	15.31
Means (leaves plant^{-1})	13.54	14.37	

$LSD_{0.05}$ Fertilizer combination = 0.47, Seaweed extract concentration = 0.46, Fc × Se Interactions = NS

Table 5. Effect of spraying with seaweed extract (Algazone Mx30) and combination of nitrogen and phosphorus fertilizers on the leaf area.

Fertilizer combinations	Seaweed extract		Means (cm^2 $plant^{-1}$)
	2 ml L^{-1}	4 ml L^{-1}	
N_0P_0	4411.30	4496.70	4454.00
N_0P_1	4463.00	4750.00	4606.50
N_0P_2	4492.00	4785.30	4638.70
N_1P_0	4501.00	4793.30	4647.20
N_1P_1	4844.30	5548.30	5196.30
N_1P_2	4848.20	5521.80	5185.00
N_2P_0	4506.70	4861.60	4684.15
N_2P_1	4850.10	5533.70	5190.80
N_2P_2	4883.70	5538.00	5210.80
Means (cm^2 $plant^{-1}$)	4644.48	5092.08	

$LSD_{0.05}$ Fertilizer combination = 40.42, Seaweed extract concentration = 53.15, Fc × Se Interactions = 59.92

combinations N_1P_1, N_2P_1, and N_1P_2 following it, with nonsignificant differences (5196.30, 5190.80, and 5185.00 cm^2 $plant^{-1}$, respectively). However, they significantly outperformed the other combinations with an increase rate of 16.66%, 16.54%, and 16.41% sequentially. The seaweed extract (4 ml L^{-1}) was markedly superior and showed the highest average for the said trait (50920.8 cm^2 $plant^{-1}$) and an increased rate of 9.64%, compared with the low concentration (2 ml L^{-1}) (4644.48 cm^2 $plants^{-1}$).

The effects of the interaction of the two factors indicated significant differences. The interaction treatments ($F_2N_1P_1$, $F_2N_2P_2$, $F_2N_2P_1$, and $F_2N_1P_2$) achieved the highest and similar leaf areas (5548.30, 5538.00, 5533.70 and 5521.80 cm^2 $plant^{-1}$, respectively). These interactions were considerably superior to the rest of the interaction treatments, with an increase of 25.77%, 25.54%, 25.44%, and 25.17%, respectively, compared with the control interaction (4411.30 cm^2 $plants^{-1}$).

Rows per ear

The addition of nitrogen and phosphorus fertilizer combinations significantly affected the rows per cob (Table 6). The combination N_2P_2 recorded the highest average (16.08 rows ear^{-1}), with an increase of 27.21% compared with the control treatment recording the lowest average (12.64 rows ear^{-1}). The said promising combination had other fertilizer combinations (N_2P_1, $N_1P_1$and N_1P_2) following it, which did not differ significantly (16.07, 16.03, and 16.02 rows ear^{-1}, respectively). These fertilizer combinations considerably outperformed the rest, with an increase of 27.13%, 26.81%, and 26.74%, respectively.

The seaweed extract (4 ml L^{-1}) showed the highest number of rows per ear (14.86 rows ear^{-1}) and significantly excelled over the low-level extract (2 ml L^{-1}), with 14.34 rows ear^{-1} and an increase of 3.62%. The interaction effects between the fertilizer combinations and seaweed extract ($F_2N_1P_1$) indicated superiority, giving the maximum average (16.46 rows ear^{-1}) and an increase of 32.20% compared with the control treatment recording the lowest average (12.45 rows ear^{-1}). The said interaction succeeded with the coefficients ($F_2N_2P_2$, $F_2N_2P_1$, and $F_2N_1P_2$), which did not differ significantly from them, having averages of 16.44, 16.43, and 16.38 rows ear^{-1}, respectively, and remarkably performing better than all other interactions.

Grains per row

The maize average number of grains per row has significant effects from adding nitrogen and phosphorus fertilizer (Table 7). The fertilizer combination N_2P_2 emerged with the highest average grains per row (37.87), with an increase of 19.23% compared with the control treatment, recording the lowest average (31.76 grains row^{-1}). The said promising combination had fertilizer combinations N_2P_1, N_1P_1, and N_1P_2 following it,

Table 6. Effect of spraying with seaweed extract (Algazone Mx30) and combination of nitrogen and phosphorus fertilizers on the number of rows per ear.

Fertilizer combination	Seaweed extract		Means (rows ear^{-1})
	2 ml L^{-1}	4 ml L^{-1}	
N_0P_0	12.45	12.83	12.64
N_0P_1	12.72	13.16	12.94
N_0P_2	12.91	13.19	13.05
N_1P_0	13.68	13.89	13.79
N_1P_1	15.61	16.46	16.03
N_1P_2	15.67	16.38	16.02
N_2P_0	14.60	14.96	14.78
N_2P_1	15.71	16.43	16.07
N_2P_2	15.72	16.44	16.08
Means (rows ear^{-1})	14.34	14.86	

$LSD_{0.05}$ Fertilizer combination = 0.26, Seaweed extract concentration = 0.43, Fc × Se Interactions = NS

Table 7. Effect of spraying with seaweed extract (Algazone Mx30) and combination of nitrogen and phosphorus fertilizers on the grains per row.

Fertilizer combination	Seaweed extract		Means (grains row^{-1})
	2 ml L^{-1}	4 ml L^{-1}	
N_0P_0	30.76	32.76	31.76
N_0P_1	32.22	35.22	33.72
N_0P_2	33.71	35.94	34.82
N_1P_0	33.85	36.04	34.94
N_1P_1	36.24	39.41	37.82
N_1P_2	36.28	39.34	37.81
N_2P_0	34.66	36.44	35.55
N_2P_1	36.38	39.33	37.85
N_2P_2	36.39	39.36	37.87
Means (grains row^{-1})	34.50	37.09	

$LSD_{0.05}$ Fertilizer combination = 0.48, Seaweed extract concentration = 0.73, Fc × Se Interactions = 0.74

with a par number of grains per row (37.85, 37.82, and 37.81, respectively), and an increase of 19.17%, 19.08%, and 16.02% compared with the control combination. The seaweed extract at a concentration of 4 ml L^{-1} showed a higher number of grain rows per ear (37.09 grains row^{-1}) and showed an increase of 7.50% compared with the low concentration (2 ml L^{-1}) of seaweed (34.50 grains row^{-1}).

In the case of interaction between fertilizer combinations and seaweed extract, the results revealed the superiority of the interaction treatment $F_2N_1P_1$, which showed the maximum average (39.41 grains row^{-1}) and an increase of 28.12% compared with the control treatment (30.76 grains row^{-1}). The better-performing interaction had the coefficients $F_2N_2P_2$, $F_2N_2P_1$, and $F_2N_1P_2$ following it, which also did not differ significantly from them, with an average of 39.09, 39.36, and 39.34 grains row^{-1}, respectively, and performing notably better than all other transactions.

Grain yield

The fertilizer combination N_2P_2 showed the highest grain yield (9.64 t ha^{-1}), with an increase of 49.92% compared with the control combination (6.43 t ha^{-1}) (Table 8). A nonsignificant difference from fertilizer combinations N_1P_2, N_1P_1, and N_2P_1 appeared, with averages of 9.62, 9.61, and 9.61 t ha^{-1}, sequentially, significantly performing better than the rest of the combinations, with an increase of 49.61%, 49.45%, and 49.45%, respectively. The foliar application of the seaweed extract (4 ml L^{-1}) substantially showed the highest grain yield (8.73 t ha^{-1}),

Table 8. Effect of spraying with seaweed extract (Algazone Mx30) and combination of nitrogen and phosphorus fertilizers on the grain yield.

Fertilizer combination	Seaweed extract		Means (t ha^{-1})
	2 ml L^{-1}	4 ml L^{-1}	
N_0P_0	6.17	6.69	6.43
N_0P_1	6.27	6.93	6.60
N_0P_2	6.53	7.13	6.83
N_1P_0	6.64	7.23	6.93
N_1P_1	8.47	10.74	9.61
N_1P_2	8.55	10.68	9.62
N_2P_0	6.88	7.93	7.40
N_2P_1	8.59	10.63	9.61
N_2P_2	8.62	10.66	9.64
Means (t ha^{-1})	7.41	8.73	

$LSD_{0.05}$ Fertilizer combination = 0.12, Seaweed extract concentration = 0.10, Fc × Se Interactions = 0.16

Table 9. Effect of spraying with seaweed extract (Algazone Mx30) and combination of nitrogen and phosphorus fertilizers on the grains protein.

Fertilizer combination	Seaweed extract		Means (%)
	2 ml L^{-1}	4 ml L^{-1}	
N_0P_0	9.97	10.45	10.21
N_0P_1	10.22	10.75	10.49
N_0P_2	10.52	11.00	10.76
N_1P_0	10.85	11.22	11.04
N_1P_1	12.89	13.81	13.35
N_1P_2	13.02	13.64	13.33
N_2P_0	11.47	13.00	12.24
N_2P_1	13.14	13.60	13.37
N_2P_2	13.25	13.66	13.45
Means (%)	11.70	12.35	

$LSD_{0.05}$ Fertilizer combination = 0.16, Seaweed extract concentration = 0.34, Fc × Se Interactions = 0.28

with an increase of 17.81%, compared with the low concentration of seaweed (2ml L^{-1}) (7.41 t ha^{-1}).

For the interaction between fertilizer combinations and seaweed extract, the results indicated the superiority of the interaction treatment $F_2N_1P_1$, giving the highest grain yield (10.74 t ha^{-1}), with an increase of 74.06% compared with the control treatment (6.17 t ha^{-1}). The promising interaction had the coefficients $F_2N_1P_2$, $F_2N_2P_2$, and $F_2N_2P_1$ following it, with a par grain yield (10.68, 10.66, and 10.63 t ha^{-1}, respectively).

Grains protein

In maize grain, the protein concentration incurred significant influences from adding nitrogen and phosphorus fertilizer combinations (Table 9). The fertilizer combination N_2P_2 recorded the highest average protein (13.45%), with an increase of 32.00% compared with the control combination, recording a lower average (10.21%). The said promising fertilizer combinations preceded N_2P_1, N_1P_1, and N_1P_2, with nonsignificant differences (13.37%, 13.35%, and 13.33%, respectively). These combinations considerably excelled the rest, with an increase of 30.95%, 30.75%, and 30.55%, respectively. The results also showed that foliar application of seaweed extract (4 ml L^{-1}) markedly exceeded, with the highest average for protein (12.35%) and an increase of 5.55% compared with the low concentration (2 ml L^{-1}) (11.70%).

On the interaction between fertilizer combinations and seaweed extract, the findings indicated the superiority of the interaction treatment $F_2N_1P_1$ as it gave the maximum average of protein (13.81%), with an increase of 38.51% compared with the control treatment, recording the lowest average (9.97%). These promising interactions preceded the coefficients $F_2N_2P_2$, $F_2N_1P_2$, and $F_2N_2P_{10}$, with nonsignificant differences and averages of protein 13.66%, 13.64%, and 13.60%, respectively. They significantly performed better than the rest of the interaction treatments.

DISCUSSION

The results enunciated that using nitrogen and phosphorus fertilizer mixture individually and in combination with foliar application of seaweed extract significantly enhanced plant growth and yield-related traits in maize crops. Nitrogen helps in cell multiplication and expansion, lengthening the internodes and increasing leaf-carrying stem nodes. The synthesis of tryptophan, the building block of auxin, increases the plant cell division and elongation, boosting the plant's stature and structure. Nitrogen is also vital in producing plant hormones that stimulate leaf-forming cells and increase the number of plant leaves. Phosphorus helps plants complete the various physiological processes that boost plant growth and its yield components (Izadi and Eman, 2010; Al-Yasari and Al-Jbwry, 2024)***.***

The maize plant performance improved as the leaf area increased because the leaf is the chief source of the plant food processing. Nitrogen and phosphorus are crucial in increasing the leaf area, enhancing the plant's ability to intercept light to form more chlorophyll (Anwar *et al*., 2017). The maize plant's response to foliar application of seaweed extract may be due to it contributing to increased vital activities of the plant and absorbing nutrients. The seaweed also has a hormonal effect that increases the plant height through its influences on the cell protoplasm and cell wall, enhancing the cell division and their elongation and activating the leaf tissues to divide and expand, producing more leaves and their leaf area (Abbas, 2017; Bashir *et al*., 2021).

With fertilization, the increased accumulation of dry matter and improved growth increased fertilization because of reducing the rate of ovarian abortion that eventually enhanced grains per ear (Iqbal *et al*., 2014). In maize, it led to an upsurge in the efficiency of the carbon assimilation process and the transfer of its products to the grains. In addition, the plant height may reduce the shading of the leaves above the ear, thus, increasing pollination and fertilization, further raising the number of grains per ear. The seaweed extract, with its nutrient contents and compounds, is critical for the plant regulation of the hormones that control the performance of auxin in developing apical dominance of the ear. Cytokinins also work to prevent the transfer of auxins from old grains to newer grains, hence, increasing the percentage of grains setting in the ear, which has a positive impact on grain yield (Amare *et al.*, 2022; Kudaibergenova *et al*., 2023).

The grain filling depends on the efficiency of the source, which, in turn, depends on the plant's leaf area, the duration of its green stay, and the rate of carbon metabolism (Bindraban *et al*., 2020; Farhood *et al*., 2020). Adding fertilizer combinations and the spraying of seaweed extract improved photosynthesis, chlorophyll biosynthesis, and metabolism by increasing the leaf area. The total chlorophyll content, which is a reflection of increasing the yield components, as well as the role of seaweed extract in the conversion efficiency of carbon metabolism and the division process in the cells responsible for seed formation, increased the grain size and weight (Abbas, 2017; Nigussie, 2021).

The improvement in the traits associated with the yield-attributing traits has positive reflections from the increase in the grain yield, which refers to the synthesis of nitrogen and phosphorus fertilizers and foliar application of the organic nutrient (seaweed extract). The said soil and plant fertilization contributed to raising the efficiency of the carbon metabolism and increasing the formation of chlorophyll, proteins, enzymes, and most growth regulators that had a prime role in enhancing the grain yield (Alshaal and El-Ramady, 2017; Al-Yasari and Al-Hilli, 2018).

The physiological processes also need to convert the cell's phosphorus energy into a component of adenosine triphosphate (ATP), which is the product of energy conversion or transfer during the process of carbon metabolism and respiration in addition to phosphorus, a component in fats, carbohydrates, proteins, enzymes, and plant metabolic compounds (Ali *et al*., 2014). The maize response to mineral fertilization and foliar application of seaweed extract for its growth and yield may be due to achieving the best nutritional balance of these nutrients within the plant, pushing the plant toward better growth, further improving the plant's opportunities to invest in growth factors better to build more and produce.

CONCLUSIONS

The presented results revealed that foliar application of seaweed extract (Algazone Mx30) and the treatment of nitrogen and phosphorus fertilizer combinations (N 150 + P 50) enhanced the vegetative growth, which boosted the photosynthesis, and, thus, improved the composition of crop components enhancing the maize grain yield with better quality. The interaction between the nitrogen and phosphorus fertilizer combination and foliar application of seaweed extract (4ml L^{-1}) was best responsive in improving the growth and grain yield-related traits in maize.

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